Wisconsin Silviculture Guide

DNR PUB-FR-805 2020

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Previous View

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FORWARD – APPLICATION OF GUIDE

Practice of Silviculture

Silviculture is the practice of controlling forest composition, structure, and growth to maintain and enhance the forest's utility for any purpose. Applied silviculture includes a wide array of vegetation management techniques or tools developed through generations of research, experimentation, and field practice. The forester or resource manager's job is to skillfully apply those tools based on stand conditions and landowner goals. Although forest management goals and objectives may vary, silvicultural systems can be adapted to achieve a wide variety of desired future forest conditions. Ultimately the practice of silviculture maintains healthy forests to meet societal needs and is the foundation of sustainable forestry.

The practice of silviculture is sometimes referred to as a science and an art, because the practicing forester uses a combination of knowledge, field experience, and professional judgement to select treatments that will best achieve local forest management objectives. Foresters must have a strong background in the foundational sciences of silvics, ecology, and economics. Every forest is different so selecting the most effective treatments (whether they are traditional methods or novel approaches) requires not only strong technical knowledge, but a careful assessment of stand and site conditions and field experience gained through practice.

Purpose of the Wisconsin Silviculture Guide

The Wisconsin Silviculture Guide is designed as a technical resource or toolbox for Wisconsin foresters and resource managers to assist with the development of forest management plans and stand-level silviculture prescriptions. The guide presents information on the predominant silvicultural systems and methods applicable to Wisconsin's forest cover types and is based on best available research findings and field practice. Revisions to this document may be necessary as new research findings become available. The guide emphasizes the importance of tending and regeneration of forest stands as critical elements of sustainable forest management within an integrated ecosystem management framework.

The Wisconsin Silviculture Guide is not a cookbook or manual, but rather a collection of silvicultural methods shown to be effective in achieving specific forest management outcomes. This guide in no way lessens the need for technical skill and sound silvicultural judgement when selecting practices to achieve diverse resource management goals, such as timber production, wildlife habitat, aesthetics, endangered resources, biological diversity and the protection of soil and water quality. The forester or resource manager has the flexibility to adapt these methods to accommodate specific stand conditions, specific operational issues, or to meet specific management objectives, if those modifications remain within the context of sound and sustainable management.

The information provided in this document is intended to aid in forest management on Department forest lands, County Forests, tax law lands, as well as other public and private forests. It is an important silvicultural resource and reference document for Department personnel and cooperating partners.

This document in intended solely as guidance and does not contain any mandatory requirements except where requirements found in statute or administrative rule are referenced. This guidance does not establish or affect legal rights or obligations and is not finally determinative of any of the issues addressed. This guidance cannot be relied upon and does not create any rights enforceable by any party in litigation with the State of Wisconsin or the Department of Natural Resources.

Any regulatory decisions made by the Department of Natural Resources in any matter addressed by this guidance will be made by applying the governing and administrative rules to the relevant facts.

Content and Organization

This guide is comprised of several chapters and appendices. The initial chapters cover broadly applicable silvicultural topics, such as prescription writing, ecological tools, natural regeneration methods, artificial regeneration, intermediate treatments, economic considerations and marking guidelines. The main body of the text is organized around silvicultural systems and methods of the major forest cover types found in Wisconsin. A standard format is followed throughout the cover type chapters presenting silvical characteristics, recommended silvicultural systems and methods, decision models, forest health information, and other management tools. Additional information can be obtained by referring to the list of publications at the end of each cover type chapter. The appendices provide a glossary of terms, a list of scientific and common names of native trees, and the Wisconsin forest cover type definitions and abbreviations.

History of the Wisconsin Silviculture Guide

Development of the Wisconsin Silviculture Guide, formerly the WDNR Silviculture Handbook, began in the 1980s to bring together the latest and best information on managing common Wisconsin forest types. Prior to that time Department foresters relied on a collection of Forest Service Manager's Handbooks, technical reports, journal articles, and local knowledge. Having one comprehensive resource was an efficient way to synthesize this information and gather the expertise of practicing field foresters.

In the 1990s, a formal Silviculture Team was established with the responsibility of writing and maintaining the Silviculture Handbook. The initial team included mostly Department forestry staff, but as the guide began to be used more widely, members were added representing WDNR Wildlife and Endangered Resources, the Wisconsin County Forest Association, forest industry, and consulting foresters.

In 2013 the Wisconsin Silviculture Guidance Team (SGT) was created to reflect a growing desire for more forestry partner involvement. SGT members are from diverse interests within the forestry community, including state and national forests, consulting foresters, forest industry, universities, conservation groups, and landowner organizations. SGT is now responsible for establishing priorities for and reviewing updates to the Wisconsin Silviculture Guide. Specialized ad hoc teams are established to research and revise assigned sections of the guide as new information becomes available.

Chapter 11

Site Productivity

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Last Full Revision: 11/12/2012
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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1 SITE PRODUCTIVITY

This chapter outlines some of the key tools and methods for evaluating forest site quality in terms of productivity and site capability (potential) in Wisconsin. For each of these methods, the forester will have to collect and evaluate a number of different measurements. For further information, refer to the forest recon sections in the Public Forest Lands Handbook (WDNR 2009a).

There are a number of ways to define a "site," including the following:

1. The area in which a plant or stand is located, considered in terms of its environment, particularly as this determines the type and quality of the vegetation the area can carry.
2. A spatially explicit, relatively homogeneous portion of land a) characterized by specific physical and chemical properties that affect ecosystem functions and b) where a more or less homogeneous forest type may be expected to develop.
3. The sum total of environmental conditions available to the plant. The physical and biotic factors interact to yield the light, heat, water, and chemicals that are directly available to and used by the plant, as well as other chemical and mechanical disturbance factors.

The concept of a site can range greatly in size from a landform, to a stand or community, to a small microsite surrounding an individual plant. In addition, the environment that characterizes a site changes across space and time, and change can vary from coarse and abrupt to fine and gradual. Sites are influenced by both past and current environments.

The reason for evaluating a site will influence the methods used. Forestry practices are most commonly carried out on stands. These may loosely be defined as contiguous groups of trees sufficiently uniform in species composition, arrangement of age classes, and general condition to be considered homogeneous and distinguishable units.

2 SITE PRODUCTIVITY (QUALITY)

Site quality in terms of productivity refers to the growth capacity of a site, usually expressed as volume production of a given species. It can also be defined by the maximum timber crop the land can produce in a given time. Site productivity varies with tree species and the time-frame chosen. Site characteristics can also greatly affect timber productivity for a given tree species. One site may exhibit very good growth, yet another site with the same species, at the same age, may grow very poorly.

Growth of trees is possible when the amount of photosynthesis exceeds respiration. Carbon dioxide, sunlight, heat, water, and chemical nutrients are required for photosynthesis, and any of these can be limiting factors. Environmental factors that affect these basic requirements for photosynthesis will, ultimately, affect tree growth and therefore site productivity. Major environmental variables influencing tree and stand growth and productivity include:

- Climate – moisture, temperature, and sunlight

- Water available in the soil – availability, amount, timing
- Nutrient content of soil - availability, amount, timing
- Topography, elevation, and aspect, as they all can influence energy, moisture, and nutrient balances
- Biota – competition for and alteration of resources required for growth

Site quality can be changed by fertilization, vegetation control, irrigation, or drainage. Only highly intensive treatment can make a productive site out of a poor one. Conversely, productivity can be rapidly lowered by poor or intense management, as well as erosion or other site degradation.

Growing a fully stocked stand of the desired species on a site for a designated period of time precisely determines site productivity for that species during a certain period of time (historic environment) and under a certain management regime. Direct measurements of site productivity include historical growth and yield, mean annual increment (MAI), and periodic annual increment (PAI). Site index and growth intercept methods may also be considered direct measures of site quality. All of these measures reflect productivity for a specific species, under a specific management regime, and under past environmental conditions, so future site productivity will vary based on these factors.

2.1 Historic Yields

Historic yields measured in terms of volume/area/unit of time can give an indication of site productivity. This method relies on data from past harvests for a particular stand or area. Interpretation of productive potential is limited to the species being grown on that particular site; it would be difficult to estimate potential for other species. The management regime used could also affect yield, especially if different management techniques or residual stocking levels were used with each harvest.

2.2 Mean Annual Increment

Mean annual increment (MAI) is defined as the total increment of a tree or stand (standing crop plus thinnings) up to a given age divided by that age. Mean annual increment (MAI) represents the average annual growth a tree or stand of trees has exhibited up to a specified age. For example, a 20-year old tree that has a diameter breast height of 10.0 inches has an MAI of 0.5 inches/year.

MAI is calculated as:

$$MAI = \frac{Y(t)}{t}$$

where Y(t) = yield at time t.

Since the typical growth patterns of most trees is bell-shaped, the MAI starts out small, increases to a maximum value as the tree matures, then declines slowly over the remainder of the tree's life. Throughout this, the MAI always remains positive. The culmination of mean annual increment (CMAI) is the age in the growth cycle of a tree or stand at which the MAI for volume, basal area, diameter, or height is at its maximum. This point at which the MAI peaks is commonly used to identify the stand's rotation age that maximizes volume over time. The MAI for timber volume provides the best estimate of the maximum production rate that can be continuously sustained by a given combination of species and site quality provided that the stands are rotated near maximum MAI (Smith et. al 1997).

In Wisconsin, an MAI of 20 cubic feet /acre/year is commonly used as a threshold to determine whether or not a site is considered productive.

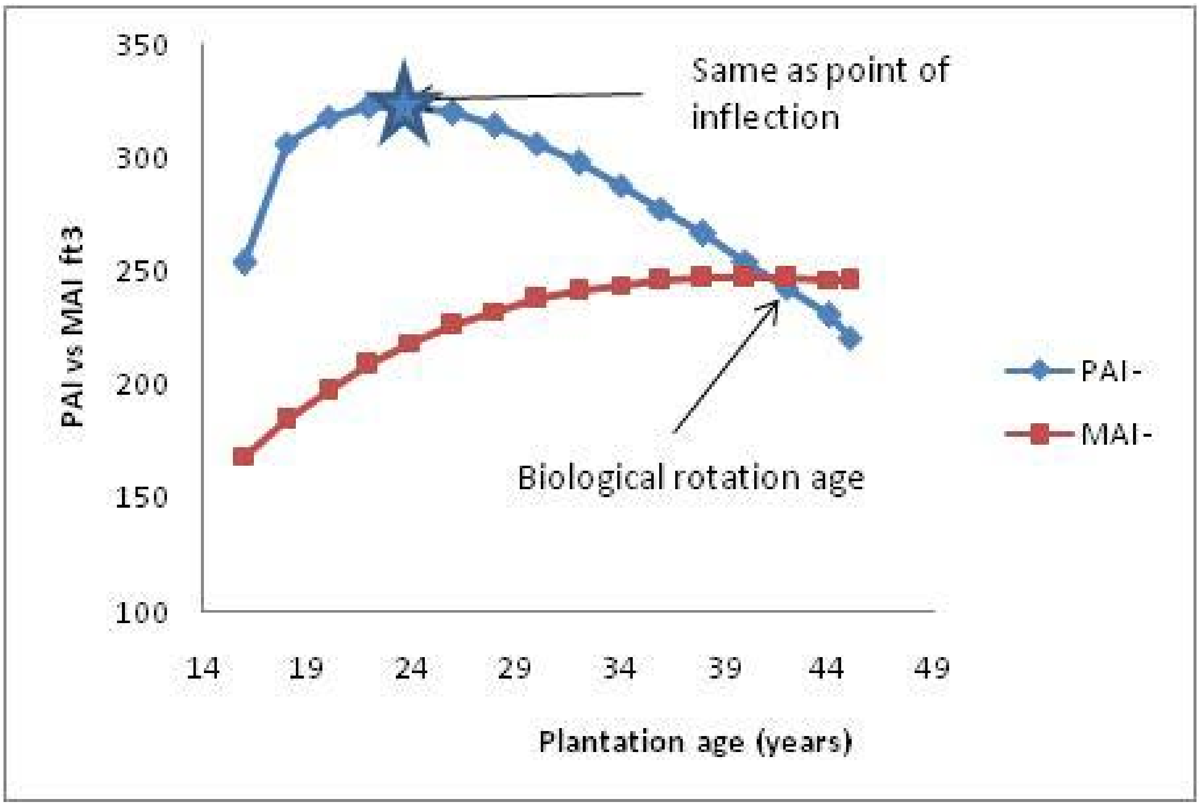

Figure 11.1. Graph of stand periodic volume growth over time showing PAI and MAI

2.3 Periodic Annual Increment

Periodic annual increment (PAI) is defined as the growth of a tree or stand observed over a specific time period divided by the length of the period. It is an indicator of a tree's capacity, at a certain age or size, to grow. PAI is species specific.

PAI is calculated as:

$$PAI = \frac{(Y_2 - Y_1)}{(T_2 - T_1)}$$

where Y = yield at times 1 and 2, T_1 = first year of the growth period and T_2 = end of the growth period.

Typically, PAI for volume growth increases fast and then quickly declines, approaching 0. It may go negative if the tree loses volume due to injury or disease. If PAI is measured using immature stands, the productivity rates appear high but cannot be sustained over a long period.

Using a period longer than one year smoothes over the effects of climatic variations, as well as errors in estimates of beginning and ending values.

2.4 Growth Intercept

Growth intercept (GI) values can be used directly to assess site quality (growth intercept indices) or indirectly to measure site index. GI, commonly defined as the total length of the first five internodes above breast height, is usually a reliable indicator of height growth for the next 5-20 years. Growth intercept is most useful in young stands (3-30 years old) of uninodal species that display annual branch whorls (e.g., pines) or for multinodal species where spring whorls are clearly identifiable. The advantages of GI include it can be used in stands too young to evaluate using standard site index curves, stand age is not required, and the length of the specified number of internodes is usually easier to measure than total heights of dominant trees. (Schreuder, et al. 1993). Effects of short-term climatic fluctuations and the fact that early growth of a stand does not always accurately reflect later growth are disadvantages of the GI method (Alban 1972). Growth Intercept cannot be used in uneven-aged stands.

When measuring GI, use only dominant or co-dominant trees without obvious insect, disease, or fire damage that are not suppressed (same criteria as for measuring site index). Use a measuring pole to measure the length of five internodes beginning at the first whorl above breast height (4.5 feet). The number of trees to measure depends on the variation among trees and the desired precision. Typically, five to 10 sample trees are selected, and 10 to 20 trees would be best. Site index for each intercept measurement can be determined from the appropriate species growth intercept table. Average the site index values to arrive at an average stand site index.

Growth intercept commonly uses the total length of the first five internodes above breast height; however, seedling establishment and early growth are strongly affected by seedling vigor, competition, animal and insect damage, which affect growth less later in life. To reduce the influence of these factors, David H. Alban (1972) recommends for red pine that the total length of the five internodes starting from the first whorl above 8 feet be measured (GI_8). Site index can then be predicted using the equation: $Ht_{50} = 32.54 + 3.434GI_8$.

2.5 Site Index

Site index (SI) is a species-specific measure of forest productivity (usually for even-aged stands), expressed in terms of the average height of trees in a specified crown class (dominants, codominants, or the largest and tallest trees) at a specified index or base age. In Wisconsin, fifty years is the most commonly used site index base age.

The height growth of seed origin trees is considered to be independent of stand density and strongly related to site quality in that better sites produce taller trees; however, it should be noted that tree height growth can be reduced at very high densities and very low densities (Larsen 1999). In addition, indicator trees should have been free to grow throughout their lives (never suppressed) and their height growth never damaged by exogenous factors. SI is species dependent, and SI values are not usually equivalent between species.

Site index curves show the expected height growth pattern for trees of the specified stand component in even-aged stands of a given site index. Site index curves convert ages other than the base age to the expected height at the given age. SI curves for a species will differ among authors and regions. It is important to consistently use the same set of SI curves.

Historically site index equations and curves were constructed from tree height/age data pairs. Anamorphic site index curves were constructed using a single guiding curve derived through regression techniques. This guiding curve was then scaled to produce other curves, harmonized to reflect the same form and trend reflecting differing site quality. The most common method since 1980 is to perform stem analysis on individual trees, and fit polymorphic curves to the growth pattern of individual trees.

2.5.1 Limitations of the use of SI:

- Factors other than site which can influence height growth are:
  - extremes of stand density
  - genetics
  - suppression
  - past management (e.g., site prep, soil compaction)
  - height growth damage (e.g., from animals, disease, or weather)
  - root or stump sprouting.

- It cannot be used in uneven-aged stands and deforested areas.
- Age seems to affect site index for certain species (University of Minnesota 1992).
- During construction of curves, extrapolation of data across range of sites and ages can introduce error
- SI is a relative measure, depending on regional variation and databases and methods used in curve construction. It is important to consistently use the same set of SI curves appropriate for the region in which you are evaluating.
- Accurate determination of site index requires careful measurement. Stand and tree selection and measurement errors can result in highly inaccurate results.
- Published curves are based on too few plots
- Curves are species-specific.

2.5.2 Field Application

Ideally, the most precise way to determine SI is to fell, measure heights, and take sections to count rings from representative trees. In practice, however, trees are typically sampled using increment cores and indirect height measurements. To obtain SI while performing routine forestry field work requires measuring the heights and ages of sample trees and then obtaining the SI from appropriate site index curves.
Stands must have the following characteristics for applying this method:

- even-aged with less than a 10 year age difference among overstory trees (excluding reserve trees);
- fully stocked;

- mostly free of trees killed by wind, insects, or disease;
- not disturbed by fire, grazing or heavy thinning from above since establishment;
- at least 20 years old and preferably more than 50 years old (actual age, not measured at breast-height); and
- representative of a large area and of relatively uniform site quality.

To measure the site index:

1. For each species, select five to 10 sample trees. Sample trees must be
   - Dominants or strong co-dominants
   - Above average diameter for the stand (considering all trees >5-inches dbh)
   - Single stemmed, no sprout clumps
   - Without serious animal, insect, disease, wind, fire, or logging injuries
   - At least a tree height away from reserve trees
   - Straight and without pronounced lean
   - Free of most surface defects, epicormics, bumps, and dead branch stubs
   - Full-Crowned, without dead tops and large forks
   - Trees that have never been suppressed (consistent growth rings)
   - Evenly distributed across the stand and occurring on micro-sites that represent average site productivity

2. Measure total tree heights with a clinometer, altimeter or similar device
3. Determine tree ages by taking increment cores at dbh and adding the proper number of years according to the site index curve publication. Count the rings carefully using a hand lens if necessary, because each 1 year error can cause a 1 to 2-foot error in site index.
4. Use tree age and height data and site index curves appropriate for the species and physiographic region to determine site index for each tree.
5. Average site index values for all sample trees to obtain the mean site index of the stand.

3 SITE CAPABILITY (POTENTIAL)

Site capability, or potential, refers to the sum total of all the factors affecting the capacity to produce forests or other vegetation. It integrates the collective physical resources (e.g., moisture, nutrients, heat, and light) available for plant growth. Different potentials facilitate growth of some species and limit growth of others. Consequently, site potential has a strong effect on plant community development.

Site type is a classification of site potential based on indirect measures utilizing site factors (individually or in combination) such as climate, topography, geology, soil, and vegetation. Classification of site types can be used as an indirect measure or estimation of potential tree and stand growth and yield (productivity), as well as potential community development.

3.1 Vegetation

In general, “vegetation” refers to the plant life or total plant cover of an area. Plants typically occur together in repeating groups of associated species, sometimes called communities. A plant community is an assemblage of plants grouped by environmental factors. Plant communities change in time and space. In plant ecology, “vegetation” refers to plant communities in terms of composition and structure, particularly the identity and growth form of the most abundant species, the largest species, and the most characteristic species (i.e., it is more than a list of flora).

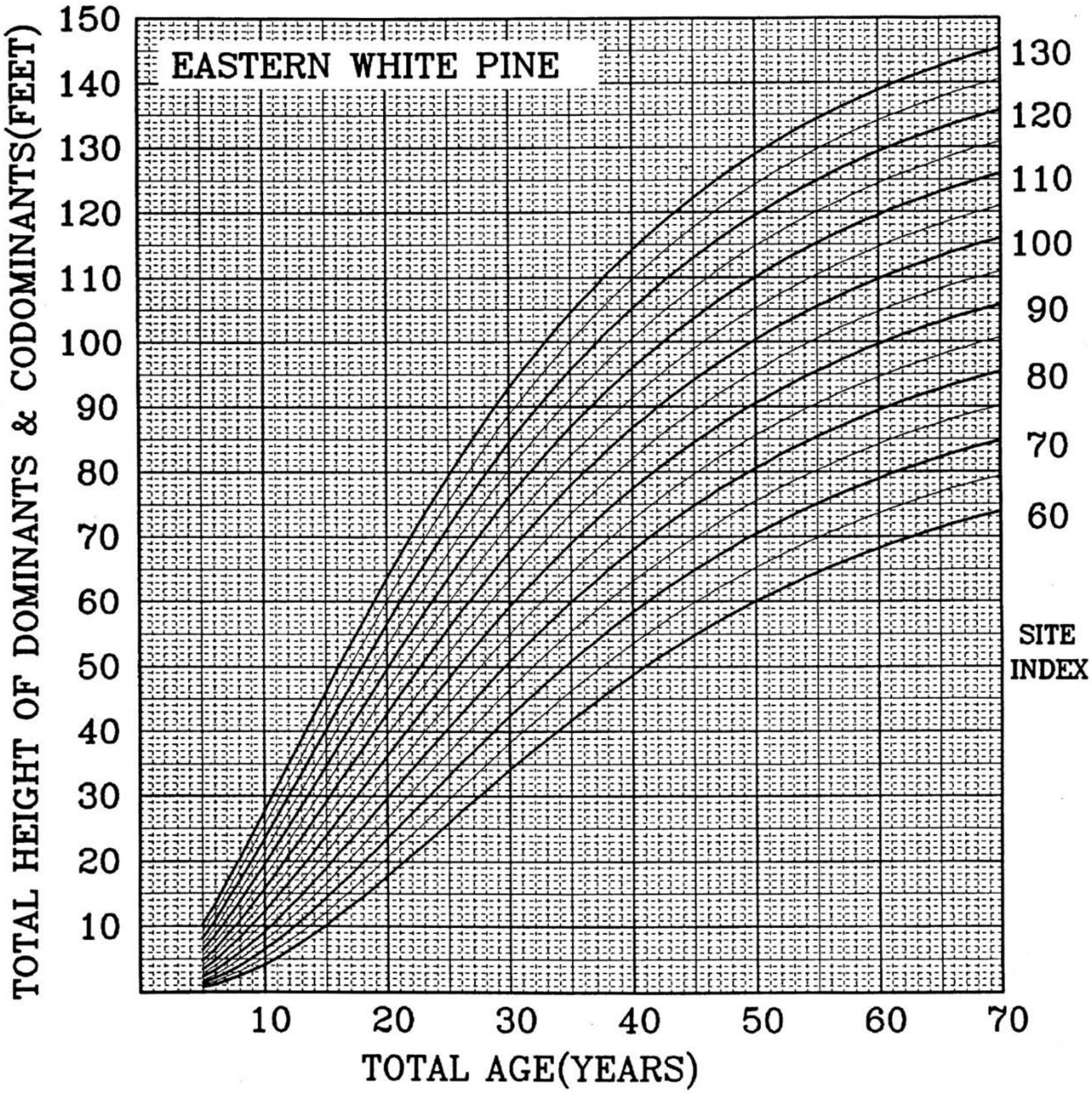

Figure 11.2. Example site index curve

3.1.1 Indicator Species

Plant indicator species are plants that, by presence, frequency, or vigor, indicate any particular property of the site, particularly of the soil. Different plant species have different environmental requirements and limitations for survival and growth. The presence of a species at a given location, particularly if abundant and vigorous, indicates that its habitat requirements are being met. For example, blue cohosh (*Caulophyllum thalictroides*) requires moist (mesic to wet-mesic) and nutrient rich soils to thrive, whereas sweetfern (*Comptonia peregrine*) commonly occurs on dry, nutrient poor soils. The abundance of either of these species across a forested site (rather than very small, isolated individual patches) indicates soil moisture and nutrient balances which influence the presence and productivity of other species, including trees. For example, potential productivity for sugar maple would be considered good for a forested site where blue cohosh is abundant, but poor where sweetfern is abundant.

3.1.2 Vegetation Associations

Vegetation associations group vegetation (i.e., plant communities) into types or kinds, based on systematic description of recurring vegetation patterns. These abstract vegetation types (typical communities) are defined and described in terms of floristic composition and structure, often including successional and developmental patterns, and environmental relationships. Vegetation development is both dependent on and modifies the environment; therefore, different vegetation associations have different environmental requirements and limitations for development. Descriptions of vegetation associations often include interpretation of management potentials.

Vegetation types are often developed through methods of classification or ordination. Classification groups sampled communities that are similar into types (i.e. group similar entities into clusters). Examples of vegetation classification systems include forest cover type and forest habitat type classification systems. Ordination interprets sampled communities in relation to one another according to their similarities and dissimilarities (i.e. represent relationships in a low-dimensional space). A classic example of vegetation ordination is the Vegetation of Wisconsin (1959) developed by John Curtis.

3.1.3 Cover Types

Forest cover types are categories of forests usually defined by dominant vegetation as based on percentage cover of trees. They are vegetation associations classified based on the dominant floristic composition (uniformity and abundance) of the forest overstory. The trees are the largest, most characteristic structures of these plant communities, and of utilitarian interest. Some tree species and cover types have similar environmental requirements and limitations.

3.1.4 Forest Habitat Type Classification System (FHTCS)

The forest habitat type classification system is a site classification system based on the floristic composition of plant communities. The system depends on the identification of potential climax associations, repeatable patterns in the composition of the understory vegetation, and differential understory species. It groups land units with similar capacity to produce vegetation. The floristic composition of the plant community is used as an integrated indicator of those environmental factors that affect species reproduction, growth, competition, and community development. This classification system enables the recognition of ecologically similar landscape units and vegetation communities.

A forest habitat type is an aggregation of sites capable of producing similar late-successional (potential climax) forest plant communities. Each recognizable habitat type represents a relatively narrow segment of environmental variation that is characterized by a certain limited potential for vegetation development. Although at any given time, a habitat type can support a variety of disturbance induced (seral) plant communities, the ultimate product of succession is presumed to be a similar climax community. Field identification of a habitat type provides a convenient label (habitat type name) for a given site, and places that site in the context of a larger group of sites that share similar ecological traits. The FHTCS provides a tool to improve the process of assessing site potential and evaluating management alternatives.

See Chapter 12 within this handbook for a more detailed description of the FHTCS in Wisconsin.

3.2 Soils

Soils and the forest litter layer are essential to tree growth, providing nutrients and physical support for trees, a medium for supplying water and air to tree roots, and sites for microbes and other soil fauna to decompose organic material and release nutrients. The physical, chemical, and biological properties of soils are all important in determining site productivity and forest composition. Most soil properties are related, directly or indirectly, to the geologic history of soil parent materials. An understanding of the geology of a site can provide insights into its productive potential.

Topography affects site productivity through moisture relationships. Sites on north and east-facing slopes are typically more mesic, supporting forests that have higher moisture and nutrient demands. Geologic processes are largely responsible for topography. Glacial features such as steep, hilly end moraines, gently rolling ground moraines, and nearly level outwash and lake plains have characteristic surface shapes related to glacial processes. The steep, dissected topography of the unglaciated area (also known as the “driftless area”) was formed by erosion processes over millions of years.

Physical properties of soils include texture, structure, porosity, density, drainage, and hydrology. Soils in Wisconsin vary widely in physical properties due to the different characteristics of parent materials. This variability includes loamy and clayey soils formed in glacial till and glacial lakebeds, stratified silty and loamy soils on alluvial plains along rivers and large streams, and droughty sand soils on glacial outwash deposits. Eroded soils occur on steep hillsides in the unglaciated area of southwest Wisconsin. Shallow soils overlying bedrock of igneous, metamorphic, and sedimentary origin are common in the unglaciated area and in other scattered locations around the state. An area near Lake Superior is formed of lacustrine clay interlayered with strata of sand, pushed up from Superior’s lakebed by glaciers. Wisconsin also has large areas of organic soils formed in wetlands. Many soils throughout the state are

overlain with an aeolian silt loam “loess cap” deposited by wind after glaciers melted, and the thickness of the loess deposit has a strong influence on soil productivity.
Soil chemical properties include nutrient status and rates of cycling, and pH. Biological properties refer to the organisms that live in soil and have a role in plant growth. These include mycorrhizae, other fungi, bacteria, and many invertebrates (Fisher and Binkley 2000). Chemical and biological properties are related to physical properties. Loam, silt, and clay soils typically have higher nutrient-holding capacities and, also, higher levels of biological activity due to the supply of moisture and nutrients.

3.2.1 Soils of Ecological Landscapes

The 16 Ecological Landscapes of Wisconsin provide a framework for a general description of the varying soil characteristics of the state. See the Ecological Landscapes of Wisconsin Handbook for more information (WDNR 2009b).

Soils of the Southwest Savanna and the Western Coulees and Ridges (WCR) Ecological Landscapes are similar to each other, but topography is steeper and more dissected in the WCR. Soils on hilltops and sideslopes are formed in loess over loamy to clayey residuum, or sandy to loamy colluvium. Many soils are shallow over limestone, dolomite, or sandstone. The dominant soil is well drained and silty with a silt loam surface, moderate permeability, and moderate available water capacity. Soil drainage classes range from well drained to moderately well drained, and soils typically have silt loam to sandy loam surface textures, moderate permeability, and moderate available water capacity. Some of the larger valleys, particularly in the northern part of the Western Coulees and Ridges, contain stream terraces deposited by outflow from glaciation and have soils formed in outwash sands. Soils of the narrower valleys are dominantly filled by silty and loamy residuum and alluvium. These soils range from well drained to very poorly drained and have areas subject to periodic flooding. Loess deposits are thickest near the Mississippi River, where some areas are mapped as having 8-16 feet of aeolian silt, and nearly all of these Ecological Landscapes has loess deposits at least two feet thick (Hole 1976). Loess forms a fertile soil with excellent moisture-holding characteristics, and floodplain soils with incorporated loess are highly productive. Upland ridges are also generally productive. Sideslopes, particularly on south- and west-facing slopes, tend to be dry and erodible, and their shallow depths to bedrock can limit management options. Johnson et al. (1993) note that the warmer and drier south- and west-facing slopes of this region are dominated by oaks and hickories, while the cooler and moister north- and east-facing slopes support central and northern hardwood tree species. Site indices for oaks and northern hardwoods on the dominant forest soils range from 62 to 74 feet (Johnson et al. 1993).

Soils of the Western Prairie Ecological Landscape are predominantly formed in loamy till glacial deposits, while some are in outwash. A loess cap of aeolian silt is 6 to 48 inches thick over the surface (Hole 1976). The dominant soil is well drained and loamy with a silt loam surface, moderate permeability, and moderate available water capacity. Beneath the silt loam loess cap, most soils are either a reddish-brown non-calcareous dense sandy loam till, or a brown calcareous non-dense loam till. Soil drainage classes range from well drained to somewhat poorly drained; soils generally have silt loam to sandy loam surface textures, moderate to very slow permeability, and moderate to high available water capacity. Some areas are shallow over bedrock of dolomite, sandstone or shale. This Ecological Landscape contains some outwash plain deposits, where soils are formed in loess or loamy alluvium over acid outwash sand and gravel, or entirely in outwash sand. Lowland soils are also present, and they are very poorly drained non-acid muck, poorly drained loamy till, or poorly drained outwash. The major river valleys have soils formed in sandy and loamy alluvium or non-acid muck. Drainage classes range from moderately well drained to very poorly drained, and some areas are subject to periodic flooding.

In the Southeast Glacial Plains Ecological Landscape, most upland soils are formed in brown or reddish-brown calcareous glacial till, ranging in texture from sandy loam to loam or clay loam. Some soils are outwash sands and gravels, or lacustrine clays and sands derived from Glacial Lake Oshkosh. A mantle of silty loess, originating from wind deposition during and after glaciation, is 6 inches to more than 48 inches thick in different parts of the Ecological Landscape (Hole 1976). Nearly all the soils are rich in calcium carbonates derived from the underlying dolomite bedrock and are highly productive. Some of the soils are reddish-colored because of the high iron content in sediments transported by glaciers from the Lake Superior basin. Upland soils range from well drained to poorly drained; they have very slow to rapid permeability and low to very high available water capacity. Most lowland soils are very poorly drained non-acid mucks, but some are silty or clayey lacustrine, or loamy till soils. Soils in the larger river valleys include loamy to silty alluvium, non-acid muck, and aeolian silts over acid outwash sand and gravel. Site indices for oaks and northern hardwoods on the dominant forest soils range from 53 to 70 feet, with lower productivity on soils with outwash in the substratum (Johnson et al. 1993).

Soils of the Southern Lake Michigan Coastal Ecological Landscape are typically loamy and clayey tills with high silt content, though near Lake Michigan there are lake plain soils formed in glacio-lacustrine clay deposits. Most soils have a thin surface layer of wind-deposited silt, six inches thick or less (Hole 1976). Upland till soils are dominantly brown calcareous silty clay loams; they are moderately well-drained with moderately slow permeability and high available water capacity. These are highly productive soils, enriched with organic material from the former prairie vegetation. Development has disturbed a large proportion of these soils, often removing the productive surface soil. The dominant soils have drainage classes of moderately well drained to somewhat poorly drained, surface textures of silt loam to silty clay loam, moderate to slow permeability, and high to very high available water capacity. Lake plain soils are formed in calcareous silty to clayey lacustrine material, with some sands deposited by wave action. Most lowland soils are very poorly drained non-acid muck or silty and clayey lacustrine. The major river valleys have soils formed in loamy to silty alluvium, drainage classes that range from moderately well-drained to very poorly drained, and areas that are subject to periodic flooding.

The Central Sand Hills Ecological Landscape has soils that are primarily sands in the northwest portion (Central Wisconsin Moraines and Outwash Subsection, 222Kb) and sandy loam tills in the southeast (South Central Wisconsin Prairie and Savannah Subsection, 222Kd). In the northwest, most soils formed in sandy glacial till, outwash, or lacustrine materials. The dominant soil has a loamy sand surface over sand, is well drained with rapid permeability, and has a low available water capacity. Some soils are calcareous. Drainage classes range from excessively drained to somewhat poorly drained, and soils generally have loamy sand to sandy loam surface textures, moderate to very rapid permeability, and moderate to low available water capacity. Most soils in the southeast formed in brown calcareous sandy loam till on moraines and drumlins. The dominant soil is well drained and loamy with a fine sandy loam surface, moderate permeability, and moderate available water capacity. The aeolian loess cap is 6 to 24 inches thick (Hole 1976). Soil drainage classes range from well drained to somewhat poorly drained, and soils generally have fine sandy loam to silt loam surface textures, moderate to moderately rapid permeability, and moderate available water capacity. Organic soils occur in wetlands throughout the Ecological Landscape. The major river valleys have soils formed in sandy to clayey alluvial material or non-acid muck. Their drainage classes range from moderately well drained to very poorly drained, and some areas are subject to periodic flooding.

Most soils in the Central Sand Plains Ecological Landscape were formed in deep sand deposits of glacial lacustrine or outwash origin or in materials eroded from sandstone hillslopes, sometimes with a surface of wind-deposited (aeolian) sand. Most of this area lacks a loess cap (Hole 1976). The deep sandy soils are typically excessively drained, with very rapid permeability, very low available water capacity, and low nutrient status. In lower-lying portions of the landscape, and where silty lacustrine material is close to the surface and impedes drainage, the water table intercepts the surface. Such areas are extensive in the western part of the Ecological Landscape, where soils may be poorly or very poorly drained with surfaces of muck or mucky peat. Thickness of these peat deposits ranges from a few inches to more than 15 feet (USDA SCS 1991). In the eastern part of the Ecological Landscape, outwash sand deposits are thicker and soils are higher above the water table. Here, many wet soils were ditched and drained and are now commonly irrigated for the growth of vegetable crops. Ditching and drainage has also taken place in other parts of the Ecological Landscape, and soil disturbance for cranberry beds is locally common. In the northwest portion of the Ecological Landscape, in the Neillsville Sandstone Plateau Subsection (222Rb), most soils formed in sandy or loamy hillslope alluvium or colluvium over Cambrian and Precambrian bedrock. These soils are typically somewhat poorly drained and sandy with a loamy fine sand surface. In major river valleys throughout the Ecological Landscape, soils were formed in sandy to clayey alluvium. Their drainage classes range from moderately well drained to very poorly drained, and some areas are subject to periodic flooding. Site indices for these soils range from 55 to 82 feet for pine species (Johnson et al. 1993).

Most soils in the Forest Transition Ecological Landscape are non-calcareous, moderately well drained sandy loams derived from glacial till, but there is considerable diversity in the range of soil attributes in this large Ecological Landscape. The area includes sandy soils formed in outwash, as well as organic soils, and loam and silt loam soils on moraines. There are many areas with shallow soils. Drainage classes range from poorly drained to excessively drained. Density of the till is generally high enough to impede internal drainage, so there are many lakes and wetlands. Soils throughout the Ecological Landscape have silt loam surface deposits of aeolian loess about 6 to 24 inches thick (Hole 1976). Lowland soils include very poorly drained non-acid muck, poorly drained loamy till or residuum, and poorly drained outwash. The major river valleys have soils formed in loamy alluvium or non-acid muck; they range from moderately well drained to very poorly drained and have areas subject to periodic flooding. In the St. Croix Moraine (Subsection 212Qa), most upland soils formed in reddish-brown non-calcareous dense sandy loam till on moraines, in loess over the till on moraines, in loamy alluvium over outwash sand and gravel on moraines and glacial drainageways, and in loamy to silty lacustrine material on lake plains. The dominant soil is moderately well drained and loamy with a sandy loam surface, moderately slow permeability, and moderate available water capacity. Soils of the Lincoln Formation Till Plain, Mixed Hardwoods (Subsection 212Qb), are mostly formed in outwash and in non-calcareous loamy till. The dominant soil is moderately well drained and loamy with a silt loam surface, moderate permeability, and moderate available water capacity. Most of the morainal upland soils in the north part of Subsection 212Qb formed in loess over reddish-brown non-calcareous dense sandy loam till. Most upland soils on the outwash plain in the center of the Subsection formed in loamy alluvium over outwash sand and gravel, or entirely in outwash sand. Upland soils at the southern end of the Subsection formed in brown non-calcareous loamy till on moraines, and in silty to loamy alluvium over residuum from sandstone and shale on pediments. Exposures of Paleozoic bedrock occur throughout the Subsection. In the Lincoln Formation Till Plain, Hemlock Hardwoods (Subsection 212Qc), most upland soils formed in loess over reddish-brown non-calcareous dense sandy loam till or brown non-calcareous non-dense sandy loam till on moraines, and in loamy and silty alluvium over acid outwash sand and gravel on glacial drainageways and outwash plains. The dominant soil is moderately well drained and loamy with a silt loam surface, moderately slow permeability, and moderate available water capacity. Soils range from moderately well drained to somewhat poorly drained and generally have silt loam surface textures, moderate to very slow permeability, and moderate available water capacity. In the Rib Mountain Rolling Ridges (Subsection 212Qd), most soils formed in loamy residuum or a mixture of residuum and till, or in outwash. The dominant soil is moderately well drained and loamy with a silt loam surface, moderate permeability, and moderate available water capacity. Most upland soils formed in non-calcareous loamy till or residuum from igneous and metamorphic rock. These soils range from well drained to somewhat poorly drained and generally have silt loam to sandy loam surface textures, moderate to moderately slow permeability, and moderate available water capacity. Igneous and metamorphic bedrock exposures are common. Site indices for some common soils in the Forest Transition range from 57 feet for red maple to 69 feet for northern red oak (Johnson et al. 1993). Upland soils of the Green Bay Lobe Stagnation Moraine (Subsection 212Ta) are formed in non-calcareous sandy loam and loamy sand till on moraines and drumlins, in loamy alluvium over acid outwash sand and gravel on moraines or outwash plains, and in outwash sand and gravel on outwash plains. The dominant soil is well drained and loamy with a sandy loam surface, moderate permeability, and moderate available water capacity. Soils range from excessively drained to somewhat poorly drained and generally have sandy loam to loamy sand surface textures (loamy sand being more typical in the southern part of the Subsection), moderate to very rapid permeability, and moderate to low available water capacity. Some soils have carbonates within a 6 foot depth, but in most soils the carbonates have leached to a deeper level. Site indices for Subsection 212Ta are higher than is typical for most of the Forest Transition, ranging up to 75 feet for northern red oak on productive soils. Aspen site index ranges from 67 to 76 feet (Johnson et al. 1993).

Most upland soils within the Northwest Sands Ecological Landscape were formed in acid outwash sand and gravel on former glacial spillway terraces and pitted outwash plains. The dominant soil is excessively drained and sandy with a sand surface, very rapid permeability, and very low available water capacity. Soils generally have sand surface textures; drainage classes range from excessively drained to somewhat poorly drained, permeability ranges from rapid to very rapid, and available water capacity is low. Xeric, droughty conditions are common on these soils. A few moraines occur in the northern, hilly portion of the Ecological Landscape, with soils formed in brown non-calcareous loamy sand till or mudflow sediments. These soils have greater nutrient availability and are slightly more productive. They range from well drained to moderately well drained and generally have loamy sand to sandy loam surface textures, moderately rapid to slow permeability, and low to moderate available water capacity. A former glacial lake plain in the southern part of the area has soils formed in gray calcareous lake sediment clay, some with a mantle of wind-blown sands. Another area in the southern part of the Ecological Landscape has soils formed in acid outwash sand over reddish-brown non-calcareous lake sediment clay over acid outwash sand. Wetland soils are typically very poorly drained acid peat or non-acid muck. The major river valleys have soils formed in sandy alluvium or non-acid muck, range from somewhat poorly drained to very poorly drained, and have areas subject to periodic flooding. Site indices for pine on a typical soil range from 55 to 60 feet (Johnson et al. 1993).

In the Northwest Lowlands Ecological Landscape, most upland soils formed in reddish-brown,non-calcareous, dense sandy loam to loamy sand till. Some soils formed in outwash sand and gravel. The dominant soil is moderately well drained and loamy with a sandy loam surface, moderately slow permeability, and moderate available water capacity. Soil drainage classes range from moderately well drained to somewhat poorly drained. They generally have sandy loam to silt loam surface textures, moderate to slow permeability, and moderate available water capacity. The dense till impedes water infiltration in some locations, creating wetlands. Many areas are underlain with igneous bedrock. Aeolian silt (loess) deposits on the surface typically range from 6 to 24 inches thick (Hole 1976). Most lowland soils are very poorly drained to poorly drained loamy till or non-acid muck. The major river valleys have soils formed in sandy to loamy-skeletal alluvium or in non-acid muck. Alluvial soils range from well drained to very poorly drained and have areas subject to periodic flooding. Soils of the disjunct portion of the Ecological Landscape, in southwest Burnett and northwest Polk Counties, are characterized by a fine sandy loam surface over calcareous sandy loam till. These soils are moderately well drained to somewhat poorly drained. The disjunct area also contains very poorly drained non-acid muck soils. Depending on the soil type, site indices for red maple can be around 56 feet, while northern red oak is 75 feet, and aspen ranges from 67 to 76 feet (Johnson et al. 1993).

Most upland soils of the Superior Coastal Plain Ecological Landscape are formed in reddish clay or silty clay loam till that was reworked from lake sediments and are slightly calcareous with pH values around 7 in B horizons, increasing with depth to around pH 8 in C horizons. The dominant soil is moderately well drained and clayey, with a clay loam surface, very slow permeability, and very high available water capacity. Soil drainage classes range from well drained to somewhat poorly drained. Surface textures are generally clay to silt loam; permeability ranges from very slow to moderately slow, and available water capacity ranges from moderate to very high. The fine texture and slow permeability of these soils gives them many of the functional characteristics of wetland soils, even when they occur on uplands.

Water moves out of them very slowly, and surface ponding from runoff can be common in basins and lower-lying areas. Special management considerations for many of these soils are warranted, as they are seldom completely dry. Along the higher elevations of the Ecological Landscape some wave-action sand is intermingled with the clayey till, making these soils unstable in cut banks. Loess deposits are less than 6 inches thick in this area (Hole 1976). Most lowland soils are poorly drained and are also formed in reddish calcareous clay to silty clay loam till. Soils in the major river valleys are formed in sandy to clayey alluvium and are moderately well drained to very poorly drained. Swamps, sloughs, and marshes along Lake Superior and in the Bibbon Marsh are very poorly drained non-acid muck or mucky peat. Site indices on typical soils range from 45 feet for white spruce to 72 feet for aspen (Johnson et al. 1993).

Upland soils of the North Central Forest Ecological Landscape are typically reddish-brown or brown non-calcareous glacial till, ranging in texture from loamy sand to sandy loam and loam. Some outwash sands are also present. Soils vary considerably due to differences in parent materials deposited by glaciation, and the influence of underlying material such as bedrock or older till. Upland soils range from well drained to somewhat poorly drained; they have slow to moderately rapid permeability and low to moderate available water capacity. A mantle of loess 6 to 24 inches thick covers nearly all of the area (Hole 1976). Topography can be steep in end moraines and drumlinized areas. Rocks of various sizes, including stones and boulders, are common on the soil surface at many locations. The Gogebic-Penokee Range has soils that are shallow to bedrock, as do the Blue Hills and a few other locations. Almost all of the Ecological Landscape is underlain by dense till that impedes drainage, so there are many areas of poorly and very poorly drained soils, and few areas of well drained soils. Organic soils are typically acid peat or non-acid muck, poorly or very poorly drained, and there are many additional wetland soils with a shallow water table in outwash sands or loamy alluvial deposits. Site indices on typical soils range from 57 feet for red maple to 75 feet for northern red oak (Johnson et al. 1993).

Most soils in the Northern Highland Ecological Landscape are formed in acid sands and gravels of glacial outwash origin, some with a loamy loess mantle (Hole 1976). The dominant soil is excessively drained and sandy with a loamy sand surface, very rapid permeability, and low available water capacity. Soil productivity, although lower than that of till soils, is still relatively high for outwash sands. Many of these soils are stratified with finer-textured glacial materials, so that drainage is less rapid and moisture availability is relatively high. Soils on outwash plains where fine-textured strata are not present tend to drain rapidly, leading to xeric site conditions and drought impacts. There are remnant moraines and drumlins in the Ecological Landscape, with loamier soils formed in glacial till. Large areas of the Ecological Landscape are wetlands, formed in kettle depressions, or in areas where the water table is held close to the surface by an underlying fine-textured soil layer. Most lowland soils are very poorly drained acid peat or non-acid muck, but there are also areas of poorly drained outwash sand. Site indices for pine on a typical soil range from 55 to 60 feet (Johnson et al. 1993).

The Northeast Sands Ecological Landscape has upland soils that were mostly formed in acid outwash sand on outwash plains or outwash heads. The dominant soil is excessively drained and sandy with a loamy sand surface, rapid permeability, and very low available water capacity. Overall, the soils range from excessively drained to somewhat poorly drained and generally have loamy sand to sandy loam surface textures, rapid to very rapid permeability, and low to very low available water capacity. Remnant moraines are present in part of the area, and they have soils formed in brown to reddish-brown non-calcareous to calcareous loamy sand, sandy loam and loam till. Igneous and metamorphic bedrock exposures are common in the northern part of the area. Most lowland soils are very poorly drained acid peat or non-acid muck. Site indices are similar to those given for the Northern Highland Ecological Landscape.

In the Central Lake Michigan Coastal Ecological Landscape, most upland soils formed in reddish-brown calcareous loamy till and lacustrine deposits on moraines and lake plains. The dominant soil is moderately well drained and loamy or clayey with a silt loam surface, moderately slow permeability, and high available water capacity. Drainage classes range from well drained to somewhat poorly drained. Soils generally have silt loam surface textures, moderate to very slow permeability, and moderate to very high available water capacity. Soils that are shallow to limestone or dolomite bedrock occur here. A few areas have soils formed in acid wind-blown sand. Along the Lake Michigan shoreline are soils formed in calcareous clayey and silty lacustrine and in acid to calcareous wave-action beach sand, silty to sandy lacustrine materials, and wind-blown sediments. Most lowland soils are very poorly drained non-acid muck, or poorly drained outwash, till, and lacustrine materials. The major river valleys have soils formed in sandy, loamy, or silty alluvium; some areas are subject to periodic flooding.

Most upland soils in the Northern Lake Michigan Coastal Ecological Landscape formed in brown to reddish-brown, calcareous to neutral loam or sandy loam till on moraines and drumlins. The dominant soil is moderately well drained and loamy with a silt loam surface, moderate permeability, and moderate available water capacity. Drainage classes range from well drained to somewhat poorly drained, and soils generally have silt loam to loamy sand surface textures, moderate to moderately slow permeability, and moderate to high available water capacity. Part of the area has upland soils formed in acid to calcareous outwash or wind-blown sand on outwash plains, lake plains, and former beach terraces. They range from excessively drained to poorly drained and generally have loamy sand to fine sand surface textures, rapid to very rapid permeability, and low available water capacity. Most lowland soils are very poorly drained non-acid muck, poorly drained loamy till, or poorly drained outwash.

3.2.2 Use of soil surveys for forest site productivity interpretations

Soil surveys include maps and descriptions of soils, along with interpretation tables that can be useful in assessing site productivity. There are limitations of soil classification based primarily on soil morphology because the influences of geologic landforms are not fully incorporated, and this contributes to variability in forest productivity within a map unit. Also, interpretations for SI provided with the soil surveys are sometimes based on a sample of a few trees regionally, so these SI values may not be accurate for some sites, particularly sites on soil map units of minor extent. See Rennie (1963), Carmean (1968, 1975), Jones (1969), and Grigal (1984) for further discussion of the uses and limitations of soil surveys in forest management.

The soil map unit is usually the area of interest in forest management since these are the units delineated on soil maps. Map units may be consociations, complexes, or undifferentiated groups. They are mapped at a scale of around 1:24,000. Usually, a map unit delineates one major component (consociation). Some map units include a combination of phases of two soils (complex). Occasionally, a map unit is based on a higher level of soil classification, such as 'Histosols', indicating that a group of soils have been mapped together (undifferentiated group). Users of soil surveys need to know which type of map unit their site is on, and how this affects variability and productivity.

A soil map unit consists dominantly of the soil for which it is named, but it also includes other soil components. A map at the scale of a soil survey cannot differentiate site-level variations that are too small to be drawn on the map (inclusions). Also, boundaries between soils are often gradual and cannot be plotted precisely on a map, so the areas of gradual change along boundaries may differ from the central part of the map unit. Some soils are so intermingled that they cannot be mapped separately, and some soils are similar enough with regard to use and management that they were not mapped separately. More information about the composition of soil map units can be found in the Soil Survey Manual, Chapter 2 (Soil Survey Division Staff 1993).

Consociations - A consociation is the most homogenous kind of map unit. Generally, at least half of the map unit is made up of the named soil component. Most of the rest of the map unit consists of soil components similar to the named soil, and major interpretations are not affected significantly. The total amount of dissimilar inclusions of other components in a map unit does not exceed about 15 percent if limiting (to management interpretations) and 25 percent if nonlimiting. The amount of dissimilar inclusions in an individual delineation of a map unit can be greater than this if no useful purpose would be served by defining a new map unit.

Complexes - Soil map units made up of complexes consist of two or more dissimilar components occurring in a regularly repeating pattern that cannot be mapped separately at the scale of soil mapping. The major components are sufficiently different in morphology or behavior that the map unit cannot be a consociation. Proportions of the major soil components may vary. The total amount of inclusions within a complex map unit that are dissimilar to any of the major components does not exceed about 15 percent if limiting and 25 percent if nonlimiting.

Undifferentiated groups - Undifferentiated groups consist of two or more components that are not consistently associated geographically and, therefore, do not always occur together within each mapped unit of the group. They are mapped together because use and management are the same or very similar for common uses. Often, steepness, stoniness, or flooding makes these soils similar for use and management.

When using soil survey information at the site level, the user should consider which type of map unit their site is on. If the map unit is a complex, it is important to know which components occur there and whether productivity may be lower or higher in different parts of the site. The possibility of inclusions should be considered on any type of map unit. The user should apply knowledge of glacial and erosional geologic processes and slope/aspect considerations; this will provide context for the soils information and help to understand soil variability.

3.2.3 Site level determinations using soils

Some forest managers will want to examine soils on their sites to get more detailed information than is available from the soil survey. Again, it is useful to first understand the geologic history of the site, including the type of soil parent material and geomorphic processes active during soil development. After this, texture, drainage (indicated by mottling), and pH are the most important site-level soil characteristics to consider in forestry applications in Wisconsin.

In general, loamy soils have moisture and nutrient status sufficient to support nutrient-demanding forest types such as northern hardwoods and oaks, while sandy soils generally support pine forests. Sandy soils with strata of fine-textured material, even when the strata occur at a depth below five feet, often have higher productivity than soils that are entirely sand. In soils of any texture, a high-water table will restrict forests to lowland types. The pH of soils varies considerably in Wisconsin depending on whether glacial deposits were enriched with limestone and dolomite, and although soils formed in acid tills will still support northern hardwoods and oaks, their growth will likely be slower than for a site on calcareous till.

Soil depth, horizon thickness, and color are other indicators of site productivity. Soils that are shallow to bedrock have less volume available for moisture and nutrient storage. Carbonate bedrock can contribute calcium and sometimes magnesium to soils, while volcanic bedrock and sandstone do not add to soil nutrients. Darker colors of surface horizons are usually associated with high organic matter content and nutrient status, although in recent years soil mixing by earthworms has changed these colors somewhat. Thicker surface layers (O, A, and B horizons) are also typically indicative of a higher nutrient status.

Soil bulk density is another indicator of productivity and can provide clues to past site impacts, but it is difficult to measure in the field. A higher than normal bulk density is a sign that compaction may have occurred, and this would be a factor to consider in choosing a prescription. Naturally dense soil layers, such as fragipans or basal till, may result in saturated conditions or seasonally perched water tables.

Because site conditions often vary from characteristics shown on soils maps, it is important for individuals making forest management decisions to evaluate the geology, topography, and soil at the site level. Site-specific information helps the manager develop individualized prescriptions to ensure that sites are utilized to best advantage, and that forest management activities retain the productive capacity of soils.

3.3 Ecological Site Classification

3.3.1 National Hierarchical Framework of Ecological Units

Wisconsin DNR’s Division of Forestry uses an ecological land classification system based on the National Hierarchical Framework of Ecological Units (NHFEU). The structure of the NHFEU was developed by staff of the USDA-Forest Service, in cooperation with federal and state partners (Cleland et al. 1997). The purpose of the classification is to distinguish land areas that differ from one another in ecological characteristics, specifically a combination of physical and biological factors including climate, geology, topography, soils, water, and vegetation. These factors are known to control or influence biotic composition and ecological processes and provide an approximation of ecosystem capability. Land areas identified and mapped based on these characteristics are known as ecological units. Maps of ecological units can be developed at many spatial scales, depending on the needs of the user. The maps, along with information about the ecological units, convey information about land characteristics and capability. An important application of this information is in planning for future land uses. Understanding an area's ecological characteristics informs management decisions about vegetation composition and structure, suitable wildlife species, and desirable recreational uses.

The National Hierarchical Framework of Ecological Units (NHFEU) is a hierarchical classification system. Ecological units at each spatial scale are nested within the broader scales. Appropriate uses of ecological units vary by scale. Table 11-1 shows the scales that have been developed within the NHFEU.

Table 11.1. Levels of spatial scale used in the National Hierarchical Framework of Ecological Units, and their applications. Scales used by WDNR are Province, Section, Subsection, and Landtype Association.

Ecological Unit	General polygon size	Map scale range	Application
Domain	1,000,000s of square miles	1:30,000,000 or smaller	National and international monitoring, assessment, modeling, and strategic planning.
Division	100,000s of square miles	1:7,500,000 to 1:30,000,000	National and international monitoring, assessment, modeling, and strategic planning.
Province	10,000s of square miles	1:5,000,000 to 1:15,000,000	National or multi-state monitoring, assessment, strategic planning and reporting. Cumulative effects analysis area for statewide or regional planning.
Section	1,000s of square miles	1:3,500,000 to 1:7,500,000	Multi-state, statewide or regional monitoring, assessment and strategic planning. Cumulative effects analysis area for Forest or County-level planning.
Subsection	10s to 1,000s of square miles	1:250,000 to 1:3,500,000	Statewide or regional monitoring, assessment and planning. Cumulative effects area for Forest, County, or project-level planning. Stratification for research and monitoring.
Landtype Association	1,000s to 100,000s of acres	1:60,000 to 1:250,000	Forest or County-level monitoring, assessment and planning. Cumulative effects area for project-level planning. Stratification for research and monitoring. Template for displaying ecological information to the public.
Landtype	10s to 100s of acres	1:24,000 to 1:60,000	National Forest project and management area monitoring, analysis, and planning. Template for displaying ecological information about projects. Stratification for research and monitoring.
Landtype Phase	Less than 100 acres	1:24,000 or larger	National Forest project area monitoring, analysis, and planning. Template for displaying ecological information about projects. Stratification for research and monitoring.

3.3.2 Provinces

The broadest spatial scale of the NHFEU used by WDNR is the Province level. Provinces are distinguished by climatic factors that control the distribution of biomes, such as solar radiation and continental precipitation patterns. Potential natural vegetation zones like those mapped by Kuchler often correspond with Province boundaries.

Province 212, the Laurentian Mixed Forest Province, encompasses the northern Lake States. Province 222, the Eastern Broadleaf Forest Province, includes southern Wisconsin as well as much of the central portion of the Eastern United States. The division between these Provinces corresponds to the area known as the "Tension Zone" in Wisconsin. Along this Zone, the northern coniferous-deciduous forest changes gradually into the southern oak forest/savanna and former prairie region.

3.3.3 Sections

Section-level ecological units are nested within Provinces. Sections are based primarily on climate and broad-scaled glacial or bedrock geology. Section boundaries in Wisconsin follow former glacial lobes of the Wisconsin glaciation and also separate the Driftless Area.

3.3.4 Subsections

Subsection-level ecological units are nested within Sections. Subsections in Wisconsin are often based on associated groups of glacial features such as morainal systems. In the parts of the state not glaciated during the Wisconsin Ice Age, patterns of topography formed by erosion on different bedrock surfaces are the basis for differentiating Subsections.

3.3.5 Landtype Associations

Landtype Associations (LTA's) are a level of the NHFEU that is used extensively in Wisconsin, primarily for property Master Plans and project-level planning. LTA’s are nested within Subsections. They are identified by surficial geology, patterns of vegetation, soil parent materials, and water tables (Jordan et al. 2001, Zastrow et al. 2001). LTA's are mapped at a landscape scale (1:60,000 to 1:250,000). Most LTA's in the Lake States are between 10,000 and 300,000 acres in size. In Wisconsin, they are usually based on glacial features like individual moraines or outwash plains. LTA's that are formed in outwash sand are often infertile and droughty, and support vegetation adapted to these harsh conditions. LTA's on moraines have nutrient-rich, moist conditions, and vegetation adapted to a rich environment.

LTA's can often be identified visually by trained individuals, because they are based on glacial features that form topographic features like hills, valleys, and plains. Some distinctive LTA's have local names (e.g. Harrison Hills), indicating that residents of the area recognize them as outstanding landscape features.

Many National Forests in the Lake States have used LTA boundaries as the basis for Management Areas and used LTA information to help describe ecological characteristics and capability. Goals for the Management Areas are developed so that vegetation objectives, wildlife management, and recreation uses will be suited to land capability. Regional Planning

Commissions and Counties have used LTA and Subsection information in similar ways for community planning projects.

LTA information can be used in project planning, to help describe the setting of the surrounding area, and particularly to address landscape considerations. The LTA is a suitable scale for examining the area around a proposed project, to see whether the project would contribute to landscape connectivity or provide a type of forest composition and structure that is scarce or declining (e.g., jack pine forest, hemlock and yellow birch, structurally complex stands). This is also an appropriate scale for examining whether a proposed project would have negative effects, such as fragmenting a large forested area, or creating a disproportionate amount of a single forest age-class.

Maps and tabular information about each LTA's are available on the WI DNR's website at: https://dnr.wisconsin.gov/ using the keyword "landscapes."

3.3.6 Landtypes and Landtype Phases

The Landtype and Landtype Phase levels of the NHFEU have not been developed in Wisconsin outside of the National Forests. A combination of Forest Habitat Types and soils are typically used for project planning and stand or site level management.

3.3.7 Ecological Landscapes

Ecological Landscapes are an application of the Subsection level of the NHFEU, used in the Ecological Landscapes of Wisconsin Handbook (WI DNR Handbook 1805.1). Some Subsections were combined, resulting in 16 Ecological Landscapes. These units are at a scale between the Subsection and Section levels of the NHFEU. The units are still relatively similar in certain ecological characteristics and management opportunities, and there are few enough of them that users can remember their general character and outstanding features.

Ecological Landscapes are primarily a tool for property-level planning, but there are applications for other types of projects, as well. The Handbook contains information about management opportunities that contribute to the ecological integrity of an area, and many of these opportunities can be implemented at the project level.

4 WATER TABLES & PRODUCTIVITY

Forests on sites that have a water table near the surface are sometimes subject to a rise in water tables after a harvest. The rise in water tables (also known as "swamping out", "watering up", or "wetting up") occurs due to the loss of transpiration by trees, and the loss of direct evaporation that occurs when trees intercept precipitation. Plant roots and soil organisms are directly affected by the lack of oxygen that results from a water table rise. Normally, oxygen needed for root respiration is obtained from air in soil pore spaces, and while water flowing through soil carries some oxygen (e.g., in floodplains), stagnant water in closed depressions is very poorly aerated. A rise in water table also limits nutrient availability, because the chemical reactions that oxidize soil nutrients to forms available to plants cannot occur under anaerobic conditions, and microbial decomposition is also limited by the lack of oxygen. Thus, a long-term rise in the water table can lower site productivity. Smerdon et al. (2009) provide an overview and description of the hydrologic effects of forest harvesting, and some management implications of water table changes.

Increases in water table levels after harvests have been observed in many locations. In Florida, water tables rose after slash pine harvesting (Riekerk 1989) and cypress harvesting (Bliss et al. 2002). Atlantic coastal plain sites in South Carolina exhibited water table rises after light selection, heavy selection, seed tree, and clearcut harvests (Williams and Lipscomb 1981, Xu et al. 2002) Clearcutting in Quebec raised water tables on seven of eight study sites, with wetland/upland transition zones being more susceptible to rises (Dube et al. 1995), and another Quebec study found a correlation between the percent basal area removed and the amount of increase in water tables (Pothier et al 2003). On fragipan soils in Idaho, the height, volume, and duration of perched water tables increased after canopy removal (Rockefeller et al. 2004).

Increases in soil moisture after harvest on susceptible sites can last for many years and inhibit regeneration (Pritchett 1979, p. 459, Dube et al. 1995). Water tables higher than pre-harvest levels were still apparent at the end of the monitoring period (4-8 years) for nearly all of the studies cited above, although some water levels showed partial decreases as vegetation re-grew.

Concerns for increased erosion and sediment transport, along with equipment limitations, have also been associated with changes in the water table, especially on soils shallow to bedrock or fragipans. Keppeler et al. (1994) noted a concern for slope stability due to increased moisture at the soil-bedrock interface that persisted for the four years monitored following clearcutting, and Rockefeller et al. (2004) described an increased potential for lateral transport, and issues with road suitability on fragipan soils.

Rises in the water table can be avoided by considering subsurface soil conditions and their effect on drainage and avoiding excessive harvesting on these sites. Swamping typically occurs on “moist, level to gently sloping sites where lateral drainage is restricted and impervious layers prevent downward movement of water” (Pritchett 1979, p. 459). Information on restricted and impervious layers can be found in soil map unit descriptions in Soil Survey Reports.

Some sites may be unsuitable for harvesting because of the potential for long-term loss of forest. Peterson and Peterson (1996) wrote, “…earlier investigators have noted the rise of water tables after aspen is harvested or burned. Elevated water tables reduce aspen suckering and sucker growth rates, in extreme cases creating sites no longer productive for future tree crops. In general, aspen should not be harvested in depressional areas, with the uncut stands left to support wildlife habitat and forest biodiversity management objectives.”

Practices that will limit water table rises to some extent during forest management include: maintaining a partial tree canopy, preserving understory vegetation, retaining woody debris, and limiting surface ponding. These practices are intended to allow some interception of precipitation and transpiration to continue after a harvest, and to facilitate drainage of surface water away from the site. For pine flatwoods in Florida, Riekerk (1989) recommends leaving more than half of the canopy. Dube et al. (1995) provided guidance for forested wetlands in Quebec. For these forests, made up primarily of Eastern white cedar, spruces, balsam fir, and red maple, strip clearcuts were not effective in preventing water table rises. Rather, “silvicultural treatments to maintain interception and transpiration by leaving logging debris, small trees, and preestablished regeneration would be more effective.” Dube et al. (1995) also noted the importance of preventing surface water ponding by careful layout of skid trails, the use of low-pressure equipment, and harvesting during frozen conditions. Other authors also note the need for caution in use of heavy equipment or road development in situations where water tables are elevated (Keppeler et al. 1994, Rockefeller et al. 2004). The use of planted “nurse crops” to promote evapotranspiration is an option to consider when regeneration has failed (Smerdon et al. 2009).

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Chapter 12

Forest Habitat Type Classification System

Last Full Revision: 2/11/2004
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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1 FOREST HABITAT TYPE CLASSIFICATION SYSTEM

The forest habitat type classification system (FHTCS) is a site classification system based on the floristic composition of plant communities. The system depends on the identification of potential climax associations, repeatable patterns in the composition of the understory vegetation, and differential understory species. It groups land units with similar capacity to produce vegetation. The floristic composition of the plant community is used as an integrated indicator of those environmental factors that affect species reproduction, growth, competition, and community development. This classification system enables the recognition of ecologically similar landscape units and vegetation communities. It is a system to classify forest plant communities and the sites on which they develop.

A forest habitat type is an aggregation of sites (units of land) capable of producing similar late-successional (potential climax) forest plant communities. Each recognizable habitat type represents a relatively narrow segment of environmental variation that is characterized by a certain limited potential for vegetation development. Although at any given time, a habitat type can support a variety of disturbance induced (seral) plant communities, the ultimate product of succession is presumed to be a similar climax community. Field identification of a habitat type provides a convenient label (habitat type name) for a given site, and places that site in the context of a larger group of sites that share similar ecological traits.

Individual forest cover types usually encompass a wide range of environmental conditions and do not accurately reflect site potential or respond predictably to given management techniques. In contrast, a habitat type is a group of ecologically similar sites in terms of vegetation potentials. Cover types combined with habitat types can comprise plant community types. Management interpretations can be refined and made significantly more accurate by evaluating a stand in terms of the current cover type (current dominant vegetation) plus the habitat type (potential vegetation).

Forest managers are often charged with the challenging task of assessing site potential and variability when developing management prescriptions and plans for forest stands and properties. The FHTCS provides a tool to improve the process of assessing site potential and evaluating management alternatives. Through application of the FHTCS, land managers are better able to assess site capabilities, identify ecological and silvicultural alternatives, predict the effectiveness of possible silvicultural treatments, evaluate feasible management alternatives, and choose appropriate management objectives.

The forest habitat type classification system serves the following basic functions:

- Management Interpretation -- It enables resource managers to develop long-term management objectives and specific prescriptions for manipulating vegetation based on knowledge of the ecological potential of the land.
- Communication - It provides managers and researchers with a common language for describing forest communities and sites.
- Research - It provides a framework for systematic gathering and interpretation of research data and empirical knowledge.

The Wisconsin Forest Accord is an agreement developed (1994) among agencies, forestry organizations, and conservation groups to provide support for the continued development, evolution, and application of the FHTCS and the National Hierarchical Framework of Ecological Units (NHFEU). It clarifies that these two ecological classification systems share objectives, are complementary, and can work together to achieve better resource communication. The FHTCS facilitates consistent assessment of ecological potentials; it provides a common language for interpreting site capabilities based on potential natural vegetation. The NHFEU divides landscapes into ecologically significant regions at multiple scales and facilitates ecosystem analysis, landscape assessment and planning, and inter-State communication and coordination. The FHTCS provides the vegetative component of the NHFEU in Wisconsin. Development of the Forest Accord has proven valuable in maintaining a consistent approach over time.

1.1 Wisconsin FHTCS Resources for System Application and Management Interpretation

1.1.1 Habitat Type Guides

The two Wisconsin habitat type guides apply to most upland forest sites and communities. Habitat types have not been defined for forested lowlands (poorly drained soils), some southern wet-mesic sites (somewhat poorly drained loams), or for some unusual (of relatively minor extent) forest site types. The guides outline basic concepts and methodologies. They include step-by-step instructions of how to accurately determine habitat types in the field with the use of the keys and tables. Plant identification is a skill critical to successful habitat type identification, therefore photographs and drawings of important understory plants are displayed. The guides include detailed ecological information pertaining to individual habitat types, groups of similar habitat types, and regional associations. Habitat types are described in terms of distribution, landforms and soils, common cover types, development of understory features, disturbance history, successional patterns, and management implications. In addition, the habitat type groups are similarly characterized and general management interpretations are presented. Each of the 11 habitat type regions is characterized individually. These two guides provide the basis for applying and interpreting the forest habitat type classification system in Wisconsin.

- *A Guide to Forest Communities and Habitat Types of Northern Wisconsin*, second edition, 2002, by John Kotar, Joseph A. Kovach, and Timothy L. Burger. Available through the University of Wisconsin-Madison, Department of Forest Ecology and Management.
- *A Guide to Forest Communities and Habitat Types of Central and Southern Wisconsin*, 1996, by John Kotar and Timothy L. Burger. Available through the University of Wisconsin-Madison, Department of Forest Ecology and Management.
- *Analysis of the 1996 Wisconsin Forest Statistics by Habitat Type*, 1999, by John Kotar, Joseph A. Kovach, and Gary Brand, USFS General Technical Report NC-207. Available through the USDA USFS North Central Research Station, St. Paul, Minnesota.

- *Wisconsin Forest Habitat Type Program*, 2004, by Peter Kourtz, John Kotar, Joseph Kovach, and Timothy Burger. Available through the Wisconsin Department of Natural Resources, Division of Forestry, Madison, Wisconsin.

1.1.2 Habitat Type Software

The Wisconsin Forest Habitat Type Program provides electronic version of most of the information contained in the two habitat type guides, and a program to identify habitat types based on entered plant lists. The information contained in the two habitat type guides has been synthesized and reorganized to limit repetition and to facilitate presentation and navigation within the electronic format. The plant photo library has been expanded.

The program to identify habitat types depends on individual plant lists that are compiled from relatively homogeneous forested sites. Most major vascular plants must be correctly identified. When accurate plant lists are collected and entered correctly, the program will correctly identify the habitat type about 80-90% of the time, which is similar to the expected accuracy of most well-trained field users. The second most likely habitat type is also identified, and the level of confidence in the computerized classification is presented. In application, the program can be utilized to confirm, check, or provide a “second opinion” of field designations. It also can facilitate the relatively rapid collection of large amounts of data by eliminating the need for field identification of habitat types; plant lists can be collected rapidly from many sites and then habitat type designation can proceed electronically. The program can help reduce significant habitat type identification errors associated with system misapplication by untrained users.

This software is available on compact disc and can be utilized through a disc drive or copied to a hard drive. Instructions (field and computer applications) and documentation are included. This software is not intended to replace the guides; it is intended to augment the classification system in Wisconsin.

1.1.3 Habitat Types and Forestry Inventory and Analysis (FIA)

During the early 1990’s most FIA forest land field plots and condition classes were visited to identify habitat types and collect plant species lists. Approximately 5600 plots were evaluated. The FIA analysis publications contain summaries and discussions of major statewide trends and management implications. Various forest attributes are summarized by habitat type. Detailed charts and tables are provided.

2 HABITAT TYPE REGIONS

The Wisconsin FHTCS subdivides the state into 11 habitat type regions (5 northern and 6 southern) to facilitate habitat type identification and interpretation (Figures 12.1 and 12.2). In addition, Door County (region 4) and the Baraboo Hills (region 7) are treated as unique subregions. Geographic floristic variation exists and warrants the delineation of region-specific floristic groupings (abstract associations). This approach allows for the construction of more reliable floristic identification keys and more precise descriptions of habitat type characteristics. Regional division is based on climate, geology, soils, physiography, and plant community composition. Because landscape floristic variation tends to be gradational, rather than

Previous View

abrupt, precise regional boundaries are difficult to determine. For convenience, counties were grouped into regions in such a way that each region can be characterized by at least one major natural feature. However, these regional boundaries are soft, and adjoining regions should be considered when applying the FHTCS near boundaries.

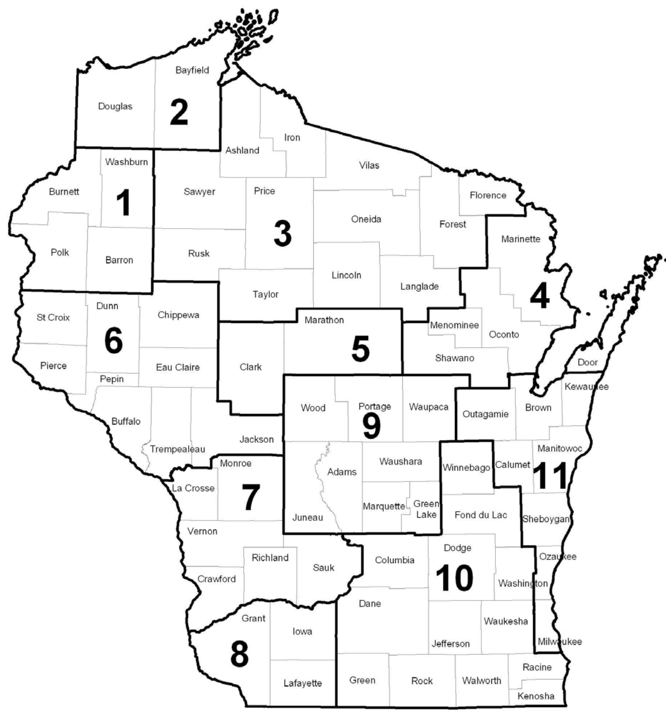

Figure 12.1. Wisconsin's 11 habitat type regions.

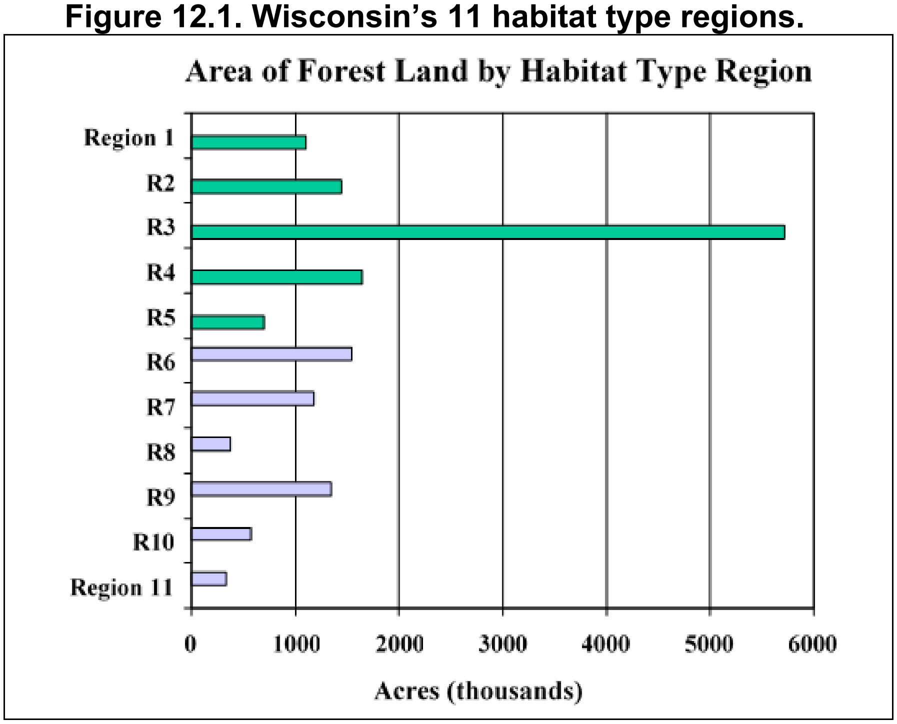

Figure 12.2. Area of forest land by habitat type region based on 1996 FIA.

3 HABITAT TYPE NAMING

Habitat types are named based on species characteristic of the potential climax community type or association. The habitat type name includes the name of the tree species most capable of perpetuating itself in the absence of disturbance, and the name of a characteristic or diagnostic understory species of that site type. An example habitat type name is *Acer saccharum*/*Hydrophyllum virginianum* (Sugar maple/Virginia waterleaf). The first part of the name (preceding the slash) represents the dominant tree species in the potential climax association. The second part of the name (following the slash) represents a characteristic and differential understory species. Sometimes two or three co-dominant climax tree species or two understory species are used in the name, resulting in a lengthy designation. Therefore, for brevity and convenience, abbreviations are normally used. For the preceding example, the abbreviation is AH.

It must be emphasized that habitat types are characterized by specific **plant associations** (definite combinations of species with predictable frequencies of occurrence relative to one another). Habitat types are NOT defined by individual "indicator" species. Casual users of the system often overlook this distinction. This can lead to misidentification of the habitat type and ultimately to mismanagement.

4 HABITAT TYPE GROUPS

Habitat types that represent similar positions on the moisture-nutrient gradient can be grouped. Within regions, some habitat types are more similar than others and for convenience can be grouped to discuss similar management interpretations. Between regions, floristically different habitat types can occupy similar positions on the moisture-nutrient gradient and be similar in terms of management implications. These similar habitat types have been organized into six northern groups and eight southern groups. The general position on the moisture-nutrient gradient of the habitat type groups and examples of some of the habitat types that comprise the groups are shown in Figures 12.3, 12.4, and 12.5. Following these three figures is a short description of each of the 14 habitat type groups. The area of forest land represented by each habitat type group and the average growing stock volume per acre that occurred on each group based on 1996 FIA are shown in Figures 12.6 and 12.7. The representation of major tree species across and within northern habitat type groups and their relative growth potentials are shown in Figures 12.8, 12.9, and 12.10; similar representations based on FIA data have not been developed for the southern groups. Tables 12.1 and 12.2 list all delineated habitat types by region and habitat type group.

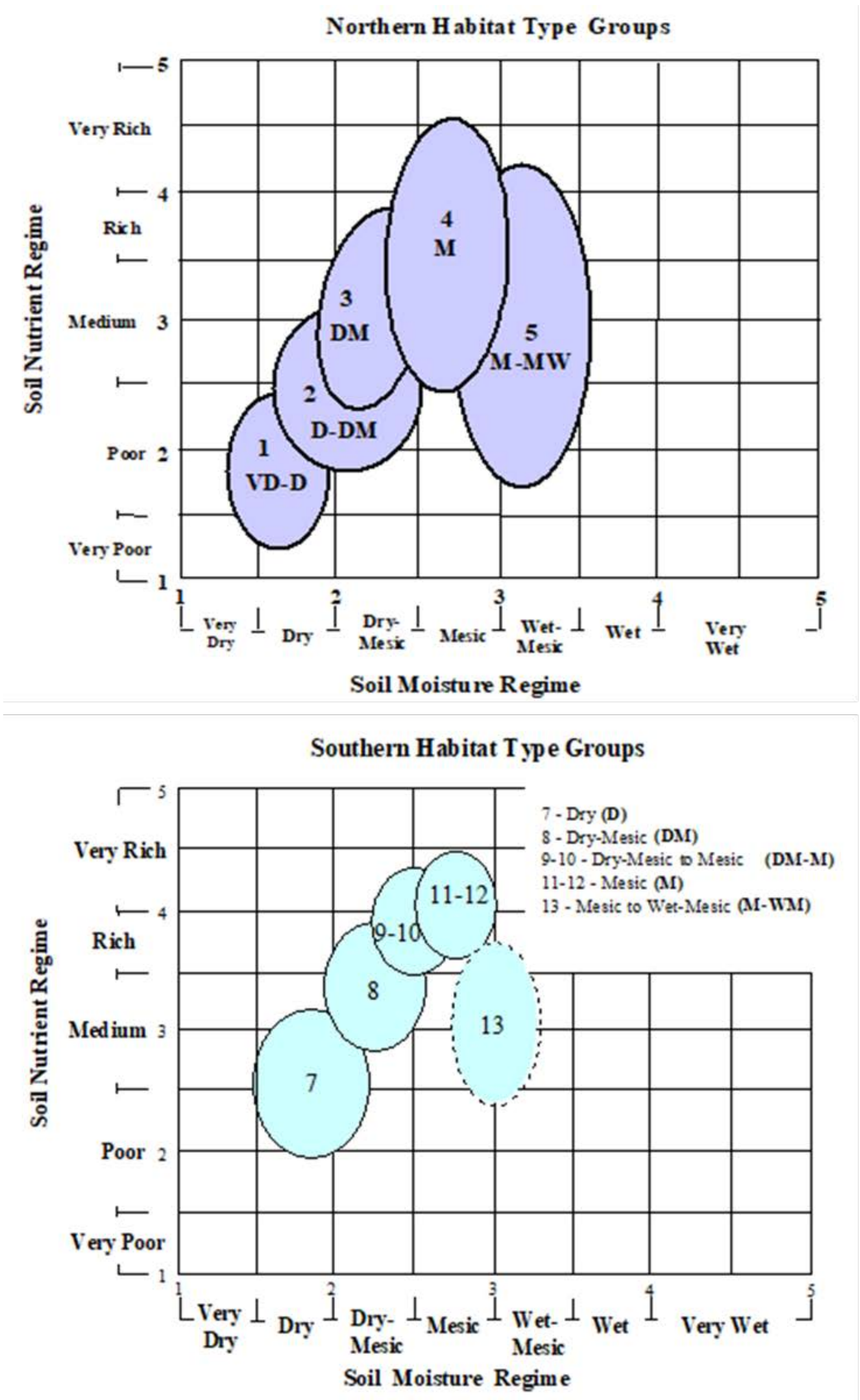

Figure 12.3. Relationship of habitat type groups to soil moisture and nutrient regimes in the northern and southern regions of Wisconsin. The position of each group is a composite of several individual habitat types. Forest lowlands (wet-mesic to wet habitat type groups 6 and 14) are not included, because habitat types have not been defined.

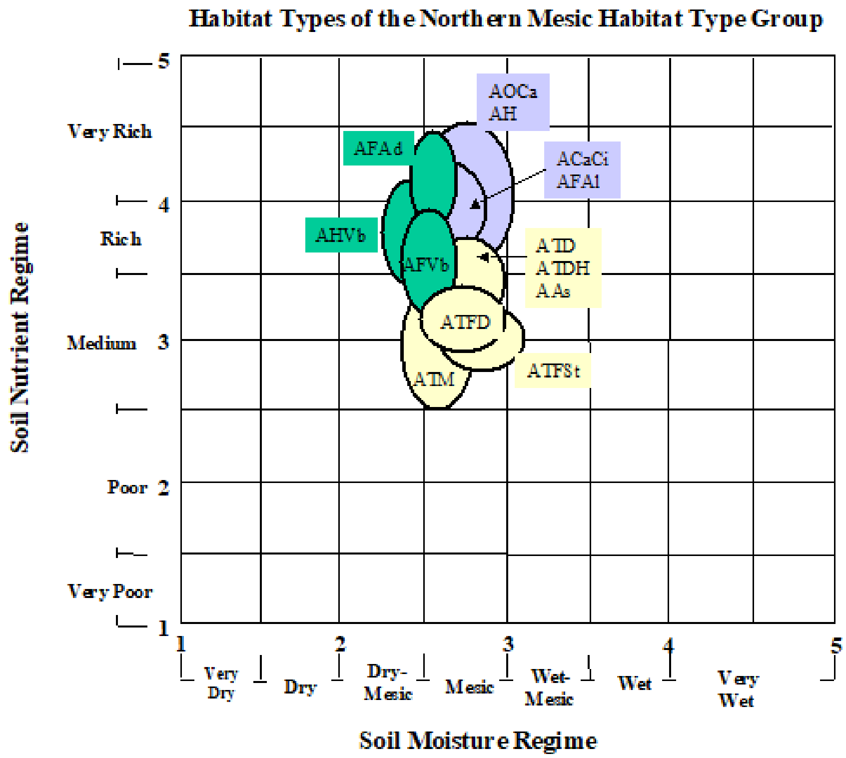

Figure 12.4. Habitat types comprising the northern mesic habitat type group (4), and their relationship to soil moisture and nutrient regimes.

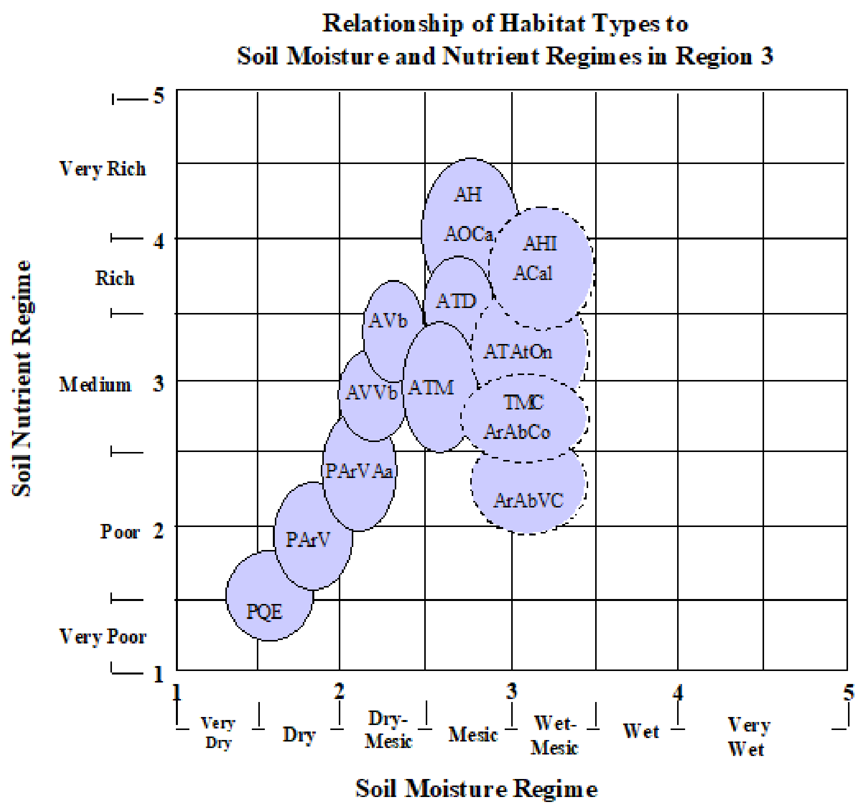

Figure 12.5. Habitat types of Region 3 (part of groups 1-5), and their relationship to soil moisture and nutrient regimes.

4.1 Northern Habitat Type Groups

4.1.1 Very Dry to Dry (VD-D) and nutrient poor

Habitat Type Series: White pine – Oak, White pine – Red maple
Habitat Types: PQE, PQG, PQGCe, PArV, PArV-U, PArVAo, QAp
This group represents the driest and most nutrient poor sites of the northern regions. Forests typically are dominated by pines (primarily jack and red) and poor to fair quality oak and aspen. White pine is sufficiently drought and shade tolerant, that where seed sources exist, it can assert dominance (with red maple and oak) in undisturbed middle to late successional stands. Red maple is the most shade tolerant species found on these sites, however it is intolerant of fire, relatively short lived, and as the sites become droughtier, development becomes poorer.

4.1.2 Dry to Dry-mesic (D-DM) and nutrient poor to medium

Habitat Type Series: White pine – Red maple
Habitat Types: PArVAm, PArVHa, PArVAa, PArVAa-Vb, PArVAa-Po, PArVPo
This group is a step up on the soil moisture-nutrient gradient from the preceding group. Forests typically are dominated by some mix of white pine, red pine, aspen, white birch, red oak, and red maple. White and red pine thrive on these types. White pine is sufficiently shade tolerant to reproduce naturally in mixed stands. Red maple is the most shade tolerant species found on these sites, however, compared to white pine, it is relatively short lived, small of stature, and less adapted to fire.

4.1.3 Dry-mesic (DM) and nutrient medium

Habitat Type Series: Sugar maple, Sugar maple – Hemlock – Beech
Habitat Types: AVVb, AVCl, TFAa, AVDe, AVb-V, ACl, AVb, AAt, ATFPo
Soil moisture and nutrients are adequate to support shade tolerant, mesic species such as sugar maple, basswood, and white ash, but not at their optimal developmental levels. Following major disturbance (e.g. fire, wind, logging), aspen, white birch, red oak, red maple, or white pine often assume dominance. Without significant disturbance, stands on these types tend to gradually succeed to mesic hardwoods.

4.1.4 Mesic (M) and nutrient medium to rich

Habitat Type Series: Sugar maple, Sugar maple – Hemlock, Sugar maple – Hemlock – Beech,
Sugar maple – Beech,
Habitat Types: AFVb, ATM, ATFSt, ATFD, AAs, ATD, ATDH, AHVb, AFAd, AFAl, ACaCi, AOCa, AH
This group represents the most favorable soil moisture-nutrient conditions in the region. Sugar maple and basswood are the most common dominants. Less shade tolerant species; such as aspen, white birch, red oak, and white pine; can gain temporary dominance only after a major disturbance, especially fire. Other common associates include red maple, white ash, yellow birch, hemlock, fir, and white spruce.

4.1.5 Mesic to Wet-mesic (M-WM) and nutrient poor to rich

Habitat Type Series: White pine – Red maple, Red maple – Balsam fir, Red maple, Sugar maple – Hemlock, Sugar maple
Habitat Types: PArVRh, ArAbVC, ArAbVCo, ArVRp, ArAbSn, ArAbCo, TMC, AAtRp, ASnMi, ATAtOn, ASaI, ACaI, AHI
This group typically occurs on somewhat poorly drained mineral soils (sands, loams, and clays), and represents a transition from upland to lowland forest. Because of the wide range of nutrient conditions, many species and cover types can occur. Early successional stands dominated by aspen or red maple (and sometimes white birch) currently are most common. In the absence of major disturbance, red maple, balsam fir, and white pine can exert dominance on the more nutrient poor sites, whereas mesic hardwoods (sugar maple, red maple, basswood, ashes, yellow birch) and hemlock can exert dominance on the more nutrient rich sites.

4.1.6 Wet-mesic to Wet (WM-W)

Habitat Type Series: none delineated
Habitat Types: none delineated
These are forested lowland sites. No specific habitat types have been delineated. Forests are dominated by swamp conifers (white cedar, balsam fir, black spruce, tamarack) and swamp hardwoods (black ash, red maple, aspen).

4.2 Southern Habitat Type Groups

4.2.1 Dry (D) and nutrient poor to medium

Habitat Type Series: White pine – Oak, White pine – Red maple
Habitat Types: PEu, PVGy, PVHa, PVCr, PVG
These types represent dry, relatively nutrient poor sandy soils, most commonly occurring within and around the central sands region. Pines, oaks, and aspen comprise most stands.

4.2.2 Dry-mesic (DM) and nutrient medium to rich

Habitat Type Series: Red maple, Sugar maple – Red maple, Sugar maple
Habitat Types: ArDe-V, ArDe, AQVb-Gr, ArCi, ArCi-Ph, AArVb, AArL
These habitat types represent better growth conditions for oaks and pines. Red maple also competes more strongly, and in the absence of major disturbance (e.g. fire, wind, logging) can assert dominance in late successional stands. Sugar maple does not compete well on these types, and its seed source generally is lacking.

4.2.3 Dry-mesic to Mesic (DM-M) and nutrient rich

Habitat Type Series: Sugar maple – Basswood – White ash
Habitat Types: ATiFrCi, ATiFrVb, ATiDe-Ha, ATiDe-As, ATiDe, AFrDe, AFrDeO

Red and white oaks grow well on these habitat types, and make up the largest volume in many present stands. Soil moisture and nutrient levels are adequate to support good growth of mesic hardwoods. In the absence of major disturbance and if seed sources are present, the mesic hardwoods can dominate late successional stands.

4.2.4 Dry-mesic to Mesic, Phase [DM-M(P)]

Habitat Type Series: Sugar maple – Basswood – White ash
Habitat Types: ATiDe(Pr), ATiFrVb(Cr), AFrDe(Vb), ATiCr(O), ATiCr(As)
These types represent soil conditions similar to those of the preceding group, but they experienced more frequent fires prior to European settlement. As a result, mesic hardwoods have been virtually eliminated from the landscape, and currently are not replacing oaks or other less tolerant species that dominate current stands.

4.2.5 Mesic, Phase [M(P)]

Habitat Type Series: Sugar maple – Basswood – White ash
Habitat Types: ATiFrCa(O), ATiAs(De)
These habitat types occupy soils similar to those of the following group, but they experienced more frequent fires prior to European settlement. As a result, mesic hardwoods have been virtually eliminated from the landscape, and currently are not replacing oaks or other less tolerant species that dominate current stands.

4.2.6 Mesic (M) and nutrient rich

Habitat Type Series: Sugar maple – Basswood – White ash, Sugar maple – Hemlock – Beech,
Sugar maple – Hemlock, Sugar maple – Beech
Habitat Types: ATiSa-De, ATiSa, ATTr, AFTD, AFH, ATiFrCa, ATiCa-Al, ATiCa-La, ATiCa, AFAs, AFAs-O, ATiH
This group represents mesic, nutrient rich sites that experienced relatively little fire disturbance prior to European settlement and continue to be dominated by mesic hardwoods. Management by light partial cutting and passive management favor sugar maple dominance.

4.2.7 Mesic to Wet-mesic (M-WM) and nutrient poor to rich

Habitat Type Series: White pine – Red maple, others not delineated
Habitat Types: PVRh, others not delineated
With one exception, specific habitat types have not been delineated. This group typically occurs on somewhat poorly drained mineral soils, and represents a transition from upland to lowland forest. Nutrient regimes can range from relatively poor on damp, sandy soils to relatively rich on damp, silty soils. Currently, stands are most commonly dominated by red maple, ashes, oaks, basswood, and aspen. In the absence of major disturbance, red maple and white pine can exert dominance on the nutrient poor sites, whereas mixed hardwoods can exert dominance on the richer sites.

4.2.8 Wet-mesic to Wet (WM-W)

Habitat Type Series: none delineated
Habitat Types: none delineated
These are forested lowland sites. No specific habitat types have been delineated. Forests are dominated by bottomland hardwoods, swamp hardwoods, and swamp conifers.

4.3 Summary Statistics and Other Figures and Tables

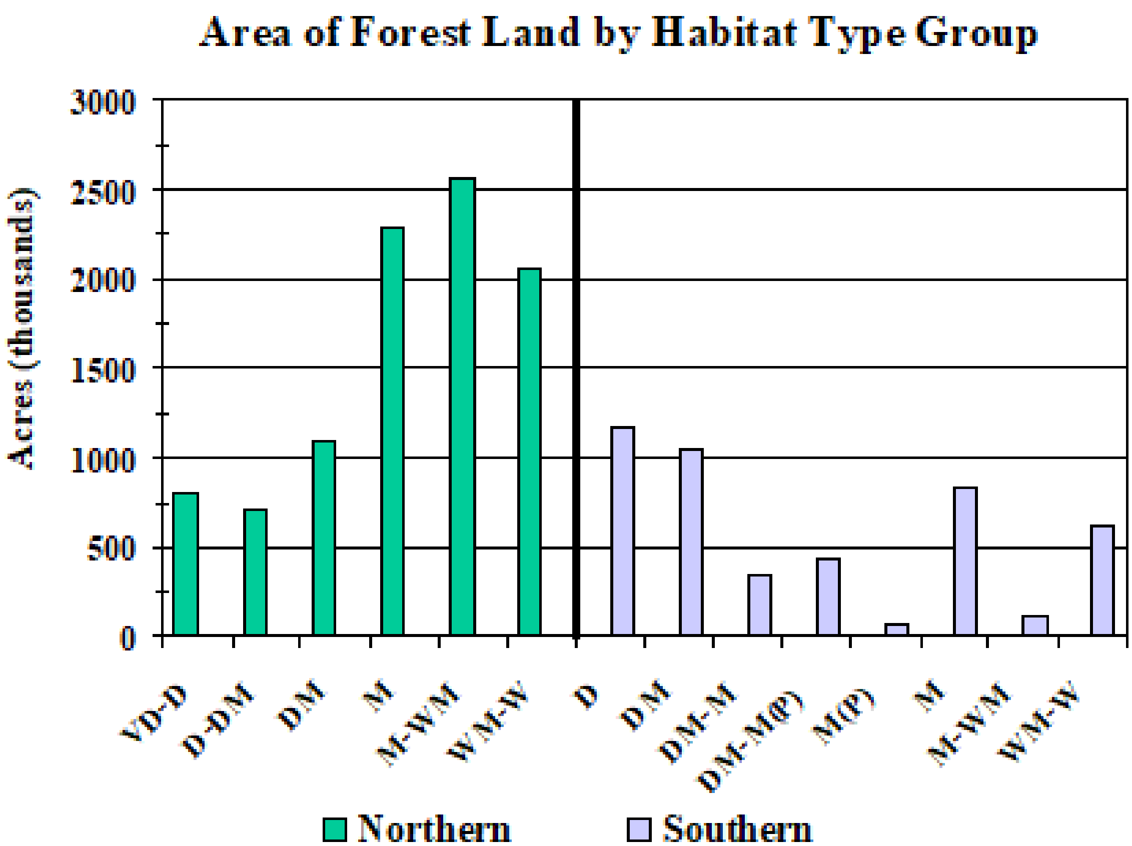

Figure 12.6. Area of forest land by habitat type group based on 1996 FIA

Approximately 2/3 of Wisconsin's forest land area is associated with northern habitat types, while 1/3 is associated with southern types. Three northern groups; M, M-WM, and WM-W; are predominant, and taken together represent nearly one-half of the total forest land base.

Previous View

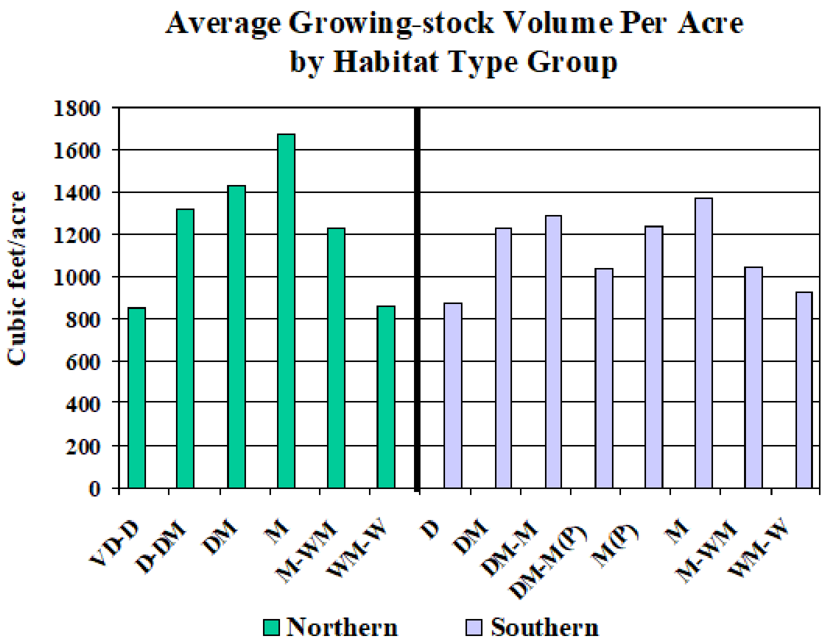

Figure 12.7. Growing stock volume per acre by habitat type group based on 1996 FIA

These volumes reflect the productive capacity of habitat type groups and collective management history. For the northern groups, the trends are reflecting primarily productive capacity. In the south, the effects of management history and pre-European settlement conditions are more evident, particularly in the two phase (P) groups.

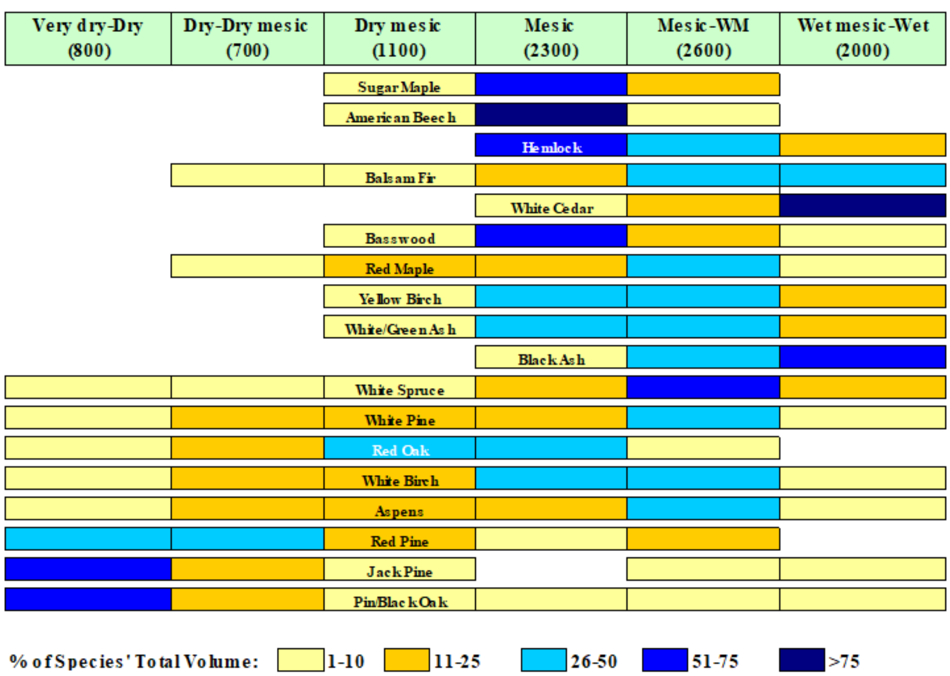

Figure 12.8. Representation of major tree species across (read in rows) northern habitat type groups as a percentage of species' total growing stock volume. Based on 1996 FIA. Numbers in parentheses are acres in thousands.

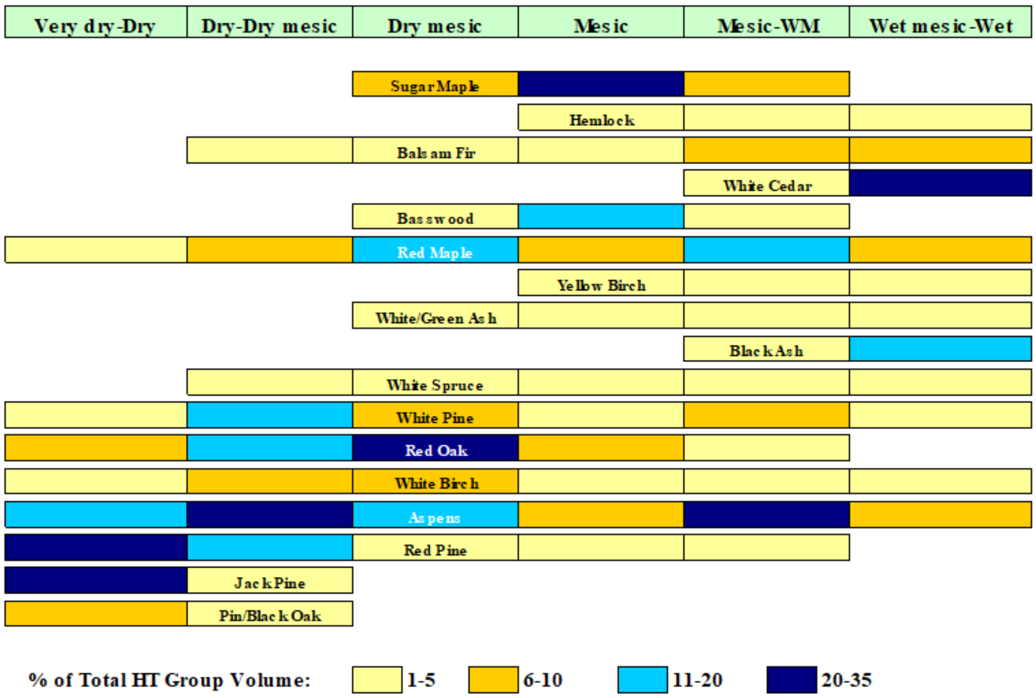

Figure 12.9. Representation of major tree species within (read in columns) northern habitat type groups as a percentage of total growing stock volume. Based on 1996 FIA.

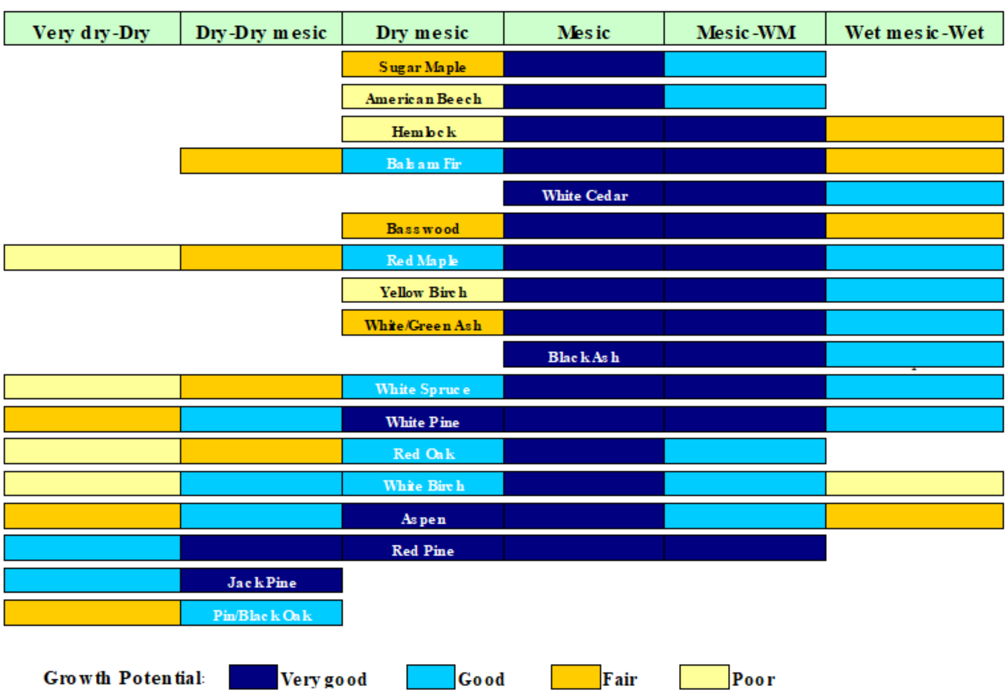

Figure 12.10. Relative growth potential of major tree species across northern habitat type groups. Only those habitat types where the species occurs naturally are considered.

Table 12.1. Northern habitat types by group and region. Within habitat type groups, habitat types are arranged top to bottom, from drier/poorer to moister/richer. Types in different regions but located on the same line are most similar in terms of management implications.

Habitat Type Group	Region 1	Region 2	Region 3	Region 4	Door Co.	Region 5
Very Dry to Dry	PQGCe QAp	PQG PArV-U	PQE PArV	PArVAo		
Dry to Dry-mesic	PArVAm	PArVAa-Po	PArVAa	PArVAa-Vb,PArVPo		PArVHa
Dry-mesic	AVDe AAt	AVCl ACl	AVVb AVb	AVb	TFAa ATFPo	AVb-V AVb
Mesic	ACaCi	ATM AAs	ATM ATD AOCa, AH	ATM AFVb ATFD ATDH AFAd AH	ATFSt AFAl	ATM AHVb AH
Mesic to Wet-mesic	ArVRp ASal	ArAbVCo ArAbSn AAtRp ASnMi	ArAbVC TMC, ArAbCo ATAtOn ACal, AHI	ArAbVC TMC ATAtOn AHI		PArVRh TMC ATAtOn AHI

Previous View

Table 12.2. Southern habitat types by group and region. Within habitat type groups, habitat types are arranged top to bottom, from drier/poorer to moister/richer. Types in different regions but located on the same line are most similar in terms of management implications.

Habitat Type Group	Region 6	Region 7	Baraboo	Region 8	Region 9	Region 10	Region 11
Dry	PVGy PVHa, PVCr	PVGy PVCr			PEu PVG		
Dry-mesic	ArDe-V AArVb ArCi, ArCi-Ph	ArDe-V ArCi-Ph	ArDe-V AArL		ArDe AQVb-Gr		
Dry-mesic to Mesic		ATiDe(Pr) ATiDe	 ATiDe-Ha ATiDe-As	 ATiCr(O), ATiCr(As)	ATiFrCi	ATiFrVb(Cr) ATiFrVb	AFrDe, AFrDe(Vb) AFrDeO
Mesic	ATiSa-De ATiCa-La	ATiSa ATiCa	 ATTr ATiCa-Al	 ATiAs(De) ATiH		ATiFrCa(O) ATiFrCa	 AFTD, AFH AFAs, AFAs-O
Mesic to Wet-mesic	PVRh	PVRh					

Previous View

Chapter 21

Natural Regeneration

WISCONSIN
DEPT. OF NATURAL RESOURCES

Last Full Revision: 1/4/2019
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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Last Full Revision: 1/4/2019
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1 NATURAL REGENERATION

The purpose of this chapter is to:

- Classify, define, characterize, and contrast natural regeneration methods and associated silvicultural systems that are commonly applied and generally accepted for the management of major forest cover types in Wisconsin.
- Identify forest cover types where each method/system is commonly applied.
- Clarify silvicultural terminology.

A ***silvicultural system*** is a planned program of vegetation treatment during the entire life of a stand. All silvicultural systems include three basic component treatments: tending, harvesting, and regeneration. Typically, silvicultural systems are named after the stand age class structure and the regeneration method employed (e.g. even-aged uniform shelterwood system).

Tending refers to treatment of the stand during the time period between stand origin and final harvest (intermediate treatments include release, thinning, improvement, pruning, and salvage). Not all managed stands require tending treatments.

Harvesting (logging) refers to the process of gathering a timber crop. It includes felling, skidding/forwarding, on-site processing, and removal of products from the site. *Cutting* (as part of logging) is the felling of trees or stands. *Harvest cutting* is an intermediate or final cutting that extracts salable trees. A *harvesting method* is a procedure by which a stand is logged, where emphasis is on meeting logging requirements while concurrently attaining silvicultural objectives.

Several terms are commonly used ambiguously when referring to forest management. In common usage, *cutting methods* are techniques for selecting which trees to cut. *Clearcutting* is the removal in one operation of essentially all the trees in a stand. *Partial or selective cutting* is the removal of only a portion of the trees in a stand. Used in this context, these cutting methods do not necessarily refer to a natural regeneration method (see unsustainable cutting methods discussion on page 24). In this chapter, the terms clearcut and selection refer to specific planned natural regeneration methods.

Regeneration (reproduction) refers to the seedlings or saplings existing in a stand. In silviculture, it is the act of renewing tree cover by establishing young trees naturally or artificially. *Natural regeneration* is the establishment of young trees through natural seeding, sprouting, suckering, or layering. *Artificial regeneration* is the establishment of young trees through planting or direct seeding (Chapter 22).

A ***regeneration method*** is a procedure by which a stand is established or renewed by means of natural or artificial reproduction. The various methods include the removal of the previous stand or cohort (usually involving a harvest), the establishment of a new one, and any supplementary treatments of vegetation, slash, or soil that are applied to create conditions favorable to the establishment of reproduction. A *regeneration cutting* is any removal of trees intended to assist regeneration already present or to make regeneration possible.

Stand age structure is an important characteristic used to characterize and classify stands and silvicultural systems. The three basic classified age structures are:

- *Even-aged*: A stand where the trees have only small differences in their ages (a single age class). By convention, the spread of ages does not differ by more than 20% of the intended rotation.
- *Two-aged*: A stand with trees of two distinct age classes, separated in age by more than 20% of rotation.
- *Uneven-aged*: A stand where the trees differ markedly in their ages, with trees of three or more distinct age classes either mixed or in small groups.
- Silvicultural systems and regeneration methods can be classified to systematize the description of the wide variety of procedures used in practice. *The following stand level (generally > 2 acres) classification of* **planned natural regeneration methods** *is based on the mode of origin of regeneration and on the arrangement of cuttings in space and time*. Gradations and hybrids between methods are inherent to the classification. Reserve trees can be included with any of the following even-aged methods (see Chapter 24).

A. **Even-aged Systems**

1. **Coppice Method**
    a. Simple Coppice
    b. Coppice with Standards
    c. Compound Coppice

2. **Clearcut Method**
    a. Uniform Clearcut
    b. Alternate (strip, patch) Clearcut
    c. Progressive (strip, patch) Clearcut

3. **Seed Tree Method**
    a. Single Seed Tree
    b. Group Seed Tree

4. **Overstory Removal Method**
    a. Uniform Overstory Removal
    b. Patch Overstory Removal

5. **Shelterwood Method**
    a. Uniform Shelterwood
    b. Strip Shelterwood
    c. Patch Shelterwood

B. **Uneven-aged Systems**

- **Single-Tree (Gap) Selection Method**
- **Group Selection Method**
- **Patch Selection Method**

The cover type chapters can be referenced for specific recommended regeneration methods and silvicultural systems. In general, the discussion of regeneration methods assumes that the stand management objectives include maintaining the current cover type, regenerating the stand promptly following harvest, and promoting stand vigor and health. When interpreting natural regeneration methods to encourage **cover type conversion**, refer to the guidelines for the target cover type; an adequate seed source or sprout/sucker stock must be available. When managing **mixed stands**, refer to guidelines for each individual cover type and adapt techniques that will facilitate each, either in patches or intermingled. Following the implementation of a regeneration method, it is necessary to assess the adequacy of regeneration and to determine the need for additional treatments.

In application, silvicultural systems are developed based predominantly on consideration of the silvical characteristics of the forest cover type, site potentials, and landowner goals. Stands and sites tend to be heterogeneous units and require adaptive interpretation and management. As stand and site characteristics vary, so do current management alternatives and potentials to meet different management objectives. General methods and systems can provide a guide to the development of stand level prescriptions but must be sufficiently flexible to respond to variable stand and site conditions and to facilitate adaptive silviculture to meet landowner goals and objectives.

2 EVEN-AGED SYSTEMS

2.1 Coppice Method

2.1.1 Definition and Description

A silvicultural method designed to naturally regenerate a stand using vegetative reproduction. Stump or root sprouts form the majority of the new stand although some seed origin reproduction may be present.

2.1.2 Characteristics

- The basic method results in even-aged stands; however, the variations can result in two-aged or multi-aged stands.
- Vegetative reproduction (low forest)
- Reproduction from stump sprouts or root suckers
- Potentially applicable to most hardwood species
- New stand regenerates after the existing stand is harvested

2.1.3 Contrast with Other Methods

Differs from other even-aged regeneration methods (seed tree, shelterwood, overstory removal, and clearcut) in that the regenerated stand is derived from vegetative reproduction rather than a seed source. Generally, there is no residual stand left as the residual can interfere with regeneration and is not necessary to shelter the regenerated stand. It differs from selection in that it is an even-aged system and the reproduction is not from seed. The method somewhat mimics catastrophic loss and replacement of a stand, but differs in the amount and distribution of residual trees and coarse woody debris.

2.1.4 Variations to This Method

1. **Simple coppice:** A complete harvest is applied to the entire stand to be regenerated. This variation produces a stand similar in composition to the parent stand except that any conifer component will be reduced. Results in even-aged stand.

2. **Coppice with Standards:** A complete harvest is applied to the entire stand with the exception of standards identified. The standards might be crop trees of the same species as the stand to be harvested but are often a different species. This variation can be used to slowly convert a stand to a different composition, to develop a seed-origin stand, or to manage mixed stands. It can result in a two-aged stand depending on the number of residual trees.

3. **Compound Coppice:** A modification of the coppice with standards method that incorporates two or more age classes of standards above the coppice stand. The age classes of the standards will be multiples of the rotation age of the coppiced stand. Results in two-aged or uneven-aged stand.

2.1.5 Application

Cover type specifics and applicability of the coppice method are addressed in appropriate cover type chapters of this Handbook. This method has potential to regenerate most hardwoods in Wisconsin. The most common use of the coppice method is in regenerating the aspens. It also is a recognized method to regenerate oak (on dry sites), red maple, and bottomland hardwoods. It may have potential for use in white birch and swamp hardwoods. No Wisconsin conifers respond to this regeneration technique.

General considerations in the application of the coppice method are:

- Spacing: For species reproducing from stump sprouts, spacing of the regenerated stand is determined by the spacing of the parent stand. For root suckering species, spacing of the parent stand is not as important of a factor.
- Sprouting capability: The vigor of the sprouting response varies with age and size of the parent trees. This response is species-specific and highly variable. In general, sprouting is most vigorous in trees that are experiencing their most rapid growth.
- Cutting season
- Site capability

- Competition
- Overstory composition, condition, and health

2.1.6 Advantages and Disadvantages

Advantages:
- Simple, dependable regeneration
- Efficiency of harvesting operations
- No site preparation is needed
- No delay in regeneration
- Growing space continuously occupied
- Longer time-period between entries reduces some vehicle impacts to soils

Disadvantages:
- Spacing of stump sprouts may contribute to poorly formed trees and an understocked stand
- Potential for water table changes on wet sites
- Higher windthrow potential (standards, adjacent stand)

Figure 21.1. Coppice with standards regeneration method - aspen regeneration (one year following harvest) with red pine standards (photo by Jeff Martin, J-Mar Photography)

2.2 Clearcut Method

2.2.1 Definition and Description

A silvicultural method used to regenerate a stand by removing most or all woody vegetation during harvest creating a completely open area leading to the establishment of an even-aged stand. Regeneration can be from natural seeding from adjacent stands or from trees cut in the harvest operation. Regeneration is established during or following stand removal.

2.2.2 Characteristics

- Even-aged
- Seed-origin (high forest)
- Used for shade intolerant, and exposure tolerant species
- New stand regenerates after the existing stand is harvested
- Best adapted for species that reproduce naturally after major disturbance

2.2.3 Contrast with Other Methods

Differs from seed tree and shelterwood regeneration methods in that no trees are left in the cut area for seeding purposes; rather, the seed source is from outside the cut area, or from the felled tops of harvested trees. Also, there is no overstory that offers protection to the regeneration. Differs from coppice in that regeneration in a clearcut is from seed. Unlike overstory removal, the regeneration in a clearcut is not present until after the harvest. Clearcut regeneration is even-aged, while that from selection methods is uneven-aged. This method partially simulates stand mortality due to major natural disturbance such as fire, but may be less patchy, removes all large wood, and produces different seedbed characteristics.

2.2.4 Variations to This Method

1. **Uniform Clearcut:** Entire stand is removed in one cut. Designed to regenerate the entire stand at the same time.

2. **Alternate Clearcut (strip or patch):** The stand is removed in two cuttings, occurring at separated periods in time. Generally, one half of the stand acreage is removed in each cutting. Cutting may be in a patchwork design or designated strips. The uncut area serves as a seed source. Stand removal is completed within a period of time, not exceeding 20% of intended rotation. The clearcut areas are best oriented so that they are at right angles to the direction of seed-dispersing winds.

3. **Progressive clearcut (strip or patch):** The stand is removed as above, except using a series of strips or patches harvested over three or more entries, usually covering an equal area on each occasion. The stand is removed within a period of time not exceeding 20% of intended rotation. In higher water table areas, this method may be chosen to reduce water fluctuations and reduce windthrow. In steeply sloping areas, this method may reduce erosion and windthrow.

2.2.5 Application

Cover type specifics and applicability of the clearcut method are addressed in appropriate cover type chapters of this Handbook. The clearcut method is a recognized method to regenerate jack pine, white birch, white spruce, balsam fir, black spruce, tamarack, cedar, and swamp hardwood cover types. It may have potential for use in regenerating aspen, oak, and central hardwood cover types. This method does not apply to red pine, white pine, black walnut, red maple, northern hardwood, hemlock, or bottomland hardwood.

General considerations in the application of the clearcut method are:

- Seeding characteristics of desired species: maturation, viability, dispersal, germination, good seed crop
- Site capability
- Seed/seedling needs for establishment and survival
- Site preparation
- Existing and potential competition

2.2.6 Advantages and Disadvantages

Advantages:

- Local, known seed source which is adapted to the site
- Efficiency of harvesting operations
- No preparatory harvest is necessary
- Maintenance of shade-intolerant species in the landscape
- Complete overstory removal can result in dense stocking and vigorous regeneration and growth for many species
- Logistically easier to treat the site to control undesirable vegetation
- Longer time-period between entries reduces some vehicle impacts to soils

Disadvantages:

- Timing relative to good seed years is difficult
- Coppice regeneration of unwanted species may dominate the site
- Dispersal, density and spacing pattern of desirable seed may be unsatisfactory
- Overexposure may cause seedling failure
- If regeneration is unsuccessful, seed source can be lost in uniform clearcut
- May require noncommercial cutting and extensive site preparation
- On wet sites, can have potential for water table changes
- Higher windthrow potential (strips, patches, adjacent stand)

A. Recent clearcut in jack pine.

B. Jack pine regeneration 8 years after clearcut.

Figure 21.2. Clearcut regeneration method applied in jack pine (photos by Clair Merrit, Purdue Univ., forestryimages.org)

2.3 Seed Tree Method

2.3.1 Definition and Description:

A silvicultural method designed to bring about reproduction on what are essentially clearcut harvest areas by leaving enough trees singly or in groups to naturally seed the area with adequate stocking of desired species in a reasonable period of time before the site is captured by undesirable vegetation. In this method only a few trees (typically 3 to 10 per acre) of the original stand are left, and this residual stocking is not sufficient to protect, modify, or shelter the site in any significant way. Seed trees may be removed after establishment or retained indefinitely.

2.3.2 Characteristics

- Even-aged
- Seed origin (high forest)
- Overstory does not significantly modify understory conditions
- Removal of overstory after establishment is optional
- Residual trees provide most of the seed to regenerate the site

2.3.3 Contrast with Other Methods

Differs from coppice regeneration methods in that regeneration comes primarily from seed rather than vegetatively. It differs from clearcuts in that the seed source for regeneration comes from residual trees within the harvest area rather than outside the cut area or relying on seed existing on or in the ground. It differs from a shelterwood in that the residual stocking is too sparse to modify the understory environment for seedling protection. Seed tree differs from overstory removal in that regeneration is not present before the stand is harvested. It differs from selection methods in that the regeneration is even-aged. The system mimics severe natural catastrophic events like wind or fire where only a few individual trees survive to propagate, however, most large wood is removed and seedbed characteristics are different from those created by natural disturbance.

2.3.4 Variations to This Method

1. **Single Tree**: The distribution of individual seed trees, typically 3 to 10 per acre, is fairly uniform across the stand.

2. **Group Seed Tree**: Clusters of seed trees are left as groups or strips distributed across the stand, but not exceeding 10% of normal full stocking level.

2.3.5 Application

Cover type specifics and applicability of seed tree method are addressed in appropriate cover type chapters of this Handbook. The seed tree method is a recognized method to regenerate white pine and jack pine. It may have potential to regenerate red pine, white birch, black walnut, red maple, white spruce, balsam fir, black spruce, tamarack, and cedar. This method does not apply to aspen, oak, central hardwood, northern hardwood, hemlock, swamp hardwood, or bottomland hardwood cover types.

General considerations in application of seed tree method are:
- Seed tree condition (phenotype), health, and composition (form, crown class, seeding potential, age)
- Seeding characteristics of desired species: maturation, viability, dispersal, germination, good seed crop
- Desired number of seed trees
- Site capability
- Seed/seedling needs for establishment and survival
- Site preparation
- Existing and potential competition
- Overstory composition, condition, and health

2.3.6 Advantages and Disadvantages

Advantages:
- Local seed source
- Efficiency of harvesting operations
- No preparatory harvest is necessary
- Seed source maintained in case of initial failure
- Fairly easy to treat the site to control undesirable vegetation
- Longer time period between entries reduces impacts to soils

Disadvantages:
- Potential loss of residual to wind and other environmental conditions
- Techniques of application are not well-developed for every species

- Timing relative to good seed crop difficult
- Added time for marking seed trees
- Regeneration density may be uneven
- May involve site preparation: chemical, mechanical, or prescribed burning
- On wet sites, can have potential for water table changes

Figure 21.3. Pine regeneration following application of the seed tree regeneration method (computer image by Andrew Stoltman, Univ. Wisc., Dept. For. Ecol. & Mgmt., Madison)

2.4 Overstory Removal Method

2.4.1 Definition and Description

A silvicultural method in which the stand overstory is removed in one cut to provide release of established seedlings and saplings. This method has also been referred to as a natural shelterwood or a one-cut shelterwood.

2.4.2 Characteristics

- Even-aged
- Seed origin (high forest)
- Release of established natural regeneration
- Overstory inhibits advancement of seedlings and saplings
- Overstory may be low or high quality
- Used for shade tolerant, mid-tolerant, and intolerant species
- Often used for species conversion or quality improvement

2.4.3 Contrast with Other Methods

Overstory removal results in an even-aged stand structure as opposed to uneven-aged. It differs from the clearcut and the coppice regeneration methods in that seedling and sapling regeneration is established prior to overstory removal. It differs from the shelterwood and seed tree methods in that no manipulation of the overstory is needed to establish regeneration. This method mimics natural deterioration of the overstory, but at an accelerated rate, with the entire overstory removed in a relatively short period of time, and most coarse woody debris removed.

2.4.4 Variations to This Method:

1. Uniform Overstory Removal: Entire stand overstory is removed in one cut, releasing well-distributed established advance regeneration.

2. Patch Overstory Removal: An overstory removal where established advance regeneration is released in patches, usually 1-2 acres in size. The entire stand is regenerated using a series of patches harvested over two or more entries, and within a period of time not exceeding 20% of intended rotation.

2.4.5 Application

Cover type specifics and applicability of overstory removal are addressed in appropriate cover type chapters of this Handbook. Overstory removal can be applied to any cover type if adequate, well established advanced regeneration is established.

General considerations in the application of the overstory removal method are:
- Overstory health, condition and composition
- Adequate stocking, distribution, vigor, and desirability of established, advance regeneration
- Existing and potential competition
- Protection of advance regeneration from harvest damage
- Site capability
- Patch overstory removal may be necessary on wet sites to reduce the chance of raising the water table, causing damage or mortality to regeneration

2.4.6 Advantages and Disadvantages

Advantages:
- Relatively simple to establish the timber sale
- Local seed source
- Site preparation is not needed
- Advancement of established and acceptable seedling population adapted to the site
- Resprouting ability of damaged hardwood regeneration
- No delay in regeneration; growing space continuously occupied

Disadvantages:
- Inability of conifer regeneration to resprout following damage

- Careful harvesting to minimize damage to the new stand will be needed

Figure 21.4. A red pine stand with well-established and well distributed white pine (and some oak) advance regeneration in the understory. This regeneration became established following past red pine thinnings. If this red pine stand were at rotation age, then the entire stand overstory could be carefully harvested in one cut to release the advance regeneration (even-aged overstory removal regeneration method).

2.5 Shelterwood Method

2.5.1 Definition and Description

A silvicultural method used to regenerate a stand by manipulating the overstory and understory to create conditions favorable for the establishment and survival of desirable tree species. The method is designed to regenerate an even-aged stand and normally involves removal of most of the overstory, in two or more cuttings, after the new stand is established. The overstory serves to modify understory conditions, create a favorable environment for reproduction, and provide a seed source. A secondary function of the overstory is to allow further development of quality overstory stems during seedling establishment to increase the efficient use of growing stock. The system is characterized by a preparatory cut (optional), seeding cut(s), and overstory removal. The most vigorous trees are normally retained and less vigorous trees removed.

2.5.2 Characteristics

- Even-aged
- Seed origin (high forest)
- Overstory modifies understory conditions - protects natural reproduction
- Overstory is removed only after regeneration established
- Method allows for variations in regeneration over space and time
- Overstory generally provides most seed

2.5.3 Contrast with Other Methods

Initial shelterwood cuttings usually resemble heavy thinnings. Natural reproduction starts under the protection of the older stand and is finally released when it becomes desirable to give the new stand full use of the growing space. This method differs from uneven-aged, selection methods in that it promotes an even-aged stand structure. It differs from clearcutting and coppice methods in that the next stand is established on the site prior to overstory removal. Shelterwood differs from seed tree cutting in that the overstory serves to protect the understory as well as distributing seed. The system partly mimics natural deterioration of the overstory, only at an accelerated rate, but is dissimilar because most coarse woody debris is removed.

2.5.4 Variations to This Method

1. **Uniform Shelterwood:** A shelterwood method applied to the entire stand, designed to regenerate the entire stand at the same time.

2. **Strip Shelterwood:** A shelterwood method in which the stand is regenerated in strips progressing across the stand over a period of time. Regeneration cutting is concentrated in certain strips.

3. **Patch Shelterwood:** A shelterwood method in which the stand is regenerated using patches 1-2 acres in size. Regeneration cutting is concentrated in certain patches.

2.5.5 Application

Cover type specifics and applicability of the shelterwood method are addressed in appropriate cover type chapters of this Handbook. The shelterwood method is a recognized method to regenerate the white pine, white birch, oak, red maple, central hardwood, northern hardwood, hemlock, white spruce, balsam fir, black spruce, cedar, swamp hardwood, and bottomland hardwood forest cover types. The shelterwood method may have potential for use in regenerating jack pine, red pine, black walnut, and tamarack. This method does not apply to aspen.

General considerations in the application of the shelterwood method are:

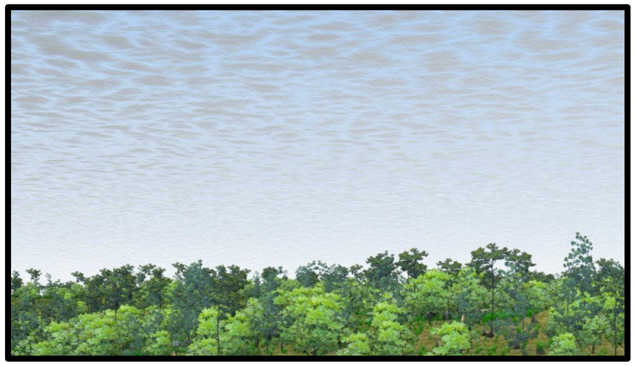
- Site evaluation (suitable to meet nutrient-moisture needs of species)
- Level/intensity of competition
- Overstory condition, health, and composition
- Seed tree condition (phenotype), health, and composition (form, crown class, seeding potential, age)
- Determination of existing stand maturity
- Evaluation of existing reproduction
- May involve a preparatory cut
- Conduct seeding cut - allow stand to develop
- Seedbed preparation
- Control competition during good seed year (fire, mechanical, chemical)
- Monitor understory development

- Conduct removal cut

A. An even-aged sawtimber hardwood stand near rotation age.

B. The same stand soon after a shelterwood seeding cut to encourage oak reproduction.

C. Five years later, the advanced regeneration is becoming well established.



D. The overstory has been removed to release the young oak stand and provide free-to-grow conditions. At this stage, full sunlight optimizes growth and vigor.

Figure 21.5. Even-aged uniform shelterwood regeneration method (computer images by Andrew Stoltman, Univ. Wisc., Dept. For. Ecol. & Mgmt., Madison)

2.5.6 Advantages and Disadvantages

Advantages:
- Local, known seed source
- High seedling numbers
- Higher seedling/stand diversity
- Can be repeated if unsuccessful
- Reproduction generally more certain and complete than clearcutting or seed tree
- Overstory develops more rapidly and achieves larger size

Disadvantages:
- Techniques of application are not well-developed for every species

- Requires technical skill to apply this method
- May involve chemical use, scarification, noncommercial cutting or prescribed burning.
- More careful logging practices often required in overstory removal to protect understory.
- Seed or preparatory cuts may require care
- Timing to seed crop
- Added time for timber sale establishment

3 UNEVEN-AGED SYSTEMS

3.1 Single-Tree Selection Method

3.1.1 Definition and Description

A silvicultural method designed to regenerate and maintain uneven-aged stands by consistently removing trees in all size classes throughout the stand at regular intervals. Single tree selection stands are maintained at each stand entry by:

- establishing or releasing new age classes
- tending trees to facilitate continual development of quality growing stock
- harvesting mature trees to reallocate growing space to new age classes.

For stands managed with the single tree selection method; regeneration, tending, and harvesting occur at each stand entry. To accomplish these goals, trees are removed singly or in small groups, creating regeneration openings (canopy gaps). Each regeneration opening covers an area equivalent to the crown spread of a one to several large trees. The spacing of regeneration openings is irregular based on the location of:

- mature trees eligible for harvest
- groups of undesirable trees (risk, vigor, quality, species)
- groups of trees from diameter classes with a surplus relative to target stocking levels
- the presence of advance regeneration.

Residual stand stocking is regulated by age (or size) class and generally maintained at a target level to promote development of quality boles (timber) and fully utilize the site. The target condition is usually defined by a combination of factors including a residual basal area (B), a maximum stand diameter (D), and a desired diameter distribution (q). This is known as the BDq regulation method. Based on cover type (species composition), site capabilities, stand history, and landowner objectives, single tree selection allows for variation in each factor with each stand entry.

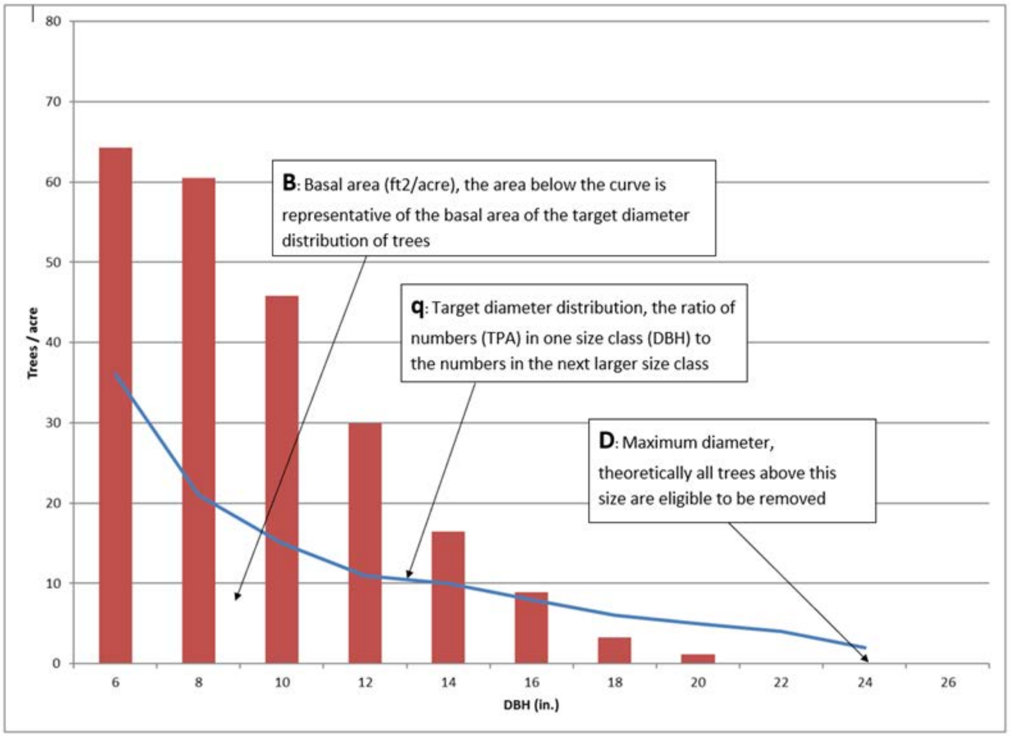


Figure 21.6. Example stand diameter distribution illustrating BDq method: B = basal area of the target diameter distribution of trees (not illustrated), D = maximum diameter, and q = target diameter distribution.

3.1.2 Characteristics

- Stand structure is relatively stable, overstory is never completely removed
- Regeneration openings are generally small, designed to recruit new age classes
- Mimics natural mortality and disturbance (e.g. senescence and low to moderate severity windthrow), but is more regulated and homogeneous
- Overstory provides a seed source, and modifies understory conditions to create a favorable environment for the reproduction, competition, and growth of shade tolerant tree species
- Regeneration is generally derived from seed origin or advance regeneration although a component can be vegetative
- Favors regeneration and maintenance of shade tolerant species
- Regeneration openings (canopy gaps), tending, and harvesting mature trees usually occur at each entry

3.1.3 Contrast with Other Methods

Single-tree selection is an uneven-aged silvicultural system; natural reproduction is established and develops in association with a permanent multi-aged overstory. In practice the single-tree selection method may resemble even-aged thinning as both select individual trees for removal or retention. Single tree selection and thinning however have different aims. Thinning does not aim to establish or release regeneration as it is not a regeneration method. Thinning also differs from single tree selection as it does not specify trees for removal or retention based on a specified target structure.

Like single tree selection, the group and patch selection methods create regeneration openings. Group and patch selection however have larger regeneration openings and regulate the distribution of age/size classes based on area occupied by cohorts of each age/size class (i.e. area regulation). Single tree selection regulates the distribution of age/size classes based on a target diameter distribution with trees of different age/size classes dispersed throughout the stand.

3.1.4 Variations to This Method:

The single tree selection method is most commonly applied when managing northern hardwood stands. In Wisconsin, many northern hardwood stands are even-aged and have an unbalanced age structure, lacking size classes or age difference between size classes. Stands that are even-aged or two-aged may be converted to single tree selection by combining tending, and canopy gap installation. The recommended procedure to adapt even-aged northern hardwood stands to single tree selection is adapted from Argonne Experimental Forest studies (USDA Forest Service 2005, Erdmann 1986).

3.1.5 Application

Cover type specifics and applicability of the single-tree selection method are addressed in appropriate cover type chapters of this handbook. This method is a recognized method to regenerate the northern hardwood and hemlock forest cover types. The single-tree selection method may have potential for use in regenerating the swamp hardwood, red maple, balsam fir, black spruce, and cedar cover types. The method is not applicable to jack pine, red pine, white pine, aspen, white birch, oak, black walnut, central hardwood, white spruce, tamarack, or bottomland hardwood cover types.

General considerations in the application of the single-tree selection method are:

- Site suitable to silvics and regeneration requirements (moisture, nutrients, light, heat) of desired species
- Seedbed requirements
- Presence of advance regeneration
- Potential seed and sprout sources – composition, condition, health
- Stand composition, size and age class structure, condition, quality, and health
- Competitive abilities of desired species, and potential levels of competition among species
- Interfering vegetation and competition control
- Gap management – smaller gaps favor shade tolerant species
  - Previous gaps needing expansion to release established regeneration
  - Number of new gaps to release advanced regeneration or establish new regeneration

  - > Size and expected closure rates (crown expansion)
- Stand growth rate
- Cutting cycle
- Protection (residual stems, crowns, root systems, advanced regeneration) from logging damage
- Herbivory – small regeneration gap sizes, typical of the single-tree selection method, may be more vulnerable to deer browse due to the limited forage, slower seedling growth rates, and lack of vegetative cover. In areas with high deer populations, larger regeneration openings and additional browse mitigation measures may be needed.

3.1.6 Advantages and Disadvantages

Advantages:

- Permanent forest with multiple age classes – the overstory is not completely removed
- Maintenance of a permanent overstory allows treatment adjustment and modification if problems arise or objectives are not initially achieved
- Relatively continuous full site occupancy
- Local, known seed source
- Reproduction relatively certain
- System favors shade tolerant species
- In general, there is little need for site preparation or competition control
- Periodic improvement of stand quality through judicious tending
- Maximizes growth and quality for some species (e.g. sugar maple)
- Can grow large, high quality trees – facilitates high levels of sawtimber production
- Periodic income can be relatively frequent (sustained yield)

Disadvantages:

- Requires technical skill and need to monitor stand conditions, detailed current stand data is required to develop stand prescriptions
- Techniques of application are not well-developed for every species or cover type
- Not a good system to regenerate and manage intolerant or mid-tolerant tree species
- Species diversity can be difficult to establish or maintain
- Careful logging practices required to protect overstory and advanced regeneration; some damage is unavoidable
- Frequent reentry increases the frequency of site disturbance
- Frequent reentry requires a more extensive and permanent network of access roads and skid trails
- Added time and cost for timber sale establishment
- Logging costs are relatively high to remove dispersed trees

Previous View

3.1.7 Figures Demonstrating the Single-Tree (Gap) Selection Regeneration Method

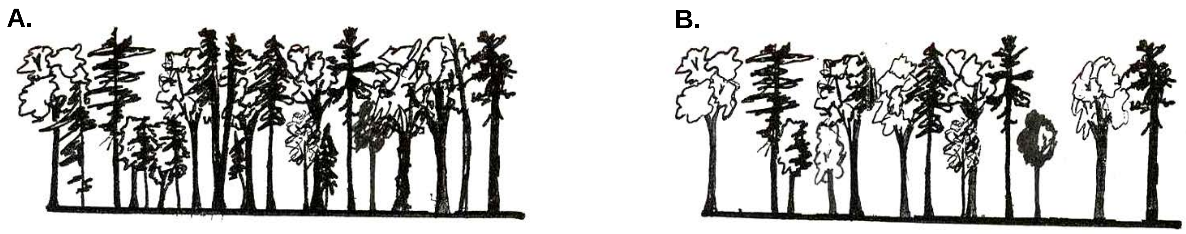


Figure 21.7. Single-tree selection – (A.) before and (B.) after cutting for harvest, thinning, and regeneration.

Figure 21.8. Uneven-aged northern hardwood stand managed by single-tree selection. Gap is being captured by sapling yellow birch. (photo by J. Kovach, WDNR)

3.2 Group Selection Method

3.2.1 Definition and Description

A silvicultural method designed to regenerate and maintain uneven-aged stands by removing some trees at regular intervals. An uneven-aged stand is maintained by periodically regenerating new age classes while manipulating the overstory structure to facilitate continual development of quality growing stock. Stand regeneration is achieved by periodically manipulating the overstory and understory to create conditions favorable for the establishment and survival of desirable tree species. Generally, most regeneration is seed origin (high forest method), although a component can be vegetative.

Trees are periodically removed in groups to create conditions favorable for the regeneration and establishment of new age classes (cohorts). *Canopy openings for regeneration may range in size from 0.1 to 0.5 acres.* Spatial distribution of regeneration openings may be regular, or irregular as dictated by variations in stand condition, such as the age, size, vigor, quality, composition, and health of groups of trees. Regeneration recruited by past cutting may require release, and the remainder of the stand is thinned. Regeneration cuts, release, thinning, and harvesting usually occur simultaneously (time), but are variable across the stand (space). Area regulation guides age distribution and silvicultural treatments.

3.2.2 Characteristics

- Uneven-aged
- Seed origin (high forest)
- Overstory never completely removed – periodic removal of groups of overstory trees to create canopy openings 0.1 to 0.5 acres in size to recruit or release regeneration (cohort).
- The smallest canopy openings are 0.1 acres, equivalent to a 75-foot diameter, circular opening. This size can be large enough to recruit some mid-tolerant species, as well as vigorous shrub and herb competition.
- The largest canopy openings are 0.5 acres, equivalent to a 167-foot diameter, circular opening, which is approximately 2X tree height.
- Overstory provides a seed source, and modifies understory conditions to create a favorable environment for the reproduction, competition, and growth of certain species
- Favors regeneration and maintenance of shade tolerant and mid-tolerant species; shading effects will vary spatially across the regeneration opening
- Method allows for variations in regeneration and structure (e.g. age class, composition, density) over space and time
- Regeneration cuts (group opening creation), release, thinning, and harvesting usually occur simultaneously (time), but are variable across the stand (space)

3.2.3 Contrast With Other Methods

Group selection is an uneven-aged silvicultural system that maintains a permanent multiage overstory. Natural reproduction is periodically established in regeneration openings 0.1-0.5

acres in size and develops in small cohorts. The overstory serves to distribute seed and modify understory conditions, favoring the maintenance of mostly shade tolerant and mid-tolerant species.

Coppice, clearcut, seed tree, overstory removal, and shelterwood are even-aged regeneration methods. The single-tree selection method regulates stands based on age/size class stocking, and canopy gaps for regeneration are <0.1 acres in size. The patch selection method creates regeneration openings >0.5 acres in size; although stands are considered uneven-aged, the larger openings are more exposed and function as small even-aged patches, the residual overstory has less influence on environmental conditions in regeneration openings, and the method encourages shade mid-tolerant species. Group selection partially simulates natural mortality and disturbance (e.g. low to moderate severity windthrow), but is more regulated and homogeneous, impacts younger stands, and removes most coarse woody debris.

3.2.4 Variations to This Method:

- NONE

3.2.5 Application

Cover type specifics and applicability of the group selection method are addressed in appropriate cover type chapters of this Handbook. This method is a recognized method to regenerate the red maple, central hardwood, northern hardwood, and bottomland hardwood forest cover types. The group selection method may have potential for use in regenerating the white pine, black walnut, white spruce, balsam fir, black spruce, white cedar, and swamp hardwood cover types. The method is not applicable to jack pine, red pine, aspen, white birch, oak, hemlock, or tamarack cover types. To convert even-aged stands to uneven-aged structure, several cutting cycles are needed to establish multiple age classes.

General considerations in the application of the group selection method are:

- Site evaluation (suitable to meet moisture and nutrient demands of species)
- Stand composition, size and age class structure, condition, and health
- Advanced regeneration
- Potential seed and sprout sources – composition, condition, health
- Regeneration requirements (moisture, nutrients, light, heat) of desired species
- Competitive abilities of desired species, and potential levels of competition among species
- Overstory impacts on understory light, heat, and moisture availability
- Regeneration openings management
    - Size of regeneration openings, and impacts on composition and growth. 0.1 to 0.5 acre openings are equivalent to 75 to 167 foot diameter circular openings.
    - Site preparation – seedbed preparation and competition control
- Area regulation
    - Number and distribution of new regeneration openings to release advanced regeneration or establish new regeneration
    - Release and thinning of many different cohorts (age and spatial differentiation)

  - > Order of removal of overstory trees for establishment of regeneration openings, release, and thinning
    - o generally, trees retained are the most vigorous crop trees
    - o generally, trees cut (individuals and groups) are high risk, less vigorous, lower quality, and/or undesirable species
  - > Cohort rotation length
  - > Cutting cycle and allowable cut

- Protection (residual stems, crowns, root systems, advanced regeneration) from logging damage

3.2.6 Advantages and Disadvantages

Advantages:
- Permanent forest with multiple age classes – the overstory is not completely removed
- Maintenance of a permanent overstory allows treatment adjustment and modification if problems arise or objectives are not initially achieved
- Relatively continuous (near) full site occupancy
- Local, known seed source
- System favors shade tolerant and mid-tolerant species; can encourage species diversity
- Periodic improvement of stand quality through judicious tending
- Periodic income can be relatively frequent (sustained yield)

Disadvantages:
- Requires technical skill and need to monitor stand conditions
- Area regulation for many small cohorts can become complex
- Techniques of application are not well-developed for every species
- For some species, may require timing to seed crop
- Site preparation and release may be needed
- Not a good system to regenerate and manage intolerants
- Careful logging practices required to protect overstory and advanced regeneration; some damage is unavoidable
- Frequent re-entry increases the frequency of site disturbance
- Frequent re-entry requires a more extensive and permanent network of access roads and skid trails
- For any given entry, income is less than a complete overstory removal
- Added time and cost for timber sale establishment

3.2.7 Figure Demonstrating the Group Selection Regeneration Method

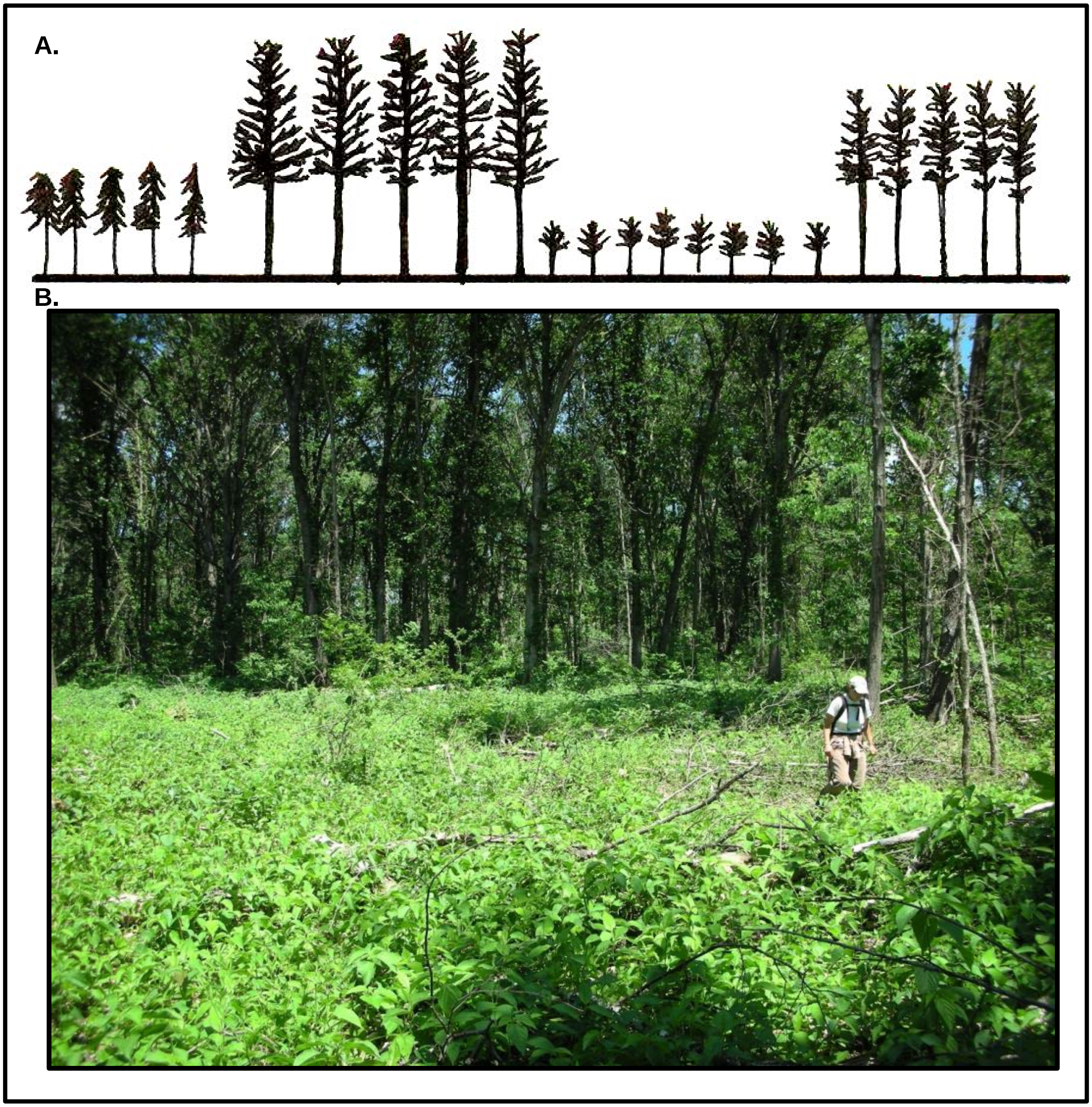


Figure 21.9. (A.) Group selection – within a regulated stand, four ¼ acre groups of different ages, (B.) A 0.35-acre group selection opening (photo by B. Hutnik, WDNR)

3.3 Patch Selection Method

3.3.1 Definition and Description

A silvicultural method designed to regenerate and maintain uneven-aged stands by removing patches of trees at regular intervals. An uneven-aged stand is maintained by periodically regenerating new age classes in patches, while manipulating the overstory structure between patches to facilitate continual development of quality growing stock. Generally, most regeneration is seed origin (high forest method), although a component can be vegetative.

Trees are periodically removed in patches to create conditions favorable for the regeneration and establishment of new age classes (cohorts). *Canopy openings for regeneration are >0.5 acres in size, and typically <2 acres in size.* Spatial distribution of regeneration openings may be regular, or irregular as dictated by variations in stand condition, such as the age, size, vigor, quality, composition, and health of patches of trees. Regeneration recruited by past cutting may require release, and the remainder of the stand is thinned. Regeneration cuts, release, thinning, and harvesting usually occur simultaneously (time), but are variable across the stand (space). Area regulation guides age distribution and silvicultural treatments.

3.3.2 Characteristics

- Uneven-aged stand, composed of even-aged patches (cohorts)
- Seed origin (high forest)
- Overstory never completely removed – periodic removal of patches of overstory trees to create canopy openings >0.5 acres (approximately 2X tree height) in size to recruit or release regeneration
- Regeneration may be advanced regeneration that is released during patch overstory removal, or regeneration may come from seed distributed prior to, during, or following harvest (usually originating within the stand)
- Generally, favors regeneration and maintenance of shade mid-tolerant species, however, relatively intolerant or tolerant species can be encouraged; shading effects will vary spatially across the regeneration opening, ranging from completely open at the center to shaded at the edge
- Method allows for variations in regeneration and structure (e.g. age class, composition, density) over space and time
- Regeneration cuts (patch opening creation), release, thinning, and harvesting usually occur simultaneously (time), but are variable across the stand (space)

3.3.3 Contrast With Other Methods

Patch selection is an uneven-aged silvicultural system that maintains a permanent multiage stand. Natural reproduction is periodically established in regeneration openings >0.5 acres in size and develops in cohorts. Although stands are considered uneven-aged, the relatively large openings are fairly exposed and function as small even-aged patches. Because the residual overstory has limited influence on environmental conditions in regeneration openings, the method generally encourages shade mid-tolerant species.

Coppice, clearcut, seed tree, overstory removal, and shelterwood are even-aged regeneration methods. The single-tree selection method regulates stands based on age/size class stocking, and canopy gaps for regeneration are <0.1 acres in size. The group selection method creates regeneration openings 0.1 to 0.5 acres in size, and the overstory modifies understory conditions, favoring the maintenance of mostly shade tolerant and mid-tolerant species. Patch selection partially simulates natural mortality and disturbance (e.g. low to moderate severity windthrow), but is more regulated and homogeneous, impacts younger stands, and removes most coarse woody debris.

3.3.4 Variations to This Method

- NONE

3.3.5 Application

Cover type specifics and applicability of the patch selection method are addressed in appropriate cover type chapters of this Handbook. This method is a recognized method to regenerate the red maple and central hardwood forest cover types. The patch selection method may have potential for use in regenerating the white pine, white birch, oak, black walnut, white spruce, balsam fir, black spruce, tamarack, white cedar, swamp hardwood, and bottomland hardwood cover types. The method is not applicable to jack pine, red pine, aspen, northern hardwood, or hemlock cover types. To convert even-aged stands to uneven-aged structure, several cutting cycles are needed to establish multiple age classes.

General considerations in the application of the patch selection method are:
- Site evaluation (suitable to meet moisture and nutrient demands of species)
- Stand composition, size and age class structure, condition, and health
- Advanced regeneration
- Potential seed and sprout sources – composition, condition, health
- Regeneration requirements (moisture, nutrients, light, heat) of desired species
- Competitive abilities of desired species, and potential levels of competition among species
- Overstory impacts on understory light, heat, and moisture availability
- Regeneration openings management
  - Size of regeneration openings and impacts on composition and growth. A minimum 0.5 acre opening is equivalent to a 167 foot diameter circular opening.
  - Site preparation – seedbed preparation and competition control

- Area regulation
  - Number and distribution of new regeneration openings to release advanced regeneration or establish new regeneration
  - Release and thinning of many different cohorts (age and spatial differentiation)
  - Order of removal of overstory trees for establishment of regeneration openings, release, and thinning
    - generally, trees retained are the most vigorous crop trees

  - o generally, trees cut (individuals and groups) are high risk, less vigorous, lower quality, and/or undesirable species
- > Cohort rotation length
- > Cutting cycle and allowable cut

- Protection (residual stems, crowns, root systems, advanced regeneration) from logging damage

3.3.6 Advantages and Disadvantages

Advantages:
- Permanent forest with multiple age classes – the overstory is not completely removed
- Maintenance of a permanent overstory allows treatment adjustment and modification if problems arise or objectives are not initially achieved
- Relatively continuous (near) full site occupancy
- Local, known seed source
- System favors shade mid-tolerant species, but intolerant or tolerant species can be encouraged; can encourage species diversity
- Periodic improvement of stand quality through judicious tending
- Periodic income can be relatively frequent (sustained yield)

Disadvantages:
- Requires technical skill and need to monitor stand conditions
- Area regulation for many cohorts can become complex
- Techniques of application are not well-developed for every species
- For some species, may require timing to seed crop
- Site preparation and release may be needed
- Careful logging practices required to protect overstory and advanced regeneration; some damage is unavoidable
- Frequent reentry increases the frequency of site disturbance
- Frequent reentry requires a more extensive and permanent network of access roads and skid trails
- For any given entry, income is less than for complete overstory removal
- Added time and cost for timber sale establishment

Figure 21.10. A 0.95-acre patch selection opening (photo by B. Hutnik, WDNR)

Table 21.1. Natural Regeneration Methods by Forest Cover Type for Wisconsin

FOREST COVER TYPES[1]	NATURAL REGENERATION METHODS							
	Coppice	Clear-cut	Seed Tree	Overstory Removal	Shelter-wood	Patch Selection (0.5-2.0)	Group Selection (0.1-0.5)	Single-tree Selection (<0.1 acre)
Jack Pine		GAP	GAP	GAP	X			
Red Pine			X	GAP	X			
White Pine			GAP	GAP	GAP	X	X	
Aspen	GAP	X		GAP				
White Birch	X	GAP[2]	X	GAP	GAP	X		
Oak	GAP	X		GAP	GAP	X		
Black Walnut			X	GAP	X	X	X	
Red Maple	GAP		X	GAP	GAP	GAP	GAP	X
Central Hardwood		X		GAP	GAP	GAP	GAP	
Northern Hardwood				GAP	GAP		GAP	GAP
Hemlock				GAP	GAP			GAP
White Spruce		GAP[2]	X	GAP	GAP	X	X	
Balsam Fir		GAP[2]	X	GAP	GAP	X	X	X
Black Spruce		GAP[2]	X	GAP	GAP	X	X	X
Tamarack		GAP[2]	X	GAP	X	X		
Cedar		GAP[2]	X	GAP	GAP	X	X	X
Swamp Hardwood	X	GAP[2]		GAP	GAP	X	GAP	GAP
Bottomland Hardwood	GAP			GAP	GAP	X	GAP	

GAP (generally accepted practice): Method generally accepted in Wisconsin and supported by literature. Applicability may vary depending on site quality, stand age and condition, ability to control competition, and other factors (e.g. herbivory). Refer to appropriate cover type chapters for application details. The generally accepted methods may not be reflected in some cover type chapters that have not been updated recently.

X: Method may have potential for application

[1] Natural regeneration methods apply to the cover type to be regenerated, not necessarily the currently existing cover type.

[2] Strip clearcutting generally recommended

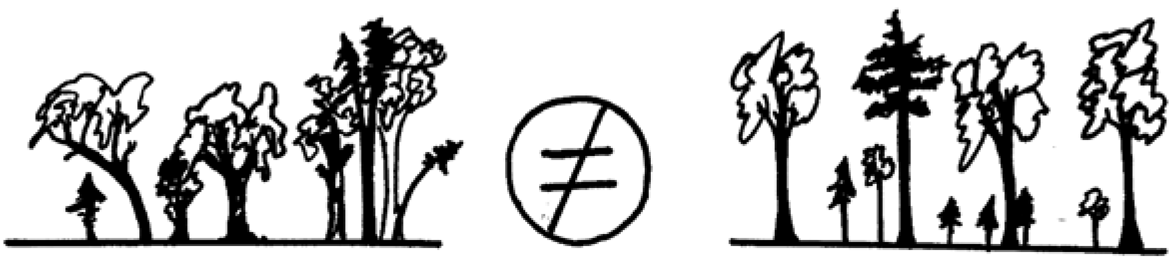
4 PRACTICES NOT PART OF SILVICULTURAL SYSTEMS THAT MAY RESULT IN NATURAL REGENERATION

4.1 Unsustainable Cutting Methods

Timber cutting methods are not necessarily tied to silvicultural systems. Sometimes, stand tending and regeneration are not adequately considered. In such cases, the lack of planning and foresight can result in stand degradation in terms of tree vigor and quality. Some examples of timber cutting methods not being part of silvicultural systems are:

1. *Economic clearcut*: A clearcut that does not include a plan for regeneration.
2. *High-grade selective cut*: A selective cut of the most valuable and highest quality trees, that leaves low value and quality trees to predominate.
3. *Diameter limit selective cut*: A selective cut of all trees greater than a certain diameter, where primary objectives do not include thinning to improve growth or quality, release of quality growing stock, or targeted quality regeneration.

These methods are often applied in an attempt to maximize short-term economic gain. In general, they do not represent sustainable forest management.



A. The high-grade selective cut removes the best trees and leaves low quality trees to predominate. This is not part of a silvicultural system.

B. Uneven-aged selection systems promote stand quality, tree quality and vigor, and targeted regeneration. Careful planning and implementation are required.

Figure 21.11. (A.) High-grade and diameter limit "selective cutting" is not the same as any of the (B.) selection regeneration methods.

4.2 Passive Management

Passive management is a deliberate decision to not manipulate the vegetation. It is a forest management system and regeneration alternative that does not conform to any silvicultural system, because of the lack of active treatment application.

5 ESTABLISHMENT AND EVALUATION OF ADEQUATE NATURAL REGENERATION

The successful regeneration of forest stands is a critical part of all silvicultural systems. Detailed planning is necessary for successful, targeted natural regeneration. There are several factors to consider in the planning process, including:

- management objectives,
- intrinsic site factors and variation (e.g. habitat type, soil, geology, physiography, site index, microsites),
- current stand composition, structure, and health (overstory and understory),
- natural dynamics (succession, structural development, and disturbance),
- silvics of current and desired species,
- sources of reproduction (advance regeneration, seed, sprouts),
- seedbed characteristics,
- potential competition (native vegetation, invasive species) and control,
- potential damaging agents and control (e.g. herbivory, insects, disease, drought, fire),
- necessary methods (type, sequence, timing, severity) to successfully establish a new age class of desired species under current conditions.

The cover type chapters provide specific information on sites, silvics, regeneration requirements, and regeneration methods.

Seed germination and seedling development are influenced by environmental variables, such as temperature, light, moisture, nutrient availability, and appropriate seedbed. Site preparation is the practice of altering site conditions to favor the establishment, survival, and growth of desired tree species. The main objectives of site preparation are to prepare a favorable seedbed and control competing vegetation. Site preparation can be accomplished through mechanical means, prescribed fire, use of herbicides, or any combination of these approaches. The timing of site preparation and canopy manipulation is important to consider. Various site preparation methods are described in the artificial regeneration chapter (Chapter 22) of this handbook.

Stands are successfully established following the initiation of a vigorous new age class of desirable species of appropriate size and density (full site occupancy). Maximum seedling numbers typically occur just before harvest (advance regeneration) or during the first few years after harvest. Stand initiation is completed when the new canopy becomes continuous and trees begin competing with each other for light and canopy space. During the stem exclusion stage, competition among trees is intense and density dependent self-thinning causes significant mortality.

5.1 Monitoring and Regeneration Surveys

After a regeneration method has been implemented, it is essential to periodically monitor and evaluate how the stand is responding. If there are problems with germination or stand development, early detection may help in correcting the problem (e.g. release, inter-planting, site preparation).

5.1.1 Survey Methods

When evaluating regeneration, it is important to assess seedling species, size, number, and distribution; seedling vigor and level of competition; and seedling health, damage, and mortality (extent and causes). Foresters often use a variety of methods to assess natural regeneration, but these methods are not always statistically accurate and do not always provide the information needed to make sound management decisions. Determining your information needs is the first step in selecting a suitable regeneration survey method.

The **stocking survey method** (i.e., stocked-quadrat method) primarily evaluates tree distribution by measuring the presence or absence of trees on a given plot size relative to full stocking at a chosen stage of stand development. For example, if a northern hardwood stand averages 100 trees/acre at maturity, each mature tree will occupy about 1/100 of an acre. If the stand is regenerated and divided into 1/100 acre circles, enough seedlings will be required within each circle to ensure that one will survive when the new stand reaches maturity.

A stocking survey can then be designed, using 1/100 acre plots, to determine how many are stocked with the necessary number of seedlings. The percent of plots meeting the stocking goal provides an estimate of the proportion of the stand being utilized by tree growth. This method provides a fast and easy way to determine if the future stand will be fully stocked because you do not need to count all of the seedlings on a plot (only those up to your stocking goal).

Stocking surveys provide limited data however and are not suitable for answering questions related to species composition, trees/acre, or seedling heights. What constitutes an adequately stocked plot at the seedling stage varies by species and by other site factors; however, the Natural Regeneration Guidelines table below provides recommended stocking survey methods that have been used successfully in Wisconsin, including both the milacre and Forest Regeneration Metric (FRM) plot sizes.

The “milacre plot” (1/1000 acre), has historically been recommended, especially for conifer species, as a rapid stocking survey method. Although this plot size does not relate to full stocking at later stages of stand development, it has been used effectively to measure adequate stocking at the end of the regeneration period. For example, at least 60% milacre stocking for established jack pine regeneration, means that ≥60% of milacre plots sampled contained at least one jack pine seedling greater than a specified minimum size. The FRM method is a combination of survey methodologies and is explained in detail below.

The **density survey method** (i.e., plot-count method) evaluates tree density by counting all of the seedlings on a plot, to determine the number of trees per acre. This method is straightforward and provides a complete inventory of species composition. Since the plot size does not have to relate to a stocking goal, it can be adjusted to accommodate easier counting based on regeneration size and number. However, a full count of seedlings on a plot is time consuming and does not assess how regeneration is distributed across the stand.

Commonly recommended plot sizes include:

- 1/1000 acre plot having a radius of 3 feet 9 inches (milacre plot size)
- 1/735 acre plot having a radius of 4 feet 4 inches
- 1/500 acre plot having a radius of 5 feet 3 inches
- 1/385 acre plot having a radius of 6 feet 0 inches
- 1/300 acre plot having a radius of 6 feet 10 inches (FRM plot size)
- 1/100 acre plot having a radius of 11 feet 9 inches

Stocking and density survey methods can be combined to measure stocking, density, and other variables on the same set of plots. Foresters may also track stocking by plot location, with the use of data recorders and GPS, to determine particular areas of the stand that may need follow-up treatments. Additional variables, such as size class, competing vegetation, and browse severity can be included to further assess regeneration. The following FRM method is a more detailed system that measures species, density, and height class information and can be combined with stocking objectives to determine percent stocking.

5.1.2 Forest Regeneration Metric (FRM)

The **Forest Regeneration Metric (FRM)** is a survey methodology designed to assess natural regeneration by seedling and sapling size classes. FRM is a type of density survey that collects information on species composition, trees per acre, tree height classes, and a variety of other information impacting regeneration success. Foresters are encouraged to use this method in conjunction with standard reconnaissance to assess understory tree regeneration or as part of pre or post-treatment regeneration monitoring. FRM captures a detailed picture of the understory regeneration within a stand, and is useful for answering a variety of management questions. The method is consistent with information already collected on USDA FIA and WDNR CFI plots, so that data can be combined on a county, regional, or statewide basis to make to broader regeneration assessments and analyses. The full FRM protocol and survey sheet are located in Appendix A.

FRM uses a 1/300th acre plot size (6’10” radius). All seedlings and saplings (<5” dbh) are counted and classified by species and height class (see Figure 21.12). Additional information is recorded on the plot, including overstory cover, understory competing vegetation, and browse severity index. Although FRM was not originally designed as a stocking survey, it can be combined with stocking objectives to determine percent stocking. Table 21.2 provides an estimate of the number of established seedlings that constitute an adequately stocked plot. The percent stocking can then be calculated as the proportion of plots in a stand that meet this stocking objective.

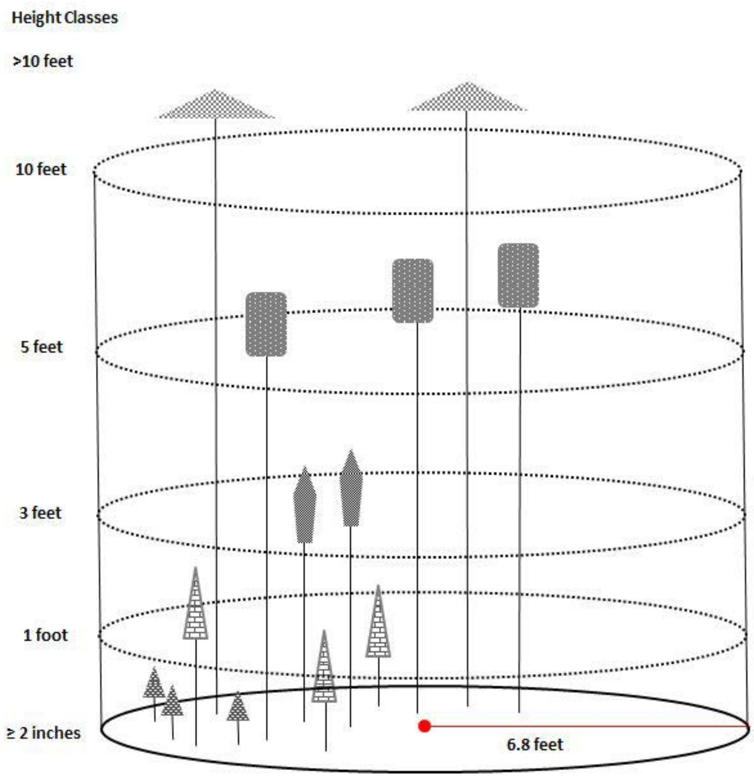


Figure 21.12. FRM plot illustration, including height classes.

5.1.2.1 Number of Plots

The recommended number of plots to measure in a stand depends on the regeneration variation and the desired level of accuracy; statistical methods should be utilized to determine the most appropriate sampling intensity. Data recorders and cruising software can make this task easier and allow for rapid calculations in the field. However, for operational reasons, there often is not time for intensive statistically accurate sampling. A common practice is simply a general survey of regeneration, sampling one-to-five plots per acre, depending on plot size, stand variability, and operational considerations.

Sample plots can be distributed across a stand systematically (most common) or randomly. Before field sampling, starting points and sample plot locations can be marked on an aerial photo or map. Natural regeneration can be quite variable, so good coverage of the sample area is often critical.

5.1.2.2 Monitoring Schedule

It is generally recommended to survey regeneration as early as 1-2 years after treatment and again by the end of the regeneration period, but this may vary depending on species, site characteristics, regeneration method, and operational considerations. Early and regular monitoring will allow for follow-up corrective actions if the stand is not developing properly (e.g., release, inter-planting, site preparation, browse protection).

Table 21.2 provides height guidelines for assessing **established seedlings**, defined as seedlings of sufficient size and vigor that are past the time when significant juvenile mortality occurs from frost, drought, weeds, and other causes. Foresters will still need to exercise professional judgment when assessing the ability of seedlings to maintain vigor for a particular set of site conditions. Additional metrics are sometimes used to determine if a seedling is established, such as age, stem caliper, and root development. An established seedling differs from a **free-to-grow tree** that has grown beyond interfering vegetation and browse height.

The **regeneration period** is defined as the time between initial regeneration cutting and the successful reestablishment of a new age class (i.e., established seedlings). Table 21.2 provides typical regeneration periods for all Wisconsin cover types. Foresters should make an assessment by the end of the regeneration period to determine if there is adequate natural regeneration present to fully stock the new stand and if there are any further treatments needed to get trees to a free-to-grow status. If adequate stocking is not present, then the forester will need to assess whether additional time or alternative regeneration methods are needed to achieve management objectives.

6 NATURAL REGENERATION GUIDELINES

The following table provides guidelines to assess the adequacy of natural regeneration by forest cover type. Information is provided on recommended minimum density, height of established seedlings, regeneration period, and stocking survey methodology. The guidelines provided are based on best-available science (see reference numbers in parentheses for more in-depth information), empirical data, and professional experience. In application, foresters will need to carefully assess natural regeneration in terms of site conditions and stand objectives and exercise professional judgment concerning the species, density, size, and distribution of regeneration needed to meet future stocking goals. More information and explanation can be found in the many of the cover type chapters.

Table 21.2. Natural regeneration guidelines.

Cover Type	Minimum Density (stems/acre)[A]	Established Seedling Height (feet)[B]	Regen. Period (years)[C]	Stocking Survey Methods: Plot Size / Adequately Stocked (# established seedlings)	Stocking Survey Methods: Minimum Stocking (%)[D]
White Pine	**700** 2–4	**1-3'** 3	**3-5** 2,4	**1/300th acre / 2-3** **1/1000th acre / 1**	**60%** 2,3
Red Pine	**400-1000** 4–6	**1-3'**	**3-5** 2,4	**1/300th acre / 2-3** **1/1000th acre / 1**	**60%** 2,6
Jack Pine	**600-1200** 4–7	**1-3'**	**3-5** 2,4	**1/300th acre / 2-3** **1/1000th acre / 1**	**60%** 2,5,6
Fir-Spruce	**600** 4	**1-3'**	**3-5** 2,4	**1/300th acre / 2-3** **1/1000th acre / 1**	**60%** 2
Swamp Conifer	**600**	**1-3'**	**3-10**	**1/300th acre / 2-3** **1/1000th acre / 1**	**60%**
Black Spruce	**600** 8,9	**1-3'** 8	**3-10** 2,8–10	**1/300th acre / 2-3** **1/1000th acre / 1**	**60%** 2,9
Tamarack	**600** 6	**1-3'**	**3-10** 2	**1/300th acre / 2-3** **1/1000th acre / 1**	**60%** 2
White Cedar	**600** 11	**1-3'** 12	**3-10** 2,13	**1/300th acre / 2-3** **1/1000th acre / 1**	**60%** 2,11,14
Hemlock Hardwood	**2000-5000**	**2-4'**	**3-8**	**1/300th acre / 7-16**	**70%**
Northern Hardwoods	**2000-5000** 1,4,7,15,16	**2-4'** 17	**3-8** 4,18	**1/300th acre / 7-16**	**70%** 1
Oak	**515 (>4')** **3100 (1-2')** 4,19,20	**Variable (based on SV)**	**3-5** 4	**1/300th acre / 10 (1-2')** **1/750th acre / SV=30+**	**70%** 19
Aspen	**6000** 2,4,6,7,21	**n/a**	**1-2** 2,4,21	**1/300th acre / 20**	**70%** 2,21
Paper Birch	**2000** 2,4,22	**1'** 23	**1-2** 2,4,23	**1/300th acre / 7**	**70%** 2,23
Black Walnut	**1000**	**2-4'**	**3-5**	**1/300th acre / 3-4**	**70%**
Swamp Hardwood	**2000-5000** 6,7,24	**2-4'** 24	**3-5** 24	**1/300th acre / 7-16**	**70%**
Bottomland Hardwoods	**2000-5000** 6,7	**2-4'**	**3-5**	**1/300th acre / 7-16**	**70%**
Red Maple	**2000-5000** 16,25	**2-4'** 16	**3-8**	**1/300th acre / 7-16**	**70%**
Central Hardwoods	**1000** 6,26	**2-4'**	**3-5**	**1/300th acre / 3-4**	**70%** 6

[A]Minimum Density: An acceptable minimum density of established seedlings expressed in stems/acre. Note - foresters may need to account for additional regeneration losses due to harvest operations.
[B]Established Seedling: A seedling of sufficient size and vigor that is past the time when significant juvenile mortality occurs from frost, drought, weeds, and other causes (i.e., not a new germinant); and that has a high probability of reaching merchantability given suitable growing conditions. Note – this differs from a free-to-grow tree that has grown beyond interfering vegetation and browse height.
[C]Regeneration Period: The time between the initial regeneration cutting and the successful reestablishment (i.e., established seedlings) of a new age class.
[D]Minimum Stocking: An acceptable minimum level of stocking; a measure of the distribution of trees expressed as a percent of plots stocked.27–33
[#]Corresponded references where criteria are published

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8 APPENDIX A.

8.1 Forest Regeneration Metric

8.1.1 Overview

This Forest Regeneration Metric (FRM) is a survey methodology designed to assess natural regeneration by seedling and sapling size classes. The design and protocol have been created to be utilized by foresters as an additional measure during their routine stand assessments. This type of regeneration metric can be used to characterize stand-level regeneration or be used in multiple stands to characterize regeneration by cover type on a county, regional, or statewide scale.

8.1.2 Plot Location and Number

Foresters have a variety of different methods to select cruising locations when assessing a forest stand. Whether it is arranging GPS points ahead of time or walking a specific bearing and distance, ensuring that a measurement location is unbiased is critical. We suggest conducting this regeneration metric at the same locations used to collect cruising data. The greater number of regeneration plots measured, the better representative the data will be of the stand.

8.1.3 FRM Procedure

1) Plot Establishment
    a) The forester will establish a plot center location. Again, it is important that the plot center location is not biased. We suggest that each forester establish a rule that is consistent across plots and stands. For example, a forester may measure regeneration at every other cruise point within a stand, and the center for the regeneration plot is always on the outside of their right foot at the location at which they stopped to cruise.

    b) A datasheet template has been provided. Foresters may use whatever means of data collection that is easiest and most convenient for them but be sure to include all the necessary data. The datasheet includes a plot number which may be arbitrary or correspond to cruise point numbers. FRM requires important stand-level information, including:
        - Date
        - Primary cover type
        - County
        - Township/range/section
        - MFL Order # (if applicable; note if NIPF non-MFL)
        - Stand
        - Stand acres
        - Compartment
        - Property
        - Management record (includes most recent past and future planned harvests)

2) Stem Counts
   a) Once a plot center is established use a stake or chaining pin to attach a measurement tape. Or the forester may want to use a pre-marked piece of rope or stick to identify the 6.8 foot radius (i.e., 6’ 10” radius, ~1/300th acre plot).

   b) Tally all seedlings and saplings (<5” dbh) by species and height class within the FRM plot. Tip – On plots with very high seedling numbers, it is acceptable to count a portion of the plot and multiply by an expansion factor. For example, count all the seedlings within one quarter of the plot and multiply by four. The height classes are:
      - 2”-1 ft. 1-3 ft. 3-5 ft. 5-10 ft. >10 ft.

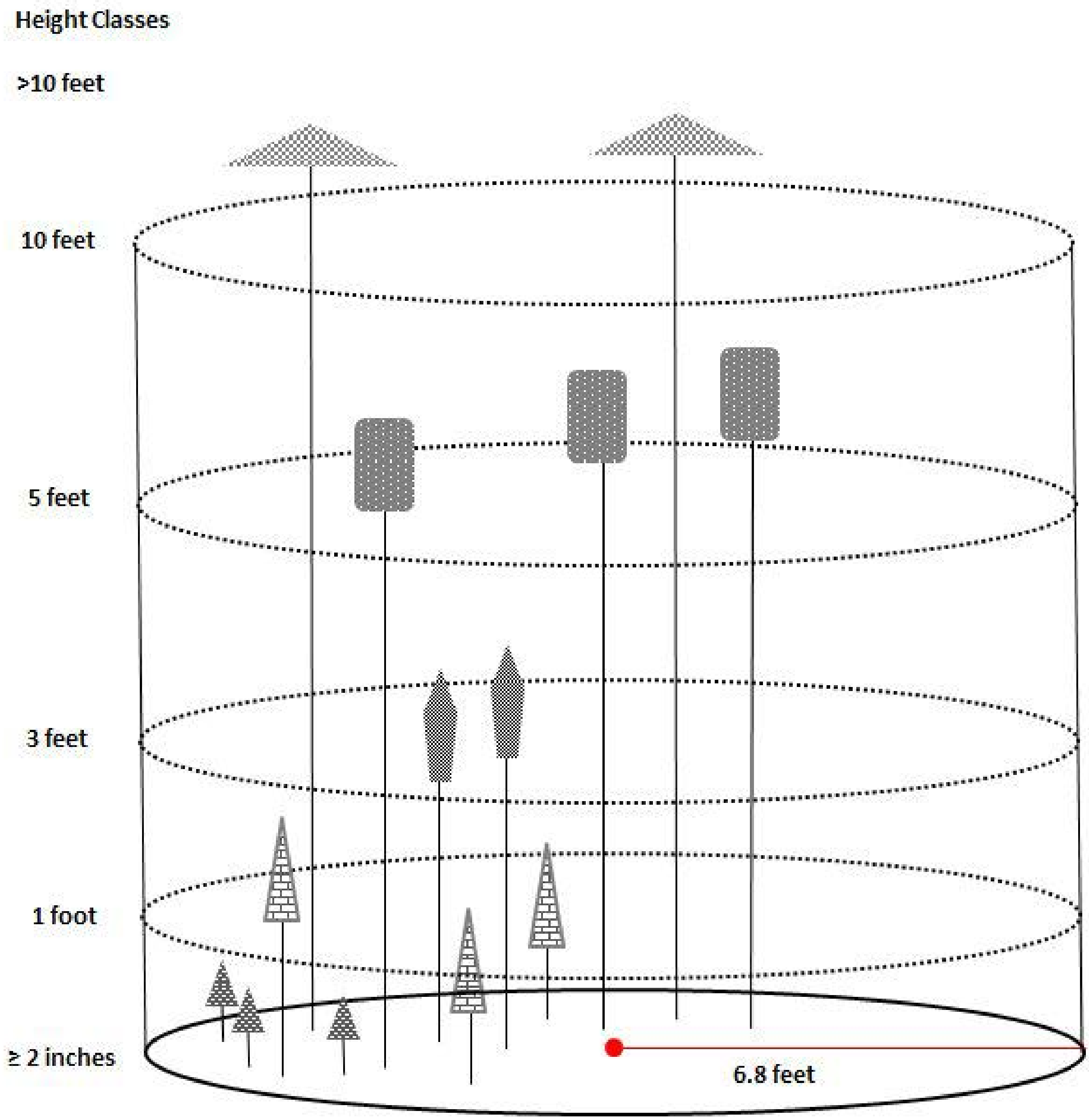
3) Overstory Shading - Note the potential available light for understory trees by recording **full sun**, **partial**, or **shade** in the *overstory shading* space on the datasheet.

4) Understory Competition - In the *understory competition* space, note the percent cover for <u>both</u> **herbaceous** and **woody** competition. Understory competition categories are as follows:

	Percent Cover				
	0%	**1-25%**	**26-50%**	**51-75%**	**76-100%**
Herbaceous	H-0	H-25	H-50	H-75	H-100
Woody	W-0	W-25	W-50	W-75	W-100

5) Deer Browse – Deer browse is recorded as the percentage of stems browsed (Browse Severity Index), rounded to the nearest whole number, and is calculated and recorded for each individual species. Unlike overstory shading and understory competition, which would be the same for all species within a single plot, the deer browse may be different for each species. The intent of this metric is to assess current browse impacts rather than historical browse. Evaluate the percentage of stems by species that appear to have been browsed in the previous 12 months (i.e., approximately the current and previous growing seasons).

6) Deer Exclosure – Record whether the FRM plot is located within a deer exclosure.


Height Classes
>10 feet
10 feet
5 feet
3 feet
1 foot
≥ 2 inches
6.8 feet

Forest Regeneration Metric Datasheet

Measurement Date :

Property:

Years since last entry:

Primary Cover Type:

Compartment:

Last harvest type:

County:

Stand:

Years to next entry:

Township/Range/Section:

Stand Acres:

Next harvest type:

MFL Order #:

Plot	Species	2" - < 1'	1' - < 3'	3' - < 5'	5' - < 10'	≥ 10'	Overstory Shading	Herbaceous Competition	Woody Competition	Deer Browse	Deer Excl.

Overstory Shade: full sun (<25% cover), partial (26-75% cover), shade (>76% cover)
Understory Competition: Percent Cover: **0** = 0%; **25** = 1-25%; **50** = 26-50%; **75** = 51-75%; **100** = 76-100%
Browse Severity Index: Evaluate the percentage of stems by species that appear to have been browsed in the previous 12 months (i.e., approximately the current and previous growing seasons). Record a browse percentage for each tree species to the nearest whole number.

Chapter 22

Artificial Regeneration

WISCONSIN
DEPT. OF NATURAL RESOURCES

Last Full Revision: 2/11/2004
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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1 ARTIFICIAL REGENERATION

1.1 Statement of Purpose

The purpose of this chapter is to aid foresters in their efforts to successfully establish forest tree plantings in Wisconsin. Whether it be to start new forest plantations, or to develop specialty plantings, the chapter will give suggestions and stimulate ideas on the details of reforestation/afforestation. Artificial regeneration can be a tool to reduce soil erosion, improve wildlife habitat, air quality, land value, watershed protection, enhance aesthetics when properly applied, introduce improved seed sources and return previously deforested land to a forest ecosystem.

This chapter will help identify landowner goals, select the best areas for reforestation/ afforestation, determine if the site has the potential for strong tree growth and what type of site preparation and regeneration scheme will work best. It will detail the costs and benefits of seeding versus planting, as well as bareroot versus containerized stock. In addition, it will discuss the planning, planting, and maintenance of plantations. It will provide a list of the labeled herbicides at your disposal to establish and protect newly planted trees. Different tree species native to Wisconsin will be profiled to help determine which species to plant on a site and appropriate regeneration schemes.

1.2 Definitions

Afforestation: the practice of planting trees with the intent of creating a forest on presently non-forested land.

Biological Diversity: the spectrum of life forms and the ecological processes that support and sustain them. Biological diversity is a complex of four interacting levels: genetic, species, community, and ecosystem.

Conversion: the changing of the species composition of forested land from one forest type to another.

Landscape scale: the appropriate spatial and temporal scale for planning, analysis, and improvement of management activities to sustain ecosystem capability and achieve integrated resource management activities.

Reforestation: the practice of regenerating and growing healthy trees on previously forested sites.

Restoration: the process by which natural flora is reintroduced into an area and maintained to prevent repeated extirpation.

2 PLANNING

2.1 Goals

The first step in plantation establishment is deciding why to start a plantation. Many of the subsequent management decisions will be based on this initial premise. Both spatial and temporal landscape characteristics should be considered when planning for potential plantations. Long-term goals and short-term objectives for the plantation need to be developed with the landowner. In defining the goals, multiple goals are possible because many of them may be compatible with each other. The more specific the goals and objectives are, the more useful they will be in fine tuning management decisions.

Know how much time and resources can be devoted to plantation establishment and care. This will allow for realistic decisions about the plantation, subsequently choose treatments and species that will fit with the intended resources and time available. Try to evaluate the initial establishment costs and eventual returns of the plantation. It is important to note however that monetary returns are not the only reason to promote reforestation. Determine the steps necessary to meet goals while staying within budget.

After you have decided what your goals for the plantation are, you need to determine which species will work toward those goals and will grow well on the site. Bear in mind that plantations can serve many different purposes at once, but that the characteristics of the plantation will change through time. The species initially planted may only serve to capture the site. The long-term goal may be to allow succession to proceed into a mixture of species.

2.2 Site Selection

When planning reforestation activities, it is important to know what you have to work with. Knowledge of the soil and topography will aid in species selection, site preparation, fertilization and other management decisions. Your site may also possess features such as wetlands, riparian management zones, or the presence of endangered species which may limit or alter your management activities. A list of endangered and threatened species can be obtained from the DNR Bureau of Endangered Resources.

2.2.1 Site Characteristics

When choosing or evaluating a site for artificial regeneration there are several things about the site to consider. They include the following:

a) Climate: total precipitation, drought, frost timing, insolation, ice storms, and snow loads.

b) Soil: parent material, texture, depth, rock content, compaction, frost heaving, organic matter, available moisture, nutrients, erosion patterns and internal drainage.

c) Topography: elevation, slope, aspect, surface drainage of moisture and air.

d) Institutional environment: access, labor, equipment, seed, or seedling availability, federal and state cost-share incentives (e.g., stewardship), taxes, regulations, and constraints.

e) Existing vegetation: seeds and advanced regeneration, competition (allelopathy) and endangered resources.

f) Animals: domestic, wild - rodents (rabbits, voles, mice), ungulates, endangered species.

g) Insects: previous history, current population trends.

h) Disease: site history, vulnerability to future infection and presence of alternate host plants.

i) Productivity: productive history and overall site quality

j) Landscape: surrounding cover types in the broad geographic area, location of site in broader landscape picture and management trends.

k) Succession: trends and probable future species composition on the site.

Consider the importance of each of these factors. Is the site still appropriate for reforestation? Is a certain species no longer appropriate? How do these factors effect potential site preparation treatments?

2.2.2 Specific Limiting Site Characteristics

When developing your regeneration prescription take a step back and look at the big picture. You will see that there is an interaction of site quality, owner objectives, economics, and difficulty of establishment. They all affect each other and will ultimately affect how you proceed. The success of your plantation will be determined by the weakest link in the series of events including site evaluation, species evaluation, site preparation, planting stock, planting or seeding, and maintenance.

While developing your prescription you should investigate the history of successful and unsuccessful plantings in the area. Why were they successful or unsuccessful? The following is a list of specific site limiting factors:

a) Frost and winter desiccation - initial damage/mortality occurs in the first growing season. Avoidance through species selection, site preparation, site avoidance, planting season, choosing well-hardened seedlings and microsite selection. Avoid planting valley bottoms prone to cold air drainage and radiative frost until later in the season.

b) Lack of Soil Moisture - determined by season, soil characteristics (organic matter, texture, density, excessive internal drainage, depth), vegetation, slope, elevation, aspect, and evapotranspiration. Avoidance through selection of drought tolerant species, spots prepared to minimize drought effects, plant during periods of sufficient soil moisture, selection of shaded/sheltered microsites (excessive transpirational demand may be placed on seedlings), use of well-hardened seedlings with well-branched woody stems to minimize transpirational losses. Avoid stock with large shoots coupled with poorly developed or small root systems. A well-balanced tree is necessary for droughty sites.

c) Lack of Soil Aeration/Excessive Soil Moisture - due to poor internal soil drainage or abundance of moisture because of surface drainage patterns. Determined by season, soil characteristics (organic matter, texture, density, depth, impeded drainage), slope, elevation, aspect, and evapotranspiration. Avoidance through selection of appropriate species, raised planting spots, and plant later in the planting season.

d) Physical Damage - snow effects (press, creep, abrasion, glide), vegetation press (herbs, grasses), animals (browsing, trampling) and falling debris. A large and robust seedling will be most able to deal with these damaging factors. Large diameter will resist trampling and are less palatable and better able to endure small mammal browsing. Planting during low cycles of rodent populations may be an effective avoidance strategy. Reduction of vegetation cover also removes rodent habitat/shelter and will assist in stock type selection. Erection of perch poles for predators has proven effective. If physical damage does occur, a well-branched stem will re-express apical dominance.

e) Vegetation Competition - potential for mechanical and physiological damage. Extraneous vegetation can damage by vegetation press and will compete for moisture, nutrients, and light. Large and vigorous seedling will fare better against competition. Appropriate site preparation treatments and routine plantation checks and releases will minimize problem.

f) Natural Range - species planted outside their natural range will have low vigor, stunted growth, will be especially susceptible to insect and disease attacks, spring and fall frosts, and winter desiccation or cold temperature damage (e.g., walnut winter kill).

g) Insects and Diseases - Recognizing and evaluating the potential for disease and insect caused losses on proposed planting sites is necessary to realistically estimate productivity and investment returns. Although precise estimates are not possible, valuable information can be gained from on-site evidence (e.g., white grubs and alternative host species), proximity to relevant problems, and historical reference. This information may forewarn of potential problems and open up other management possibilities. The likelihood that your planting will develop serious insect or disease problems can be reduced with mixed plantings, using genetically variable species, and avoiding growing the species on unsuitable sites. Planting stock survival and disease control depend upon selection of low disease-risk sites, appropriate site preparation, and use of healthy planting stock suited to the local environment and adapted to local pathogens.

2.2.3 Site Potential

2.2.3.1 Soils

If possible, you should examine your soil to a depth of 2-5 feet for information on soil texture, depth of the topsoil and organic matter, type of substrate, internal drainage (mottling), and bulk density (hardpans). These are characteristics that affect rooting depth and moisture relations. You can have your soil tested if you suspect nutrient deficiencies. If your soil is not uniform throughout the site, different tree species may have to be planted to accommodate these soil changes.

There are two additional methods for using soils information in determining the suitability of different species for reforestation. The first involves determining the soil series from soil survey reports or soil keys. Tracts in question can be identified on individual map sheets in the back of the soil survey reports. On-site verification should be conducted since soil surveys may contain site specific inaccuracies, especially for the woodland soils. If no soil survey report is available, soil mapping units can be determined from a key available from the Natural Resource Conservation Service (NRCS). Mapping units are determined by the physiographic province, landscape position, nature of the soil parent material, key soil profile characteristics, and drainage class.

The second involves submitting soil samples from specific areas for lab analysis. This requires that soil samples from the upper 6 inches be collected. Soil samples should be collected from throughout the field. The University of Wisconsin Soil and Plant Analysis Lab offers a special test for pH, organic matter, total nitrogen, extractable phosphorous, exchangeable potassium, calcium and magnesium, and provides interpretations for seven tree crops. A forester following a field check can determine which species are appropriate based on aspect, exposure, depth to groundwater, pH, silt plus clay content, and organic matter content.

The soil test is helpful because it will aid in determining the following:

1) Production potential: Not all soils will support trees. Tree growth rates are quite variable on differing soils and moisture regimes.

2) Limitations of equipment and use: If your soil has a high bulk density or has the potential to be compacted or puddled, your management options will be narrowed because heavy equipment will exacerbate the problem. Compacted soils have reduced water infiltration, lowered hydraulic conductivity, and reduced oxygen availability.

3) Insect and disease hazard: Certain soil factors such as poor nutrition and poor aeration have been linked to insect and disease problems. The site itself may have a history of insect or disease problems.

4) Species selection: Match planting stock to sites to fully utilize the productive capacity of the site. Start by selecting the best adapted species and then select the appropriate individual sources within that species.

5) Fertilizer requirements: These will vary depending on the nutrient content presently in the soil.

6) Pesticide use: Soil moisture, texture, and organic matter affect performance and application rates.

7) Goals: Review original goals and confirm that site is appropriate for initially established goals

2.2.3.2 Forest Habitat Type Classification System

This site classification and evaluation tool, when appropriately applied and interpreted, can help evaluate forest establishment and management alternatives. Applicable management considerations include inherent site capability (biological potential), relative soil moisture and nutrient availability, suitability and productivity for specific tree species, potential cover types, competition, successional trends, and potential responses to disturbance. Specific applications for artificial regeneration include site selection, species selection (ecological characteristics and silvicultural options), plantation design and spacing, site preparation, and plantation maintenance.

The preferred method to determine the forest habitat type class is on-site evaluation of summer vegetation within a mature forest. This may not be possible for many sites where artificial regeneration is being considered. The following procedures can be utilized to estimate the habitat type for non-forested sites:

1) evaluate and identify the vegetation currently on site; depending on management history some diagnostic species may be present,

2) identify the soil type and landform type, and then determine associated habitat types, and

3) identify habitat type in nearby woodlots if soil, topography, and landform are similar.

The Forest Habitat Type Classification System is defined, discussed, and referenced in another chapter of this Handbook. Each cover type chapter identifies the range of associated habitat types, along with potential productivity and competition.

The Field Guide for Forest Habitat Types of Northern Wisconsin and the Guide to Forest Communities and Habitat Types of Central and Southern Wisconsin are published by the Dept. of Forestry, University of Wisconsin -Madison and the WDNR. Copies may be ordered from: Department of Forestry, University of Wisconsin-Madison, 1630 Linden Drive, Madison, WI 53706.

2.3 Plantation Design

Plantation design will detail the specifics of your plantation, including the placement of the access roads, fire breaks, fences, etc. Your final plantation design plan should include acreage, species, number of trees ordered, spacing, arrangement, site preparation, and method of planting. Ideally, a plantation should be designed to provide financial return, aesthetics, wildlife needs, and diversity through proper design. Examples of goals and design considerations are as follows (remember these design considerations are not mutually exclusive):

If your goal is *timber management* you may want to consider some of the following:

- provide access to the trees through spacing to facilitate thinning, pruning, and harvesting
- include 20 feet wide harvest roads and firebreaks in larger plantings
- buffer powerlines, underground cables and gas lines
- match area markets with species planted
- avoid steep slopes and wet areas
- avoid frost pockets
- include some semi-shade tolerant species to serve as seed source for future natural regeneration
- enhance biological diversity and complement the surrounding landscape
- assess future regional wood marketing opportunities

Those also interested in *wildlife management* should consider the following suggestions:

- enhance biological diversity and complement the surrounding landscape
- offer habitats that are in short supply in the area
- choose tree and shrub species which are preferred food for various species
- choose tree and shrub species which provide cover (e.g., nesting habitat and winter thermal cover)
- leave islands unplanted that are encroaching to other tree and shrub species
- establish travel corridors to connect habitats
- plant around existing wolf trees
- create wildlife openings in the planting
- use a wide variety of species in the plantation, including wildlife shrubs
- create islands of differing sized/aged trees
- frost pockets and odd corners should be left unplanted to improve habitat and biodiversity

- plant artificial openings, such as isolated old fields, to create larger blocks of “interior” forest habitat

The following suggestions will help with *erosion* control:

- leave buffer zones near streams to prevent siltation
- plant trees along contours to prevent runoff
- don't use site preparation that might increase erosion
- concentrate trees in trouble areas
- keep drainage pathways covered with grass
- plant tree species in riparian zones that have a long-life expectancy

To improve the *aesthetic* quality of the plantation you can:

- vary layout and location of plantings
- use a wide variety of species in the plantation, including wildlife shrubs
- plant along contours
- use non-row plantings or curve rows for more natural effect
- create irregular plantation edges
- leave openings within the planting
- create islands of differing sized/aged trees
- planting parallel to roads reduces 'fiber factory' appearance
- frost pockets and odd corners should be left unplanted to improve habitat and biodiversity
- create or retain scenic views
- retain landmarks, distinct features (wolf trees)
- locate hiking trails to take advantage of scenic quality
- plant species with desirable fall color

2.4 Spacing

Spacing will be dependent on:

1. the product desired
2. the likelihood and intensity of intermediate stand treatments
3. the expected initial survival and spatial distribution of seedlings.

Be aware that initial spacing will affect both the biological and the operational factors of the plantation.

Height growth is reduced at extremely high and low densities. Most decisions about the spacing of trees is based on an assumption that 'normal' densities fall in a range that does not reduce dominant height. Diameter growth is unaffected by spacing until competition begins. The period of fast, early diameter growth is longer at wider spacings. But trees will have a large amount of taper; this may not be a desirable form. Wide spacing will also result in branch retention leading to knotty woods.

Spacing may also be affected by which species you select to regenerate. Relative shade tolerance and the species growth pattern will affect initial spacing. Additionally, spacing may be affected by the equipment available for planting, maintenance, thinning and harvesting.

Spacing will affect your thinning schedules. Wide spacings provide little selection opportunity for removing low-quality trees. Close spacing allows undesirable trees to be removed. The advantage of close initial spacing is that larger volumes accumulate in the early years. Also, close spacing will mean faster crown closure. This will reduce the need for weed control and may disrupt the life cycle of some harmful insects. Though crowded, stagnated stands will be more susceptible to insect and disease attacks. Vigor needs to be maintained through stocking control. Establishment costs are also a factor. Close initial spacing will have higher site preparation, planting, and seedling costs.

A general rule for spacing is to plant closer on higher quality sites and further apart on less fertile sites. Tight spacing helps to control competing vegetation and fully utilize the site. Generally, for high quality hardwood tree production seedlings should be spaced closer together to encourage straight boles and smaller lower branches that self-prune. Table 22-1 lists the number of trees per acre by spacing. The shaded areas are the more commonly recommended spacings.

Table 22.1. Number of trees per acre by spacing.

	4 feet	5 feet	6 feet	7 feet	8 feet	9 feet	10 feet	12 feet	15 feet
4 feet	2722	2178	1815	1556	1361	1210	1089	907	726
5 feet		1742	1452	1244	1089	968	871	726	581
6 feet			1210	1037	908	807	726	605	484
7 feet				889	778	691	622	518	415
8 feet					681	605	545	454	363
9 feet						538	484	403	323
10 feet							436	363	290

Advantages of wide spacing: planting costs are less, trees will attain larger diameters and become merchantable sooner, competition from other trees is reduced, they may produce seed earlier, undergrowth will provide food for wildlife.

Disadvantages of wide spacing: increased fire hazard, weed competition is extended longer into the rotation, erosion control is reduced with less crown areas, more biomass is allocated to branches and foliage reducing stem quality, poor drainage problems may be exacerbated.

2.5 Species Selection

When selecting a species, it must meet your management goals and suitable sites must be available. After determining the potential positives and limitations of your site, select a species or combination of species that can emphasize the positives and overcome the limiting factors. Along with selecting the best species, you should select the best seed source and stock type for your needs. With these goals in mind, the factors that should be considered when selecting species include growth rate, site requirements, climatic suitability, genetic variability, wood and fiber properties, aesthetics, wildlife value, biological diversity, erosion control and potential insect and disease problems.

The use of tree species not native to Wisconsin should be contingent on credible evidence confirming that the species in question is not invasive, will not create significant risk to forest health, and is from appropriate provenances that are well adapted to the site. If non-native trees are used, their provenance and the location of their use should be documented, and their ecological effects monitored.

Recently conifer and hardwood mixtures have been recommended for afforestation in Wisconsin. The benefits of these conifer-hardwood mixtures include conifers assist in capturing the site earlier, the cost of plantation establishment is less than a pure hardwood plantation, conifers improve the quality of hardwoods by shading out lower branches and forcing hardwoods to grow upwards, provide wind protection for the planting and the conifers offer a easy alternative for a first thinning. The real disadvantage to this mixture is that once established the options for chemical release of the plantation is narrowed significantly. Subsequently, initial site preparation treatments are critical for successful conifer-hardwood plantations.

Appendix 22- A contains a profile of species commonly utilized in Wisconsin's reforestation program.

2.6 Seeding vs. Planting

The first thing to decide when dealing with stand establishment is which method of artificial regeneration is appropriate. Planting is generally considered more expensive than direct seeding of conifers, but for hardwoods the reverse may be true depending on the cost and quantity of seed used. However, by using seedling several years of development are realized with a new planting.

Seeding is an excellent technique to inexpensively regenerate small areas, or to quickly reforest large acreage. Direct seeding is attractive because if successful, it will establish a more uniformly stocked stand, as opposed to a naturally regenerated stand. Direct seeding is more flexible, faster, less expensive, and since there are large numbers of seed spots per acre, successful trees will benefit from the best available microsites. It can be used where access, terrain, or soil conditions make planting difficult. Seeded trees often have better developed root systems and are often better suited to their environmental niche than planted seedlings. On old-field sites the additional benefits of planting seedlings versus direct seeding often does not justify the additional cost. Direct seeding can be an economically viable alternative to planting, although success with seeding requires knowledgeable selection of species/site combinations and proper seed handling and storage. Additionally, conifer seeds can be stored for a long time and used when needed.

The disadvantage with direct seeding is that often times it is not successful, though many of these cases can be attributed to improper planning. This uncertainty has led many to choose either natural regeneration or artificial regeneration through planting. Seeding is not an efficient use of genetically improved seed. Density is difficult to control. Losses of seeds and small seedlings can be high. Hardwood seed is difficult to obtain in most years and does not store very well. Another concern is that the likelihood of successful establishment of oaks with direct seeding is less because openings need to be large (2.5 acres), intensive site preparation is often necessary and follow up weed control is critical.

Sites to be avoided when considering direct seeding are areas where seeding has already failed. Avoid sites prone to frost or frost heaving. Avoid sites where grazing could occur, standing water may cover seed, soils are deep excessively drained sands (except for the direct seeding of jack pine), and highly erodible soils or steep slopes where seed could be washed away. Always use seed of appropriate seed sources that has been properly stored, stratified, and treated with the necessary repellents.

The ideal sites for seeding are where regeneration would have occurred if seed had been present. Direct seeding of sites can also be accomplished when planting is not feasible. Direct seeded oaks develop roots on site so there is none of the root injury associated with bareroot stock. On shallow-soiled sites direct seeding is easier than planting large bareroot stock. When seeds are purchased, those harvested in a good seed year are best. Collect from the best phenotypes. Try to use seed collected from within 100 miles from the eventual planting site to optimize an individual tree's potential for growth. If possible, select seed from trees on sites similar to those on which you intend to seed. Collect mature seeds just after, or right before they fall. Avoid trees that are isolated because pollination may have been poor. Proper seed collection, handling and storage is critical to successful establishment of a direct seeded plantations. Also, seed crops vary in quantity and quality, for example with red oak a good seed crop generally only occurs once every three to seven years.

2.7 Seed Source Selection

Seed source selection is an often overlooked, but critical component in a successful reforestation program. Selecting appropriate seed sources for the reforestation site will improve overall growth rate of the plantation since the trees are planted into an environment in which they are adapted. Appropriate seed source selection will also reduce catastrophic plantation losses due to maladapted genetic material. The literature and experience have demonstrated numerous times that these maladapted seed sources often survive and thrive for many years prior to a catastrophic event (e.g., frosts, cold winter weather, drought, flooding, etc.). All your efforts can be wasted by ignoring the importance of selecting the appropriate seed sources for a reforestation project.

The general rule of thumb for reforestation is that unless proven otherwise local seed sources (e.g., Wisconsin) are the most appropriate to use for reforestation. Genetic tests have revealed that certain non-local seed sources are adapted to Wisconsin's environmental conditions and can offer improved growth characteristics over local seed sources. Examples of this include southern Ontario white spruce and southern Appalachian white pine in southern Wisconsin. Additional seed source recommendations are made in Appendix 22-A, Individual Species Planting Considerations.

2.8 Stock Type Selection

Selection of the stock type is a biologically and economically crucial phase of the reforestation process. Selection of the stock type allows land managers to exert some control over the morphology of their seedlings. Selection of the most effective stock type for a given situation depends upon the identification of the site-specific factors that determine seedling establishment and growth.

This section provides advice for selecting stock type, stock quality and maintaining vigor throughout the planting process. Proper seedling stock type selection will have the greatest influence on the establishment and early growth phases. Proper seedling selection will also help to minimize the early limiting factors of the site.

The following is a list of stock selection factors that need to be addressed during the stock selection process:

1. Review the original goals and confirm that goals and site are still appropriate.

2. Select species/ seed lot. Species selection should be based on ecological acceptability; production goals; silvicultural system; forest health; and local experience. The use of less expensive stock may save on initial costs, but there are risks and expenses that come with variable performance. Seed lot selection should be based on availability, quality, and local seed lot performance.

3. Determine site preparation requirements to overcome limiting factors that the stock type alone cannot. It can help by customizing microsites and improving plantability.

4. Determine the limiting factors stock will have to overcome.

5. Decide which seedling characteristics are needed to surmount the identified limiting factors.

6. Evaluate historical stock type performance and experience.

7. Identify the stock type most likely to overcome limiting factors.

8. Look for a stock type that is appropriate for several or all limiting factors.

9. Consider altering the species or site preparation prescription if no stock type is suited to overcoming limiting factors.

10. If multiple stock types appear equally suited to the site, examine costs, desired stocking, and the logistics of handling and planting.

In addition, the following is a list of operational factors that could affect the stock type selection and the planting operation:

1. Stock cost

2. Stock availability

3. Planting cost

4. Site location, accessibility, and conditions

5. Storage facilities and handling - Prolonged storage reduces a seedling carbohydrate reserves and reduces overall vigor, though spring lifted and shipped seedlings are less sensitive to this type of deterioration of stock quality.

6. Transportation availability and cost (due to site accessibility) - If refrigerated transport cannot be assured it is wise to ship only what is necessary. Storage under ambient conditions is not advised for extended periods.

7. Planter availability and experience - If experienced planters are not available provisions for training and supervision should be made.

The next step in stock type selection is whether to use containerized or bareroot seedlings. The following is a list of attributes, advantages, and disadvantages of containerized and bareroot stock. It should help you decide which type of stock is best suited to your needs.

2.8.1 Containerized Stock

Containerized stock can be less than one-year-old, and trees are grown, shipped, and planted in a medium of peat, perlite (or vermiculite), and sand. Average stem caliper is 2-3 mm and height 10-15 cm. Historically, primary usage has been with conifers in the Lake States, but recent advances in pot sizes has allowed the production of containerized hardwoods.

Advantages of containerized stock include: can be grown in 6-15 weeks; outplanting in the rooting medium; high productivity due to plantability; extends planting season, reducing peak demands on labor; can be planted on rocky sites where it may be difficult to open a hole for bareroot seedlings; higher survival rates at outplanting; more efficient use of seed; superior initial height growth; more uniform seedlings; greater flexibility with tree planting machines; less likelihood of transplant shock; perform well on adverse sites. Containerized seedlings are more resistant to the heat and drying stress than bareroot seedlings so 3-5 days' worth can be shipped at once and a cool van is not as necessary.

Disadvantages of containerized stock include: less able to compete with weeds; more vulnerable to browse damage; lower survivorship when insolation is high; more prone to frost heaving when planted on bare mineral soil; need transport designed for the bulky containers; more expensive than bareroot stock; paper containers can fail to decompose fast enough; paper needs to be covered or it will wick away needed moisture; require more attention while growing; often smaller in size; may need more intense site preparation; the conditions that speed development are also conditions conducive to disease development and nutritional imbalances; fewer can be transported to the field at a time. Moisture level in the root masses needs to be checked regularly.

2.8.2 Bareroot Conifer Stock

Bareroot conifer stock is obtained as 1- to 3-year-old trees and either as seedlings or transplants. A designation such as 2-0 means the tree spent two years in a seedbed, while a designation of 2-1 means the tree spent 2 years in the seedbed and 1 year in the transplant bed (transplanting improves root development). In general, this stock should have a 4-6 mm caliper and a 2:1 shoot/root ratio. Seedlings intended for dryer sites should have smaller tops to reduce transpirational losses.

Advantages of bareroot conifer stock include better able to compete with weeds and survive both browse damage and sites with high insolation; easily transported and stored; less prone to frost heaving on heavy soils; less expensive. Bareroot seedlings are more readily available than containerized seedlings in Wisconsin. In addition, with the availability of differing age classes and nursery cultural regimes there is a wider selection of stock type attributes.

Disadvantages of bareroot conifer stock include takes longer to grow; exposed roots dry out very quickly; lower planting productivity; shorter planting season; prone to root damage and root deformity during planting.

2.8.3 Bareroot Hardwood Stock

Bareroot hardwood stock is generally produced as 1- to 3-year-old seedlings. Recent studies have demonstrated the importance of lateral root formation as the most critical factor in hardwood seedling survivability and future growth. Generally, a minimum of five primary lateral roots (>1 mm in diameter) are required for hardwood nursery stock.

Advantages of bareroot hardwood stock include regenerate roots rapidly; not subject to lodging by competition; sprouts readily; mast for wildlife.

Disadvantages of bareroot hardwood stock include large seedling size requires special planting considerations; requires large storage area; site preparation and follow up maintenance required to ensure success; more expensive than conifers.

2.9 Seedling Quality Characteristics

a. Shoot height is the most obvious and easily determined seedling attribute. Alone this measurement is of little value, but along with root-collar diameter and shoot architecture it becomes important.

b. Root-collar diameter is one of the most useful morphological measures of seedling quality. Diameter often reflects seedling durability and the size of the root system. A larger diameter will mean a seedling is supported better, resists damage better and can sustain higher levels of insect and animal damage. It will also be better insulated.

c. Root architecture is an important attribute when selecting high quality stock. An expansive, fibrous root system that contacts multiple soil layers upon planting is a sign of quality nursery stock. The more fibrous the root, the greater hydraulic conductivity the seedling will have, and it will be less susceptible to various stresses.

d. Shoot architecture should be an appropriate size for the root system. Leaf arrangement should provide adequate sunlit leaf area, but too much leaf area can cause transpirational demands to be excessive.

e. Shoot to root ratio is the most widely used parameter in determining seedling quality. A 2:1 ratio is often recommended for conifer nursery stock, but it can be of limited usefulness since the ratio changes with time and tree age. On drier sites you will want a lower shoot to root ratio, and on moist sites the opposite may be true.

f. The physiological condition and carbohydrate reserve of a seedling is important in determining its resistance to stress and its ability to establish quickly.

g. Presence of mycorrhizae on the roots. Mycorrhizae increase the surface area of the roots and the ability to provide water and nutrients to the seedling.

2.10 Stock Health and Condition

Stock health and condition must be considered when selecting a stock type and when accepting planting stock. The following should be evaluated when receiving nursery stock or removing stock from storage conditions:

a. Succulence: Succulent shoots are more sensitive to handling stress than hardened-off stock and should not be shipped; it is better to wait for them to re-harden.

b. Root dieback: Root dieback can persist on stock and cause reduced growth and mortality. A conservative strategy should be used to reject stock that displays dieback symptoms.

c. Foliage and stem diseases: Stock displaying symptoms should not be accepted. Selection of larger stock types can help minimize the impact of foliage diseases.

d. Heating: Stock that has been improperly stored, handled or transported will heat, causing damage to the seedlings. A conservative strategy should be used to reject stock that displays heating symptoms.

3 SITE PREPARATION

Site preparation is the creation of a favorable growing environment for tree seeds or seedlings. The main objective is to establish plant communities of desired quantity (# trees/acre) and quality (species and form). A successful plantation establishment depends on accurate assessment of the site, biotic and abiotic factors, and the site specific prescription.

Plants are affected by sunlight, relative humidity, foliage and soil temperatures, soil moisture, fertility, bulk density, animals and plant pests. Site preparation has the potential to address all the plants requirements and influences which factors will ultimately affect survival and plantation development. Site preparation must create sufficient numbers of suitable, well-spaced growing sites for the establishment and growth of tree seedlings without causing excessive soil disturbance. Site preparation should also be done in a manner which facilitates subsequent management and achieves results at the lowest cost.

Effective site preparation often will alter residual vegetation, alter slash load, expose mineral soil, increase root zone temperature, reduce the risk of frost damage, reduce competing vegetation, reduce the risk of insect damage, increase oxygen in the soil, and enhance nutrient availability. When site preparation is done incorrectly it can cause increased soil erosion and water quality degradation, increase soil compaction, create landslides, aggravate moisture problems, and negatively impact biodiversity and wildlife habitat.

When choosing a method of site preparation, stacking treatments can become very expensive quickly. There is a need to keep costs reasonable without selling out the seedling's chances of surviving. If you are planning to do your site preparation after a harvest, consider making the site preparation part of the logging activities. For example, the skidding of large trees can expose mineral soil and drop seed. Combining the activities can reduce total expense, but it does require increased planning, development of contract specifications and requirements to meet objectives, an experienced labor force and possible reduced timber sale revenue.

If seedlings are not provided a proper microsite through site preparation they can be vulnerable to short-term changes in their environment. If conditions are severe, just a few hours of certain conditions can be damaging, especially immediately after out planting.

It is crucial that you get the right number of quality planting spots/acre or the result will be an understocked stand that may not have the form you desire. Check the operator's work daily. You have to communicate your desires for all aspects of the operation; people are not mind readers. Understand the site characteristics and match the site preparations accordingly. Costs are variable depending on the site and operator's skill.

The are many different types of site preparation including manual, mechanical, chemical, and burning. Manual is rarely used as it is appropriate for only the smallest plantings or most difficult sites. The method and extent of site preparation can leave long lasting effects which can impact future management decisions.

3.1 Mechanical Site Preparation

Mechanical site preparation includes blading, raking, plowing, ripping, mixing, chopping, scalping, mounding, dragging, trenching and rotovating.

1. Blading is the use of an angled blade to scarify the soil prior to a harvest or to clear a path through slash and small residual trees. The process is best on boulder-free flat terrain. Rocks protruding from the soil bend and dull the blade edges making it ineffective. Depending on the management objective, the process may expose mineral soil. For scarification purposes, blading works best in frost free conditions. For shearing purposes, blading works best in cold weather (better shearing ability) and when there are < 250 trees/ac. and trees are < 10 in. DBH. Blading may produce scarified patches, windrows and nicely prepared strips depending on management objectives. For scarification work in a forest understory, the process requires a skilled operator and a large prime mover (270 HP). Windrows on treated sites can be attractive to rabbits which feed on seedlings. Blading prepares the site for planting but does little for competition. Depending on the depth of blading, the action does not deter sprouting.

   An example of a blading implement is the KG Blade. The KG blade is 12'4" wide and weighs 11,380 pounds. It needs a D8 tractor with a 300 HP engine. It can be used when amounts of slash are high (>50 tons/acre). Slopes >15% can cause problems for the shearing action.

2. Raking removes brush and medium-heavy slash loads and can be used on slopes. Some mineral soil exposure is possible depending on the skill of the operator. Fixed teeth are easy to install and require less maintenance than a flexible tooth rake. They also require a trained operator and have lower productivity. Flexible tooth rakes yield cleaner piles, don't catch stumps and the rake can be fine-tuned to the site. Daily maintenance is required.

3. Plowing is the use of a front mounted V-plow on a prime mover. Plowing controls competing vegetation, removes slash, and exposes mineral soil. It works to prepare for hand planting, or it can coincide with mechanical planting. It works on level to slightly rolling sites. It is good with medium-heavy slash loads. Sites with large residual trees, shallow soils, and thin humus layers should be avoided. Wet sites should also be avoided as the furrows may fill with water. Furrows should follow natural contours to minimize erosion. It can be difficult to regulate the depth of scarification with plowing.

4. Ripping is used to rehabilitate compacted skid trails, roads, and landings. Hydraulic mounted tines with wings rip through the soil reducing bulk density. A large (D7-D9) prime mover is required. Ripping should be done with the contours and can be done when the ground is frozen, but not if the soil is wet. A skilled operator is needed.

5. Mixing is the mechanical blending of mineral and organic soil layers. It controls competing vegetation and exposes mineral soil but does not mend compacted soil. Mixing provides an excellent growing environment for seedlings. It provides good soil aeration and lowered bulk density for root development and better soil/water relations, while nutrients are retained in proximity to the seedling.

   Coarse mixing involves large (1,500-2,000 pound) disks and heaps the mixture in a raised bed which is dryer, has better aeration and is warmer. It works best on flat loams and fine textured soils. It does not work on rocky sites or sites with residuals or stumps. A large (D6-D9) prime mover is required. It works best in dry or slightly frozen soil. It provides vegetation control that lasts, but it is expensive and has low productivity, especially if a prior treatment is required. Equipment is also limited and requires high maintenance.

   Fine mixing chops all surface vegetation and mulches it with mineral and organic soil. It produces a high-quality product, but the process requires a large PM and is expensive because the mixing is very slow, and a pretreatment may be necessary.

   Spot mixing uses an implement on a boom such as an auger screw to produce individual planting sites. This can be used on a wide variety of sites and can be highly productive. It works best with dry to lightly frozen soil. A skilled operator is needed who knows the microsite needed. Treatments may need to be followed with herbicide to control competing vegetation.

6. Chopping is the cutting or flattening of brush, shrubs, and small trees. Chopping is best on even terrain with loamy or sandy soils that are not wet or thin because it requires heavy equipment. Chopping is limited on sites where the residual trees or stumps are large or where large rocks/exposed bedrock are present. Chopping is not appropriate for aspen regeneration because the blades reduce sucker vigor, but if the objective is increase stand diversity by reducing the aspen component a roller chopper would be an appropriate site preparation treatment.

   The Marden roller chopper is equipped with cutting blades and partially filled with water (the sloshing effect provides more effective cutting action). The Marden roller chopper is pulled by a D5 crawler tractor.

   The 2-drum roller features opposed rolling drums for better chopping action. It is best when used on vegetation that is a few years old so that it doesn't spring back easily. This chopper is not very maneuverable, can only be turned in one direction and is best on large tracts of land.

These rolling brush cutters reduce slash and competing brush to facilitate planting machines or scarifiers of sod for hand planting. Rolling brush cutters are often used where slash or residual brush is medium to heavy, rocks are absent, stumps are low, residuals over 6 in. DBH are few, and on areas where seed area or fire hazard reduction are needed.

A third type of chopper is the Pettibone Slashmaster which features highly effective front-mounted cutting hammers. The Slashmaster reduces slash, debris, and standing unmerchantable stems to small manageable pieces. The Slashmaster is faster and more maneuverable with its articulated frame, but it is only for controlling slash and brush. It works best in conifer slash at a rate of about 1 acre/hour. In principle the machine performs between a rake and a roller chopper though it won't remove organic matter as raking does or ride up on green material as roller choppers can. It is good on dry or frozen ground and little operator training is necessary, but daily maintenance is necessary.

7. Scalping or patch scarification is the creation of intermittent patches of exposed soil for direct tree planting or manual seeding. Scalping provides access to layers of both mineral and organic soil and leaves unused land unaffected. Scalping works well on dry sites with thin humus layers. Scalps must be of good size or competing vegetation will take over. Wet sites should be avoided to prevent the submersion of seedlings. It is preferable to scalp in the late summer or fall preceding planting and allow the scalp to stabilize over winter.

   The Bracke scarifier is an example of a scalper. It works best on flat to rolling hills with <25% slope and can handle light/medium slash. Stumps and heavy slash cause problems because the scalper will ride above the soil. Thick duff can also reduce penetration. The Bracke is rugged, creates regular patches and mounts easily. Unfortunately, it is not maneuverable and wheel slippage can disrupt scalp spacing. The Bracke scarifier needs a 90-130 HP prime mover with rubber tires or a JD450.

   It has a productivity range of 2-4 acres/hour. Its good in areas where erosion may be a problem because the scalps do not create a water travel way.

   The Leno scalper mounts directly to a 160-180 HP prime mover and is highly maneuverable and compact. The scalping action is independent of the prime mover. It produces a shallow scalp and is highly productive. It also requires regular maintenance. Patch size should be monitored closely. It is not for use on rocky terrain, shallow soils, thick organic matter, heavy clay, frozen soils, contours with >30% slope, or on sites with a high water table. The Leno works in light to medium slash.

   The Quicktatch scalper is a four-tined shield mounted on a small (90 HP) prime mover. Scalps are created through the periodic raising and lowering of the tines. It works wherever the prime mover can go. Thin soils, rocks, and stumps do cause problems. A skilled operator is necessary, but it is portable, easy to mount and relatively maintenance free.

8. Mounding is the production of raised intermittent mounds with deeper pits and higher mounds than scalps. They make good planting sites in cold moist environments or on soils with thick organic matter. The mounds are aerated, above the water table and handle competing vegetation if they are high enough. Mounds are typically 4-6 inches though they can be higher on wetter sites.

9. Dragging of chains or drums across a site is used to control brush, expose mineral soil (if organic layer is not too thick) and to crush older slash. Dragging works on flat to rolling terrain and is not limited by rocks or soil depth. It is often used with raking and can enhance natural regeneration.

   Sharkfin barrels are an effective piece of dragging apparatus which create trenches or patches of mineral soil. They do require a more powerful (150 HP) prime mover and are limited to sandy sites.

10. Trenching produces continuous trenches of exposed mineral soil with multiple planting sites along the wall of the trench, increasing planter productivity. Seedlings can then be planted where the microsite will be best. For example, seedlings can be planted in the bottom of trenches on dry sites. It works best on dry to medium sites. Trenching with discs removes competition. Avoid heavy soils, rocky soils and heavy slash.

    Trenching with discs can be an effective tool to reduce woody tree and brush competition because the disc penetrates the soil to a sufficient depth and severs the root system. This 'discing' requires a D8 tractor and can treat 2-3 acres per hour. Heavy slash reduces efficacy and should be raked from the site. Material <3 inches in diameter will not reduce operations greatly. Slopes greater than 20% can be difficult. Stumps can be limiting if they are high and fresh. Wet soils should be avoided as well as very grassy areas because the discing can stimulate further grass and weed development.

11. Rotovating produces a continuous band of tilled soil. Used generally on old agricultural sites. Need to let soil settle prior to planting as air introduced into the soil by rotovating can cause seedling desiccation. Ideal to do rotovating in the fall prior to planting the following spring to allow for the soil to settle. Avoid heavy soils, rocky areas, wet soils, and areas with slash.

    Rotovators come in varying sizes, ranging from 18 inches to 6 feet in width. The type of tractor required to power a rotovator is strictly dependent on the size of the rotovator.

3.2 Chemical Site Preparation

The use of chemicals in site preparation does not alter the slash load or expose mineral soil the way mechanical site preparation does, but it can be an effective means to control competing vegetation and improve tree growth. The use of herbicides for weed removal will increase the amounts of sun and water available to seedlings. It will stimulate growth by increasing foliar and root zone temperatures. Herbicides will also kill plants that may be providing shelter for seedling-feeding pests thereby reducing tree mortality and disease.

See Appendix 22-B for the Herbicide Effectiveness Chart and the Herbicide Comparison Table. They are meant to be used in conjunction with each other. They contain large amounts of information on herbicides labeled for forestry uses and are updated annually.

The first step is determining your need for chemical site preparation. The Effectiveness Chart will tell which herbicides are effective on a certain weed species or group of species as derived from the pesticide label. It is important to note that an herbicide label rarely notes all the weed species that a product is effective on. The Comparison Table will help if you are looking for a herbicide to apply by a particular application method or for a particular use. The information in the tables and charts about this section are likely to be dated so they should only be used as a guide and should not be considered recommended treatments.

Always read the label and material safety data sheet (MSDS) before recommending, purchasing or handling any pesticide. Pesticide labels have the force of federal law and directions must be followed precisely. Persons using any of the products listed assume responsibility for their use in accordance with label directions.

When making a pesticide recommendation always inform the individual to read and follow the label directions and to adhere to the MSDS.

The tables in Appendix 22-B provide a cross reference of tree species and herbicides. They are meant to encourage those intending to plant in the spring to plan weed control before trees are in the ground.

3.3 Fire as a Site Preparation Tool

Site preparation burns can be an effective treatment for artificial or natural regeneration because it accomplishes multiple objectives. Prescribed burning prepares a suitable seedbed by reducing organic layers; access for planters is facilitated by the removal of slash; plantable microsites are created; competing vegetation is removed or reduced; access for secondary site preparation is facilitated; the soil nutrient regime is often temporarily positively affected through increased levels of cations and accelerated mineralization rates; and soil temperature is improved through altered surface albedo and reduction in the insulating organic layers. Burning prior to planting has also been shown to positively affect ectomycorrhizal development, and seedling health and survival. Burning of dead grasses on farm fields can be helpful in controlling mouse and meadow vole habitat and reducing the girdling of planted seedlings.

A word of caution though, on sites that have been burned and immediately planted, soil temperatures at the ground line near the seedling can be significantly higher then the ambient air temperatures due to the absorption of heat by the black ash. This can lead to increase seedling mortality on these sites if daily air temperatures exceed 90 degrees shortly after planting. Subsequently, plan ahead and burn in the fall or at minimum a month prior to planting seedlings.

Prescribed burning is a regular occurrence in the regeneration of a number of species. Jack pine with its serotinus cones is adapted to regeneration following fire. A helpful hint is don't burn jack pine slash expecting to prepare a mineral seedbed for the seed contained in the cones on the slash. The cones and seed are also burned up in the prescribed fire. Possible alternatives include to prescribe burn the site and then direct seed jack pine or to mechanically scarify the site lightly to expose mineral soil and scatter the jack pine slash uniformly across the site. Prescribed burning has been used to stimulate oak regeneration, while controlling species not adapted to fire ecosystems. The mineral soil seedbed and reduced organic layers provided by burning provides excellent conditions for natural white pine, red pine, white spruce, black spruce and aspen regeneration.

Prescribed burning is a tool but is by no means a cure-all for forest management problems. It requires extensive training and experience to effectively plan, implement and control prescribed fires. Other disadvantages associated with prescribed fire include escaped fire scenarios, increased deer browse and reduced effectiveness of herbicides. In areas where fire has never played a natural role, its use may be inappropriate and detrimental.

4 COVER CROPS

Cover crops are appropriate for afforestation sites where they are grown to replace or build soil organic matter levels, increase soil aggregation, structure, and water holding capacity. They can aid in soil-stabilization, reclaim nutrients that have moved to lower soil levels, reduce leaching losses, and break up hard pans when their roots penetrate these layers. Cover crops also prevent invasion by competing vegetation, provide erosion control and additional wildlife habitat. They may also aid in breaking insect and disease cycles.

When selecting a cover crop, choose a species that will not adversely affect the growth and development of trees. Grasses can compete fiercely with trees. Legumes on the other hand have a number of advantages that can benefit seedlings. Legumes add nitrogen to the soil, increasing the fertility level; conserve moisture and nutrients; improve the soil physical condition; build up the soil organic matter; enhance microbial activity; decrease erosion; and provide a mulching effect. Most legumes have shallow roots that are not as finely branched as grasses making them less able to compete with tree roots for water and nutrients. Cool season legumes (such as hairy vetch) complete most of their growth during the early spring before moisture becomes limiting. Stems and leaves then form a mulch during the summer, conserving moisture and releasing nutrients. The disadvantage of hairy vetch is that it can smother smaller seedlings.

Small grain crops such as winter wheat, rye and oats can be useful cover crops. Generally, these grain crops can be planted directly into with seedlings. On sites prone to erosion, herbaceous legumes have been seeded in to reduce weed competition and bolster soil nitrogen.

5 OLD FIELD SITE PREPARATION (AFORESTATION)

5.1 Grass fields

The more intense site preparation you use the less weed control will be necessary immediately following planting. Plowing, disking and herbicide application are often used in combination for sod and woody vegetation control. The site preparation chosen will depend on the composition of the soil, topography, accessibility, density and composition of the existing cover, and cost.

For spring planted areas a proven method of site preparation consists of vegetation eradication with herbicide (glyphosate) in the previous autumn followed by plowing or disking 1 to 2 weeks after spraying. This kills deep rooted perennials, improves soil aeration and water movement, and stimulates microbial activity while incorporating organic matter into the soil. It is important that the site be plowed in the fall, not the spring. Spring plowing can create excessive soil aeration just prior to planting causing seedling mortality. Fall plowing allows the soil to settle through the winter and provides for excellent planting conditions in the spring. Simazine can also be a useful herbicide for site preparation.

Another common method of site preparation is the fall application of glyphosate and then an application of simazine, a pre-emergent herbicide, in the spring immediately following planting. Simazine seems to be the most effective in controlling the re-invasion of weed competition on a site when it is applied to a site that has had the existing weeds previously killed.

Spot treatments on open fields should be at least 5 feet in diameter. Spot treated sites never fair as well as sites that receive full treatment due to encroachment of neighboring weeds on the planting spot.

An intermediate treatment between broadcast herbicide and spot herbicide treatment is a strip herbicide treatment. The advantages of strip treatments are the reduction of erosion on sloping fields and the reduction in amount of herbicide required when compared to broadcast applications. This has proven an effective treatment when incorporated with between row maintenance (e.g., mowing) to prevent annual weed problems. The major disadvantage is the eventual encroachment by perennial weed species from the neighboring un-sprayed strips.

Knowledge of herbicide dosage is critical because too much herbicide can cause injury to seedlings while too little won't control vegetative competition. Always read the label and material safety data sheet (MSDS) before recommending, purchasing or handling any pesticide. Pesticide labels have the force of federal law and directions must followed precisely. Persons using any of the products listed assume responsibility for their use in accordance with label directions.

WHEN MAKING A PESTICIDE RECOMMENDATION ALWAYS INFORM THE INDIVIDUAL TO READ AND FOLLOW THE LABEL DIRECTIONS AND TO READ THE MSDS.

5.2 Former row crop fields (previous year)

Site preparation on fields that were in row crop production (e.g., corn, soybeans) the previous year generally involves the use of a pre-emergent herbicide following planting in the spring. Generally, the site will be bare soil with crop residue on the surface. Additional items that should be considered when planting trees on fields that were in agricultural production the previous year include the presence of a plow layer (hardpan) at 8 to 9 inches deep, topsoil erosion patterns, soil fertility levels, soil pH, and the presence of weeds. Site preparation possibilities to deal with these items include soil ripping to break up hardpans; sowing of a cover crop to stabilize soil, prevent soil erosion and weed invasions; and the addition of soil amendments to the site prior to tree planting to adjust fertility and pH.

The downside of these former agricultural fields that were in row crops the previous year, is that loam and clay soils in the springtime can be very muddy sites to mechanically plant trees. When scheduling tree planting, consider planting these agricultural fields with heavier soils towards the end of the tree planting season. Additionally, on agricultural fields formerly treated with atrazine, simazine may not be sufficiently effective due to resistant weed populations. So, anticipate the potential of a late summer annual weed problem.

5.3 Alfalfa fields

Alfalfa can be an extreme competitor with young seedlings for moisture and nutrients. It grows to about three feet in height and can completely shade out young seedlings. More important is that alfalfa lives many years and develops a deep, heavy root system which makes it difficult to control with conventional herbicides.

In order to control alfalfa, the root system must be killed. Moldboard plowing and rototilling are effective site preparation treatments for controlling alfalfa, but these mechanical methods can expose the site to soil erosion. Herbicides are effective on alfalfa when applied during the active growing season when the plant is translocating nutrients to the root system. Ideally, the tops of the alfalfa should be greater than 6 inches in height and in the early bud to flower stage. Alfalfa that has already reached the stage where seed has been set should be harvested and allowed to resprout prior to treatment. Additionally, alfalfa that is growing slowly because of stress from environmental conditions (e.g., drought) will not be effectively controlled by herbicide applications. In droughty conditions alfalfa has little translocation occurring, even though the top will dieback and the plant will look dead, the root system will still be alive and resprout vigorously.

Test results have shown late summer (mid-September in southern Wisconsin) applications of herbicides are effective in controlling alfalfa. Herbicides that have proven to be effective include glyphosate, dicamba and 2,4-D. Especially with dicamba and 2,4-D fall treatment is recommended since these growth hormones prevent the plant from becoming cold hardy. Even if the herbicide fails to kill the alfalfa, the cold winter temperatures will kill the plants.

An herbicide with a 24(c) special label for Wisconsin that is effective in controlling alfalfa and other broad leafed weeds is clopyralid. It is registered for use either initial site preparation treatments or for release. The label states that it can be used over the top of white pine, red pine, white spruce, white ash, red oak, black walnut, sugar maple and other species at any time during the growing season when weeds are actively growing.

6 DIRECT SEEDING

Seeding is an excellent technique to inexpensively regenerate small areas, or to quickly reforest large acreage.

6.1 Direct Seeding Equipment

1. Seeding Sticks - essentially a long tube with handles, a seed metering and release mechanism and a seed storage reservoir. The seed release mechanism injects the seeds into the soil from the bottom of the tube and can be adjusted based on the number of seeds desired per planting spot and the type of seed. Often used in areas too rocky for conventional seedling establishment. Advantages are they are simple mechanical devices, light weight and require little maintenance. Disadvantages include that site preparation (usually scalping) must be done in a separate step, they are not appropriate for larger direct seeding areas and changing species to be sown requires changing bushing within the seed metering device

2. Shelter Sowing Sticks - similar to seeding sticks in that it places a small quantity of seed in each planting site, but in addition a small, conical, degradable plastic shelter covers the seed. The shelter protects the seed from birds and rodents and provides favorable microsite for seed germination and seedling growth. Advantages include the protection of seed from animals and provide a favorable microsite. Studies have shown germination to be improved by as much as 60 percent. The main disadvantages are that the plastic shelters must be carried by the operator, the shelters can be removed from the planting site by strong winds or animals and the increased cost of the shelters.

3. Seed Dribblers - distribute seed from prime movers directly during the site preparation operations. Seed dribblers consist of a seed reservoir, seed metering/trip device and a long tube to aim the seed to the desired locale. Types of equipment that seed dribblers are made to attach to include Bracke scarifiers, fire plows, harrows, dozers and dozer blades. Advantages of this system include the automatic dispensing of seed during site preparation, little additional cost associated with seeding, and the prepared seed microsite is generally favorable for plant establishment. The main concern is that it is difficult to tell how uniformly the seed has been distributed across the site and ultimately to predict the results.

4. Hand Broadcast Seeders - consist of a seed hopper, a hand crank operated distribution device and an adjustable metering slot. Operation consists of filling the hopper and turning the hand crank while walking across the site to broadcast the seed. Advantages

include the simplicity of operation, reliability, and inexpensive mechanisms that require little maintenance and are useful to seed small areas rapidly. Disadvantages are that it is slow and labor intensive. In addition, it is difficult for operators to achieve uniform seed distribution, requires an enormous amount of seed and seed is exposed to damaging agents (animals, insects and disease) or may be removed from the target site by environmental conditions (wind and water).

5. Mechanical Broadcast Seeders - are mounted on various prime movers, including crawler tractors, skidders, wheeled tractors, ATVs or snowmobiles. Similar in design to hand broadcast seeders but these mechanical seeders are powered by electric motors or vehicle PTOs. Advantages include the rapid seeding on sites accessible to vehicles and that they can be attached to prime movers involved in site preparation treatments. Disadvantages include the enormous amount of seed required and the greater exposure of the seed to damaging agents and environmental influences.

6. Aerial Broadcast Seeders - similar to other broadcast seeders but are utilized on helicopters or fixed-wing aircraft and usually powered by an electric motor or by the aircraft's hydraulic system or PTO. Can be economically feasible for seeding very large sites. Advantages include the ability to easily seed rough or inaccessible terrain and large areas rapidly. Disadvantages include the difficulty in obtaining uniform application rates across the site, small hopper capacities, large amounts of seed required and again the seed is exposed to damaging agents and environmental influences.

7. Direct Seeding Hardwood Seed Drills - similar in design to a tree planting machine in that a shallow furrow is opened up and the seed is placed into the furrow then packing wheels close the furrow. Being used for direct seeding of large seeded hardwood species like oaks and walnuts.

6.2 Direct Seeding Methods for Conifers

6.2.1 Broadcasting (shotgun approach)

a. Aerial application provides good dispersal, but helicopters and planes are expensive. In reality, it may only be practical on large inaccessible plots.

b. Barrel seeders can be attached to sharkfin barrels to simultaneously accomplish scarification and seeding. It is best done in the late spring or early fall.

c. Cyclone spreaders are designed for small woodlots. Productivity is low but they are easy to use and transport.

d. Hand spreading has very low productivity.

e. Requires large quantities of seed and seed efficiency (number of seed required to produce an established seedling) is very low.

f. Seed is exposed to damaging agents and environmental influences.

6.2.2 Spotting (rifle approach)

a. Generally done in conjunction with spot scarification, like a Bracke scarifier.

b. Is a more efficient use of seed.

c. Controls the number of seed and eventually seedlings and stocking better.

6.3 Direct Seeding of Oaks

With the difficulties and expenses associated with regenerating oak forests, land managers are seeking information on why past regeneration efforts have sometimes failed and what can be done to ensure oak forests remain in a position of prominence in the future. Direct seeding is one possible method of regenerating oak and other hardwoods in Wisconsin, especially on old agricultural field sites.

6.3.1 Seed tree selection

Priority should be given to selecting seed from trees that are either on site or from sites as near and as similar to the planting site as possible. This will reduce the chance of an introduction of foreign and potentially deleterious genes into oak populations neighboring the planting site and will increase adaptability to the planting site. If oaks are absent from the site and nearby areas, one should collect from oak species that can be identified from reliable historical information as relevant to the restoration site.

In order to maximize the genetic diversity of seed harvested, avoid collecting acorns from closely related individuals. This may be difficult, though acorns rarely travel far from their maternal tree (usually from one to perhaps two adult-crown diameters). Theoretically, acorns should be collected from trees separated by at least two crown diameters.

6.3.2 Acorn collection

Acorns should only be picked when ripe. While on the tree the acorns are undergoing developmental processes that are vital to seedling survival. Premature harvesting may reduce viability or cause potentially disastrous early germination. Ripening dates can vary tremendously among species as well as within a species in a single population. For example, southern Wisconsin bur oak usually ripens in mid-August, white oak in late August to early September and red oak in mid-September.

Acorns with signs of parasite damage should be discarded because seedlings of low vigor are usually produced. Diagnostics of insect damage include premature acorn drop, softening of the acorn, tiny oviposition holes, and larger larvae exit holes. The oviposition holes may be located just below the lip of the cap and bacteria can enter the hole and cause disease.

Neither mean stand diameter nor mean basal area of the stand is correlated with acorn yield. Acorn production in oak is sporadic, infrequent, and unpredictable. This makes accurate acorn seed crop forecasts nearly impossible until shortly before seed-crop maturity. White oak and bur oak acorns are produced the same year as the flower. Red oak acorns however mature the year after flowering and an estimate of the acorn seed crop for the upcoming fall can be determined from the one year nutlets on branches in the previous winter.

Mature acorns are denoted by the following characteristics:

a. The pericarp of mature acorns turns from green to tan or brown at maturity.

b. Caps of mature acorns separate easily from the pericarp without being forced and without leaving pieces of the cap attached to the acorn. An exception is bur oak, where the cap can almost enclose the pericarp and doesn't separate easily even when ripe.

c. The cap scar is "bright" in appearance after cup removal. Fresh cup scars are bright yellow or orange for red oak, though this color soon fades after cup removal.

d. The cross-section of mature oak acorns show light creamy white to yellow cotyledons.

e. Floating acorns in water is good method for separating quality acorns from damaged or immature acorns. Sound, mature acorns sink in water. Defective acorns will generally float. Defects include parasite damage, cracked pericarps, rodent damage, mold, deformed pericarps, black spots on the pericarp, and acorns with dull-brown or gray cap scars or difficult to remove cups. Water flotation also facilitates the removal of leaves, acorn cups, and other debris making sowing of the acorns easier.

Hints to collecting quality acorns:

a. The first acorns to fall are usually defective, either due to incomplete development or exposure to a damaging agent.

b. Acorns can be collected from the tops of felled trees if they were felled when the acorns were ripe. Do not pick immature acorns, they cannot be artificially ripened.

c. Acorns should be collected from dominant oaks with tall, straight boles, good diameter growth rates and well-developed crowns.

d. Light acorn crop years usually have a higher percentage of insect infested acorns.

e. A sample from each seed source should be inspected and evaluated for soundness, maturity, and quality by cutting the acorns in half.

f. Acorns on the ground are subject to predation and rapid decline, especially in dry weather. If collecting from the ground, do so shortly after the main release of acorns occurs.

g. If there is ever a choice, choose the larger acorns. It only makes sense that the larger acorns will have larger nutrient reserves and some studies have indicated a positive relationship between acorn size and subsequent acorn germination, seedling survival and height growth.

6.3.3 Germination

An acorn's ability to germinate is often used as a diagnostic to estimate the potential of seed lots and determine sowing rates. White oak acorns lack embryo dormancy and begin germinating in the fall, subsequently they must be sown almost immediately after collection. Germination tests also are not feasible to perform on fall sown red oak acorns. A cutting test can be used to estimate the number of sound seed in a seedlot for white oak and fall sown red oak acorns.

Germination will drop off sharply once weight loss of the acorn exceeds 10%. Weight loss also dramatically reduced respiration of the acorns. This weight loss in acorns is generally associated with the loss of moisture during storage, even short-term storage. Acorns must be kept damp throughout germination and especially just prior to radicle emergence because the imbibed water provides the turgor necessary to push the radicle through the pericarp.

Assuming sound acorns, germination between 30 and 40 percent is common. In the state nurseries oak acorns are sown at a rate of approximately 200 sound acorns to produce 100 plantable seedlings. Germination may be significantly reduced due to damage caused by low temperatures (less than 5 degrees C), desiccation and fungal infections. White oak acorns will not germinate though after a loss of 30 to 50% of seed moisture content.

6.3.4 Acorn storage

White oak acorns should be sown immediately following collection. Red oak acorns should be sown as soon as possible after collection, but if you desire to temporarily store red oak acorns, the following should provide direction on the requirements needed.

Conditions coinciding with successful red oak acorn storage after seed fall include continually high moisture content of the acorn; opportunity for gas exchange with the environment; temperatures near freezing and no fluctuations of temperature during storage. These conditions walk the fine line between causing cold injury and permitting germination once dormancy requirements are met.

Polyethylene bags of 4 to 10 mil thickness without any packing medium work well for stratification and storage of acorns. They are permeable to carbon dioxide and oxygen, while remaining largely impermeable to water. Container tops should not be completely sealed to allow for adequate aeration. Bags should be stored on shelves for good air circulation.

The key to maintaining acorn quality is to avoid desiccation. Seed moisture content should be determined at the time of collection as well as periodically throughout the storage of the acorns. If moisture content drops below 35%, soak acorns in water at room temperature until moisture contents are above 40%. Seed moisture contents must be kept high (>40% based on oven-dry weight) and adequate aeration for the acorns must be provided. Water immersion for 24 to 48 hours before storage results in acceptable acorn moisture content.

Storage temperatures that go much higher than the recommended range of 1 to 3 degrees C will result in increased germination in storage of white oak. Microorganisms can kill radicle tips during storage and radicles can be broken. This may be advantageous however, as a damaged radicle may result in a multiple-rooted seedling which will survive out planting better.

When deciding if acorns will be germinated under refrigeration or in the ground, note that under refrigeration, germination can be delayed until field conditions are ideal for seeding, herbivore and pathogen damage is reduced, and monitoring of the germination process can take place. On the negative side, refrigeration can desiccate acorns and result in losses of seed viability. Prolonged storage should be avoided because it increases the risk of infection and adds to the loss of energy reserves through respiration.

6.3.5 Site preparation

Direct seeding of acorns requires site preparation for the same reasons that site preparation is needed for planted seedlings (i.e., reduce vegetative competition, reduce slash loads, create a favorable growing environment, reduce rodent habitat, and increase nutrient and water availability). Adequate site preparation is critical to insure a successfully established oak stand by means of direct seeding acorns.

Soil preparation and vegetation control should be carried out before sowing acorns, though it does not seem to have any great influence on the initial emergence of seedlings, it is critical to the seedling's initial growth and survival. Although many seeds germinate best in a mineral seedbed, the removal of the humus layer during site preparation does have an adverse effect on seedling emergence and should be avoided. Soil preparation often increases soil temperature which positively influences root growth and water uptake of young seedlings. Soil preparation also reduces the mechanical resistance to the growth of the young roots.

In preparing the site, eliminate rodent habitat over large areas by removing or reducing forest litter, logging slash, and vegetation. Methods for accomplishing this include prescribed burning, mechanical scarification, and chemical weed control. Without site preparation, sown acorns can be totally eaten by herbivores within a week. Acorn predation will be directly influenced by the size of the opening made. Vegetation and litter removal directly around the seed spot only will not reduce predation. Generally, an opening of 2.5 acres or larger is required to have an impact on rodent predation.

6.3.6 Sowing

Those that advocate spring sowing of acorns do so because there are lower rodent populations and the length of time that seed is exposed to predation is reduced. Spring sowing is only possible with acorns from species in the red oak group, acorns from white oak, swamp white oak and bur oak germinate in the fall after falling from the tree. Fall sowing may be beneficial because the germination rate is higher, overwinter storage is eliminated, at sowing time food alternatives are present for rodents, germination happens earlier than with spring sowings, and germination is less likely to be affected by a dry spring. Sowing an abundance of seed, such as occurs naturally during a good acorn crop year, may be a successful strategy due to predator satiation.

A covering of litter or soil will prevent desiccation and is necessary for good germination. Most research reports recommend sowing acorns to a depth of 2.5 to 5 cm unless rodents are problematic, or soil moisture and temperature are a concern. The rule of thumb in the state nursery is to plant seed to a depth twice the diameter of the seed.

Broadcast sowing results in poorer germination rates, costs are much greater than spot or row seeding, and is generally felt to be a waste of a value seed resource. Rates that have been used in broadcast direct seeding trials in Wisconsin are 8 bushels of acorns/acre.

Density of sowing is a factor of the desired stocking, the germinative capacity, and the level of predation. A 35-50% germination is typical for red oak and 1000 to 1500 acorns per acre can be expected to produce 300 to 485 one-year-old seedlings per acre. Recommend sowing rates are twice as many spots as trees desired and plant 3 to 4 acorns per spot. There is no upper limit on sowing density if the strategy is to provide acorn predators with more acorns than they can eat. It has been hypothesized that bumper crop years are an evolutionary response to cope with heavy seed predation.

Assuming sound acorns, germination of sown acorns between 30 and 50 percent is attainable. A seeding rate of 1500 acorns per acre in 500 well-spaced seed spots should be adequate for most objectives. Acorns should be sown about 1 foot apart at each seed spot. One study found that seed spot spacing of between 3 and 5 feet should allow for adequate stocking on areas with moderate to light mouse populations.

An additional idea is to sow a seed mixture of varying hardwood species appropriate to the site along with the acorns. This also benefits diversity in the future planting and reduces seed costs.

Other ideas being implemented include alternating rows of planted conifers and of direct seeded hardwoods. A hardwood seed drill has been used to sow acorns in bands 20 feet apart and within these bands in three parallel rows 15 inches apart. Within these bands a row of conifers is planted to act as a nurse crop for the hardwoods. Seeding rates of 2 bushels of acorns/acre were used. Early results look promising, and this seems to be the best use of the limited hardwood seed resource.

6.3.7 Rodents

Most oak seeding efforts fail due to rodents digging and destroying acorns. There is a relationship between rodent activity and amount of forest or grass cover. Seeding under a canopy is often victim to predation while seeding in a 2.5 acre or larger forest opening is more likely to be successful and rodent damage insignificant. Predation of acorns may be substantially reduced if covered by 5 cm of mineral soil.

Mice, voles, chipmunks, and squirrels usually damage acorns before they germinate and during the early stages of seedling development. In one study seedling survival was better on bare areas because of the reduced mouse damage as compared to litter-covered areas. Mice pilfered acorns before germination and after germination while seedlings were still persisting on food reserves stored in the acorns. Seeding was almost a complete failure when litter remained in areas highly populated with mice. Where mouse populations were not high, the improved germination did not justify the expense of litter removal.

Poisoned baits, chemical repellents and scent-treated acorns have been unsuccessful in reducing acorn predation. Plastic tree shelters and wire screens provide protection to oak acorns if they are installed immediately after sowing and are set below the soil surface. Unfortunately, such measures are prohibitively expensive. The use of diversionary foods such as sunflower seeds and oat kernels has not yet been used for oak reproduction, but it has been successful in aiding in the regeneration of some western conifers.

In old field situations it may be critical to the establishment of the plantation to first reduce the mouse and vole population by eliminating the protective grass cover and using rodenticides in rodent bait stations. In addition, raptor poles can be established in larger fields to assist in rodent control. In one experiment, oaks benefited from mowing between rows in the early years to control rodent habitat and reduce vegetative competition.

7 PLANTING

Planting seedlings may have a higher initial cost than seeding, but the chance of success is also higher. Planting also gives you a head start of several years over seeding. It can also be designed to facilitate future management activities.

7.1 Seedling Handling

Before the actual planting of seedlings, they need to be handled carefully. Keeping them healthy requires minimizing physical damage and keeping them at a constant low (33-40 degrees) temperature with a high relative humidity. They must remain in a state of dormancy from the time of lifting to the time of planting. If temperatures rise, so will respiration and young seedlings can quickly lose their energy reserves.

To prevent desiccation, keep relative humidity between 90% and 95%. If root hairs become damaged, they will never properly uptake water and nutrients.

Seedlings are often packaged and shipped in plastic-lined boxes that provide both physical and moisture protection for the seedlings. Bags are used for smaller quantities of seedlings. They do not protect seedlings from physical damage. Bales are seedlings packaged with a moisture-retaining material such as saw dust or sphagnum moss. They are used for very short storage or transpiration.

Until you are ready to plant, do not handle your seedlings individually. Leave them in their packaging to minimize physical damage.

Transportation is a vital consideration for all sizes of orders. For large orders (>1000 seedlings) a refrigerated truck is optimal. If one is not available, the following steps should be taken with a pickup truck:

1. place foam sheets on the bed and spacer boards between the foam and the boxes for ventilation.
2. with bags, or bales, build a frame to allow for air flow about the packages.
3. cover packages with a damp canvas tarp.
4. cover the canvas tarp with a solar-reflective tarp
5. fasten the load securely.

If the order is small, a refrigerated van is still the best way to go. If this is not possible, and the packages fit into your car, air conditioning on maximum along with insulation and ice packs is advised. Only a few minutes in a hot trunk can damage seedlings permanently. If you suspect that the seedlings have not been kept cool since leaving the nursery, you may want to open the package and sprinkle the roots with water.

Seedlings should not be 'heeled-in' or planted in shallow soil pits for long-term storage. Do not immerse seedling in water as this can drown root hairs. Do not delay planting while waiting for optimal soil conditions. Since most people do not have truly adequate long-term storage, seedlings are better off in the ground. If your planting job is large, consider receiving staggered seedling shipments to minimize storage time. The less time your seedlings spend out of ideal storage, the more vigorous they will be.

Root pruning of seedlings is a necessary process for seedlings with long fibrous root systems. Recommendations for root pruning 2-0 conifer nursery stock is to clip the root system off at 8 to 10 inches below the root collar of the seedlings. Remember, the shoot to root ratio is critical for conifer stock survival and performance, subsequently for larger conifer nursery stock, like 3-0 and transplants, a larger root system is required. For hardwood nursery stock the root system can be pruned to 8-10 inches in length and the laterals can be pruned at 4 inches in length from the main tap root. Again, the key to hardwood establishment and survival is to plant as large and vigorous root system as possible. If severe root pruning is required to plant hardwoods with the current equipment available, it would be wise to invest in new tree planting equipment designed specifically to plant hardwood seedlings.

Root pruning should be done in a controlled environment where the seedlings root system will not be exposed to drying effects of the sun and wind, where water is available to re-moisten the seedlings and the ambient air temperature is relatively cool (e.g., 40-50 degrees Fahrenheit). The worst place to do root pruning of seedlings is on the tree planting site itself.

7.2 Planting Procedures

7.2.1 Hand Planting

When planting by hand be sure to:

– keep seedlings shaded and cool until planting
– minimize handling of the seedlings.
– carry seedlings in a bucket or planting bag along with wet burlap to keep seedlings moist.
– never carry seedling exposed to the air or immersed in water.
– seedling roots should hang freely and just touch the bottom of the hole.
– long anchor roots may need to be pruned back.
– the new soil line should be just above the old soil line.
– pack the soil after planting

A rough estimate is that an inexperienced, but physically fit, tree planter can plant by hand 500 seedlings per day.

7.2.2 Machine Planting

Mechanical planting is suitable for especially large orders to be planted on even terrain. Generally, a 30-50 horsepower tractor and a crew of three is sufficient. The principles of seedling protection listed above certainly apply. Experience in operation of tree planters comes quickly and a crew can usually plant 5000 seedlings a day. The plantings should be checked early and often to make sure they are done correctly. Become intimately familiar with the tree planting machines and their adjustment. Routine maintenance of hydraulic system and other mechanical parts can prevent disastrous breakdowns in spring planting season.

If involved in scheduling of tree planting machines for private landowners a couple of pointers to remember including:

a. Do not schedule the tree planter for use each day of the week, spring weather and breakdowns will ruin the schedule in a hurry. For example, leave Wednesdays and Sundays free.

b. Find an individual or organization to provide movement of the equipment from landowner to landowner.

c. Stick with the schedule, even if the landowner who has the machine currently is not completed.

d. Schedule bare fields with heavier soils and lower lying areas later in the tree planting season.

e. Inform the landowners to pick up their trees at least the day prior to arrival of the tree planting machine.

f. Try and meet with the landowners on the first day the tree planting machine arrives if they are unfamiliar with the tree planting equipment to get them started properly.

7.3 Seedling Ordering

For seedling order forms or for general questions you can write or call your nearest state nursery:

Griffith Nursery, 473 Griffith Avenue, Wisconsin Rapids, WI 54494 (715) 424-3700

Hayward Nursery, 16133 Nursery Road, Hayward, WI 54843 (715) 634-2717

Wilson Nursery, 5350 Hwy. 133 E, Boscobel, WI 53805 (608) 375-4123

Seedlings for reforestation purposes are also available from private nurseries. The Wisconsin Nursery Stock Source Guide (DNR publication FR-095) lists by species and stock type the nurseries that produce or provide these trees.

8 PLANTATION MANAGEMENT AND MAINTENANCE

8.1 Monitoring

Monitoring is the operational practice of evaluating the outcome to improve its effectiveness. Successful plantations are identified for repetition and failures are evaluated to determine why objectives were not met.

8.1.1 Characteristics of a successful monitoring program:

a. Incentives. Without benefits to be gained by improving regeneration performance monitoring becomes inconsequential and inefficient.

b. Linkages. Evaluate how the interactions of climate, site factors, and seedling condition and timing factors affect the outcome of the regeneration treatments.

c. Stratification. Differences in site and stand conditions as well as treatments should be distinguished to explain the effects of a treatment on the site, seedlings (species, age, stock type), and planting practices.

d. Objectives. Program objectives must be defined before the effectiveness of the activity can be evaluated.

e. Evaluation. Determine effectiveness of the treatment in terms of the objectives set.

f. Records. Keep clear, concise, and current records.

g. Feedback. Monitoring results should be passed to those setting objectives and performing treatments to alter treatments.

h. Adaptive design. Activities change as knowledge improves objectives and treatments.

8.1.2 Survival Checks

One of the most important things to do after planting is to evaluate survival. This is a necessary step because you may need to replant to ensure that you meet your management goals. It also provides an opportunity to observe signs of animal, insect, disease, or competition problems. If adequate stocking of regeneration is not present, then supplemental planting should be implemented.

Survival counts are done 4-5 months after planting, and again after three years. The preferred method of conducting survival counts is to use random plots to evaluate survival. The common plot size utilized is 1/100 acre. You need a stake and a rope 11' 10'' long (the radius of a 1/100-acre circle). Select a plot randomly and circle the rope around as you count the number of live trees and total number of trees both live and dead. The number of live trees multiplied by 100 is the average trees/acre. The number of live trees/acre divided by the number of total trees planted/acre is the survival percentage. Sample randomly throughout the plantation and average the values from all the plots tallied to determine the survival of the whole plantation. The number of plots required to obtain a reliable survival estimate depends on the size of the plantation and the variability of survival within the plantation. A rule of thumb is to do one survival plot per acre for the first ten acres and one additional plot for each additional five acres of plantation.

Another method is to randomly select a row and walk down it while counting the live and dead trees. Switch rows periodically to sample across the entire plantation. Survival percentages can then be calculated.

8.2 Maintenance

8.2.1 Vegetation Control

To help your seedlings to continue growing vigorously post-planting weed control with the use of herbicides may be necessary until the trees are the dominant vegetation. Weed competition control is necessary for at least 3 years following establishment in hardwood plantings to give the hardwoods time to reach a competitive height. Refer to Appendix B for proper herbicide selection.

Post planting weed control and seedling growth can be maximized by shallow disking or rototilling between rows. Mowing will reduce weed seeding and rodent shelter, but it can also stimulate weed root growth and intensify competition for soil nutrients and moisture.

8.2.2 Animal Control

To control the damage done by browsing to your plantation you will need to discourage wildlife. Elimination of damage is not possible. There are two approaches to dealing with animal damage: prevention and containment.

Prevention is done by manipulating the environment to discourage invasion or controlling the target animal population. An example would be to plant a stretch of unpalatable vegetation, i.e., spruce, around the primary planting to dissuade animals from entering. The use of human hair clippings, perfumed soap, and sprays can be effective as temporary repellents, but their effectiveness is reduced with time. Population control methods include encouraging hunting for whitetails and rabbits and the use of rodenticides for control of rodent populations. Baits are hazardous and can affect non-target organisms. Rodenticides and repellents should only be used as a last resort.

Another method for controlling rodent browse is to remove their shelter. By keeping grass down, you reduce rodent access to seedlings and provide opportunity for predators to control the population. If the dens, nests, and perches of foxes, coyotes, owls, and hawks are left undisturbed it will naturally limit pest numbers. To encourage raptors perch poles can be erected throughout the plantation. For rabbits, the removal of brush and hedgerows virtually eliminates damage since they do not venture far from their shelter.

Containment includes devices such as electric fences, tree shelters, bud cap protectors, and bud nets. The key is to make sure that they remain intact.

8.2.3 Insects

Insects will affect every part of your plantation trees. Those causing the most damage fall into three categories: stem and root pests; shoot or branch pests; and defoliators. Common insects that can affect young plantations during the establishment phase include the following:

8.2.3.1 Main stem and root pests

1) white grubs - conifer planting sites should be checked prior to planting for presence of white grubs. White grub densities that are above 2 grubs for every 10 square feet of soil may cause heavy seedling losses due to feeding on the root systems. Old farmland with heavy grass sod is often infested with white grubs, especially on sandier sites. Control alternatives include delay planting of site for 2 to 3 years until the grub population declines or plan on accepting some losses and adjust planting densities appropriately.

2) pine root collar weevil - jack and red pine planted on nutrient deficient, sandy sites are susceptible to root collar weevil attack and subsequent death by girdling of the stem in the root collar region. Other hazardous conditions include planting a seedling with the root collar well below the soil surface, understocked stands, and

proximity to infested scotch pine stands. Prevention measures include not planting red pine and jack pine within 1 mile of infested scotch pine stands, planting seedlings with the root collar no deeper than 1 inch below soil surface, planting stands at densities greater than 800 trees per acre and controlling competing vegetation during early development stages of the stand.

3) pales weevil - red pine and white pine seedlings planted on sites with recently cut pine stumps are susceptible to feeding injury and death by pales weevil. Prevention measures include the removal of freshly cut pine stumps during site preparation, delay planting for two years after harvesting pines to allow stumps to dry out so they no longer can support pales weevil and treat pine stumps in early spring with an insecticide to preclude pales weevil egg laying in them.

8.2.3.2 Shoot or branch pests

1) Saratoga spittlebug - hazardous situations are sites where red pine (primary host) and the combination of sweet fern, willow and berry bushes (alternate hosts) cover 20% or more of the site. Prevention measures include adequate site preparation treatments to remove alternate host species or do not plant red pine on sites where the alternate hosts cover more than 20% of the site.

2) European pine shoot moth - Open stands of young red pine trees with lower branches extending below snow line are susceptible to European pine shoot moth attack. The hazard zone in Wisconsin extends from southern Door County to southern Lake Winnebago to Walworth County. To avoid problems with European pine shoot moth, promote early stand closure by planting 800 or more trees per acre and controlling competing vegetation in early development phases of the stand.

3) Pine Tortoise Scale - a sap-sucking insect of jack pine that can cause branch and seedling mortality. Prevention measures include insecticide spraying in severe infestations during June or July and planting or at least 800 trees per acre to promote stand canopy closure.

4) *Acrobasis* sp. - Two species of *Acrobasis* damage black walnut by mining the expanding buds in the spring; one of the two species then bores in and kills the new shoots. Rarely, populations become high enough to kill young trees less than 3 feet in height. Monitor local Acrobasis populations in young walnut stands during the winter months when small gray eggs are located near the buds. Spray with a registered insecticide if population becomes high enough to kill reproduction.

5) Kermes oak scale - Full grown female Kermes scales have the appearance of a gall about 3/8 inch in diameter. They are sapsucking insects that weaken and kill twigs when they attach in groups of three or more. They occasionally cause moderate twig damage in planted red oaks. On higher quality sites, the red oak usually will outgrow the problem. On very poor sandy sites, planted red oaks can

be kept in a perpetual bush stage by repeated attacks. Avoid planting red oak on poor quality, sandy sites. On high quality sites, spraying has been effective in reducing the scale population but is seldom necessary.

8.2.3.3 Defoliators

1) <u>Spongy moth (formerly known as gypsy moth)</u> - Spongy moth caterpillars kill mainly oak reproduction by defoliating seedlings. The caterpillars originate in nearby heavily infested hardwood stands and individual trees. The problem can be prevented by establishing new stands at least L’ mile from susceptible stands. Where this is not possible, monitor the spongy moth population in nearby hardwood stands and spray with a registered insecticide when population is high enough to threaten high-value reproduction.

2) <u>redhead pine sawfly</u> - red pine and jack pine trees are susceptible to redheaded pine sawfly defoliation. Hazardous conditions to avoid include shallow, disturbed, or eroded soils; proximity of northern hardwood stands (esp. sugar maple); and heavy competition from grasses, bracken fern or sweet fern. Prevention in future plantations can be accomplished by avoiding planting red pine on disturbed, eroded, or shallow sites. Leave at least a 50 foot buffer strip between red pine plantings and northern hardwood stands. Do appropriate site preparation and follow up releases to control competing vegetation. Plant 800 or more seedlings per acre to promote early canopy closure.

Additional information concerning insects can be obtained from this Handbook in the specific cover type chapters.

8.2.4 Diseases

Diseases can be classified into two broad categories: root rots; and cankers, rusts and shoot blights. Root rots cause trees to have slow twig and leader growth and a yellowing of the crown which may be especially evident in the leader. Mushrooms or fruiting bodies can be found about the base of the stem and disease often occurs in distinct infection pockets. Cankers and rusts cause dieback and the tell-tale sign is the presence of a swelling and/or lesion on stems and branches. Foliage diseases cause mottled spots on the affected foliage. Other foliage diseases cause browning or curling of foliage. Common diseases that can effect newly established and young plantations include:

8.2.4.1 Root rots

<u>Armillaria root rot</u> - this root rot is caused by a fungus that feeds on and decays hardwood and conifer stumps. Pines planted on previous hardwood forest sites are susceptible to this disease. Preventative measures include avoidance of planting red pine or white pine stands on or near previous hardwood sites with known root rot infestations or delay planting these sites for 7 to 10 years after harvest to allow the fungus to die out. Another option, though definitely more costly, is to remove hardwood stumps during site preparation.

8.2.4.2 Cankers, rusts and shoot blights

1) Sirococcus shoot blight - a fungus disease spread from older red pine to younger trees by raindrops in northern Wisconsin. Sirococcus causes mortality of young seedlings and saplings. Prevention can be accomplished by planting new red pine stands with a buffer zone of 150 feet from existing red pine stands.

2) White pine blister rust - a fungus which requires white pine (primary host) and gooseberry or current bushes (alternate hosts) to complete its life cycle. Statewide avoid small forest opening, bases of slopes, V-shaped valleys, and other topographical depressions. Other preventative measures include planting white pine on dry or sandy hilltops, steep slopes, or open fields; and use white pine blister rust resistant seedlings or consider alternative species.

3) Diplodia shoot blight - red pine seedlings under stress due to poor site, drought or frost are susceptible to infestation by diplodia shoot blight. Preventative measures include the avoidance of planting red pine on dry sites or sites that have a history of serious Diplodia infection.

4) Eastern gall rust - a fungus which requires jack pine (primary host) and oaks (secondary host) to complete its life cycle. Jack pine seedlings growing in the vicinity of oak trees are susceptible. Improved jack pine seedlings from DNR seed orchards have had resistance to jack pine gall rust as a criterion in the selection process.

8.2.5 Weather and Environmental Damage

It is important to be able to recognize tree injury caused by weather and environmental injury.

1) Drought - trees damaged by drought have wilted and yellow/brown foliage. The symptoms should be similar throughout the plantation. Recovery is possible if seedlings get water before extensive root damage is done. Drought will weaken seedlings and predispose them to biotic attacks.

2) Frost - damage occurs commonly in "frost pockets" and will curl foliage and kill it quickly. Frost damage is also a precursor for the tree to other biotic attacks.

3) Desiccation - dry winter winds cause desiccation of conifers, especially white pine. This causes the needles of the tree to turn reddish brown in color. Usually just an aesthetic concern.

4) Herbicides - improper application or timing of herbicide can cause damage. Signs are usually yellowed needles and distorted growth of the needles or leaders.

5) Pollutants - damage from pollutants can resemble many different problems and are extremely hard to identify. Sulfur dioxide and ozone are the major pollutants. Remember to avoid planting white pine in areas frequently exposed to air pollution and along major highways.

6) Fire - to deal with the risk of fire on your plantation your only option for prevention lies in reducing the amount of fuel. Keep vegetative debris to a minimum and see that a ready supply of water for fire suppression is available. The presence of weed-free firebreaks and access roads will allow fire trucks to reach fires and will make it more difficult for flames to spread.

9 OTHER REFORESTATION AIDES

9.1 Tree Shelters

Shelters protect trees from animal browse and improve initial growth rates by creating a 'greenhouse effect' around each tree. The 'greenhouse' traps carbon dioxide and moisture around the tree while light passes through. There are literature reports of height growth being increased from 100-200% versus non-sheltered trees after three seasons, but trials in Wisconsin have shown mixed results. This increase in height growth is generally associated with a reallocation of resources within the tree. Trees growing within a tree shelter have increased height growth, reduced stem caliper growth and decreased root system growth.

The best test results with tree shelters have come from use on open-field plantings, the shelters block a significant quantity of incoming light so use of tree shelters in shelterwood is questionable. Remember, shelters do not alter site quality, poor planting, or inappropriate species selection!

The tree shelters are used mainly on high value hardwood seed or seedlings such as black walnut and red oak. Shelters will generally increase survival and make the seedlings easier to locate for follow up maintenance. They also protect trees from herbicides, windblown sand and debris, and careless workers. Shelters do not however eliminate the need for vegetation management. Weeds in and about the shelters should still be controlled.

The decision to use a shelter should be based on initial shelter and stake cost, installation, site quality, species planted, the extent of competition, animal browse damage expected and future return on investment. Generally, for operational reforestation programs use of tree shelters cannot be economically justified.

Netting should be added to the top of shelters to reduce accidental bird deaths. Bluebirds and indigo buntings investigate the inside of the shelters for possible nest sites and then are not able to escape the shelter.

Recommended stakes include treated southern pine, plastic, cedar, oak and redwood heartwood. Stakes should be placed 2 inches from the seedling on the windward side. The base of the tube should be driven 1 inch into the soil.

Shelters require yearly maintenance, generally to re-attach shelter ties to the stakes, replace bird netting, and replace broken stakes.

9.2 Mulches

Mulch is also a valuable tool in the regeneration effort. Mulch protects seeds, seedlings and seedbeds from sun, wind, and excessive rainfall. Mulch can be made of straw, sawdust, bark, or wood chips. Anything that reduces erosion and competition while helping to maintain a beneficial microsite can be used as a mulch. Mulches must be applied to a depth adequate to suppress weed growth, generally 2-3 inches deep. The mulch should be deeper toward the outside of the tree and less near the base of the seedling. The disadvantages of natural types of mulch is that they can be attractive to rodents for nesting.

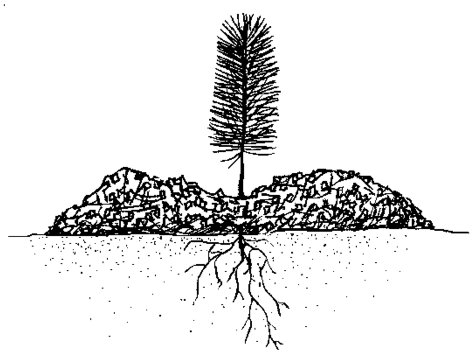

Figure 22.1. Diagram showing proper mulching technique.

Sometimes mulch mats made of polypropylene, polyethylene, kraft paper, wood fiber, grass mats, or polyester are used around new seedlings for protection. Mulch mats form a protective barrier around seedlings that blocks out competition without negatively affecting water relations. They can be expensive, but are invaluable if neither chemicals or fire are an alternative for vegetation management.

9.3 Root Dips and Gels

These products generally consist of a hygroscopic starch polymer that gels when wet. Coating of a seedling root system with a hygroscopic gel is done to reduce desiccation of the seedling during handling and planting operations. It is used often as a preplanting dip to reduce transplanting shock and mortality caused by short duration droughts immediately following planting. However, their effectiveness is uncertain and appears to decline with severe and long-term droughts.

10 SPECIALTY PLANTINGS

10.1 Windbreaks

A windbreak is a tall, dense, continuous wall of vegetation. A windbreak will generally reduce wind speeds to a distance of 10 times its height and reduce wind speed by 70% immediately inside the barrier. They are generally located to the north and west of areas that need protecting as that is the direction of the most damaging winds.

People use windbreaks because they can reduce heating and cooling costs by 10-15%. Windbreaks also provide a sound barrier from machinery, traffic, and animals. Windbreak plantings can beautify property and benefit wildlife. They also trap snow and act as a living snow fence, reducing maintenance costs and making roads safer. A windbreak is a valuable asset to any property.

The reduction in wind velocity reduces soil erosion and improves irrigation effectiveness, soil productivity and the quantity and quality of crops. Evaporation is reduced, soil moisture is conserved, and soil temperature is moderated. Windbreaks protect plants from abrasive and drying winds.

Multiple-row plantings can be used along with grass plantings to help filter animal wastes, pesticides, and fertilizers from irrigation water before entering streams and reservoirs. Windbreaks also serve as a valuable tool in the protection of livestock. Trees can moderate the chilling and drying effects of the wind. This results in animals needing less water in hot months and less feed in the cold winter months. Use of windbreaks can also reduce the occurrence of udder damage.

For the typical farm, windbreaks offer energy conservation, muted wind chills, beauty, snow control, reduced noise, wildlife sanctuary and potential wood products.

Mass plantings are an alternative to windbreak row plantings. Trees are planted at random intervals are often very close to each other. This type of planting works because the closely spaced plants protect each other from wind, sun and reflected heat. Species must be selected on their shade tolerance, root competition and moisture availability.

Along roadsides, mass plantings provide visual improvement, traffic control, and privacy. Along streams they are used to stop sheet and rill erosion or to filter sediments. Grass and forb cover may supplement the soil retention capacity of the trees. The barrier effect created by the addition of trees also reduces erosion by reducing the overland traffic of animals and vehicles.

Mass plantings are affective as buffers and can be aesthetically pleasing. They provide visual privacy, attenuate noise, diminish air pollution, reduce and slow storm runoff, maintain water quality, increase property values, benefit wildlife, moderate microclimates, and reduce heating and cooling demands.

10.1.1 Windbreak Planning and Design Considerations

The standard DNR windbreak packet contains 200 spruce and 100 white pine. This is enough for a 3-row planting, 800 feet long. Leaving 10-15 feet between rows is a good guideline. The second row should be staggered or offset from the first and third rows to provide better wind protection. The windward and leeward edges of the planting should be planted with a shade tolerant species that won't self-prune. White spruce or Norway spruce are good candidates for this position because they will provide a barrier near the ground even as they grow taller. The inner trees should be a species with considerable height. White pine, red pine, Imperial Carolina poplar or green ash would be good choices. Be cautious of establishing windbreaks along roadways with white pine due to salt toxicity.

Adding addition rows can greatly improve the wildlife holding capacity of your planting by adding shelter, food, and nesting habitat.

Windbreak plantings have a high individual value because each tree will eventually play a role. For this reason, each tree needs to be given a favorable microsite in which to grow. The way to do this is through proper site preparation. Competing vegetation can choke out young seedlings by robbing light and water or through the production of harmful chemicals. You can reduce grass competition by rototilling, fall plowing, and/or discing between rows. Do not plow in the spring, as too much air in the soil dries the young seedling's delicate root systems. Mowing can also knock back competing vegetation. Competition can be controlled with selective herbicides.

You may even want to consider protecting it with a fence in the early years. Weed control will continue to be necessary to remove both vegetative competition and mice and vole habitat.

Replace dead trees every year until every spot that should have a tree does.

10.1.1.1 Location of Windbreaks

- Position the planting as close to perpendicular to the prevailing winds or noise as possible.
- For wind protection place the row with the tallest growing trees species from 2-5 tree heights (estimated at age 20) from the protection area. If the area to be protected is uphill, the planting must be move closer.
- When wind and noise are coming from multiple directions, two legs rather than one will improve protection.
- Roads or paths through row plantings need to be oriented at an angle to the prevailing winds or wind will be funneled through the gap in the trees. No access roads should go through plantings in snow drift hazard areas. In these areas, the access roads should be placed 100-500 feet from the ends of the windbreaks to minimize problems.
- If soil differences exist within the planting strip, you should consider planting different species.
- Incorporate existing tree into your windbreak plan only if space is limiting.

10.1.1.2 Number of Rows

This number of rows will vary depending on the situation. Where wind, snow and noise are a factor, 3-5 rows are recommended. It is recommended that two to three rows of different species be used since one species could be decimated through insect or disease damage. Though the actual number of rows is important to note, the key is the density. Different species have different densities, and this will affect the number of required rows. Be sure you maintain density through proper species selection.

10.1.1.3 Row Arrangement

Shrubs, short trees, and slower growing trees should be located in the outer rows while the inner rows should have the taller growing species. If rows are going to be cultivated in between, the rows must be spaced far enough apart for the equipment to pass through. Common row spacing is from 12-20 feet.

Another type of row arrangement is called twin-row high density where narrow and wide spacings between rows are combined. Each twin-row contains two rows of the same species 4-6 feet apart and each twin-row is 25-50 feet from the next twin-row. This spacing leaves many options open for future renovation without damaging trees. Within row spacing will depend on the density and light and nutrient requirements of the species used.

10.1.1.4 Snow Management

A properly located shelterbelt can deposit snow on the lee side and prevent drifting. The snow is "trapped" in the wind shadow or dropped in front of the barrier.

The outside row must be 100-200 feet from the area of protection. All areas needing protection should be in the 2-5H zone. Locate any new roads at least 100 feet from the ends of the windbreaks to minimize drifting problems. For snow trapping, multiple row and twin-row high density plantings work best. The barrier length is simply determined by the size of the area to be protected. The length of the snow fence should extend 100 feet past either side of the area to be protected. The addition of 1 or 2 shrubs 500 feet from the windward side of the planting will benefit the snow management aspect of your planting. By trapping snow on the windward side of the shrubs as well as between the shrubs and the first trees you can count on snow removal being that much easier.

As trees grow, they can cause hazards, so plantings must be at least 30 feet away from the edge of a roadway to reduce ice on roads due to shading. Plantings should also be at least 20 feet away from power lines.

There are several characteristics of trees and shrubs that affect the quality of the windbreak. Wind movement and velocity are affected by leaf character, branching pattern, and stem form.

10.2 Noise Buffer Plantings

One potential benefit of buffer plantings is the reduction of noise pollution. Reduction of noise pollution can lower stress, anxiety, and can improve productivity. Buffers can improve health, happiness, and quality of life by reducing audible noise levels by 50%.

Sound is controlled by plants through absorption, reflection, deflection, or refraction. Trees and shrubs are effective as noise barriers because they can absorb sound energy. Trees also deflect sound toward the ground which should be covered with a thick grass layer which is an effective sound absorber.

Key points in designing a noise reduction buffer planting are:

1. Put barriers as close to the source as possible; they will be more effective.
2. Row plantings are not necessary, but they do aid in maintenance. If row plantings are used, use at least three rows with the narrowest row to row spacing possible.
3. Year-round effectiveness is most dependable when evergreens are used.
4. Shrubs should go on the source side of the planting.
5. Center trees should reach at least 45 feet at maturity.
6. Planting length should equal twice the length as the distance from the noise source to the receiver.
7. A diverse group of trees, shrubs, and grasses should be used for noise barriers

10.3 Plantings for Riparian Management Zones (RMZ)

The DNR defines RMZ as the areas next to lakes and streams where management practices are modified to protect water quality, fish and other aquatic resources. RMZ are one of the most important ecotones and deserve special consideration. RMZ plantings help filter sediments and nutrients, improve water infiltration, improve stream structure, stabilize banks and shores, shade streams, and provide food and habitat for wildlife. Research indicates in areas where conifers are indigenous that long lived conifers should be planted within one tree length of streams to eventually restore in-stream large woody debris structure. Species composition plays an important role in habitat next to water and the riparian use for bird and mammal travel corridors.

Plantings in these areas should be to enhance compositional features of the landscape. Additionally, in areas dominated by hardwood species planting or seeding of alder, willow, cottonwood, elm, or other mesic species is recommended to preserve water quality.

10.4 Interplanting

Sometimes forests will fail to regenerate as expected after canopy removal. Problems like this and other regeneration failures are potentially solvable through supplemental interplanting. Interplanting is defined as "establishing young trees among existing forest growth, planted or natural." Two factors determine the conditions that justify hardwood interplanting. The first is an absence of adequate advance reproduction of desirable species and the second is site quality. Good quality sites are obviously better candidates for interplanting. Evaluation criteria should consider the number, size, and spatial distribution of desirable advance reproduction. Don't forget to factor in the contribution of expected sprouts to fill all or part of the reproduction deficiency. It is conceivable that if there is little desirable advance reproduction that an herbicide treatment to re-capture the site may be required.

Interplanting is almost always accomplished by hand planting. Interplanted trees will be in competition with other vegetation so their success can be measured against the growth of dominant competing vegetation, subsequently existing vegetation control may be required. Generally, larger sized seedlings (e.g., 2-0 or 3-0 hardwoods and conifer 3-0 or transplants) are needed in interplantings situations in order to compete with this advance reproduction and stump sprouts. These types of plantings generally will require some type of release early in the establishment phase.

10.5 Underplanting

Another tool is to underplant seedlings in mature stands. Underplanting establishes desirable species without the cost of site preparation. This may allow the root systems of the planted trees to become well established before competition escalates after cuttings. Underplanting eliminates the difficulty associated with planting in slash. With underplanting, understory and overstory density control may be required to produce the light and soil moisture conditions necessary for adequate development of planted trees prior to the final cut.

Factors to consider in determining whether to underplant a stand is the time prior to removal of the overstory and the damage caused to the seedlings due to removal of the overstory. Generally, the time to schedule an underplanting of an existing stand is three to five years prior to expected final overstory removal. Depending on treatments to the stand prior to the underplanting (e.g., establishment of a shelterwood harvest) control of the existing vegetation may be required prior to planting.

As with any planting effort the size, physiological condition and overall quality of the planting stock can determine success or failure. Generally, larger sized seedlings (e.g., 2-0 or 3-0 hardwoods and conifer 3-0 or transplants) are required in underplantings situations.

10.6 Restoration Plantings

The purpose of restoration planting is to bring back landscapes that thrived in the past but today are dwindling due to human pressures on the land. Whenever possible, the chance to diversify the landscape with restoration plantings should not be overlooked. If you can feasibly restore a prairie, a pine barren, or an oak savanna it should be considered as part of your land use plan. Not only will you be adding aesthetic and biological variation you will be benefiting a unique or rare community type.

10.7 Wildlife Plantings

Woody wildlife cover in Wisconsin along roadsides, fencerows and field borders has rapidly disappeared. Wildlife cover plantings placed in any odd corner of a farm or property will attract some form of wildlife during the lifetime of the planting. However, if the placement of these plantings is done with recognition given to existing travel corridors; surrounding topography; potential nesting cover; proximity to wetlands; and food and watering areas - then the payoff in diversity and quantity of wildlife using the planting will be great.

One type of wildlife planting is the creation of hedgerows that provide travel corridors between habitats, wildlife cover and food. These are easily created along existing fencerows by just increasing the width of the fencerow with 2-3 additional rows of small trees and wildlife shrubs. Species that are ideal in this situation include silky dogwood, red osier dogwood, ninebark, hawthornes, elderberry, sumac, wild plum, American highbush cranberry, nannyberry, American hazelnut and wild grape.

One of the primary benefits of well-located wildlife planting is providing relief for wildlife from mid-winter winds and extreme cold temperatures. In Wisconsin, severe northerly and westerly winds are a concern in winter, subsequently winter cover plantings on southern and eastern facing slopes that receive direct sunlight should be preferred locales. The arrangement of these plantings is critical to provide the intended benefits of wind protection and thermal protection. Planting designs with depth are preferable to long, thin planting. The planting should provide an area to catch snow on the west and north sides of the planting with inner rows of conifers to provide shelter and fruit bearing trees and shrubs on the downwind side. It consists of two rows of dense shrubs on the windward side to catch snow, a 35–50-foot grassy space for the snow to be deposited and then rows of small hardwood trees, conifers, and shrubs.

Another consideration to take into account in these types of planting is to incorporate a wildlife food plot near the wildlife cover planting. A few smaller scattered food plots, one-half to one acre in size, are preferable to one large food plot.

Also, please remember that it is not always appropriate to plant trees. Some types of wildlife, like prairie chickens, prefer wide open grassy areas. Good intentioned wildlife plantings in these areas can actually be detrimental to certain species by breaking up the habitat or providing perches for raptors. Remember to consider the entire landscape when developing prescriptions or management plans for a landowner.

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12 APPENDIX 22-A: INDIVIDUAL SPECIES PLANTING CONSIDERATIONS

12.1 Conifer Species

12.1.1 TAMARACK, Larix laricina

12.1.1.1 Introduction

Tamarack is capable of tolerating a wide range of sites and exhibiting rapid growth. Tamarack is more tolerant of poorly drained soils than other *Larix* species and can be found naturally in bogs and similar areas. Its best growth occurs on well-drained upland loams and sandy loam soils, though it will do surprisingly well on sandy sites with a high water table.

12.1.1.2 Planting Considerations

In lowland situations mounding is a common site preparation treatment for tamarack establishment. Tamarack seedlings are sensitive to many herbicides so existing vegetation control is best implemented either chemically or mechanically prior to planting.

Note that tamarack is sensitive to close spacing; when crowns close, diameter growth is considerably reduced. A spacing of 8' x 8' is common in artificial reforestation.

12.1.1.3 Nursery Stock

In most situations a 2-0 bareroot seedlings is utilized in Wisconsin’s reforestation program.

12.1.1.4 Direct Seeding

Direct seeding of tamarack has not been utilized extensively mainly due to the difficulty in obtaining suitable quantities of seed and the low germination rates associated with tamarack seed. Research in Minnesota has shown that sites that were burned or sites where full tree skidding exposed mineral soil provided the best sites for naturally regenerated tamarack. This is an important consideration if planning to direct seed tamarack, seed it into bare mineral soil.

12.1.1.5 Seed Source Considerations

A genetic test of several tamarack seed sources in Forest County, Wisconsin demonstrated local Wisconsin sources, a Maine source and a Nova Scotia, Canada source performed well in height growth and survival, while sources from Minnesota and Michigan did not perform as well as these sources.

12.1.2 WHITE SPRUCE, *Picea glauca*

12.1.2.1 Introduction

White spruce can tolerate a range of moisture conditions, but good growth depends on a reliable supply of well-aerated water. Spruce does not tolerate poorly aerated soils which reduce rooting volume. It will grow on dry sites if they are fertile; in general fertility needs are high. Spruce grows best on well-drained loamy soils and has higher minimum soil-fertility requirements than other conifers. Spruce grows in soils from pH 4.7 - 7.0 and higher. The potential height and diameter of white spruce on good sites are trees 100 feet tall and 2-3 feet in diameter.

12.1.2.2 Planting Considerations

Full sun is required for adequate diameter growth of white spruce. Planting sites need to have good cold air drainage to prevent spring frost damage which new growth is susceptible to at the time of flushing. Slow initial root growth makes young seedlings and transplants susceptible to frost heaving especially on soils with adequate water for ice formation. Plantings should also be avoided on shallow soils because windthrow will likely be a future problem.

Site preparation for white spruce is critical to ensure survival and growth. White spruce seedlings do not compete with other vegetation as effectively as other conifers after establishment, so vegetation control at time of establishment and follow up releases are required. White spruce seedlings planted in fields with heavy grass competition commonly experience what is described as "planting check". This condition is where the seedling basically survives but does not exhibit anywhere near its growth potential. Research has indicated controlled burning; mechanical or chemical site preparation are all effective in the establishment of white spruce seedlings. If the site preparation is not going to be accomplished, select another species to plant.

12.1.2.3 Nursery Stock

Commonly, 2-0 and 3-0 white spruce nursery stock is utilized in Wisconsin's reforestation program. With the smaller 2-0 being commonly hand planted or machine planted, and the larger 3-0 machine planted on heavier soils. White spruce seedlings can be sensitive to transplant shock. Through proper planting, root pruning, and competition control you can reduce the likelihood of shock.

12.1.2.4 Direct Seeding

For direct seeding purposes germination of white spruce is optimal at 50-75 degrees. Prechilling or stratification of seed at 36-39 degrees for 60 days may improve germination rates for spring seeding. The seed to seedling ratio varies from 5 to 30 depending on the amount of mineral soil exposed and the amount of vegetative competition and leaf litter present. Late fall, early winter or early spring direct seeding are recommended.

12.1.2.5 Seed Source Considerations

Genetic tests of white spruce in the region have shown the superiority of local Wisconsin selections and white spruce from Ontario's Ottawa Valley region. These seed sources are represented in Wisconsin's seed orchards and the nursery stock from the state nursery program is all from seed orchard origin.

12.1.3 BLACK SPRUCE, *Picea mariana*

12.1.3.1 Introduction

Black spruce usually grows as pure stands on wet organic soils, though they will grow in mixed stands on mineral soil sites. In Wisconsin, black spruce grows in peat bogs and swamps that have formed on old glacial lake beds and in muck-filled seepages on peat deposits that range in thickness from 20 inches to 20 feet. Productive stands are on dark brown to blackish peats. Good sites will yield trees 40-65 feet tall and 9 inches in diameter.

12.1.3.2 Planting Considerations

Black spruce is shade tolerant. Seedlings can develop in as little as 10% of full sun, though survival improves in the open.

12.1.3.3 Nursery Stock

Black spruce is a relatively slow grower, even in a nursery situation. Subsequently, 2-0 nursery stock is generally only 3-4 inches in height. This can be utilized on sites that will be hand planted and in which competing vegetation can be controlled. For machine planting a 3-0 seedling is recommended. Though more expensive, nursery grown transplants or larger seedlings will survive better on difficult sites.

12.1.3.4 Direct Seeding

Seedbed scarification will increase stocking of your young black spruce stand. Sowing 32,000 viable seeds/acre in the spring should result in 60% stocking of receptive seedbed sites which should be adequate for regeneration.

12.1.3.5 Seed Source Considerations

There are currently no definitive genetic tests in Wisconsin in which to base seed source recommendations on. Subsequently, local seed sources are recommended.

12.1.4 JACK PINE, *Pinus banksiana*

12.1.4.1 Introduction

Jack pine has rapid growth rates, low site requirements, good pulp properties, and is easily established and genetically variable. Jack pine is a pioneer species that rapidly invades sites after fire or other disturbances that expose mineral soil. Mature trees are generally 55-65 feet tall with a DBH of 8-10 inches.

Jack pine is usually found on sandy soils. Well stocked stands in central Wisconsin have a moisture holding-capacity of 3 to 17% in the top foot of soil. Site index is improved with the presence of fine sand, silt and clay in the upper soil layer due to improved water holding and cation exchange capacity. Jack Pine is generally considered a drought tolerant species.

12.1.4.2 Planting Considerations

Optimal conditions for seedling establishment are where mineral soil has been exposed, competition is not fierce, the water table is high and there is some shade. The organic matter layer should not be greater than 0.5 inches thick.

Normally, 750-900 seedlings per acre are planted.

12.1.4.3 Nursery Stock

For hand planting on sites where the competition has been controlled or lacks significant competition 1-0 jack pine seedlings are preferred. On higher quality jack pine sites, where competition is greater and where machine planting is to be utilized, 2-0 jack pine seedlings are recommended.

12.1.4.4 Direct Seeding

When direct seeding it is important to note that germination takes from 15 to 60 days (though 100 days may be required for some seed) when air temperatures reach 64 degrees. Germination will be markedly reduced if light isn't ample. Though shade cast by slash and snags on cut-over areas can reduce surface temperatures and drying to improve germination on harsher sites.

Drag scarification with simultaneous redistribution of the cone-bearing slash is one of the most dependable methods of regenerating jack pine. The object is to produce well-distributed patches of mineral soil totaling 40-50% of the area and having a light cover of cone-bearing branches over them. Direct seeding can also be used with drag scarification. A rate of 1/4 pound of seed per acre is recommend in direct seeding operations. Burning and seeding can be used on problem sites where mechanical scarification is too expensive or difficult.

12.1.4.5 *Seed Source Considerations*

The Wisconsin State Nursery system at this time is procuring seed from first generation seed orchards of jack pine for seedling production. Estimated genetic gains in height, volume, stem form and pine-oak gall rust are significant with this material. Genetic tests have shown seed sources which are acceptable in Wisconsin are local sources and those from lower peninsula Michigan. These sources are recommended for direct seeding purposes.

12.1.5 RED PINE, *Pinus resinosa*

12.1.5.1 *Introduction*

Red pine's high yield and variety of products make it an attractive species for artificial regeneration. They are straight-growing trees with little taper and strong wood. Mature red pines reach (depending on the site) 70-80 feet in height and 36 inches DBH. Red pine is one of the most drought resistant conifers in the region. Because of shade intolerance red pine grows best in even-aged groups or stands.

Best growth is on acidic sandy-loam soils. Natural stands of red pine are most often found on sandy soils that are low in fertility. It grows especially well on soils that are naturally sub irrigated with a well aerated surface layer and a water table at a depth of 4 to 9 feet. Red Pine needs soils with a pH of 4.5 to 6 in the upper 10 inches. Red pine grows sporadically on heavier soils due to heavy competition from more aggressive species. In southern Wisconsin, health problems with red pine on heavier soils develop about twenty years after planting.

12.1.5.2 *Planting Considerations*

Plantations of red pine are normally established at a rate of 750-900 seedlings per acre.

Red Pine seedlings are fairly resistant to herbicides used to control competing vegetation, though caution must be used with the herbicide Oust. There is a need for release usually with red pine two to three years after planting since young stands can be quickly out competed - competition needs to be controlled early on.

12.1.5.3 *Nursery stock*

Planting is usually done at the rate of 700-1200 trees per acre. Bareroot stock should be planted in the spring. Container-grown seedlings can be planted throughout the growing season but fall planting can be risky on fine-textured soils where frost-heaving can kill the seedlings. For hand planting 2-0 stock is preferred, while machine planting of 2-0 and 3-0 nursery stock is acceptable. The 2-0 red pine nursery stock generally is a seedling with a better shoot to root ratio.

12.1.5.4 Direct Seeding

For direct seeding red pine seeds should be sown in mineral soil 1/8 to 1/4 inch deep. However, they are often broadcast after site preparation at the rate of 15,000 viable seed per acre. Because germination requirements are difficult to meet and impossible to control planting red pine is more popular. Most seedlings emerge after temperatures reach 70-86 degrees where there is high moisture and some shade. Germination is inhibited when full sun exceeds four hours per day. Seedlings grow best on a soil media with good water retention, a high CEC and a pH from 5.1-5.5. Establishment is possible with 35% full sun and only 45% full sun is necessary for maximum height growth to the age of 5.

12.1.5.5 Seed Source Considerations

Red Pine is noted for its lack of genetic variation as compared to other conifers. Genetic variations within the species is small, so care should be taken to plant in strategic locations to diversify age classes and forest cover types as part of an IPM (integrated pest management) program.

The state nurseries currently procure red pine seed from northern and central Wisconsin. In addition, there is three seedling seed orchards of red pine. It is recommended to use Wisconsin seed sources for reforestation purposes.

12.1.6 EASTERN WHITE PINE, *Pinus strobus*

12.1.6.1 Introduction

White pine is one of the faster growing conifer species in Wisconsin and as such it is an excellent candidate for artificial reforestation.

White pine will grow on nearly all soils within its range, but it does best on well-drained loamy sand soils of low to medium site quality where it regenerates naturally, competes readily, and can be managed most economically. White pine can also grow on fine sandy loams and silt-loams when there is no hardwood component during establishment. Avoid planting in heavy clay soils and poorly drained bottom land sites.

12.1.6.2 Planting Considerations

There is a concern with white pine with white pine blister rust (*Cronartium ribicola*). Trees are susceptible to this highly virulent fungus throughout its lifetime and throughout the range of white pine. The fungus is fostered by cool wet weather and the presence of its alternate host, plants of the genus *Ribes*, also known as gooseberry or currant. Reforestation opportunities exist even within the high hazard zones for blister rust, either by utilizing blister rust resistant seedlings available from the state nurseries or through individual site evaluation you can determine that blister rust can be managed. See additional details in the White Pine chapter of this Handbook.

Sites selected for white pine should maximize tree vigor and have a low incidence or potential for blister rust. Sites to avoided include bottom land of narrow valleys; bases of slopes; and small openings which have low daytime temperatures and prolonged daytime wetness.

White pine is subject to heavy browse damage by whitetail deer and is a preferred browse species of rodents. Browsing can cause severe loss of productivity and potentially plantation failure. Plantation maintenance strategies must recognize this potential problem.

12.1.6.3 Nursery Stock

If planting, site preparation and follow up maintenance usually is necessary to reduce competition. For hand planting on lighter soils, sites with little competition or excellent site preparation, 2-0 nursery stock is generally utilized. For machine planting on heavier soils 3-0 nursery stock is preferred.

12.1.6.4 Direct Seeding

Germination of white pine does not require mineral soil; seeds can germinate on both disturbed and undisturbed litter layers. Favorable seedbed conditions include full sunlight and moist mineral soil, polytrichum moss, or a short grass cover of light to medium density. While some shade is beneficial, dense shade can be detrimental to young stands. Overstory shade from a shelterwood-type cut provides protection during germination and early seedling stages of growth (at least 20% of full sun is required to keep seedling alive). Direct seeding rates of 1/4 pound of seed per acre have been used successfully in the Lake States to regenerate white pine.

12.1.6.5 Seed Source Considerations

The state nurseries currently have seedlings available from the White Pine Blister Rust Resistant Seed Orchard and are distributing these to the high hazard counties in northwest Wisconsin. Genetic studies in Wisconsin have shown the benefit of local seed sources. In southern Wisconsin, southern Appalachian white pine has performed quite well, though during the initial years of establishment it winter burns excessively.

12.1.7 NORTHERN WHITE CEDAR / ARBORVITAE, *Thuja occidentalis*

12.1.7.1 Introduction

White cedar is native to Wisconsin's north and as well as the eastern shoreline. It grows on a wide variety of organic and mineral soils. It does not develop as well on excessively wet or excessively dry soils. It is most often associated with cool, rich, moist sites, particularly on organic soils near streams or other drainageways or on calcareous mineral soils.

12.1.7.2 Planting Considerations

Northern white cedar is a compact tree with thick branches and foliage making it a good windbreak species as well as a good cover for birds. Seedlings do best on neutral to slightly acidic soils. A soil pH from 5.5 to 7.2 is common. Northern white cedar grows rapidly on well-drained sites, but also does well on moist soils.

White cedar seedlings may need extra attention when they are young because they are a favorite food for deer. If deer populations are high, you may want to use an alternate species.

12.1.7.3 Nursery Stock

The state nurseries offer 3-0 white cedar seedlings which generally are fairly large. Transplants can be obtained from private sector nurseries if a very large plant is required.

12.1.7.4 Direct Seeding

Germination is best at high temperatures (84 degrees), so it may not occur until July or August. Seeds will germinate on a variety of surfaces, but seedlings require constant moisture and warm temperatures to become established.

12.1.7.5 Seed Source Considerations

There are no definitive genetic tests in Wisconsin, so the state nurseries believe local seed sources are the best to utilize at this time.

12.1.8 HEMLOCK, *Tsuga canadensis*

12.1.8.1 Introduction

Hemlock is the most tolerant of the conifers in Wisconsin and regenerates well under heavy shade conditions. Hemlock restoration efforts have been mainly driven by wildlife and fisheries concerns. It provides a long-lived species next to riparian corridors and winter thermal cover for wildlife. Hemlock stands in large northern hardwood forest stands are ideal for wildlife.

12.1.8.2 Planting Considerations

Hemlock is a species that is highly susceptible to drought and browsing pressures. Numerous studies have indicated that in areas of high deer populations an enclosure is needed to protect the hemlock seedlings from browse.

Hemlock seedlings should be established under an existing canopy to provide shade which will help in alleviating moisture stress. Hemlock is not considered established until it reaches 5 feet in height.

12.1.8.3 Nursery Stock

Hemlock seedlings are very slow in growth initially. Subsequently, the state nurseries produce 3-0 and occasionally 4-0 hemlock seedlings. Larger seedlings are required due to extreme browsing pressures from rodents and deer.

12.1.8.4 Direct Seeding

Direct seeding of hemlock has not been tried extensively throughout the Lake States. Most likely due to the difficulty in collecting cones and obtaining viable seed.

Research has indicated that mechanical disturbance of the soil in stands with a basal area of 60-160 square feet/acre and a significant hemlock component increased natural regeneration of hemlock seedlings in the scarified plots. Subsequently, hemlock direct seeding sites will require a high density overstory, 70-80% crown cover, and a continuous availability of moisture in the upper soil horizons throughout the growing season. Operational seeding rates for hemlock direct seeding in Wisconsin are yet to be determined, but an initial estimate would be 6-8 ounces/acre.

12.1.8.5 Seed Source Considerations

Locally adapted Wisconsin seed sources are currently recommended.

12.2 Hardwood Species

12.2.1 SILVER MAPLE, *Acer saccharinum*

12.2.1.1 Introduction

Silver Maple is a specie associated with riparian forests. Its rapid growth rate has made it an ideal specie for research on biomass plantations. One of several hardwood species that produces seed in the springtime.

12.2.1.2 Planting Considerations

Quality silver maple sites require adequate moisture throughout the growing season.

12.2.1.3 Nursery Stock

Common age-classes produced are 1-0 and 2-0 silver maple seedlings. The 1-0 seedlings can be difficult for machine planting and the 2-0 can be too large for hand planting. Survival generally is quite excellent with silver maple seedlings if planted in early spring when the soils are moist.

12.2.1.4 Direct Seeding

There is not a considerable amount of information available on direct seeding silver maple. Factors to consider would include the site would require adequate moisture throughout the growing season, soil disturbance prior to seeding and seeding will have to be done in early June. Seeding rates for silver maple should be at a rate of 4-6 pounds/acre.

12.2.1.5 Seed Source Considerations

Local seed sources should be utilized in Wisconsin.

12.2.2 SUGAR MAPLE, *Acer saccharum*

12.2.2.1 Introduction

Sugar maple grows on sandy loams, loams, and silt loams, but it does best on well-drained loams and silt loams. It does not grow well on dry shallow soils. The soil pH for sugar maple ranges from 5.5 - 7.3.

12.2.2.2 Planting Considerations

Planting or other regenerative methods are rarely needed if a seed source of sugar maple is nearby. Open field plantings of sugar maple can be susceptible to sun scalding in the first few years following establishment. Sugar maple seedlings do not compete very well with grass on old field sites; therefore, sugar maple seedlings require excellent weed control for the first three years following planting to become established.

12.2.2.3 Nursery Stock

Commonly 2-0 and 3-0 sugar maple seedlings are utilized for reforestation in Wisconsin. The height and caliper of sugar maple seedlings vary more than any other hardwood species, both within and between years.

12.2.2.4 Direct Seeding

No information is available.

12.2.2.5 Seed Source Considerations

Local seed sources of sugar maple should be utilized for reforestation in Wisconsin.

12.2.3 WHITE ASH, *Fraxinus americana*

12.2.3.1 Introduction

White ash is native throughout Wisconsin. Its wood is strong, durable, and is highly resistant to shock. It is rarely the dominant species in the forest. White ash seed is a source of food for many wildlife species.

12.2.3.2 Planting Considerations

White ash grows best on rich, moist, well-drained soils, as it has demanding soil fertility and moisture requirements. White ash grows commonly on soils with a high nitrogen content and a moderate to high calcium content. Depth to bedrock or a hardpan should be at least 18 inches. It should only be planted on the best of sites for moisture and nutrients.

12.2.3.3 Nursery Stock

White ash is commonly available as 2-0 and 3-0 nursery stock. White ash seed does not all germinate in the first year so it is very common to have multi-aged nursery stock in a single bed (1-0 and 2-0), thus white ash generally will have a fairly high cull rate associated with it.

12.2.3.4 Direct Seeding

Natural germination is fostered if the soil, humus, or leaf litter is wet in the spring. Seedlings develop well in just 50% of full sun, so direct seeding under a shelterwood is a possible silvicultural system for white ash. White ash seed can lay dormant on the forest floor for several years prior to germination.

12.2.3.5 Seed Source Considerations

Local seed sources of white ash are recommended for Wisconsin.

12.2.4 BLACK ASH, *Fraxinus nigra*

12.2.4.1 Introduction

Black ash is a species found along stream banks, lakes, and lowlands.

12.2.4.2 Planting Considerations

Requires moisture throughout the growing season, especially as a young seedling. Relatively slow grower requiring vegetative control for first couple of years.

12.2.4.3 Nursery Stock

Black ash seedlings are currently grown to a 2-0 or 3-0 age class. Black ash seed never germinates all in the same year, subsequently you have multi-aged nursery stock in the same nursery bed. Therefore, black ash has a fairly large cull percentage when ordered bulk from the state nurseries.

12.2.4.4 Direct Seeding

No information is available.

12.2.4.5 Seed Source Considerations

Local Wisconsin seed sources should be utilized for reforestation efforts.

12.2.5 GREEN ASH, *Fraxinus pennsylvanica*

12.2.5.1 Introduction

Green ash is a small hardwood (50-60 feet) whose seed is the preferred food of wood ducks, cardinals, and grosbeaks. They can grow on dry upland sites, but more often they are found along streambanks, floodplains, and wet upland sites.

12.2.5.2 Planting Considerations

Moisture is a critical factor in selecting green ash planting sites.

12.2.5.3 Nursery Stock

Available as 1-0 and 2-0 seedlings. Very hardy seedling, with excellent survival and juvenile growth characteristics.

12.2.5.4 Direct Seeding

Green ash seed can lay dormant on the forest floor for several years prior to germination.

12.2.5.5 Seed Source Considerations

Local Wisconsin seed sources should be utilized for reforestation plantings.

12.2.6 BUTTERNUT, *Juglans cinerea*

12.2.6.1 Introduction

Butternut has been dramatically affected by butternut canker throughout most of Wisconsin. This disease has rendered butternut to a minor component in most stands. The value of butternut currently is in the hard mast production for wildlife.

12.2.6.2 Planting Considerations

Butternut should not be established in pure plantings but should be inter planted throughout a hardwood plantation. Butternut should be planted on the best of sites, high in moisture holding capacity and nutrient availability.

12.2.6.3 Nursery Stock

Butternut is available as a 1-0 or 2-0 seedling. Characteristics of a quality seedling would be more than 5 first order lateral root greater than 1mm thick and a stem caliper of 1/4 inch.

12.2.6.4 Direct Seeding

Seed of butternut is difficult to procure in significant quantities, but direct seeding would be similar to black walnut direct seeding. Direct seeding of pure stands of butternut is not advised due to disease considerations. Recommend just mixing butternut seed into a direct seeding mixture, possibly to as high as 10% of the seed mix.

12.2.6.5 Seed Source Considerations

Local Wisconsin seed sources are recommended.

12.2.7 BLACK WALNUT, *Juglans nigra*

12.2.7.1 Introduction

Black walnut is a valuable lumber and veneer species native to southern Wisconsin and areas along the Mississippi River. Black walnut is sensitive to soil conditions and develops best on moist, fertile, deep, well-drained, and nearly neutral soils. Walnut grows best on moisture retaining soils such as sandy loam, loam, or silt loam textured soils but decent growth is often possible on silty clay loam soils. Walnut is common on limestone soils and grows exceptionally well on deep loams, loess soils, and fertile alluvial deposits. Agricultural soils that do not have a fragipan are also good black walnut soils. Greatest size is often reached along streams and on the lower portion of north or east facing slopes.

12.2.7.2 Planting Considerations

Black walnut is intolerant of shade. Young walnuts develop a large taproot and planted seedlings typically survive well.

Excellent results have come from planting black walnut along other species, especially conifers or with nitrogen fixing species to bolster soil fertility. They do require weed control during the first 2 or 3 years to grow well.

12.2.7.3 Nursery Stock

The most commonly utilized reforestation nursery stock in Wisconsin is the 1-0 age class. Target seedling research in Wisconsin has identified the following seedling characteristics as being critical to successful black walnut plantation establishment:

1) First order lateral root development is critical to seedling survival and subsequent growth. The minimum number of first order lateral roots, greater than 1 mm in diameter, that an acceptable black walnut seedling should have is seven to nine. A seedling with greater than ten first order lateral roots is the best.

2) First order lateral roots should be trimmed to 3-4 inches in length prior to planting

3) Minimum root collar diameter of 1/3 inch

4) Main tap root of 8-10 inches in length

5) Seedlings should have been grown in a nursery at a density of 4-6 seedlings per square foot to encourage proper root development

12.2.7.4 Direct Seeding

Direct seeding of black walnut has become a fashionable alternative to planting seedlings. The current recommendations are to use a hardwood seed drill as opposed to broadcast seeding of walnut due to economics and seed needs. Current sowing rates with a seed drill of eight bushels hulled walnuts per acre seem to be adequate. In several planting a bushel of red oak acorns was added to the mix to sweeten the seeding. Broadcast seeding rates of 20 bushels of hulled walnuts per acre have been done successfully.

12.2.7.5 Seed Source Considerations

Genetic tests in Wisconsin have shown that seed sources from southern Wisconsin and northern Illinois have performed the best in regards to survival, height growth and form. Current recommendations are for black walnut to be obtained from counties adjacent to the Wisconsin River and south to northern Illinois.

12.2.8 HYBRID POPLARS (Cottonwood), *Populus sp.*

12.2.8.1 Introduction

There has been a resurgence in the interest of planting hybrid poplars for biomass production. Potential yields are reported between 3 to 6 dry tons of wood plus bark per acre per year.

12.2.8.2 Planting Considerations

Poplar clones should be established on deep, fertile sandy loam to clay loam soils with a pH between 5.0 and 7.5. The site should have a high water holding capacity or be shallow to groundwater (1 to 6 feet). They should be considered almost as an agricultural crop in initial establishment. Requiring clean tillage, excellent weed control, fertilization (especially nitrogen) and potentially irrigation.

Several different clones should be planted to reduce the potential impact from insects and diseases. Spacing is typically 8 feet by 8 feet. Prior to planting, with the buds pointing upwards, immerse 3/4 the length of the cutting in water for five to seven days. Cuttings are ready to plant when the buds just begin to elongate. The soils should be moist when planting. Cuttings are planted with one bud exposed above the soil surface.

12.2.8.3 Nursery Stock

Nursery stock available is of unrooted cuttings and rooted cuttings. Cuttings should be 10 inches in length and have a caliper between 3/8 inches and 1 inch. The cuttings should have several well-developed buds and be free from disease or bark damage. The ends of the cuttings should be wax coated to prevent desiccation of the cutting.

12.2.8.4 Direct Seeding

Not recommended.

12.2.8.5 Seed Source (Clone) Considerations

The following clones are currently recommended for the Lake States area: NM-6, DN-1, DN-2, DN-5, DN-17 (Robusta), DN-34 (Eugenei, Imperial Carolina), DN-182 (Raverdeau) and Bucky.

Additional clones are being developed and tested by the USDA-Forest Service and the University of Wisconsin-Madison. Release of new materials should be occurring in the next couple of years.

12.2.9 QUAKING ASPEN, *Populus tremuloides* and BIGTOOTH ASPEN, *Populus grandidentata*

12.2.9.1 Introduction

Aspen can be found on a variety of soils ranging from shallow and rocky to deep loamy sands. Good aspen soils are usually drained, loamy, and high in organic matter, calcium, magnesium, nitrogen, and potassium. Sandy soils offer poor growth conditions because of low levels of moisture and nutrients. Clay soils are not desirable because of limited available water and poor aeration.

Aspen is quick to pioneer disturbed sites where there is bare, moist mineral soil. The tree is fast growing and short lived. Mature trees are typically from 66-82 feet tall and from 7-12 inches in diameter. Aspen benefits many wildlife species.

12.2.9.2 Planting Considerations

Aspen should be planted into situations where it will receive full sun to become established. It doesn’t compete well with grasses or other woody vegetation. Initial site preparation is critical since there are limited chemical release options with aspen seedlings.

12.2.9.3 Nursery Stock

Aspen seedlings are generally available as 2-0 nursery stock. Research has indicated that a larger aspen seedling survives and provides the best growth potential.

12.2.9.4 Direct Seeding

Has not been done to date.

12.2.9.5 Seed Source Considerations

Aspen seed sources should be from local Wisconsin sources.

12.2.10 BLACK CHERRY, *Prunus serotina*

12.2.10.1 Introduction

Black cherry throughout the state of Wisconsin. It is generally considered an early successional species and also a favorable specie for wildlife in Wisconsin.

12.2.10.2 Planting Considerations

Black cherry can survive and grow on a wide variety of sites, but performs best on deep, well drained, fertile soils. It has proven to be a excellent hardwood seedling for regeneration since it competes well with competition due to its rapid juvenile growth.

12.2.10.3 Nursery Stock

Black cherry is commonly available as 1-0 and 2-0 nursery stock.

12.2.10.4 Direct Seeding

Black cherry seed can be used as a component in most hardwood direct seeding projects. The seed is relatively abundant most years and is available early in the fall.

12.2.10.5 Seed Source Considerations

Local seed sources are recommended. Genetic studies in other states have shown that local seed sources perform as good if not better than non-local sources and that there is more stand-to-stand variation, then within stand variation.

12.2.11 WHITE OAK, *Quercus alba*

12.2.11.1 Introduction

White oak is an important lumber species and an important source of mast for many types of wildlife. Its Wisconsin range includes the southern 3/4 of the state. It is found on sandy plains, gravelly ridges, rich uplands, and well-drained loamy soils. Growth is good on all but the driest, shallow soils; poorly drained flats; and wet bottom land. Sites that best favor white oak are north and east facing slopes. Moderately dry slopes and ridges are also good sites. Wetter, mesophytic sites yield somewhat larger oaks than the drier west and south facing slopes, but these drier slopes usually support a greater abundance of oaks.

12.2.11.2 Planting Considerations

Seedlings can be planted under an overstory of about 60% stocking as long as the understory competition is not too competitive. White oak seedlings that are planted at the time of canopy removal often develop too slowly to become a major component of the new stand. Seedlings of white oak should be several feet tall at time of final canopy removal to better insure them a place in the new canopy structure.

There is evidence that the periodic use of fire is an effective tool to regenerate oaks. The oaks are resistant to the fire which kills competing vegetation, freeing up resources for the oaks. Subsequently, an oak planting that is suffering from woody competition can be burned and the oak will resprout vigorously.

12.2.11.3 Nursery Stock

White oak seedlings are commonly produced as 2-0 nursery stock. Seedling quantities are often limited because of a lack of acorns.

Recent research on red oak target seedlings has demonstrated the importance of the following seedling characteristics to ensure successful plantation establishment, it is believed these would also be critical for white oak seedlings:

1) First order lateral root development is critical to seedling survival and subsequent growth. The minimum number of first order lateral roots, greater than 1 mm in diameter, that an acceptable oak seedling should have is five to seven. A seedling with greater than ten first order lateral roots is the best.

2) First order lateral roots should be trimmed to 3-4" in length prior to planting

3) Minimum root collar diameter of 1/4 inch

4) Main tap root of 8-10 inches in length

12.2.11.4 Direct Seeding

See section on direct seeding of oak earlier in this chapter.

Acorns germinate rapidly in the fall after dropping. They do not store for any appreciable length of time and should be direct seeded as soon as possible after collection. Germination is favored at soil temperatures between 50 and 60 degrees. Seedling establishment is best on loose soil where the radicle can penetrate into the soil. Litter cover should be light to moderate and light reaching the seedling should be at least 35% of full sun.

12.2.11.5 Seed Source Considerations

Local Wisconsin seed sources are recommended at present for reforestation in Wisconsin.

12.2.12 SWAMP WHITE OAK**,** *Quercus bicolor*

12.2.12.1 Introduction

Swamp white oak is predominately found along riparian areas throughout the southern 2/3 of Wisconsin. It occurs on lands that are periodically inundated, such as river valleys, margins of lakes and sloughs. Swamp white oak is an ideal mast specie for wildlife, especially ducks and yet is a commercially viable forest tree species.

12.2.12.2 Planting Considerations

Swamp white oak should be planted along riparian areas.

12.2.12.3 Nursery Stock

Swamp white oak seedlings are commonly available as 1-0 and 2-0. Characteristics of a quality seedling include similar characteristics of oak seedlings in general:

1) First order lateral root development is critical to seedling survival and subsequent growth. The minimum number of first order lateral roots, greater than 1 mm in diameter, that an acceptable oak seedling should have is five to seven. A seedling with greater than ten first order lateral roots is the best.

2) First order lateral roots should be trimmed to 3-4 inches in length prior to planting

3) Minimum root collar diameter of 1/4 inch

4) Main tap root of 8-10 inches in length

12.2.12.4 Direct Seeding

No results of direct seeding with swamp white oak are available, but it is similar to white oak in that the acorns germinate in the fall after falling from the tree.

See section on direct seeding of oaks earlier in chapter.

12.2.12.5 Seed Source Considerations

Current recommendations are for local swamp white seed sources to be used for reforestation in Wisconsin.

12.2.13 BUR OAK, *Quercus macrocarpa*

12.2.13.1 Introduction

Bur oak occurs on a variety of sites throughout its native range, which covers nearly the entire state of Wisconsin. It is considered a highly drought resistant species and is often associated with calcareous soils. In the driftless area bur oak can be found on the limestone ridges. It has the potential to dominate severe sites with thin soils, heavy claypan soils, gravelly ridges, and coarse-textured loessial hills. Bur oak though is also an important bottomland species. As a bottom land species, it is relatively intolerant of flooding and prefers a mesic, fertile environment. In Wisconsin bur oak is most known for being the major tree species associated with oak savannas.

12.2.13.2 Planting Considerations

Height growth in bur oak seedlings is relatively slow when compared to other oaks. Bur oak allocates resources to initially establish a large and deep root system at the expense of top growth.

Bur oak is commonly associated with oak savanna restoration efforts in Wisconsin.

12.2.13.3 Nursery Stock

Bur oak seedlings are generally available as 1-0 and 2-0 seedlings. The important factor in seedling quality of bur oak is the root system. It should have from five to seven first order lateral roots greater than 1 mm thick.

12.2.13.4 Direct Seeding

No long-term results of direct seeding with bur oak are available in Wisconsin. Bur oak is an oddity in the white oak group in that some acorns will germinate immediately in the fall, while others will delay germination to the springtime.

See section on direct seeding of oaks earlier in the chapter.

12.2.13.5 Seed Source Considerations

Local Wisconsin seed sources are recommended for bur oak restoration projects.

12.2.14 RED OAK, *Quercus rubra*

12.2.14.1 Introduction

Red oak is an important lumber species with moderate to fast growth. Mature red oaks grow to between 65 and 98 feet tall and are 2 to 3 feet in diameter. It has good form and dense foliage. Its native range includes the entire state. Red oak is generally found on spodosols. The soils vary from clay to sand. It grows best on deep well drained sandy loams to silty loams, to clay loam soils. Red oak prefers lower and middle slopes with northerly or easterly aspects on soils with a thick A horizon. Growth is most common at altitudes less than 3,500 feet above sea-level.

Red oak is intermediate in shade tolerance. Like white oak, newly planted red oak seedlings cannot compete with other vegetation after clearcutting on the better sites. The amount of red oak in the new stand will be proportional to the amount of advance regeneration of large, well-rooted seedlings before canopy removal, plus the amount of anticipated stump sprouts.

12.2.14.2 Planting Considerations

Larger 2-0 red oak seedlings can be difficult to plant with conventional machine tree planters. Requirements for an acceptable tree planting machine for red oak include a coulter near 36 inches in diameter and shoe width of 3 inches. The machine planter must be able to create a slit in the soil at least 8 to 12 inches deep and then properly pack the soil once the seedling has been planted.

A serious disease of red oak is oak wilt caused by the fungus (*Ceratocystis fagacearum*). Oak wilt can kill a tree in a single year and sites with a recent history or new signs of the disease should be avoided for reforestation with red oak unless proper treatment of infected stems and sprouts is accomplished. In order to plant red oak seedlings in a recently infected oak wilt pockets the following steps need to be accomplished:

1) Root barriers should be installed if the pocket is continuing to expand

2) Healthy red oak trees (>3 inches in diameter) need to be cut within the pocket

3) Infected trees with the bark attached need to be cut and treated to prevent

4) Stumps of cut red oak need to be treated with an herbicide to prevent stump sprouting

Older oak wilt pockets with no active spread of the disease can be planted with red oak.

12.2.14.3 Nursery Stock

Seedlings of red oak in Wisconsin are generally planted as 1-0 or 2-0. For underplanting red oak, you should control undesirable woody vegetation; plant under a shelterwood at 60% stocking; use large caliper (1/2 inch) nursery stock with clipped tops; and remove overstory after 3 growing seasons.

Recent research on red oak target seedlings has demonstrated the importance of the following seedling characteristics to insure successful plantation establishment:

1) First order lateral root development is critical to seedling survival and subsequent growth. The minimum number of first order lateral roots, greater than 1 mm in diameter, that an acceptable red oak seedling should have is five to seven. A seedling with greater than ten first order lateral roots is the best.

2) First order lateral roots should be trimmed to 3-4 inches in length prior to planting

3) Minimum root collar diameter of 1/4 inch

4) Main tap root of 8-10 inches in length

5) Seedlings should have been grown in a nursery at a density of 4-6 seedlings per square foot to encourage proper root development

6) 2-0 seedlings should be undercut in the nursery during their second growing season to encourage production of more and heavier first order lateral roots

12.2.14.4 Direct Seeding

See section on direct seeding of oaks earlier in the chapter.

12.2.14.5 Seed Source Recommendations

Red oak seed source recommendations are for Wisconsin seed sources currently.

12.3 Wildlife Shrub Species

12.3.1 SILKY DOGWOOD, *Cornus amomum*

Dogwoods attain heights of 4-10 feet and the fruit is a favorite food of turkey, grouse, quail, and many songbirds. Dogwoods will grow on moist to well-drained soils and do best in full sunlight.

12.3.2 RED OSIER DOGWOOD, *Cornus stolonifera*

12.3.3 AMERICAN HAZELNUT, *Corylus americana*

A moderate sized shrub that is commonly found along woodland edges, old pastures and thickets. American hazelnut prefers full sun for best growth and development. Though it can grow and persist in partial shade, plant density and fruit production are greatly reduced. It is a medium to fast growing species, that suckers moderately, eventually producing a multi-stemmed, clump appearance. American Hazelnut grows to a height of 8-12 feet and with a crown spread of 10 to 15 feet. The species adapts well to a range of soil pH and types but does best on well-drained loams. The nuts produced by American hazelnut are a preferred mast by squirrels, deer, turkey, woodpeckers, pheasants, and other animals. The male catkins are a food staple of ruffed grouse throughout the winter.

12.3.4 COCKSPUR HAWTHORNE, *Crategus crus-galli*

Hawthornes are small trees, growing 20-24 feet tall. They are attractive to ruffed grouse and numerous songbird species. Hawthornes need full sun and should not be planted on moist, wet, or extremely dry soils. Silt loam soils are best.

12.3.5 PRAIRIE CRABAPPLE, *Malus ioensis*

Is a hardy southern Wisconsin tree that grows to 15-30 feet in height. Its fruit is utilized by many species of birds and animals. The crabapple prefers well-drained loam soils, but it can tolerate a variety of soils.

12.3.6 NINEBARK, *Physocarpus opulifolius*

A multi-stemmed, arching shrub, reaching 10 feet in height at maturity. Small clusters of white flowers develop into brownish capsules in September. Ruffed grouse eat the buds and songbirds eat the small seeds. Ninebark provides excellent wildlife cover. It has the ability to grow on a wide variety of sites from goat prairies to sedge meadows. One of the few shrub species that does well on very droughty sites.

12.3.7 AMERICAN PLUM, *Prunus americana*

A large shrub which can reach 15 feet in height. It forms dense thickets which are good for nesting. The wild plum grows best in full sun on well-drained silt loams.

12.3.8 AMERICAN HIGHBUSH CRANBERRY, *Viburnum trilobum*

Can attain heights of 10-13 feet and requires well-drained to moist sites for proper development.

13 APPENDIX 22-B: HERBICIDES FOR FOREST MANAGEMENT

The herbicide tables contain a large volume of information from the labels of herbicide products that are registered for various forestry uses. To be listed here a product's labeling must contain wording specific to forestry.

The tables can be used in several ways. If you are looking for a product to control a particular species of weed, consult the **Herbicide Sensitivity Table** for herbaceous or woody species. If you are looking for a product to use as a "**broadcast spray"** or "**directed spray**", consult the **Herbicide Comparison Table**.

Two tables, "**Wisconsin Forest Tree Planting Herbicides**", provide a quick cross reference for tree species and herbicide products that are registered for tree planting. They are meant to be photocopied and handed out to encourage land managers who will be planting trees to plan weed control measures before their trees are planted.

Quality improvement: Users of these tables are encouraged to comment and make suggestions to improve their usefulness. Comments can be directed to:

Forest Health Coordinator
Wisconsin DNR
3911 Fish Hatchery Rd.
Madison, WI 53711
608-275-3273 (temporary)
Jane.Cummings-Carlson@dnr.state.wi.us (temporary)

Herbicide products and labels change often, so these tables are updated annually and should be used as a guide only and not considered a recommendation. The latest version of the tables can be found on the DNR web site at:

https://dnr.wisconsin.gov/topic/foresthealth/herbicides

Current labels and MSDSs can be found at:

https://www.cdms.net/Label-Database

Chapter 23

Intermediate Treatments

WISCONSIN
DEPT. OF NATURAL RESOURCES

Last Full Revision: 9/23/2010
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter

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1 INTRODUCTION

Intermediate treatments include any silvicultural manipulation of forest vegetation occurring after establishment of regeneration and prior to final harvest of the stand (or cohort). These **tending** operations can occur throughout the life of the forest stand, but do not include efforts directed at establishing regeneration. Intermediate treatments are designed to enhance stand composition, structure, growth, health, quality, and the production of specific benefits desired by the landowner. These treatments can be non-commercial, requiring outright investment, or commercial, providing monetary income. **Timber stand improvement (TSI)** is a commonly applied term that refers to non-commercial intermediate treatments.

Intermediate treatments can be broadly grouped into **release**, **thinning** and **improvement**, **salvage** and **sanitation**, and **pruning**. TSI would include pruning, most release treatments, and some thinning, improvement, and sanitation applications.

Cutting is the primary silvicultural tool to manipulate forest vegetation and control forest development to satisfy landowner property goals and stand management objectives. Additional physical and chemical techniques, as well as fire, can be utilized in specific situations.

The basic methods to kill undesirable plants and control competition are:

- Cutting:
  - Most effective against species that don't sprout (e.g. most conifers).
  - Species that sprout may require repeated treatments to effectively control.
    - Cutting in late spring and summer is most effective.
  - Relatively expensive, unless a product can be harvested.
- Girdling:
  - Most effective against species that don't sprout.
  - Most effective when done in late spring and summer.
  - Generally applied only to trees greater than 4 inches dbh.
- Physically remove the plant from the soil:
  - A very effective but expensive method.
- Fire:
  - Usually kills trees by girdling.
  - In Wisconsin, generally not currently used for intermediate treatments for sustainable forest management.
- Herbicides:
  - Very effective, and often the most inexpensive method.
  - Methods of application include: aerial spraying, ground-level foliar spraying, basal spraying, stump application, and bark incisions.
  - Herbicides are toxic chemicals. Toxicity can be highly selective and short-term, depending on the herbicide used. Products and guidelines change rapidly. It is imperative that label directions be followed. Select the appropriate product for the job and determine the best method and rate of application. Local regulations governing herbicide use are highly variable.

Most of the guidelines provided in this chapter are designed to enhance forest tree and stand vigor and quality, and therefore generally coincide with long-term economic sustainability. Chapter 24, Marking Guidelines, provides additional guidelines and considerations in applying intermediate treatments for a variety of management goals, particularly timber and biodiversity. Chapter 24 defines crop trees and a standard order of removal. It also provides tree and snag retention guidelines to sustain wildlife and biodiversity.

2 RELEASE

Release is a treatment designed to free young trees (saplings and seedlings) from undesirable, usually overtopping, competing vegetation. The purpose is to regulate species composition and to improve growth and quality. Release is designed to provide potential crop trees with sufficient light and growing space, by freeing their crowns and controlling competition.

When assessing needs and planning release operations, it is necessary to predict how the vegetation, both the desired species and the competition, will respond and develop (e.g., relative growth rates and health). Biological and economic costs and benefits of different treatments and intensities (including no action) should be evaluated. Entire layers of vegetation can be controlled, or only selected individual trees can be favored.

2.1 Complete release

Entire layers of competing vegetation are controlled (kill or retard growth) to allow the desired species to gain dominance. Examples are cut or apply herbicide to all aspen saplings to release suppressed white pine saplings (following overstory removal) and cut or apply herbicide to all red maple stump sprouts to release oak saplings and seedlings (following shelterwood).

- Potentially provides the greatest beneficial effect on the desired stand, but costs typically are greater than for partial release.

2.2 Partial release

- Release only selected exceptional individuals (crop trees).
  An example is: cut all crown competitors within 5 ft. of the largest and best formed, healthy oak sapling at approximately 20 ft. by 20 ft. spacing (full crown release of 100 crop trees per acre).
- Determine minimum crop tree selection criteria, based on landowner objectives, and tree species, vigor, quality, and health.

- Determine maximum number of well-spaced crop trees per acre; usually 50-200 trees/acre.
- Determine desired average spacing between crop trees.

Crop tree average spacing calculation where S = spacing in feet, and n = number of crop trees/acre

$$S = \sqrt{\frac{43560}{n}}$$

- Remove all trees with crowns that touch or interfere with each crop tree. A 5–7-foot opening around each crown is often recommended.
- Control only direct competitors. Remove only what is necessary to accomplish the purpose; there is no need to eliminate any plant that is not going to suppress, endanger, or hamper the growth of desired individuals.
- In sprout clumps, cut all but the best one or two stems. Individual sprout characteristics to favor include low sprouts originating from the root collar, U-shaped stem attachment, vigorous spouts with well developed crowns, relatively large sized, well-shaped and healthy (see further discussion under “Thinning Clumps of Trees”).

When needed, release operations should be implemented early in the life of the stand, typically before 15 years of age. The best growth responses are generally exhibited by the youngest stands. However, when selecting crop trees, it may be necessary to wait until growth characteristics and competitive relations are expressed. Seedlings and saplings usually respond to release with significant increases in vigor and growth.

There are three types of release treatments: weeding, cleaning, and liberation. They are differentiated based on the type, age, and size of vegetation eliminated. Within a stand, they can be applied individually or in concert, and once or multiple times.

2.3 Weeding

Weeding is a release treatment that eliminates or suppresses undesirable vegetation (including shrubs and herbs) regardless of crown position. It is typically combined with cleaning or liberation treatments that control competing trees. Weeding can be used to control diseases (interrupt pathogen life cycles) or invasive plants.

2.4 Cleaning

Cleaning is a release treatment designed to free favored trees from less desirable individuals (trees) of the same age class that overtop them or are likely to do so. The main purpose is to regulate species composition; improving growth and quality is an important secondary objective. In practice, trees eliminated or suppressed typically include undesirable species and any low-quality individuals that are competing directly with desired crop trees.

2.5 Liberation

Liberation is a release treatment designed to free favored trees from competition with older, overtopping trees. It is applied when a young crop of potentially good trees is overtopped by older, less desirable trees. Considerations in removing the unwanted overstory:

- Effective methods of killing the older, overtopping trees are cutting, girdling, and applying herbicides.
- Cutting may allow the realization of income, but protection of the young stand from felling and harvesting operations is critical.
- Care should be taken that following liberation the increase in sunlight does not result in intense crown competition from sprouts or the release of fast growing weed species.

Older, overtopping trees can be retained as reserve trees to achieve desired benefits (Chapter 24). These reserve trees will limit the availability of some resources needed for the most vigorous growth of younger trees in close proximity. Considerations when maintaining reserve overstory trees are:

- Reserve trees can provide benefits related to wildlife, aesthetics, water and soil quality, protection of special or sensitive sites, landmarks, and timber production.
- Older, overtopping trees can reduce the growth, cause stem deformation, and even cause mortality of young trees growing in their shade. In most cases, nearly full sunlight is preferred to promote optimum growth of young, established stands. Shade is increased by:
  - Increased numbers of overstory trees.
  - Trees with larger and denser crowns.
  - Crown expansion (growth) over time.

- Within a stand, the point at which the negative effects of overstory shade become significant depends on landowner objectives, site quality, the number and species of overstory trees, the number and species of understory trees, understory competition, and potential damaging agents.
- Where objectives include the retention of reserve trees, residual crown closures of <20% generally will not significantly impede the development of the young stand.

3 THINNING

Thinning is a cultural treatment conducted in stands past the sapling stage to reduce stand density, primarily to improve tree growth, enhance tree health, or recover potential mortality. It entails the removal of trees to temporarily reduce stocking to concentrate growth on the more desirable trees. Normal thinning does not significantly alter the gross production of wood volume. Thinning does impact stand growth, development, and structure. It provides the main method, implemented between regeneration and final harvest, to increase the economic productivity of stands. Individual thinnings can be commercial or non-commercial (TSI), depending on landowner objectives and local markets for materials cut in the thinning operation. Regeneration is not an objective of thinning; overstory gaps are small and should close rapidly.

Objectives of thinning include any of the following:

- Enhance the vigorous growth of selected trees through the removal of competitors. Larger diameter, more valuable trees can be grown in a shorter period of time.
- Enhance tree health. Thinning anticipates losses and maintains tree vigor and strength.
- Harvest most merchantable material produced by the stand during the rotation. Trees that would die from competition are harvested and utilized for timber products.

Application of thinnings can increase economic yields:

- Harvest anticipated losses of merchantable volume.
- Yield of income and control of growing stock during rotation.
- Increased value from rapidly growing larger diameter trees.
- Increased value from improvements in product quality.
- Opportunity to modify stand composition, prepare for the establishment of the next rotation (manipulate sources of regeneration), and reduce the risk of damage (maintain more vigorous and structurally sound trees).

How and when thinnings are applied depend on:

- Landowner objectives and desired benefits.
- Ecological considerations (e.g., site quality, species composition, stand structure, and stand condition).
- Economic considerations (e.g., costs and benefits, incentives, local markets).
- Social considerations (e.g., regulations, aesthetics).
- Other past and planned management activities.

A schedule of thinning for a stand should identify the thinning methods to be used, the intensity of application, and when thinnings will occur. Ideally, the application of a thinning schedule should be a systematic, yet flexible endeavor consistently followed throughout the rotation.

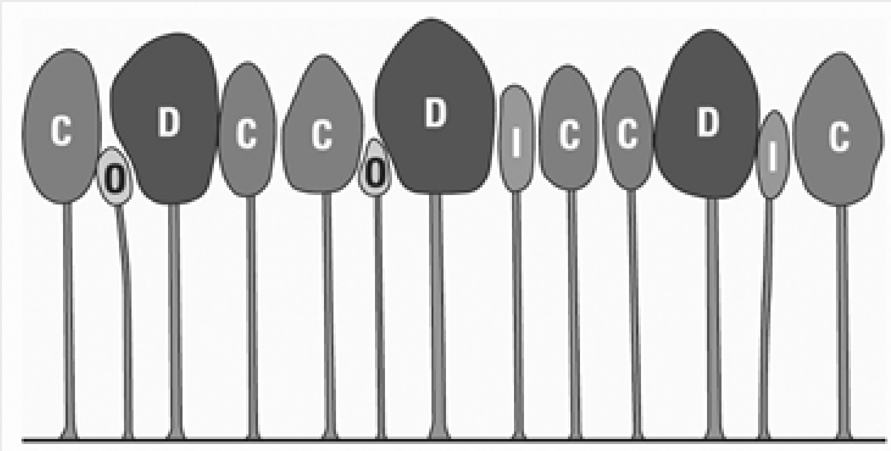

Figure 23.1. This illustration shows the relative positions of trees in the different crown classes in an even-aged stand that has not been thinned. (Adapted from © David M. Smith, 1962, The Practice of Silviculture, Seventh Edition, John Wiley & Sons, Inc.)

Dominant (D): Dominant trees have crowns extending above the general level of the crown cover, and receive full light from above and partly from the side. Dominant trees are larger than the average trees in the stand and have well-developed crowns that may be somewhat crowded from the sides.

Codominant (C): Codominant trees have crowns forming the general level of the crown cover and receive full light from above but comparatively little from the sides. These trees usually have medium-sized crowns that are often crowded on the sides.

Intermediate (I): Intermediate trees are shorter than dominant and codominant but have crowns extending into the crown cover formed by codominant and dominant trees. Intermediate trees receive a little direct light from above, but none from the sides. They usually have small crowns that are considerably crowded on the sides.

Overtopped (O): Overtopped, also called suppressed, are trees with crowns entirely below the general level of the crown cover. Overtopped trees receive no direct light either from above or from the sides.

3.1 Thinning Methods

There are four basic methods of thinning: mechanical thinning, low thinning, drown thinning, and free thinning. Figure 23.1 identifies and defines the four crown classes used to help differentiate the thinning methods and to guide tree selection during thinning operations. The positive action of selecting which trees will remain should be emphasized. Stand conditions and thinning needs vary over time, often resulting in the application of more than one method over a stand's rotation.

3.1.1 Mechanical Thinning

Mechanical thinning is the removal of trees in rows, strips, or by using fixed spacing intervals.

3.1.1.1 Application:

- Mechanical thinnings are typically applied as the first thinning(s) in young stands that are densely crowded or relatively uniform with little differentiation into crown classes. The method becomes less suitable as variation in the size and quality of the trees increases.
- Row thinning (figure 23.2):
  - Trees are cut in lines or strips at fixed intervals throughout the stand.
  - Often utilized for the first thinning(s) in plantations where the rows are readily apparent. The removal of every second or third row are common practices.
  - Utilized to provide systematic access for machinery in dense, unthinned stands.

- Spacing thinning:
  - Trees at fixed intervals are chosen for retention and all others are cut.
  - Most commonly applied as the first thinning in very overcrowded young stands developed from dense natural reproduction.

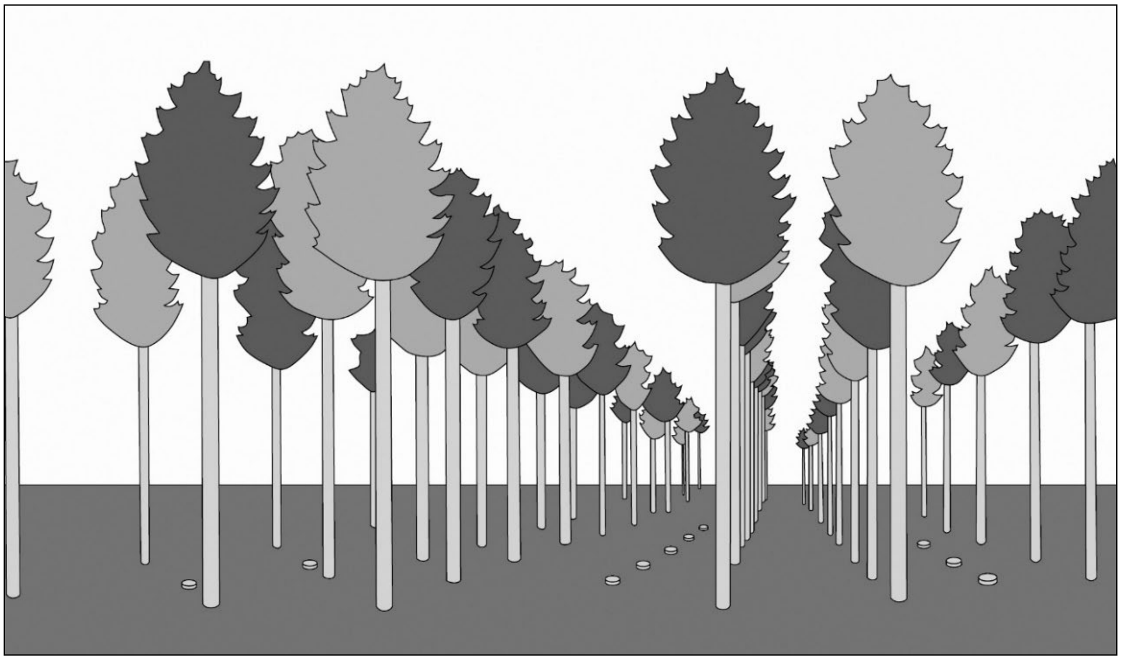

Figure 23.2. A mechanical row thinning in a pine plantation in which every third row of trees has been removed. The opening in the canopy should close in a few years. (Adapted from Fact Sheet G3398, Wisconsin Woodlands: Intermediate Cuttings in Forest Management, University of Wisconsin Extension).

3.1.2 Low Thinning (Thinning From Below)

Low thinning (figure 23.3) is the removal of trees from the lower crown classes to favor those in the upper crown classes. This strategy accelerates and simulates somewhat the natural elimination of the lower crown classes through competition.

Application:

- The marketability of the relatively small trees removed can sometimes be difficult.
- Light to medium intensity low thinnings remove only suppressed to intermediate trees. These strategies generally are not recommended except in specific cases. They facilitate utilization of the trees that would probably die due to suppression (competition), but the release of the remaining trees from competition is minimal.
- Heavy low thinning generally is recommended. This strategy removes suppressed, intermediate, and the poorest codominant trees (least desirable competitors, high risk, low vigor, poor quality). The removal of some codominants creates canopy openings and releases the crowns of crop trees to stimulate their growth.
  - Utilize stocking guides to help determine target residual stand density (of evenly spaced codominant and dominant trees).
  - Crop tree selection and order of removal criteria (Chapter 24) help define characteristics of which codominants to favor and which to preferentially remove.

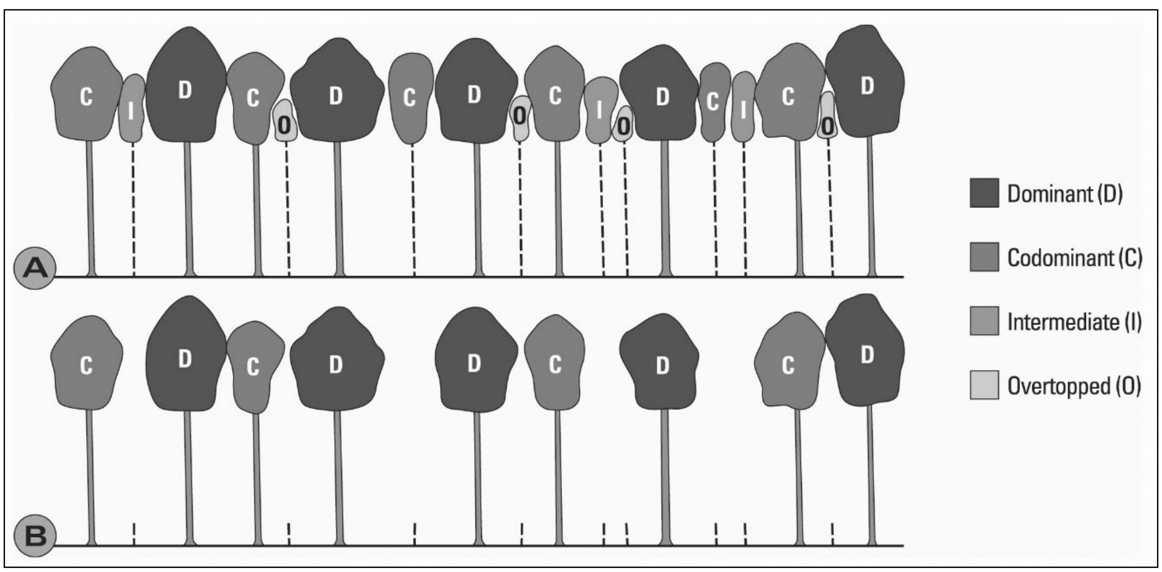

Figure 23.3. How a stand might look before (A), and after (B), a low thinning. The letters on the tree crowns denote crown classes. (Adapted from © David M. Smith, 1962, The Practice of Silviculture, Seventh Edition, John Wiley & Sons, Inc.)

3.1.3 Crown Thinning (High Thinning, Thinning from Above)

Crown thinning (figures 23.4 and 23.5) is the removal of trees from the dominant and codominant crown classes in order to favor the best trees of those same crown classes. Large intermediates that interfere with crop trees also can be removed. The method stimulates the growth of selected, preferred trees (quality) without sacrificing the production of quantity. Crown thinning is recommended to develop and manage quality hardwood stands for the production of high value sawtimber and veneer logs.

3.1.3.1 Application

- Often conducted as commercial operations. The trees removed are relatively large.
- Release the best dominant and codominant crop trees. Ideally, these crop trees are selected, favored, and carried through the entire rotation.
  - Determine minimum selection criteria (see crop tree selection criteria in Chapter 24).
  - Determine maximum number of well-spaced sawtimber crop trees per acre, and average desired spacing.
    - Usually, 40-150 crop trees per acre.
    - Landowner objectives.
    - Tree species, vigor, quality, strength, and health.
  - Mark to release crowns.
    - Remove strong crown competitors
    - 4-sided, in fast growing, young stands, with small-crowned competitors.
    - 1-3 sided, in slower growing, older stands, with larger-crowned competitors.
- To optimize stand growth, it is recommended to thin through the remaining stand, releasing the best dominant and codominant trees (these trees may be removed in later thinnings) by removing higher risk, lower vigor, and lower quality competitors (see standard order of removal in Chapter 24).
  - Utilize stocking guides to help determine target residual density (of evenly spaced trees).
- The intensity and timing of thinnings can be varied to manage stem form and natural pruning.
- Requires skill to apply (tree selection, density management, and timing).

Canopy gaps created during each thinning are mostly filled through crown expansion of residual dominants and codominants, however some may be partially captured through the growth of released intermediate or suppressed trees. Crown thinnings are most applicable to stands composed of shade tolerant species or a mixture of species. When applied to stands of intolerant or mid-tolerant species, alternation of crown thinnings with low thinnings may be preferable, if utilization of the suppressed and intermediate trees is desired (free thinning integrates crown and low thinning methods into a single application).

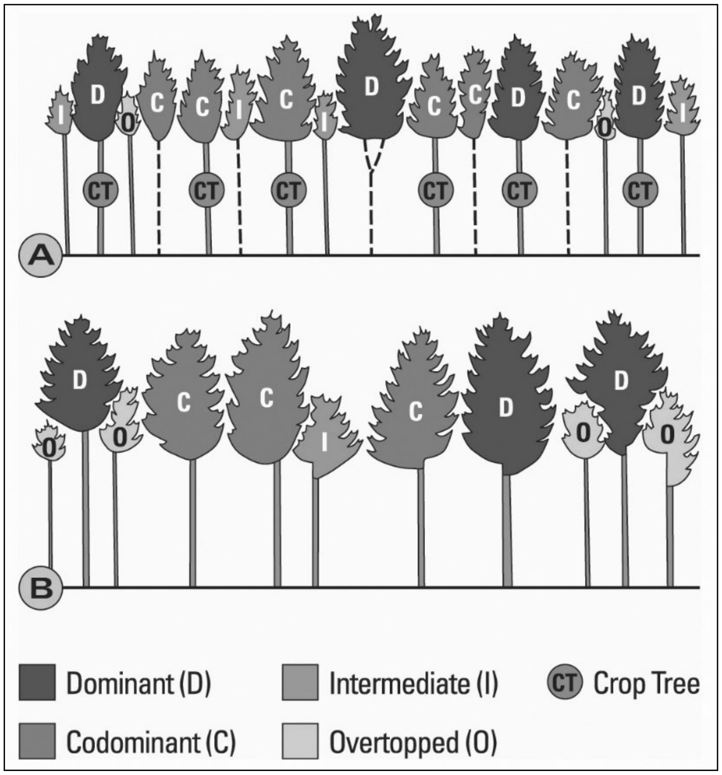

Figure 23.4. The upper sketch (A) shows a coniferous stand immediately before a crown thinning. The crop trees are indicated by the circles marked "CT". The lower sketch (B) shows the same stand about 20 years after the crown thinning, which has reclosed to the point where a low thinning would be desirable. (*Adapted from © David M. Smith, 1962, The Practice of Silviculture, Seventh Edition, John Wiley & Sons, Inc.)*

Figure 23.5 This crop tree, released on two to three sides by cutting competing trees, is now free to grow. (Photo by J. Martin, J-Mar Photography)

3.1.4 Free Thinning

Free thinning is the removal of trees to control stand density and favor desired crop trees using a combination of thinning criteria without strict regard to crown position. In application, this method is a free combination of selected concepts and techniques garnered from both low and crown thinning methods. **Follow crop tree selection and order of removal guidelines (Chapter 24).** Utilize stocking guides to help determine target residual density. Free thinning is recommended to develop and manage quality hardwood stands for the production of high value sawtimber and veneer logs. To be most effective, free thinning requires considerable skill in tree selection and density management.

3.1.4.1 Application

To manage stands to develop quality sawtimber without sacrificing quantity:

- Free thinning is a recommended thinning method.
- Crown thinning is a recommended thinning method.
- Occasional low thinnings can be incorporated.
- Mechanical thinnings can be prescribed for the initial thinning when appropriate.

To manage stands to produce pulpwood, poles, or other small diameter wood products:

- Low thinnings are often recommended.
- Occasional crown thinnings can be incorporated.
- Occasional free thinnings can be incorporated.
- Mechanical thinnings often are appropriate for the initial thinning(s).

Thinning operations are more critical to increase value from the production of quality sawtimber, especially at reduced time scales, than to the production of timber quantity. Where timber production objectives are of minor importance, creative thinning regimes can stimulate the development of specific tree and stand conditions to satisfy other landowner objectives.

3.2 Intensity of Thinnings

The intensity of thinning refers to the regulation of stand density. Thinnings that remove a greater proportion of the stand are heavier, while those that remove lesser proportions are lighter or less intense. As intensity increases, the frequency of thinnings usually decreases. A thinning schedule should indicate the intensity of thinning at each entry.

If the production of quality sawtimber is a management objective:

- Identify three categories of trees at each thinning: the best sawtimber crop trees, trees to be retained until later thinnings, and trees to be removed in the current thinning.
- The primary objective of thinning is to crown release the sawtimber crop trees, and also harvest high risk trees (those not retained as wildlife trees). The intensity depends on the number of crop trees and the degree of release, and the number of high-risk trees. In some cases, this may be the only operation.
- To optimize stand growth and yield, the rest of the stand should also be thinned, favoring the best and removing the less desirable individuals, while considering risk,

vigor, quality, species composition and spacing (see Chapter 24). Apply stocking guides.

Stocking guides (figure 23.6) can help define target residual stand density:

- Stocking charts provide a statistical approach to density management based on observed relationships between stand density, growth, and wood value. Target stocking levels are determined based on optimizing stand growth and merchantable yield for a specific forest cover type.
- The area between the A-line and B-line indicates the range of stocking where trees can fully occupy and utilize the site (fully stocked stand). Within this range, optimum stand growth and volume yield can be maintained.
  - The A-line represents the maximum stocking level that can maintain optimum stand growth and yield. Allowing stand density to surpass the A-line (overstocked) will reduce merchantable board-foot volume growth and yield. Maintaining stocking levels near (but below) the A-line will produce comparatively more trees, but of smaller diameter.
  - The B-line represents the minimum stocking level that can maintain (fully occupy the site) optimum stand growth and yield. Reduction of stand density below the B-line (understocked) will reduce stand volume growth and yield. Maintaining stocking levels near (but above) the B-line will produce larger diameter trees faster, but comparatively fewer trees.
  - The C-line, on some charts, show the limit of stocking necessary to reach the B-line level in 10 years on average sites.

- Stocking charts display the relationship between basal area, number of trees, and mean diameter.
- To utilize stocking guides, statistically accurate estimates of at least two stand variables must be obtained, including basal area per acre, number of trees per acre, and/or mean tree diameter. Depending on the specific stocking guide, these variables may be measured only for canopy trees or for all trees ≥5 inches dbh.
  - Mean diameter is the calculated quadratic mean diameter (QMD, dbhq), which is the diameter corresponding to the mean basal area of the trees in the stand (the tree of average basal area); it is not the arithmetical mean of the diameters.
  - QMD calculation where B = basal area/acre, and n = number of trees/acre

$$QMD = \sqrt{\frac{B}{(0.005454 \times n)}} \quad \text{or} \quad QMD = \sqrt{\frac{\frac{B}{n}}{00.005454}}$$

– QMD calculation where d = dbh of tree, and n = number of trees measured

$$QMD = \sqrt{\frac{\sum d^2}{n}}$$

- Stocking charts function as useful guides for when and how much to thin. Stand density is allowed to fluctuate between defined limits (A- and B-lines). When designing and implementing a thinning regime for a stand, do not reduce stand density to below the B-line or allow it to surpass the A-line. Thinning can occur at any time as long as stand density is maintained between the A-line and B-line. The A-line is not a thinning "trigger." When and how much to thin depends on management objectives, stand conditions, and feasibility.
  – Typically, for the production of quality sawtimber, thinning is implemented when average stand stocking is halfway or more between the B-line and A-line, and then stocking is reduced to slightly above the B-line. Regular reduction of stand density to the lowest level at which full occupancy is maintained (near B-line) should result in the most rapid diameter growth that can be maintained without reduction in total merchantable board-foot volume yields. As stands age, residual density should slowly increase.
  – Higher levels of residual density may be desired where greater yields of pulpwood or poles are the objective of management. Other reasons to maintain higher densities include considerations for natural pruning, stem taper, specific wood characteristics, and landowner objectives.

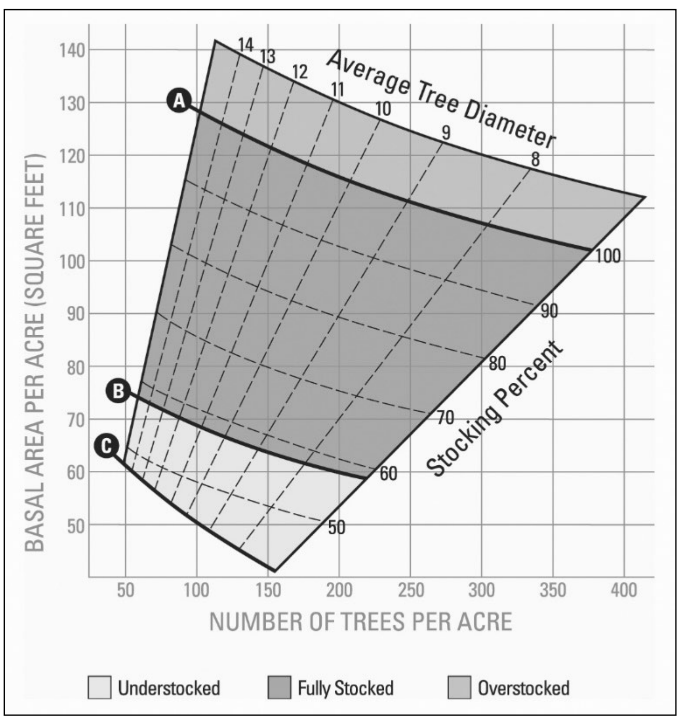

Figure 23.6. Stocking guide/chart for upland central hardwoods displaying the relation of basal area, number of trees, and average tree diameter (the tree of average basal area) to stocking percent. The area between the A-line and B-line indicates the range of stocking where trees can fully utilize the site. C-line shows the limit of stocking necessary to reach the B-line level in 10 years on average sites. Similar guides are available for each major species. (*Adapted from I. L. Sander, 1977, Managers Handbook for Oaks in the North Central States, USDA Forest Service Gen. Tech. Rep. NC-37, North Central Experiment Station, St. Paul, MN)*

In overstocked stands, thin lightly and frequently, with increasing intensity, for the first several thinnings, to safely develop tree crown vigor and strength, and until target residual densities (near the B-line) are achieved. A general guideline is do not remove >50% of the basal area in any one thinning operation.

Within a stand, thinning gradually develops resistance to damage (insects, disease, wind, etc.), however it can also temporarily predispose stands to damage, particularly where trees are not vigorous or strong. It is also important to control logging damage when thinning; logging wounds can predispose the remaining trees to disease and decay. Consider space to fell trees and to maneuver equipment.

3.3 Variable Density Thinning (VDT)

Variable density thinning varies target residual stocking (thinning intensity) in even-aged stands and creates non-uniform conditions at the stand level. Portions of the thinned stand remain at different residual densities, from relatively close spacing (high density) to relatively open spacing (low density). VDT can provide the traditional benefits derived from thinning but can also increase spatial heterogeneity and ecological diversity across the stand.

In application, the majority of the stand (matrix) is thinned to the target residual basal area selected to achieve landowner goals and stand management objectives. Delineated areas may be thinned to higher (denser) or lower (less dense, more open) residual basal areas, but residual stocking should be maintained between the B-line and A-line. Consider management goals and objectives and stand and site conditions when locating areas of variable density. Sections of the stand thinned to different densities should be mapped.

3.4 Timing of Thinnings

If a landowner desires to realize the types of benefits associated with thinning, then the failure to thin is simply a lost opportunity to develop those benefits. In deciding when to thin, a landowner needs to clarify what investments they are willing to make and what benefits (economic, social, ecological) are desired. However, if stands become overstocked (above the A-line) or understocked (below the B-line), then stand growth and timber volume yield will be compromised.

Initial thinnings can begin once the crowns begin to touch each other. Precommercial thinning (TSI) requires an investment but can increase net returns over the rotation. However, it is most typical to postpone the initial thinning until an immediate profit can be produced.

The effects of thinnings are temporary. After each thinning, the remaining trees grow taller, diameters increase, crowns expand, and canopy gaps close; stand density increases. Periodic thinnings can maintain crown vigor and accelerated diameter growth rates of crop trees.

Criteria that can be used to indicate the need for further thinning:

- Declining live crown ratios of crop trees.
- Declining rates of diameter growth of crop trees.
- Accumulation of sufficient timber volume to justify operations.
- Thinning often is prescribed when stand density increases to near specified upper limits (A-line) delineated in stocking charts developed as thinning guides. However, thinning can occur anytime that stocking is above minimum limits (B-line); regular reduction of stand density to the lowest level at which full occupancy is maintained should result in the most rapid diameter growth that can be maintained without reduction in total volume yields.

Thinning can improve tree and stand vigor, enhancing both growth and tree health. However, thinning is a disturbance and causes temporary stress to the stand and community. In addition, residual trees may be damaged during timber harvesting operations, and wounding predisposes trees to disease and decay. To encourage beneficial biological responses (e.g., tree growth and health) and minimize negative responses (e.g., disease and mortality) to thinning, sufficient time should be allowed between thinning operations for the stand to recuperate from stress and for vigorous development.

Thin every 8-15 years is a recommended general guideline for commercial thinnings. Frequent, light intensity thinnings can provide the best sawtimber yields. Less frequent, heavier thinnings are more common due to operational and biological considerations. Stands of young trees should be thinned more frequently (than stands of older, larger trees), because they close more rapidly due to high growth rates and small crowns.

4 THINNING CLUMPS OF TREES

Clumps are defined here as root, root collar, or stem sprouts, as well as trees of seed origin growing in close proximity to one another, so their lower boles contact each other or have the potential to contact each other. They commonly occur in hardwoods. Clump thinning is the removal of some, but not all, tree members of a clump. This practice can predispose residuals to butt rot, stain, or wilt disease, which enter directly from adjoining cut sprouts or wounds made while clump thinning (Campbell 1938, Houston 1993, Roth 1956). To minimize decay in the lower bole and to avoid some wilt diseases, it is generally recommended to avoid clump thinning pole-sized or larger clumps by either leaving or removing all stems in a clump.

When deciding whether or not to thin, leave all, or cut all stems occurring in clumps, one should consider several factors:

- logging operability, equipment, and proximity of clump stems
- origin of clump stems (e.g. root, root collar, or stem sprouts)
- shape and angle of clump stem unions (e.g. V- or U-shaped union)
- stem size
- stem quality
- vigor
- species susceptibility to decay and disease
- stocking
- stand quality
- future stand treatments and timeline

4.1 Seedling and Sapling-sized Clumps

Thinning seedling or sapling-sized clumps as early as possible is most desirable (Campbell 1938, Godman 1992, reviewed in Tubbs 1977). One reason for this is the earlier the clumps are thinned, the less likely it is their boles will be close to one another and the smaller the chance for residual damage. Also, young clump members generally have not formed heartwood, so decay transfer from a cut stem to an adjoining stem is less likely. When thinning young sprouts, one needs to consider all the factors listed above, but the general recommendation is to remove those that arise from the parent stump above the root collar (i.e., retain those that attach to the parent stump at the root collar), and reduce clumps to one or two vigorous stems, which should be well spaced and not connected to one another. Doing this work before stands are 20 years old is recommended (Campbell 1938). If stands are over 20 years old, see recommendations in the below section, “Pole-sized and Larger Clumps.”

If young clump stems are connected to one another, stems less than 2 inches DBH can be thinned without concern for promoting significant decay, regardless of their stem union shape or stem origin (Campbell 1938, reviewed in Roth 1956). If the stems are greater than 2 inches DBH, see the section below, “Pole-sized and Larger Clumps.”

4.2 Pole-sized and Larger Clumps

Though it is best to thin clumps before trees reach pole-size or larger, many stands will have an overabundance of clumps in larger diameter classes for a variety of reasons. The proximity of stems to each other (i.e., logging operability), the origin of clump stems, and stem union shape and angle are three important factors to consider when deciding whether or not to thin clumps of pole-sized or larger trees. See other factors listed above that should also be considered.

Stems connected in a V-shape above the root collar share stem pith (Figure 23.7). These are defined here as stem sprouts. This trait promotes the development of decay in the residual stem once connected stems are cut. Therefore, trees connected by V-shaped unions above the root collar (i.e., stem sprouts) should all be removed, or none removed (Roth 1956). Stems originating at the root or root collar but meeting in a V-shape are not as susceptible to decay after clump thinning (Campbell 1938, Shigo and Larson 1969). However, during thinning, the likelihood of damaging a residual stem connected by V-shaped union, especially one where the stems meet in a narrow angle, is high, regardless of stem origin (i.e., the logging operability is poor) (Figures 23.8 and 23.10). Logging damage is a common source of decay in residual clump members (Campbell 1938, Shigo and Larson 1969).

Thinning clumps with U-shaped unions has been shown to cause less decay in the residual, in contrast to thinning V-shaped unions (Roth 1956). Also, trees connected by U-shaped unions oftentimes lend themselves to better logging operability, although it is still important to consider whether the equipment can harvest stems without damaging the residual stems (Figure 23.9). Unfortunately, field observations indicate V-shaped unions are much more common than U-shaped unions.

Finally, note that the flexibility and smaller sized equipment used in manual felling makes it a more desirable method for clump thinning than mechanized felling.

4.3 Species Considerations

Individual species' susceptibilities to decay and the timeline for subsequent stand entries should be considered when deciding whether or not to thin clumps. See cover type chapters in this handbook to review specific species' susceptibilities to decay.

Other disease introductions also need to be considered when deciding whether or not to thin a clump. Sapstreak disease in sugar maple occurs when the fungal pathogen enters the tree through a wound on the lower bole, which includes the stump created after cutting a connected tree (Houston 1993). Sugar maples are susceptible to infection by the sapstreak fungus from late spring through early summer. Therefore, leave all or take all connected sugar maples when thinning during times and in locations where sapstreak disease transmission is likely to occur (Figure 23.10).

Likewise, clump thinning could cause residual oaks to become infected by oak wilt if thinning occurred between April and October. Regardless of whether oak stands have clumps of oaks or not, intermediate treatments during this period in oak stands increase the risk of oak wilt transmission to the stands. Be sure to review the Wisconsin DNR's "Oak Wilt: Harvest Guidelines for Reducing the Risk of Introduction and Spread in a Forest Setting."

4.4 Management Recommendations Summary

If the stand has the potential to produce quality hardwood logs, consider the complete removal or full retention (versus thinning) of clumps, since hardwood stump sprouts tend to exhibit poor form and have a predisposition for butt rot that enters directly from the decaying parent stump or the stubs of adjoining cut sprouts (Campbell 1938, Roth 1956). When choosing to thin clumps, thin those whose tree members originate at the root or root collar, connect in a U-shape, and whose stems allow for thinning without wounding residuals. Do not thin sugar maple clumps during times and in locations where sapstreak transmission is likely to occur. See "Decision Model for Evaluating the Potential to Thin Clumps" (Figure 23.11) for a summary of these recommendations.

Figure 23.7. Avoid thinning sprouts that attach to each other above the root collar like the cut stem sprouts shown here (white arrows). These residual basswoods will develop butt-decay in them because of this practice.

Figure 23.8. A residual tree with butt-rot due to clump thinning. The cut stem appears to have been connected to the residual stem in a V-shape. Poor logging operability caused the logger to wound the residual (see the white arrow points to a chainsaw wound), which facilitated decay in the residuals butt log. Also, decay may have transferred directly from the cut stem into the residual stem.

Figure 23.9. One of these sprouts could be thinned without great risk for decay in the residual because they are connected in a U-shape at their root collars. Thinning clumps with U-shaped unions has been shown to cause relatively less decay in in the residuals than thinning clumps with V-shaped unions.

Figure 23.10. A sugar maple clump with stems originating at the root collar and meeting in a narrow-angled V-shape. Thinning is not recommended because the chances of wounding the residual in this clump is high. It is recommended to take or leave both stems. In addition, if this clump was thinned between late spring and early summer, the residual may become infected with sapstreak disease.

Decision Model for Evaluating the Potential to Thin Clumps

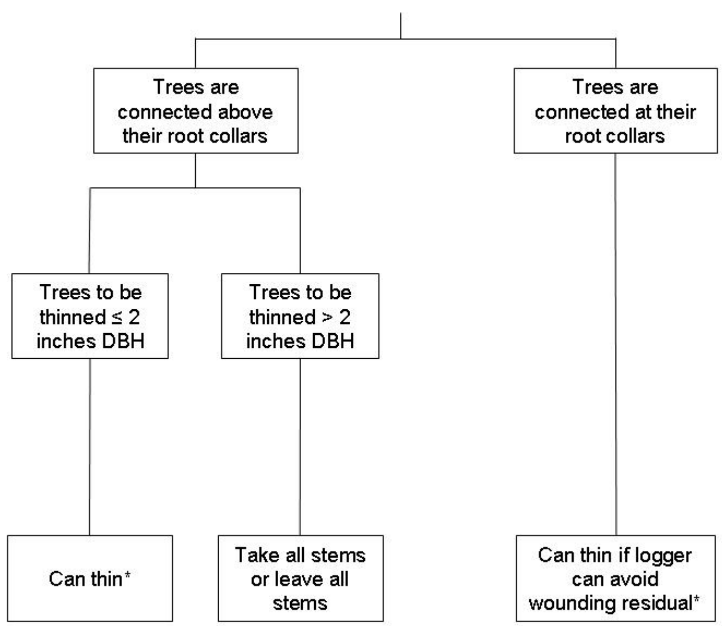

Figure 23.11. Use this key to determine whether or not thinning clumps is recommended.
*Note that thinning oak and sugar maple stands increases risk of disease transmission during specific periods in the year.

5 IMPROVEMENT CUTTING

Improvement cutting is the removal of less desirable trees of any species in a stand of poles or larger trees, primarily to improve composition and quality to achieve landowner goals and objectives. Trees are removed to encourage the growth of more desirable trees within or below the main canopy. Trees considered for removal include undesirable species, trees of poor vigor, trees of poor quality, and injured or unhealthy trees (risk). Potential crop trees should be preferred species and relatively well formed, vigorous, and healthy. Management goals, objectives, and considerations, as well as crop tree selection criteria and standard order of removal guidelines (Chapter 24), guide marking for improvement cutting.

Improvement cutting is usually applied in stands that have been unmanaged, neglected, or poorly managed. Sometimes, improvement cutting is essentially a delayed release treatment. Sometimes, these stands consist of many poor quality trees of multiple size and age classes resulting from past abuses such as high-grading. The intent is to remove undesirable material and set the stage for productive management to accomplish landowner objectives. In cases where the current stand is of such poor quality that rehabilitation is untenable (depending on landowner objectives, cover type, number of crop trees, and site quality), the preferred choice may be to initiate regeneration to develop a vigorous, new stand.

Where needed, improvement cuttings should be implemented as soon as possible. They are preliminary operations leading to systematic thinnings and reproduction methods. In most cases, stand improvement can be completed in one to three operations. Improvement cuttings can be commercial or non-commercial, depending on landowner objectives, treatment intensity, tree characteristics, wood quality, and local markets. In practice, techniques of improvement and thinning often are combined during initial treatments.

6 SALVAGE AND SANITATION CUTTINGS

6.1 Salvage Cutting

Salvage cutting is the removal of dead, dying, or damaged trees resulting from injurious agents other than competition, to recover economic value that would otherwise be lost. Salvage operations are done for profit, with the intent of utilizing damaged trees and minimizing financial losses.

In forests, across large landscapes and long rotations, partial and catastrophic stand damage is inevitable. The intensity of salvage operations depends on the severity of damage, accessibility, potential economic losses, and landowner goals. Where landowner goals are in accordance, salvage should be conducted as soon as possible following the damaging event. Dead trees deteriorate rapidly during the first spring and summer following their death.

Deterioration varies by species, tree size, site quality, and type of damage. Severe stand damage will require the implementation of regeneration methods.

Before implementing salvage operations, consider management goals and objectives relative to wildlife and biodiversity. Large diameter decaying trees, dying trees, snags, and down coarse woody debris provide critical habitat for many organisms. Following severe stand disturbance, these structures can provide habitat that facilitates species perpetuation on site, re-colonization, dispersion, and landscape connectivity.

During salvage operations, consider retaining some unsalvaged patches at least one tenth acre in size to provide habitat structure. These patches should include large diameter reserve trees, mast trees, cavity trees, snags, and down course woody debris if present. Unsalvaged patches can often be located to complement multiple management objectives and stand conditions; such as the protection of critical areas, riparian management zones, travel corridors, or areas with poor logging access. Many salvage operations will contain significant unsalvaged patches simply due to the operational constraints of working in severely disturbed stands. The extent and distribution of unsalvaged patches may need to be modified if retention would interfere with effective sanitation methods to control insect and disease outbreaks or be deemed a threat to human health and safety (e.g., wildland fire fuel treatments).

Presalvage cutting is the removal of valuable trees at high risk of injury or mortality from damaging agents. The method attempts to anticipate damage by removing vulnerable trees that are in imminent danger of being damaged or killed. Important tree criteria include species, vigor, mechanical structure, and position in the stand.

6.2 Sanitation Cutting

Sanitation cutting is the removal of trees to improve stand health by stopping or reducing the actual or anticipated spread of insects or disease. It is precautionary protection implemented to reduce the spread of damaging organisms or in anticipation of attacks in an attempt to prevent or delay the establishment of damaging organisms. Sanitation cuttings eliminate trees that are present or prospective sources of infection for insects or fungi that might attack other trees. The removal of trees must actually interrupt the life cycle of the organisms sufficiently to reduce their spread to other trees.

7 PRUNING

Pruning is a silvicultural technique, typically applied to improve timber quality and value. It is the removal, close to the branch collar or flush with the stem, of side branches and multiple leaders from a standing tree. Lateral pruning removes branches because they form knots, which are a common defect of lumber and reduce timber value. The retention of large, dead branches low on the trunk is particularly counterproductive. Corrective pruning removes multiple leaders to improve stem form. Sometimes, pruning is applied to control disease, improve aesthetics, or improve accessibility.

Natural pruning or self-pruning is the natural elimination of branches. It is a slow process that varies by species, tree vigor, and stand density. Maintaining dense stands promotes natural pruning, but vigor and diameter growth are reduced. For some species, poor natural pruning and slow growth rates in dense stands require long rotations to produce quality timber.

Pruning is expensive. Only the best quality crop trees on good sites (those that support acceptable tree growth rates) are selected for pruning. It is most commonly applied to conifer plantations for species which are poor natural pruners, but which can significantly increase value by producing clear lumber (e.g., white and red pines). Pruning can enable more aggressive thinning strategies, if the promotion of natural pruning is no longer a concern. Thinning promotes the production of clear wood and stimulates the rapid healing of wounds. Combining pruning and aggressive thinning can facilitate the production of increased value in a shorter period of time. Pruning is an investment and should be implemented carefully; careless, poorly implemented pruning can cause tree injury and damage quality. Keeping records of pruning operations could be economically beneficial.

7.1 Operational Considerations

- Site quality: Prune only on good sites (those that support acceptable tree growth rates) for the target species.
- Tree characteristics: Most vigorous, healthy, dominant (tallest), and largest diameter crop trees for the dominant age class – the very best individuals.
- Number of trees: Typically 50-200 crop trees per acre.
- First pruning:
  - The first corrective pruning should occur in seedling or sapling stands.
  - The first lateral pruning should occur in young, vigorous poletimber stands before the lower branches become relatively large, and should follow early initial thinning.

- Pruning height:
  - The higher the pruning, the more difficult and expensive.
  - Typical final objective is a clear trunk to 17 feet; prune at least to 9 feet.
  - Each time, prune to topmost whorl of dead branches or into lower portion of live crown.
  - Maintain live crown:tree height ratio greater than 50%.

- Number of pruning operations: Typically, 2-3.
- Season to prune: Dormant season – fall to late winter best.

- Prune branches less than 1½ - 2 inches diameter. Removing large, live branches can damage quality.
- Avoid excessive green pruning of live branches. The best time to remove a branch is just before death or within several years thereafter.
- How to cut (figure 23.12): Cuts should be made close to the branch collar. For species lacking a distinct branch collar or callus ridge, cuts should be made flush with the stem but without damaging any bark. Don't tear or loosen bark around branch stub. No splinters or broken stubs.
- Tools: Combining hand and pole saws provides an effective and economical choice. Other tools and machines are available, and may be preferable depending on species, limb characteristics, and pruning height.

Some of the cover type chapters contain additional species specific pruning guidelines.

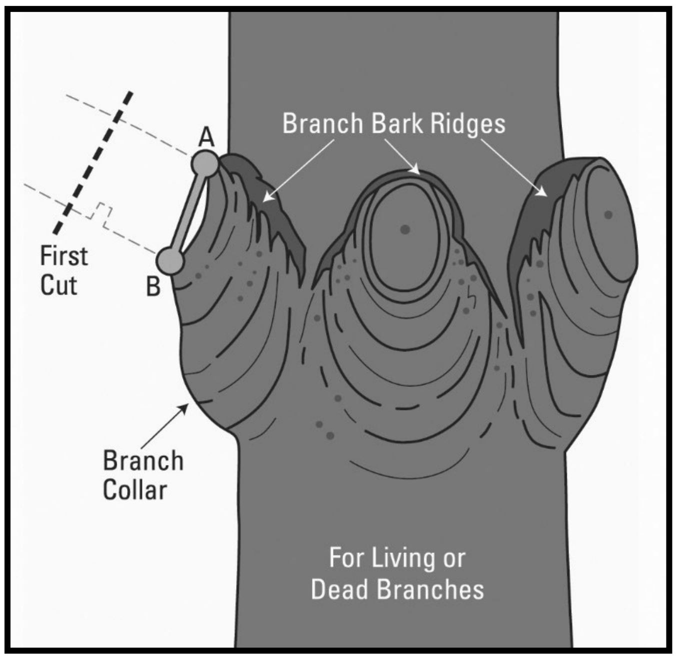

Figure 23.12. When pruning, leave the branch collar. Cut from point "A" to point "B".

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Chapter 24

Tree Marking & Retention Guidelines

WISCONSIN
DEPT. OF NATURAL RESOURCES

Last Full Revision: 11/12/2012
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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1 INTRODUCTION

Silvicultural practices are prescribed to address sustainable landowner goals and achieve stand management objectives. When stand management prescriptions and marking guides are developed, the desired characteristics of the remaining and/or regenerating trees and stand are of primary importance. The desired residual and future stand composition and structure guide the selection of trees for retention and trees for removal. The purpose of this chapter is to:

- Clarify concepts and considerations related to why and how trees are selected and marked, including appropriate silvicultural methods.
- Clarify silvicultural terminology. Provide silvicultural recommendations for selecting trees to retain and remove to accomplish specific stand management objectives.
- Provide recommendations for stand-level tree and snag retention to accomplish sustainable forest management goals.
- Recommend content of written marking guides for prescription implementation.
- Provide example of suitable marking guide templates

Selecting and marking trees to retain and/or remove is a fundamental practice and key element of many silvicultural systems. The selection of trees to retain and remove is commonly applied as part of intermediate treatments (ex. timber stand improvement, thinning), even-aged regeneration methods, and uneven-aged regeneration methods. Specific tree characteristics can also be defined to achieve specific management objectives; for example, high quality sawtimber tree or wildlife tree characteristics can be specified. Often, multiple objectives are identified for individual stands, and a variety of tree characteristics may be desired. Sometimes, individual trees can satisfy multiple objectives; for example, a large oak tree can provide wildlife mast and habitat, aesthetics, soil and water protection, and quality sawtimber when harvested.

During intermediate treatments, the focus is on which trees will be retained and managed until the next entry and beyond. In this case, tree selection commonly focuses on removing as many undesirable growing stock trees as possible and retaining as many desirable growing stock trees as possible to achieve prescribed goals, objectives, and targets. Foresters, however, should recognize that variability within stands will sometimes result in situations where acceptable growing stock will be marked, or undesirable growing stock will be retained to achieve marking objectives. Conditions in previously unmanaged stands, for example, are commonly variable and will require flexibility in the application of intermediate treatments.

When applying even-aged regeneration methods, the focus is on controlling stand composition and structure to facilitate the recruitment and development of desirable regeneration. However, some trees can be selected for retention beyond the regeneration period to achieve objectives other than regeneration. Uneven-aged stand management systems integrate regeneration, thinning, and harvesting practices; tree retention focuses on which trees will be retained and managed until the next entry and beyond, including wildlife trees and snags, and other non-timber objectives. The selection of trees to retain guides marking operations and strongly influences the selection of trees to cut. The number of trees to retain and the desired residual stand density depend on management objectives, silvicultural methods, forest type and species, stand and tree condition, and site.

2 TIMBER MANAGEMENT CONSIDERATIONS

2.1 Growing Stock Classification Systems

Selecting the best trees to cut or leave depends on both stand level considerations (e.g., target stand composition and structure, density, rotation age, tree retention, other silvicultural system criteria) and tree level considerations related to the ability of individual trees to increase in volume, form, quality, and value after being released. Growing stock classification systems are field tools designed to help foresters assess and rate individual trees based on their quality, risk and vigor characteristics. Information on the growing stock class, in combination with other silvicultural prescription criteria, can be used to guide both the selection of cut/leave trees, as well as inform stand level assessments of growing stock quality.

Growing Stock Classification Systems for Timber Management located in Appendix C of this chapter has been developed to help foresters evaluate and rate growing stock for timber management purposes. The interrelated systems allow the forester to choose from two, three, or five tree classes depending upon stand assessment needs. The simplest 2-class system rates trees as either acceptable growing stock (AGS) or unacceptable growing stock (UGS) based on the criteria listed in Figure 24.10 and Table 24.4. The poorest criteria generally determine the class. The 3-class and 5-class systems provide increasing levels of detail. The systems are nested so that the quality, risk, and vigor criteria for the 5-class system can be combined to define criteria for the 2 and 3-class systems. The 3-class system has been recommended for most tree marking and stand assessment operations where the forester wants a balance between detail and ease of application. The 5-class system has been suggested for pre-sale cruising of stands that require a detailed analysis of stand quality, such as for supporting prescription development in a regulated northern hardwoods stand managed with single-tree selection.

2.2 Selecting Trees to Remove or Retain

The cover type chapters in this handbook provide silvicultural recommendations which strive to balance tree and stand vigor with forest product production. Most silvicultural practices implemented over the life of a stand focus on quality development, density management (e.g., residual basal area), and the selection of trees to retain or remove. Selecting and marking trees to retain and/or remove is a critical part of most silvicultural practices implemented to achieve a landowner’s land management goals.

Before selecting trees to remove or retain, it is vital to identify a desired future condition (DFC). A DFC is based largely on a landowner’s goals and management objectives. Informed by site conditions and characteristics, marking criteria are prescribed to achieve a desired residual stand composition and structure consistent with the DFC. If all trees except seed trees or reserve trees will be cut, then marking criteria will need to specify seed or reserve tree objectives and characteristics. Marking criteria may also specify the removal of all other trees to a minimum diameter. For partial cuts, the characteristics of trees to cut are also delineated.

For intermediate treatments, particularly thinning, and uneven-aged selection treatments, trees with the potential for high timber quality or at least the ability to improve in grade may be favored, unless specified in a prescription, to become a component of a future commercial harvest. These trees are selected for retention and their crowns are released from competition to improve vigor and focus growth on the most desirable trees, dependent upon a stand's management prescription. Acceptable growing stock (AGS) trees are trees that contain or are potentially capable of producing high quality logs and are expected to maintain or improve their present quality through the next cutting cycle or until the next stand entry. The number of AGS trees to retain and the desired residual stand density depend on landowner objectives as reflected in the management prescription, silvicultural methods, forest type and species, stand and tree condition, and site. **Since management objectives may vary, growing stock status should not be viewed as direction for marking but rather as a tool used by foresters to aid in designing prescriptions to achieve objectives.** The selection of trees for retention strongly influences which trees will be removed.

If stand management objectives include the promotion of stand and tree vigor and the production of high quality sawtimber products, then the selection of trees to remove and retain could apply the following sequence for removal and retention to achieve the desired residual stand composition and structure.

2.2.1 Common Priorities for Removal and Retention (see definitions below)

1. Remove trees with high risk of mortality, failure, or loss of quality and/or value
2. Release acceptable growing stock (AGS) trees
3. Remove trees with low crown vigor
4. Remove trees with poor stem form and quality
5. Remove less desirable tree species
6. Remove trees to improve spacing

The Common Priorities for Removal & Retention are most often applied during intermediate treatments, particularly thinning, and uneven-aged selection treatments. Foresters will need to review the application of The Common Priorities for Removal & Retention with each practice to ensure proper application. The Common Priorities for Removal & Retention will often vary depending on landowner goals, stand management objectives, and silvicultural treatment; for example, a shelterwood seed cut or the presence of exotic invasive species may elevate the removal of undesirable species. **The recommended sequence for removal & retention is not a silvicultural prescription but rather a marking guide element designed to aid in implementing a prescription**.

Definitions

Following are definitions and specifications for the terms quality, risk, vigor, desirable species, and spacing as used in the Common Priorities for Removal & Retention. These are not the only factors that need to be assessed but may be the least clear in application. Some forest cover type chapters detail additional cover type specific criteria and guidelines.

Quality (timber): the capability of a tree to produce high quality timber products. Quality can be based on a tree's current or potential condition (ex. the ability to jump product class especially in the lower ½ of the tree and/or improve in grade). Quality is evaluated based on current or potential merchantable volume (diameter and log height), tree grade (value-limiting defects), and form (i.e., sweep or crook). Timber quality can vary significantly, depending on the type and severity of a defect, tree species, and other site factors. Quality is not necessarily related to the size of a tree. Due to this complexity, information specific to defect types and tree species is not described in this chapter. Some cover type chapters detail species specific indicators of timber quality.

Risk: the probability or potential that a tree will die, suffer structural failure (*physical risk*), decrease in quality and/or economic value (*quality risk*) due to internal degradation within a specified period or cutting cycle, or have a lower rate of economic return than that targeted by a landowner (*economic risk*). Table 24.4 can be used to evaluate potential physical and value risk to individual trees based on common indicators of defect or poor health. Factors that determine a landowner's desired economic return and economic risk may include net present value (NPV), internal rate of return (IRR), rate of value growth (RVG), etc. If utilized, these factors should be defined in the prescription to clarify economic risk marking criteria. Levels of risk tolerance may vary between landowners based on landownership goals and risk perception. Identification of excessive risk within a substantial portion of a stand is a well-founded reason to assess and prescribe new stand management practices.

Vigor: active, healthy well-balanced growth of individual trees. It describes the tree's potential to grow at a rapid rate and increase in volume. Vigor is evaluated based on tree characteristics which reflect recent and potential growth. Table 24.4 can be used to evaluate an individual tree's vigor based on crown class, crown silhouette, foliage condition, and bark character.

Desirable Species: Tree species which are compatible with sustainable landowner property goals, stand management objectives, site quality, and stand conditions. Desirable species are also well-adapted or potentially adapted to the site, and of commercial value.

Spacing: the distance between stems and crowns of desirable trees, and the equal distribution of growing space.

2.3 Marking Guides

A silvicultural prescription is a planned series of treatments designed to change the current stand condition to one that meets landowner goals and objectives and is an integral part of the overall forest management plan. Marking guides are tools to help foresters with on-the-ground implementation of a silvicultural prescription. Marking guides often take the form of written instructions that aid in the selection or marking of trees to retain or remove from the stand. Based on stand management prescriptions, marking guides may include information to help foresters implement a practice.

Marking guides should be recorded and discussed with the marking crew before field marking operations are initiated. Written stand management objectives, prescriptions, marking guides, and evaluations of results provide valuable information which should be documented and filed for future reference. Example of marking guide templates can be found in Appendix D.

3 TREE MARKING EVALUATION METHODS

3.1 Evaluation of Prescription Implementation, Marked Timber Evaluation

In many situations, foresters need to assess whether a silvicultural prescription has been implemented successfully. To determine if timber sale establishment field work or a post-harvest stand is consistent with prescribed management, evaluation criteria and tools may be used. These criteria and tools are applicable to marked, unmarked, and designated harvests where a harvest prescription establishes a post-harvest desired condition. Other considerations needing evaluation may include: BMPs for water quality, invasive species, Natural Heritage Inventory (NHI), archeological, historical, cultural, tree retention, and paint marks. These should be assessed separately. Marking for intermediate non-commercial practices (i.e., timber stand improvement) and other silvicultural treatments will need to be evaluated using different stand assessment criteria as well.

The use of evaluation criteria and tools should be tailored to assessment needs. Foresters may want to proactively assess marking for many reasons including self-assessment, providing clients with assurance of project completion, etc. Assessment of prescription implementation is not, however, mandatory.

Many methods may be used to determine if a project meets prescription goals and objectives. The Marked Timber Evaluation Procedure and Evaluation Sheet, found in Appendix A, and the general criteria for assessing prescription success (see below) were developed to assist with evaluating a marked harvest. It is up to professional judgment of the evaluator to determine whether to utilize either of these evaluation processes. Measuring whether a marked harvest has successfully implemented a silvicultural prescription is measurable but involves professional judgment as well. Professional judgment should also be used to determine if marking evaluation is warranted over an entire sale area or only on a subsample of the sale area.

If appropriate stand-level inventory data is available or can be collected, success in achieving sound forestry and prescription goals can be determined by comparing prescription targets with cut vs. leave / post-harvest information. For intermediate thinning and generally accepted natural regeneration methods, general criteria for measuring success specific to each practice have been established. Successful implementation is measured by comparing these criteria against post-treatment data. Where a deciding factor is whether the result is "within acceptable limits of variation above or below the identified target," the acceptable degree a variation may be somewhat different based on cover type, stand condition, or landowner objectives. Foresters should refer to the appropriate cover type chapter to help formulate both the appropriate target and expected range of variation in results. For intermediate thinning and generally accepted natural regeneration methods, general criteria for assessing prescription success are:

1. Intermediate Thinning

a. Thinning from below (low thinning)
   i. The percent of AGS basal area increases
   ii. The average merchantable stand diameter increases. Note, this can also be documented with a d/D score <1.
      - d/D = QMD of trees removed / QMD of pre-harvested stand
   iii. Residual BA within acceptable limits of variation above or below the prescribed target
   iv. Other potential criteria
      - Range of within stand basal area variance is smaller unless specified in harvest prescription
      - The proportion of suppressed and intermediate trees decreases

b. Thinning from above (crown thinning)
   i. The percent of AGS basal area remains approximately the same or increases.
   ii. The average merchantable stand diameter remains the approximately the same.
      - d/D ≈1
   iii. Residual BA within acceptable limits of variation above or below the prescribed target
   iv. Other potential criteria
      - The proportion of dominant and codominant trees remains approximately the same

c. Row thinning
   This may be modified to reflect other marking criteria if coupled with removal of trees in retention rows
   i. The percent of AGS basal area does not change significantly
   ii. The average merchantable stand diameter does not change significantly
   iii. Residual BA within acceptable limits of variation above or below the prescribed target
   iv. Rows designated for removal are consistent with prescription objectives and operational needs

d. Free thinning
   This will be modified to reflect other marking criteria and will depend greatly on the harvest prescription. Note, free thinning prescriptions will need to be more detailed to fully assess success.
   i. The percent of AGS basal area remains the same or increases.
   ii. Residual BA within acceptable limits of variation above or below the prescribed target

iii. Other potential criteria
- The proportion of suppressed and intermediate trees decreases

2. Even-Aged Management

a. Coppice: simple, compound, and/or with standards
   i. Residual trees per acre or basal area within acceptable limits of variation above or below the prescribed target

b. Clearcut: uniform, alternate, or progressive
   i. Residual trees per acre or basal area within acceptable limits of variation from prescribed target

c. Seed Tree: single and group (aggregated)
   i. Residual trees or numbers of seed tree clusters per acre within acceptable limits of variation above or below the prescribed target
   ii. Residual trees are predominantly the target species
   iii. Residual trees have near term ability or potential to produce sufficient and desirable seed (i.e., large crowns, high vigor, dominant or codominant, sufficient seed tree spacing, desirable phenotypes)

d. Overstory Removal: uniform and patch
   i. Residual trees per acre or basal area within acceptable limits of variation above or below the prescribed target
   ii. Adequate regeneration (see Table 21.2) is present (number of seedlings / saplings per acre) and within acceptable limits of variation from identified threshold for overstory removal

e. Shelterwood: uniform, strip, and patch
   i. Preparation cut
   - The percent of AGS basal area remains the same or increases.
   - Residual basal area within acceptable limits of variation above or below the prescribed target
   - Other potential criteria
     (a) The proportion of suppressed and intermediate trees decreases
     (b) Potential seed producing trees crown released

   ii. Seeding cut
   - Residual stand crown cover or basal area is within acceptable limits of variation above or below the prescribed target
   - Residual trees are the target species identified in the harvest prescription
   - Residual trees have the potential to produce sufficient and desirable seed (i.e., large crowns, high vigor, dominant or codominant sufficient seed tree spacing, desirable phenotypes)

iii. Overstory removal
- Residual trees per acre or BA within acceptable limits of variation from identified target
- Advance regeneration (number of seedlings / saplings per acre and height class) is within acceptable limits of variation from identified target, based on species silvics or cover type guidance

3. Uneven-Aged Management

a. WDNR Northern Hardwood Conversion Process (even-aged / two aged → single tree selection)

i. The percent of AGS basal area increases

ii. Residual basal area within acceptable limits of variation above or below the prescribed target

iii. The number and size of installed gaps is within acceptable limits of variation

iv. Other potential criteria
- The proportion of suppressed and intermediate trees decreases

b. Single-tree selection

i. The percent of AGS basal area remains approximately the same or increases

ii. Residual stand diameter distribution or BA distribution is closer to identified target distribution

iii. Residual BA within acceptable limits of variation above or below the prescribed target

iv. Other potential criteria
- The proportion of suppressed and intermediate trees decreases

c. Group/patch selection

This may be modified to reflect other criteria if group/patch selection is coupled with removal of trees in the intervening matrix

i. Numbers of regeneration openings per acre or amount of area occupied by openings is within acceptable limits of variation from prescribed target

ii. Average size of established regeneration openings is within acceptable limits of variation from prescribed target

iii. Adequate regeneration (see Table 21.2) present within regeneration openings created to release established regeneration

4 WILDLIFE MANAGEMENT CONSIDERATIONS

Prior to cutting a stand, identify specific trees that have high value for wildlife. Retain sufficient numbers of these wildlife trees to meet landowner goals and to provide for sustainable management of forest-dependent wildlife. Both stand and landscape level considerations may play a role in the decision process. Wildlife trees provide important structure (standing or as down woody debris) and function when managing an ecosystem. Wildlife trees can be periodically re-evaluated. Removal of wildlife trees can occur, but some should be allowed to senesce and die.

In southern Wisconsin, black cherry is a good example of a wildlife tree; large, vigorous specimens are uncommon and their fruit is eaten by many birds and mammals. In the north, large, tall white pines or hemlock groves are often reserved. Any current or future cavity or mast-producing tree is a good candidate to retain. If a few very large trees remain from previous harvests, continuing to reserve these trees can contribute to cavity, snag and species diversity objectives.

A variety of mast-producing trees suited to the habitat type should receive management consideration. Vigorous trees of a variety of species will best provide the benefits of mast production. Mast trees may provide other wildlife benefits. As an example, the "wolf tree" is often chosen as a wildlife tree. Though reserving wolf trees may mean sacrificing some timber production, they are among the best mast and cavity producers.

Wisconsin's wildlife Species of Greatest Conservation Need (SGCN) were identified by WDNR (2005). SGCNs that utilize snags and/or cavity trees include northern flying squirrel, Osprey, Red-headed Woodpecker, Black-backed Woodpecker, northern long-eared bat, silver-haired bat, and hoary bat. Bat species prefer large, spreading, snags with the bark still on. SGCNs associated with large trees are Bald Eagle, Northern Goshawk, Red-Shouldered Hawk, Acadian Flycatcher, Cerulean Warbler, and Prothonotary Warbler. Coarse woody debris associates among the SGCN include Louisiana Waterthrush, four-toed salamander, and American marten. In addition to these, many of the more common forest wildlife species benefit from the presence of large trees, cavity trees, snags, and coarse woody debris.

To minimize the impact of timber harvest on cavity-dwelling wildlife, it is important that a reasonable number of appropriate snag and cavity trees be left after harvest. For most forest ecosystems the current understanding of the biology of cavity-using wildlife is too limited to employ species by species estimates of snag requirements. A guideline of three or more cavity trees and as many snag trees as possible per acre should meet the requirements of most cavity-dwelling wildlife. A range of sizes and decay stage of snags will best achieve the objective of providing this habitat requirement. Large snags (18" DBH or larger) are particularly valuable. Large snags can accommodate a variety of wildlife. Larger wildlife species require larger trees, while smaller species can still use the large snags. Additionally, large cavity trees tend to remain available for a longer time. Some long-lived wildlife species will use this resource seasonally over a period of years and some species will use the same resource across generations. Cavity-dwelling wildlife range in size from bats and chickadees to pileated woodpeckers and black bears.

The long-term nature of snag and large diameter cavity tree availability must also be considered. To maintain an appropriate number of snags, the recruitment rate for snags must balance the rate of loss through decay. One solution is to leave some trees with poor form and low economic value to serve as future snag trees. Cavity requirements might sometimes be more easily attained with living trees since the number of residual snags is so unpredictable. Because one can assume that a portion of those trees set aside to become the second generation of snag trees will fall down before they die, it is advisable to leave more than will ultimately be needed as snags.

Some individual trees are favored by wildlife for a variety of reasons. They may be better producers of a food resource or they may be well suited to be used as a territorial marker. As an example, the Yellow-bellied Sapsucker is a common primary cavity excavator. Individuals tend to return regularly to the same trees for foraging. If preferred trees are removed, then excavations will be transferred to another tree. Maintaining trees with signs of sapsucker activity will concentrate this activity to relatively few trees and reduce impacts on timber yields. Retain trees with signs of sapsucker activity or other regular wildlife use.

In addition to selecting trees with poor form as future snag trees, it is sensible to choose trees that are infected with heart rot. These trees will be of low value and may already have cavities. Diseased trees can be identified by the presence of conks of heart rot fungi, wounds such as broken branch stubs and fire scars, dead portions of the crown, and woodpecker holes. These trees may provide habitat niches to species requiring loose bark which may not be available on older snags.

Within forests, inclusions may be found where seasonal ponding of water occurs. These ponds are called “vernal pools” (Rogers and Premo 1997). Vernal pools are characterized as small, seasonal, ephemeral, pools or ponds that lack predatory fish (Colburn 2004). Due to the lack of predators, these pools are important areas for amphibians and invertebrates to reproduce. The actual size used as definitional criteria of these “small” pools is debatable. Rogers and Premo (1997) described size range of vernal pools as “from a puddle to an acre or more.” Vernal pools contain species of aquatic flora and fauna not found throughout the terrestrial matrix. The frequency and distribution of vernal pools are of importance to their function in maintaining or enhancing biodiversity. Prior to timber harvesting, vernal pools should be identified and assessed, and for those pools deemed important to achieving biodiversity conservation goals (e.g., pools infrequent on the landscape and pools with known concentrations of uncommon species), protection measures should be specified. Some vernal pools should be buffered to protect amphibian foraging and breeding habitat. Retention of down woody debris nearby will improve habitat for some amphibians. Harvesting should avoid felling trees into or skidding through vernal pools and avoid rutting in the nearby vicinity. Vernal pools may not be apparent at certain times of the year due to their ephemeral lack of standing water or during periods of snow cover. Signs of vernal pools include water marks on tree trunks, changes in ground layer vegetation, and discoloration of litter on the forest floor.

Many of the forest cover type chapters in this guide provide wildlife management considerations, and specific species are sometimes addressed. Guidance for more specific snag and den tree management prescriptions can be found in *"A Landowner's Guide to*

Woodland and Wildlife Management" (University of Wisconsin-Extension, Publication Number 193578). This publication was developed to help the private landowner better manage woodlands for wildlife. It is a good source of information for specific snag requirements of some of our most common cavity-using birds and provides other information useful when managing mature forests for wildlife.

4.1 Wildlife Tree and Snag Retention Criteria

- Large trees for habitat structure (e.g. nest trees)
  - Some low risk, good vigor trees to sustain long life
  - Some moderate to high risk, moderate to low vigor (decadent) trees to provide near-term future snags and coarse woody debris
  - Desirable species; strive for species diversity
- Mast trees for food
  - Low risk
  - Good crown vigor
  - Strive for species diversity; hard-mast producers generally preferred over soft-mast producers
- Cavity (den) trees for shelter
  - With cavities in bole
  - Larger diameter cavity trees are particularly desirable
  - Strive for species diversity
- Snags for habitat, shelter, and food
  - Larger diameter snags are particularly desirable
  - Strive for diversity in species and level of decay

Large trees are at least 12 inches DBH, and preferably greater than 18 inches DBH. Large trees >18 inches DBH are uncommon. However, they provide structural diversity that increases the availability of habitat niches and can benefit an array of wildlife. Important structural features include tall canopies that contribute to vertical stratification, large crowns and branches, and loose, furrowed bark. Importantly, the development of large trees is required for the recruitment of large cavity trees, snags, and down coarse woody debris.

Mast trees are living trees that produce fruit and nuts that are consumed as food by wildlife. Large crowned vigorous trees generally produce the most mast. Increasing numbers of mast trees facilitate increased populations of some species. Retain as many mast trees as possible.

Cavity (den) trees are living trees that are partially hollow and used by wildlife for shelter. Large diameter cavity trees, especially those >18 inches DBH, can provide the greatest array of benefits. Increasing the number and size of cavity trees facilitate increased populations of some species. Retain as many large diameter cavity trees as possible.

Figure 24.1. Large yellow birch tree (photo by Colleen Matula).

Figure 24.2. Cavity tree (photo by Joseph O'Brien, USDA Forest Service, Bugwood.org).

Figure 24.3. Snag (photo by Jeff Martin, J-Mar Photography).

Figure 24.4. Mast (photo by Paul Wray, Iowa State University, Bugood.org).

Snags are standing dead trees. Snags benefit many species of wildlife; large diameter snags can provide the greatest array of benefits. Eventually, snags become downed coarse woody debris that also benefits wildlife and other ecosystem processes. Increasing the number and size of snags facilitates increased populations of some species. Other than the physical space occupied, snags do not compete with living trees. Retain all snags present that do not provide a threat to human safety; those that are determined to be a threat can be cut and retained on site as coarse woody debris.

For general wildlife management objectives, retain as many large trees, mast trees, cavity trees, and snags as possible in concordance with stand management objectives and landowner property goals. Wildlife trees retained can be scattered uniformly or irregularly distributed, as single trees, groups, and patches. Large trees and mast trees may benefit from crown release. Cavity trees do not necessarily require release, but in some cases crown release can prolong tree life and cavity benefits. Clearly designate, in writing and/or by marking, which trees should be retained (not cut) prior to any cutting operations.

5 AESTHETIC MANAGEMENT CONSIDERATIONS

Forest Aesthetics management guidelines should be referenced when designing aesthetic considerations for forest management application. Aesthetics involves not only individual marking decisions but long term planning and design. General aesthetic tree retention criteria have been developed, but specific characteristics and retention design will be highly variable depending on landowner preferences and stand specific considerations.

5.1 Aesthetic Tree Retention Criteria

- Low risk
- Good crown vigor
- Desirable species depend on landowner goals and site conditions, and may consider:
  - Lifespan
  - Foliage color
  - Flowers and fruits
  - Bark characteristics
  - Crown architecture, such as large spreading crowns and unusually shaped trees

6 WATER QUALITY MANAGEMENT CONSIDERATIONS

Wisconsin Best Management Practices (BMP) for Water Quality guide forest management practices to maintain water quality. Forest management in stands where the maintenance of water quality is a primary objective and concern, involves not only individual marking decisions but long-term planning and design. General water quality tree retention criteria have been developed, but specific characteristics and retention design will be highly variable depending on landowner goals and specific stand and site conditions and considerations.

6.1 Water Quality Tree Retention Criteria

- Low risk
- Good crown vigor
- Desirable species depend on landowner goals and site conditions, and may consider
  - Lifespan
  - Tolerance of saturated soils and flooding

7 BIODIVERSITY AND ENDANGERED RESOURCE MANAGEMENT CONSIDERATIONS

Figure 24.5. Biological legacies following windstorm (photo by Joe Kovach).

Many biodiversity and endangered resources issues are addressed at the landscape level, and then through the protection of special habitats. Within managed stands, identify and protect element occurrences and special habitats. Follow general wildlife management guidelines; select and retain wildlife trees, including reserve trees as dispersed and aggregated individuals, groups, and patches. By integrating the identification of special habitats and microsites with the retention of reserve tree patches, multiple benefits can be achieved. Areas to consider when selecting patches for retention include groups of trees that are older or have high species diversity, sites where understory composition exhibits high diversity or uncommon species, vernal pools, seeps, wet depressions, cliffs, rock outcrops, ravines, and caves. Some of the forest cover type chapters in this guide provide biodiversity management considerations, and specific species are sometimes addressed.

Figure 24.6. Biological legacies following fire (photo by Joe Kovach).

Biological legacies are organisms, reproductive portions of organisms, and biologically derived structures and patterns inherited from a previous ecosystem. Compositional legacies influence ecosystem function, and can include trees, understory plants, fungi, invertebrates, and other animals. For example, mycorrhizal fungi and microbial decomposers are potential compositional legacies whose nutrient cycling functions are essential in maintaining site productivity. Structural legacies, such as trees, snags, and surface organic matter (including down woody debris) also influence ecosystem function and provide habitat for organisms.

In forests managed for timber production, variable retention harvesting retains biological legacies from the harvested stand for integration into the new stand to achieve ecological objectives. Structural legacies selected for retention often include large trees, large snags, and large down logs to provide refugia and to structurally enrich the new stand. Large structures take a long time to develop and are not easily replaced. Important characteristics of trees selected as biological legacies are: species diversity; size class representation, especially very large trees; tree health, including both healthy and decadent trees; and heterogeneous distribution as dispersed individuals and aggregated patches. Reserve trees intended for future harvest provide biological legacies as living (usually large) trees. Reserve trees can be allowed to persist, developing into large trees, snags, and eventually large coarse woody debris. Management of biological legacies requires adaptive silvicultural methods to promote stand level heterogeneity, compositional and structural complexity, and ecosystem diversity.

8 RESERVE TREES

Reserve trees are living trees, ≥5 inches DBH, retained after the regeneration period under even-aged or two-aged silvicultural systems. They are retained well beyond stand rotation, and for purposes other than regeneration. They may be harvested eventually or retained to complete their natural lifespan (becoming a snag and then coarse woody debris). Reserve trees can be dispersed uniformly or irregularly, as single trees or aggregated groups or patches, or any mixture thereof. Synonyms include standards and green tree retention.

A legacy tree is a specific type of reserve tree that is usually older (past typical rotation age) and sometimes a remnant of a previous stand. Legacy trees may not be present in some stands, depending on management and disturbance history. These trees are individual old trees that function as refuges or provide other important structural habitat values. Legacy trees are meant to provide long term ecological benefits and are generally kept in perpetuity.

The characteristics of desirable reserve trees are highly variable and depend on the intended benefits, the species present, stand condition, and site. Desired compositional and structural attributes may be present when trees are selected and stands are rotated, or additional time may be required for development.

Typical characteristics of desirable individual reserve trees (either scattered or within patches) include:

- Large size (tree height, diameter, crown dimensions) for the species and site.
  - If large trees are lacking, then potential future large trees can be selected.

- Older trees with large size and rough bark.
- A mix of vigorous and decadent trees.
  - Vigorous trees of long-lived species can enable long-term retention and potentially yield a variety of benefits.
  - Decadent trees can provide current and future cavity trees, as well as future snags and down coarse woody debris.

- A mix of species, including locally uncommon species and mast trees.

The development and maintenance of large structures (vigorous trees, cavity trees, snags, down woody debris) and species diversity is typically encouraged.

Generally, poor candidates for individual reserve trees include:
- Relatively small (height, diameter, crown), suppressed to intermediate trees.
- Relatively young trees within the stand.

These smaller, younger trees are retained in reserve groups and patches along with larger, older trees.

Exceptions to these typically desirable and generally poor reserve tree characteristics will occur.

Note: Application of the tree retention guidelines for County Forests is slightly different than stated within the guide. Refer to a County's 15 Year plan for details on tree retention for a particular County Forest. That version should be used to evaluate and approve sales for that respective County forest. Foresters should be aware that other third party certified lands may have their own tree retention guidelines.

8.1 Benefits of Reserve Tree Retention

Silvicultural practices are designed to manipulate vegetation to achieve management objectives. At its foundation, silviculture is based on understanding and working with ecological processes. Silvicultural practices that more closely emulate natural disturbance and stand development processes are more likely to sustain a wide array of forest benefits. Most natural disturbance regimes and events retain compositional and structural legacies in heterogeneous patterns and create ecological complexity. Silvicultural practices that develop and maintain reserve trees in managed stands can enable the promotion of ecological complexity – composition, structure, and pattern.

The retention of reserve trees can provide a "lifeboat" function that contributes to the conservation of biological diversity (see preceding section). These structures facilitate the perpetuation of some biota (plant and animal species and genotypes) on site. They also perpetuate habitat for re-colonization and occupation. They can improve landscape connectivity, facilitating the movement of some organisms. Reserve trees influence reorganization and recovery processes in post disturbance ecosystems; they can sustain functional roles and modify the post-disturbance environment.

The actual benefits achieved through the retention of reserve trees can be variable, depending on such factors as landscape composition and structure, stand composition and structure, site, retention design, and management objectives.

Some specific potential benefits include:
- Timber Production
  - Reserve high quality trees for future harvest
  - Perpetuation of tree species diversity

- Wildlife and Plant Habitat (Biodiversity)
  - Cover
  - Cavity (den) and nest trees

  - Display locations
  - Food (foraging, hunting)
  - Future snags and down woody debris (coarse and fine)
  - Habitat diversity
  - Protect special habitat
  - Travel corridors

- Aesthetics
  - Limit line of vision
  - Break up “clearcut” look
  - Retain visually unique trees
  - Provide diversity in future stand

- Water and Soil Quality
  - Reduce run-off
  - Reduce erosion
  - Maintain water and nutrient cycles

- Miscellaneous
  - Buffer adjacent stands
  - Protect cultural resources
  - Landmarks, such as marker trees and witness trees

8.2 Potential Costs of Reserve Tree Retention

The retention of reserve trees in actively managed stands can provide ecological benefits desired by landowners and society. However, there are also costs or trade-offs. The primary potential cost is reduced timber yield at the stand-level. Also, retention can result in less available habitat for some wildlife species, particularly those that prefer open, treeless habitat. However, impacts on long-term forest ecosystem sustainability and productivity are uncertain; current understanding suggests that the maintenance of ecological complexity will more likely sustain long-term productivity.

Some specific potential costs include:

- Potential additional operational costs to manage reserve tree retention
- Potential for reduced timber growth rates maintained by larger, older trees
- Potential for reduced short-term stand-level timber yields by foregoing harvest of some trees
- Potential for epicormic branching
- Potential for stem and crown damage during stand harvest
- Potential for crown dieback and mortality following harvest
- Potential for windthrow, particularly on wet or shallow soils, or for shallow rooted species
- Potential damage to younger stand if reserve trees are harvested during mid-rotation
- Reduced growth rates of regeneration occurring beneath reserve trees
- Potential sites for pathogen breeding and maintenance
- Potential for reduced habitat for or increased predation of certain wildlife species

8.3 Considerations for Reserve Tree Retention

Reserve overstory trees will shade portions of a newly developing stand. Increased numbers of dispersed reserve trees and trees with larger and denser crowns will cause more shading. Furthermore, reserve tree crowns can expand over time, increasing shading effects. Shading by reserve trees potentially can reduce growth within portions of newly developing established even-aged stands. The point at which growth reductions become significant depends on a variety of factors, including: stand management objectives (for reserve trees and young trees), growth rates and potential development of reserve trees, growth rates and shade tolerance of species comprising the new stand, site quality, understory competition, and potential damaging agents. In general, to promote optimum growth of established even-aged stands of reproduction, (nearly) full sunlight is preferred. Under even-aged management systems, when objectives include the retention of reserve trees beyond the regeneration establishment phase, crown cover of <20% generally (for most species and conditions) will not significantly reduce vigor, growth, and development of most of the developing stand. If reserve trees are dispersed and expected to survive and grow, crown cover will increase over time; 15% crown cover is a generally recommended maximum for dispersed retention at final rotation. If reserve trees are aggregated, then shading impacts will be reduced; total crown cover retained could be greater and will depend on stand management objectives.

Excessive shading may also be a concern when regenerating shade intolerant species in small stands or in narrowly linear stands, surrounded by relatively mature forest. In such cases, it may be necessary to retain fewer reserve trees. Alternatively, there may be opportunities to redesign stand boundaries creating a larger stand with increased opportunities for internal tree retention.

Reserve tree retention is a generally recommended silvicultural practice for stands ≥10 acres. It is encouraged in smaller stands, but operational, shading, and other biological issues may limit application.

Insect and disease issues and potential impacts on tree health should be another consideration in reserve tree selection and design. Regeneration methods are designed to foster the vigor of the regenerating stand. Although the imminent mortality of some reserve trees may be desirable or acceptable, typically some vigorous trees will be retained with the expectation of continued growth and survival (perhaps for a long time). When regenerating a stand and retaining reserve trees, potential risks to tree health should be evaluated, and methods implemented to reduce risks while achieving stand management objectives. In most cases, well designed regeneration and retention strategies can minimize risks; however, stand and site conditions may limit options in some cases. Refer to the cover type chapters in this guide and forest pest management guidelines to appropriately consider and address insect and disease risks when selecting and designing regeneration methods and reserve tree retention for a specific stand and site.

Two examples of how insect and disease considerations can influence reserve tree selection and design:

- Red pine: Retaining red pine reserve trees when regenerating a new red pine stand may significantly increase the risk of Sirococcus and Diplodia incidence within the young stand. This risk is highly variable geographically; where experience has shown the risk to be significant, then retaining red pine reserve trees over red pine regeneration would be poor silviculture. In such cases, retain other species (e.g., oak) as reserve trees if available; if not available, then it may not be possible to retain reserve trees as generally recommended, but consider including representation of other species as part of stand regeneration to provide increased options for future managers. Red pine can be an excellent reserve tree when regenerating other species (e.g., aspen or oak).

- Jack Pine: In general, retaining jack pine reserve trees when regenerating a new jack pine stand is not recommended, because of the risk of budworm outbreaks. When regenerating jack pine, other species (e.g., oak) should be retained as reserve trees if available. Jack pine can be retained as a reserve tree when regenerating other species.

Representation of reserve trees can range from none to many. If silviculture is to simulate, to some extent, natural disturbance processes, then most actively managed stands should include some level of structural retention. To accomplish general sustainable forestry goals that include multiple stand management objectives, recommended representation could typically range from 5-15% of stand area or crown cover. In some stands, particularly intensively managed single objective stands (e.g., maximize short-term economic returns, maximize pulp production, or maximize populations of wildlife species that prefer completely open, treeless habitat), landowners may choose to not retain reserve trees. In some stands, with appropriate species and site characteristics, where the optimization of tree vigor and timber quantity and quality is a minor concern, adaptive silvicultural practices that retain 20-60% cover could be considered by the landowner. It is recommended that sound reasons and expected impacts be documented when the decision is to retain reserve trees at less than or greater than the recommended level of 5-15% of stand area or crown cover.

Distribution of reserve trees can be evenly or irregularly dispersed individuals, groups, and patches.

Retention in aggregated patches generally provides the most benefits, including:

- patches of habitat that maintain forest floor, understory plants, and vertical structure within the patch, and increase compositional and structural diversity,
- more heterogeneity across the stand,
- less damage to retained trees during harvesting operations, and
- less impact on regeneration in stand matrix.

Patch retention should consider retention of large trees, cavity trees, and snags within the patches. Reserve patches can be thinned during the even-aged rotational harvest of the matrix; however, retention of unthinned patches potentially provides the greatest benefit. Patches can be located to complement other management objectives or respond to stand conditions; for example, patches can be located in riparian management zones, to provide connectivity between stands, and to protect sensitive sites (e.g., cliff faces and vernal pools) or endangered resources. Patches should be >0.1 acres and generally <2.0 acres, but can be larger; patches, particularly large ones, should be documented as retention patches.

Figure 24.7. Reserve trees retained in patches (photo by Jeff Martin, J-Mar Photography).

Retention of evenly dispersed individual trees also provides unique benefits, including:

- retention of comparatively more large trees, and
- wide distribution of structural benefits (large trees, snags, and coarse woody debris) and seed sources.

Table 24.1 Patch sizes for retention and approximate dimensions (circular and square).

Area (acres)	Diameter (feet)	Square (feet)
0.1	74	66 x 66
0.25	118	104 x 104
0.5	167	148 x 148
0.75	204	181 x 181
1.0	236	209 x 209
1.5	288	256 x 256
2.0	333	295 x 295

Retention of irregularly dispersed individual trees and small groups provides another strategy; this can be particularly useful to develop feathered edges to stands and reduce abrupt transitions and edge effects.

The general recommended strategy is to retain irregularly distributed patches along with scattered groups and individuals.

Stand representation and spatial distribution patterns of reserve trees can be highly variable. The goal of heterogeneity of conditions indicates a wide array of retention strategies. Retention design, including amount to retain, species, and distribution, can enable the production of increased benefits and minimize potential costs. Criteria to consider when determining desired representation and distribution include landowner goals and stand management objectives, current and desired stand and community condition, characteristics of current and desired plant and animal species, potential damaging agents, site, and landscape characteristics. Detailed landscape analysis and planning that clearly addresses the sustainable allocation of resources, including the production of timber and the conservation of biodiversity, can improve upon stand-based management guidelines (such as those offered herein).

Figure 24.8. Reserve trees retained as a group (photo by Joe Kovach).

Figure 24.9. Reserve trees retained irregularly as individuals (photo by Joe Kovach).

8.4 Recommendations for Retention in Managed Stands: Reserve Trees, Mast Trees, Cavity Trees, and Snags

Sustainable forest management is implemented within a framework defined by landowner goals and objectives, ecosystem condition and potential, and sustainable silvicultural systems and practices. Forests are cultivated to provide a variety of socio-economic and ecological benefits. Sustainable forest management integrates multiple management goals and objectives into most silvicultural systems and the management of most stands and landscapes.

Most stands that are actively managed include timber production as a management goal (often in concert with other goals). Tree retention typically focuses on crop tree selection and regeneration methods. To satisfy multiple objectives and provide multiple benefits, retain additional trees to achieve non-timber management objectives. Integrate the following recommendations for tree and snag retention into the management of most forest stands:

- Even-aged rotations
  - Retain ≥3 (if available), preferably large, snags per acre.
  - Retain reserve trees and/or patches at 5-15% crown cover or stand area, including large vigorous trees, mast trees, and cavity trees. Reserve tree retention is a generally recommended silvicultural practice for stands ≥10 acres. It is encouraged in smaller stands, but operational, shading, and other biological issues may limit application.

- Even-aged intermediate treatments
  - Retain ≥3 (if available), preferably large, snags per acre.
  - Retain ≥3 (if available), preferably large, cavity trees per acre.
  - Retain ≥3 (if available), preferably large, mast trees per acre.
  - If previously established, manage reserve trees and patches. Management may include timber harvesting or passive retention. Consider retaining ≥3 trees per acre to develop into large, old trees and to complete their natural lifespan. These trees may also satisfy cavity and mast tree recommendations. These trees will often become large snags and coarse woody debris.

- Uneven-aged systems
  - Retain ≥3 (if available), preferably large, snags per acre.
  - Retain ≥3 (if available), preferably large, cavity trees per acre.
  - Retain ≥3 (if available), preferably large, mast trees per acre.
  - Consider retaining ≥3 trees per acre to develop into large, old trees and to complete their natural lifespan. These trees may also satisfy cavity and mast tree recommendations. These trees will often become large snags and coarse woody debris.

In cases where these recommendations for retention are not applied, then sound reasons and expected impacts of deviation should be documented.

When applying retention recommendations, be sure to consider:
- Individual trees can provide multiple benefits and fulfill the intent of more than one of the above recommendations. For example, three large oak trees with cavities could satisfy the mast tree and cavity tree recommendations, as well as the large, old tree consideration.
- Retention of both vigorous and decadent trees will provide an array of benefits.
- In general, species diversity is encouraged when selecting trees to retain.
- Large trees and snags are >12 inches DBH, and preferably >18 inches DBH.
- Trees retained can be scattered uniformly throughout a stand or irregularly dispersed, as single trees, groups, and patches. The general recommended strategy is to retain irregularly distributed patches along with scattered groups and individuals.
- Retention in aggregated patches generally provides the most benefits for wildlife and biodiversity. Also, patches retained can satisfy multiple benefits; for example, at stand rotation, an internal or adjacent unharvested buffer along a stream (RMZ) could provide a portion of reserve tree retention as well as satisfy BMP (water quality) recommendations. Patches should be >0.1 acres and generally <2.0 acres, but can be

larger; reserve tree patches, particularly large ones, should be documented as retention patches.

- Estimating the amount of retention can be measured using the following techniques: crown area of retention trees, GPS area around a retention patch, densitometer of crown closure, and basal area of residual trees.
- Harvesting of reserve trees may occur in the future or may be foregone to achieve other benefits. Retain reserve trees for at least one-half the minimum rotation age of the new stand (e.g., retain reserve trees at least 20-25 years if regenerating aspen). Consider retaining some trees to develop into large, old trees and to complete their natural lifespan; these trees will often become large cavity trees, snags, and coarse woody debris.
- Retaining down coarse woody debris already present. Minimize disturbance, including crushing, fragmenting, and displacing existing down coarse woody debris except on roads, skid trails, and landings.
- Retain as many snags as possible. Retention of snag diversity (species and size) can potentially provide the greatest array of benefits. Snags that are determined to be a threat to human safety can be cut and retained on site as coarse woody debris.
- Clearly designate, in writing and/or by marking, which trees should be retained prior to any cutting operations.

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10 APPENDIX A. MARKED TIMBER EVALUATIONS PROCEDURE & EVALUATION SHEET

This evaluation sheet can be used to evaluate marked uneven-aged harvests and even-aged, intermediate thinnings. Stand management objectives, prescriptions, and residual target basal area should be clearly stated prior to marking. The attached field data collection sheet and procedure is designed as a tool to help evaluate how effectively the prescribed silviculture system has been applied. Once the timber harvest has been marked, it may be evaluated for meeting criteria set forth in the WI DNR Wisconsin Silviculture Guide, forest management plan, and/or cutting prescription (i.e., MFL Cutting Notice or public land Timber Sale Notice and Cutting Report Form 2460-001).

10.1 Number of Plots

Recommendation for the minimum number of variable radius plots (10 BAF) to measure: 1 plot for every 4 acres of the sale area with a minimum of 5 well-spaced plots per stand within the sale area (e.g., 32-acre sale / 4 = 8 plots). Plots shall be systematically spaced to sample the entire sale area; except on large timber sales, professional judgment can be used to determine if marking evaluation is warranted over the entire sale area or only on a subsample of the sale area if initial results are good. If the initial sample does not pass for any reason, additional sampling may be necessary. Note: It is not the intent of the evaluation to take a statistically sound number of plots. Plot intensity will increase if problems are noted in the initial sample(s). The follow-up sample(s) may be up to one plot per acre.

10.2 Plot Sampling

Basal Area and Individual Tree Quality: At each plot, data will be collected on the Marked Timber Evaluation Sheet. The data includes marked (**C**ut Tree) and residual (**L**eave Tree) basal area (BA) by species and size classes (5-11” pole, 11-14” sm. saw, 15-19” med. saw, and 20+” lg. saw). BA will be determined using a 10 BAF tool. At each plot, tally individual trees under species code (if needed) and also under basal area size class columns. It may be easiest to first tally marked trees (C - Cut) and then residual trees (L - Leave). Trees may be tallied with “dot tally” or utilizing the growing stock classifications listed below. Classifying the trees may help paint a picture of the quality of the marking job.

Each tree may be classified based on tree risk, vigor and quality as follows:

- “**1**” means crop tree: See definition in Wisconsin Silviculture Guide Ch. 24
- “**2**” means average tree: Better than class 3 but not a crop tree; acceptable growing stock.
- “**3**” means obvious cut tree: High risk (See definition in Wisconsin Silviculture Guide Ch. 24); obvious low vigor/quality tree to release higher classified tree; unacceptable growing stock.

10.3 Plot Evaluation

The marking of each individual plot will be evaluated (graded) on the following basis:

- Residual basal area
- Stand quality - order of removal is followed to achieve target residual basal area
- Other considerations: canopy gaps, paint marks, insect & disease concerns, BMPs, wildlife considerations, endangered resource considerations, etc.

If any of these criteria receive an unacceptable rating, then the plot receives an unacceptable rating. Each of these criteria are described in greater detail below.

Basal Area Rating: For an individual plot to be rated acceptable, the residual basal area must fall within the following range around the stated Target BA:

- For Target BA ending in zero: the acceptable range will be from Target BA minus 10 to plus 20 ft^2 (e.g., Target BA 90 ft^2 then acceptable for plot is ≥ 80 and ≤ 110 ft^2).
- For Target BA ending in five: the acceptable range will be from Target BA minus 15 to plus 15 ft^2 (e.g., Target BA 85 ft^2 then acceptable for plot is ≥ 70 and ≤ 100 ft^2).

However, no matter which method is utilized, the lower acceptable BA will be no less than the B-line for even-aged stocking guides and 70 ft^2 for NH uneven-aged stands.

The plot will be rated based on the residual BA as follows:

- **"+"** The residual basal area falls within the following range around the stated Target BA:
    - ✓ Target BA ending in zero: residual BA within -10 to +20 ft^2
    - ✓ Target BA ending in five: residual BA within -15 to +15 ft^2

- **"–"** The residual basal area falls outside the specified range around the stated Target BA

- **"NA"** Used for plots that have an acceptable reason for not falling within the target BA range, for example:
    - ✓ Initial BA was below the target BA range
    - ✓ Residual BA was below target BA range after only high risk trees were removed
    - ✓ Plot is within an uneven-aged gap
    - ✓ Aspen patch to be removed (stand inclusions)
    - ✓ Residual BA is > the target BA range and silviculture guidelines were followed leaving the BA appropriately higher than target range. Examples might include the following:
        - ∗ No more than 1/3 of the initial BA should be removed
        - ∗ Hemlock or white cedar are present as stand inclusions (at least 50% of BA)

* High percentage of basswood

Stand Quality Common Priorities for Retention and Removal Rating: Designation of trees for harvest at each plot will be evaluated and rated in regard to improving and maintaining overall stand quality by correctly applying the order of removal as agreed upon in the cutting prescription, or, if not listed in cutting prescription, as defined in Ch. 24 of the Wisconsin Silviculture Guide.

Application of the standard common priorities for retention and removal (See Wisconsin Silviculture Guide Ch. 24):

1. High risk of mortality or failure (unless retained as a wildlife tree)
   - Were high risk trees removed?

2. Release crop trees
   - Did crop trees needing release have at least partial release by marking neighboring tree of lesser quality?
     Note: Some crop trees may already have full or partial release, therefore requiring no further release.

3. Low crown vigor
   - Were trees of the low crown vigor marked for removal?

4. Poor stem form and quality
   - Were trees with poor stem form and quality relative to adjacent individual trees marked for removal?

5. Less desirable species
   - Is species diversity maintained and desired species composition achieved?

In order to better quantify what is and is not acceptable variation in order of removal marking, the growing stock classification system listed above (i.e., crop tree, average tree, obvious cut tree) may help in the evaluation process. The order of removal criteria can then be individually evaluated and rated. Finally, each plot is given a total order of removal rating as follows:

- **"+"** **Good**: tree designation correctly applied within the plot.
  - Example: If the marking follows the order of removal, then the rating is "+" (Good).

- **"0"** **Acceptable**: Tree designation is not perfect <u>but</u> is acceptable (still meets stand objectives).
  - Example: If you are questioning a tree that is marked vs. lesser quality tree left, and they both are in the same classification (both are average), then, although not desirable, this would be an example of acceptable variation and the rating is "0" (Acceptable).

- **“–”** **Unacceptable**: Tree designation is not consistently and correctly applied within the plot (cutting marked tree(s) will result in degradation of stand quality and/or vigor).
    - Example: If the marked tree is in a higher classification than the lesser quality tree retained (average class tree marked and obvious cut tree left, or crop tree marked and average class tree left), then this would be unacceptable and the rating is “-“ (Unacceptable).

- **“NA”** Used for plots that have an acceptable reason for not following criteria.
    - Example: No high risk trees, no crop trees on plot, or desired residual stocking achieved before a criterion applied.

***Other Plot Evaluation Considerations*:** Other considerations, as stated in the cutting prescription, that may need to be evaluated on plot include: canopy gaps, paint marks, insect & disease concerns, BMPs, wildlife, and endangered resources. These considerations can be rated, such as the canopy gap example below, or described in plot remarks.

Canopy Gap Rating - For uneven-aged management, evaluate canopy gaps (appropriate size & cleaned of poor quality saplings & poles). Criteria are found in the Wisconsin Silviculture Guide, Chs. 21 and 40.

- **“+”** means appropriate size gap (see table 40.8), and it is designated to be cleaned.
- **“–“** means the gap was not appropriate size or not correctly designated to be cleaned.
- **“NA”** means a gap did not fall within the plot.

Paint Marks - Marked trees must have an adequate volume of paint and have adequate stump mark at ground level. Preferably stump marks will be located in crevasses of the stump. In order to facilitate marking, checking, and harvesting, there should be at least two marks on opposite sides of the tree.

***Plot Evaluation Remarks*:** Use space below stand quality rating for plot remarks, including other considerations.

***Plot Grade*:** Grade each plot as good, acceptable, or unacceptable based on basal area, order of removal, and other considerations. If any of these criteria receive an unacceptable rating, then the plot is graded unacceptable.

- **“G” or “+”** **Good**: Marking correctly achieved basal area target range, and quality factors correctly applied.
- **“A” or “0”** **Acceptable**: Marking achieved basal area target range, and quality factors acceptable.
- **“U” or “-“** **Unacceptable**: Marking did not achieve basal area target range and/or quality factors incorrectly applied.

10.4 Sale Evaluation

The data collected may be used to assess compliance of stand wide timber marking with acceptable silviculture guidelines and/or stated cutting prescriptions. Summarize the data, and compute average cut and residual basal area, as well as plot grades. Whereas it is acceptable for wider individual plot BA variation, stand averages should be closer to the target BA (+/- 10%).

Minimum requirements for sale approval are:

- Average residual BA within +/-10% of target BA
- At least 70% total plot grades tally "G" or "A"
  - ✓ If excessive number of plots are rated A (>40%), then a follow-up discussion should occur with the marker with possible corrections and/or opportunities for improvement.

If evaluation determines that the proposed treatment meets these minimum timber marking standards and conforms to stated silviculture guidelines as found in the WI DNR Wisconsin Silviculture Guide and/or cutting prescription (i.e., MFL Cutting Notice or public land Timber Sale Notice and Cutting Report Form 2460-001), then the sale will be deemed to meet silvicultural standards.

If evaluation determines that the proposed treatment does not meet these minimum timber marking standards and/or does not conform to stated silviculture guidelines as found in the WI DNR Wisconsin Silviculture Guide and/or cutting prescription (i.e., MFL Cutting Notice or public land Timber Sale Notice and Cutting Report Form 2460-001), then the sale does not meet silvicultural standards and corrective action should be implemented. Once corrected, the sale may be re-evaluated using the above process.

MARKED TIMBER EVALUATION SHEET Rev. 6/10	Property:	Sec.	T	R	Desc.
Estimator:	Date:	Covertype:			Page ___ of ____

Pt. #	Species Code						Basal Area (Target BA______)						Stand Quality - Order of Removal					Total OOR Rating	Other Rating e.g.Gap	Total Plot Grade
							Pole 5-9/11	Saw-Sm 9/11-14	Saw-Md 15-19	Saw-Lg 20+	TOTAL	BA Rating	Risk Trees Removed	Crop Trees Released	Vigor	Quality	Species Selection			
1C																				
1L													Comments:							
2C																				
2L													Comments:							
3C																				
3L													Comments:							
4C																				
4L													Comments:							
5C																				
5L													Comments:							
6C																				
6L													Comments:							
7C																				
7L													Comments:							
8C																				
8L													Comments:							
9C																				
9L													Comments:							
10C																				
10L													Comments:							
C-Tota												C-Total	Comments regarding the stand:							
C-Avg												C-Avg								
L-Tota												L-Total	**Stand Quality Rating: Each aspect of stand quality is rated separately.**							
L-Avg												L-Avg	+ = Good: Plot met expectations for Order of Removal.							

TREE CLASSIFICATION: (Trees recorded by class for species and basal area size class.)	0 = Acceptable: Plot did not fully achieve Order of Removal, but still meets management objective.
1 = Obvious crop tree: See definition in Silviculture Handbook Chapter 24	- = Unacceptable: Plot did not implement the Order of Removal correctly.
2 = Average tree: Better than class 3, but not a crop tree.	**Other: Paint volume, Stump marks, Canopy gaps, I & D, Marks on two sides, etc.**
3 = Obvious cut tree: High risk, suppressed, low vigor to release higher classed tree.	**TOTAL PLOT GRADE: G = Good; A = Acceptable; U = Unacceptable.**

11 APPENDIX B. SUMMARY TABLES

Table 24.2. Wildlife tree and snag selection criteria

- Large trees for habitat structure (e.g., nest trees)
  - Some low risk, good vigor trees to sustain long life
  - Some moderate to high risk, moderate to low vigor (decadent) trees to provide near-term future snags and coarse woody debris
  - Desirable species; strive for species diversity
- Mast trees for food
  - Low risk
  - Good crown vigor
  - Strive for species diversity; hard-mast producers generally preferred over soft-mast producers
- Cavity (den) trees for shelter
  - With cavities in bole
  - Larger diameter cavity trees are particularly desirable
  - Strive for species diversity
- Snags for habitat, shelter, and food
  - Larger diameter snags are particularly desirable
  - Strive for diversity in species and level of decay

Table 24.3. Recommendations for tree and snag retention in managed stands

Recommendations:

- Even-aged rotations
  - Retain ≥3 (if available), preferably large, snags per acre.
  - Retain reserve trees and/or patches at 5-15% crown cover or stand area, including large vigorous trees, mast trees, and cavity trees. Reserve tree retention is a generally recommended silvicultural practice for stands ≥10 acres. It is encouraged in smaller stands, but operational, shading, and other biological issues may limit application.
- Even-aged intermediate treatments
  - Retain ≥3 (if available), preferably large, snags per acre.
  - Retain ≥3 (if available), preferably large, cavity trees per acre.
  - Retain ≥3 (if available), preferably large, mast trees per acre.
  - If previously established, manage reserve trees and patches. Management may include timber harvesting or passive retention. Consider retaining ≥3 trees per acre to develop into large, old trees and to complete their natural lifespan. These trees may also satisfy cavity and mast tree recommendations. These trees will often become large snags and coarse woody debris.
- Uneven-aged systems
  - Retain ≥3 (if available), preferably large, snags per acre.
  - Retain ≥3 (if available), preferably large, cavity trees per acre.

- Retain ≥3 (if available), preferably large, mast trees per acre.
- Consider retaining ≥3 trees per acre to develop into large, old trees and to complete their natural lifespan. These trees may also satisfy cavity and mast tree recommendations. These trees will often become large snags and coarse woody debris.

When applying retention recommendations, be sure to consider:

- Individual trees can provide multiple benefits and fulfill the intent of more than one of the above recommendations. For example, three large oak trees with cavities could satisfy the mast tree and cavity tree recommendations, as well as the large, old tree consideration.
- Retention of both vigorous and decadent trees will provide an array of benefits.
- In general, species diversity is encouraged when selecting trees to retain.
- Large trees and snags are >12 inches dbh, and preferably >18 inches dbh.
- Trees retained can be scattered uniformly throughout a stand or irregularly dispersed, as single trees, groups, and patches. The general recommended strategy is to retain irregularly distributed patches along with scattered groups and individuals.
- Retention in aggregated patches generally provides the most benefits for wildlife and biodiversity. Also, patches retained can satisfy multiple benefits; for example, at stand rotation, an internal or adjacent unharvested buffer along a stream (RMZ) could provide a portion of reserve tree retention as well satisfy BMP (water quality) recommendations. Patches should be >0.1 acres and generally <2.0 acres, but can be larger; reserve tree patches, particularly large ones, should be documented as retention patches.
- Harvesting of reserve trees may occur in the future or may be foregone to achieve other benefits. Retain reserve trees for at least one-half the minimum rotation age of the new stand (e.g. retain reserve trees at least 20-25 years if regenerating aspen). Consider retaining some trees to develop into large, old trees and to complete their natural lifespan; these trees will often become large cavity trees, snags, and coarse woody debris.
- Retain as many snags as possible. Retention of snag diversity (species and size) can potentially provide the greatest array of benefits. Snags that are determined to be a threat to human safety can be cut and retained on site as coarse woody debris.
- Clearly designate, in writing and/or by marking, which trees should be retained prior to any cutting operations.

12 APPENDIX C. GROWING STOCK CLASSIFICATION SYSTEMS FOR TIMBER MANAGEMENT

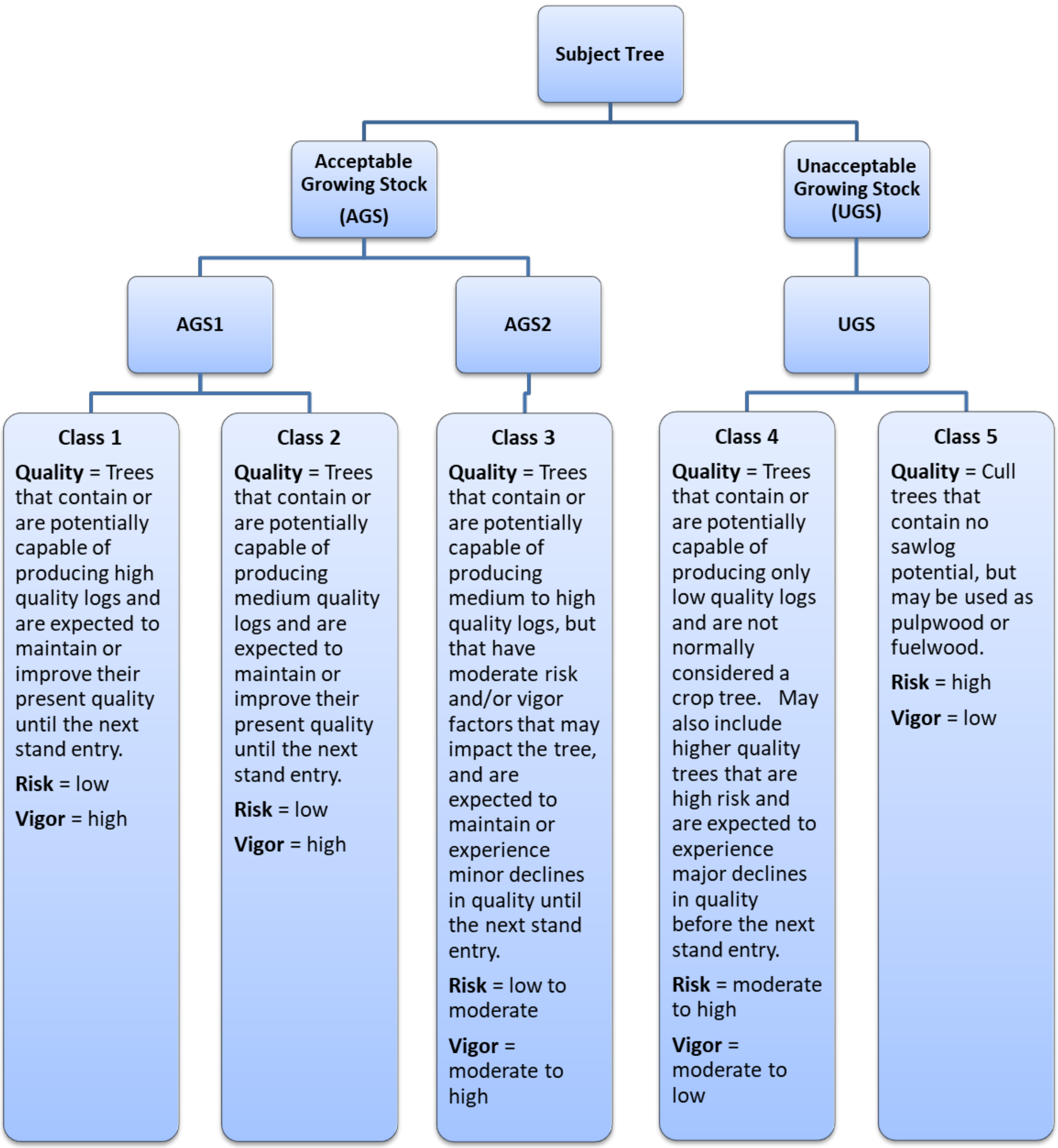

Figure 24.10. Relationship among 2, 3, and 5-class growing stock classification systems.

Table 24.4. General 5-class system decision criteria to help better define subject tree classification.

	CLASS 1	CLASS 2	CLASS 3	CLASS 4	CLASS 5
QUALITY[1]		**high**	⟵⟶	**low**	
min. log height (potential)	16’ (butt log)	16’ (butt log)	8’	8’	none
tree grade (potential)	1	2	2 or better	3	cull
bole form (sweep or crook)	none or minor (cuts out)	none or minor (cuts out)	moderate	heavy	heavy
RISK[2]		**low**	⟵⟶	**high**	
lean	<10%				>30%; recent root lifting; associated horizontal or long vertical cracks and buckling wood
forking	no acute (V-shaped) forking; no cracks allowed at forks		Acute (V-shaped) forking confined to upper bole and crown		Acute (V-shaped) forking on lower bole
crown damage/dieback	<10%		10-49%		≥50%
stem rot/decay	none		minor		major; indication of major heart rot such as conk fungus; decay affects ≥40% stem cross-section
seams/cracks	none		minor; relatively straight, shallow, little evidence of internal decay		major; open, deep, spiral, evidence of internal decay
cankers	<10% stem circumference; main stem structurally sound		10-49% stem circumference; main stem structurally sound		≥50% stem circumference
bole wounds	minor; dry, hard, no evidence of decay, well above root collar		minor; dry, hard, no evidence of decay		major
cavities	<10% stem cross-section; confined to upper stem, main stem structurally sound		10-39% stem cross-section; main stem structurally sound		≥40% stem cross-section
root damage	<10% compromised		10-33% compromised		>33% compromised
insect/disease	no concerns within next cutting cycle				major impacts likely within next cutting cycle

VIGOR[3]		high	⟷		low
crown class	dominant	codominant		intermediate	suppressed
crown silhouette	hardwoods - full concentric; conifers - >30% live crown ratio		hardwoods – ½ to ¾ full concentric, indications of minor crown competition; conifers - 20-30% live crown ratio		hardwoods - <1/2 full concentric, indications of major crown competition, flattened crown; conifers - <20% live crown ratio
foliage condition	healthy		fair		poor
bark character	rough-barked species – furrows vertical, narrow, light color; smooth-barked species – smooth and thin				rough-barked species – furrows with cross checks in vertical pattern, broad furrows, ridges soft and corky; smooth-barked species – rough with large flaky plates

[1]**Quality:** Refers to stem form, soundness, and potential timber value of individual trees. Timber quality is evaluated based on log length, diameter, and defect.
[2]**Risk:** The probability that a tree will die or fail (main stem will break) within a specified time period. It is an estimate of probable mortality or failure within the next cutting cycle.
[3]**Vigor:** Active, healthy, well-balanced growth of individual trees. It describes the tree's potential to grow at a rapid rate and increase in volume.

13 APPENDIX D. MARKING GUIDE ELEMENTS AND TEMPLATES

Management History

- O Land use history
- O Recent timber sales

Site Considerations

- O Site quality
- O Stand access
- O Presence or absence of roads, trails, and landings
- O Presence or absence of streams, wetlands, and vernal pools
- O Presence of invasive species
- O Presence of Natural Heritage Inventory (NHI) listed communities and species

Stand Details

- O Species composition
- O Diameter distribution
- O Growing stock classification or quality assessment
- O Presence or absence of advance regeneration

Goals and Objectives

- O Desired future condition (DFC)
- O Stand management goals
- O Stand management objectives, specific purpose of the marking treatment

Marking Instructions

Silvicultural system: Intermediate treatment or regeneration method

- O Preferred stand composition, desired species mix
  - Species priority
  - Preferred tree characteristics
- O Target residual density (BA, TPA, or crown cover)
- O Target residual structure: target diameter distribution
- O Target number and size of canopy gaps or patches, total or per acre

Tree retention: characteristics of trees to retain (e.g. wildlife trees, reserve trees, legacy trees)

- O Number and distribution (dispersed or aggregated)
- O Snag management, including size, number, and distribution

Tree and boundary designations

- O Tree marking methods (ex. leave tree, cut tree, row designation)
- O Sale boundaries
- O Property lines
- O Paint colors and marking symbols

Special Considerations

- O Water quality BMP's
- O Comments and remarks useful for the marking forester

Figure 24.11. Suggested Marking Guide Elements

Table 24.5. Ontario Prescription and Marking Guide Template.

TREE MARKING PRESCRIPTION

OWNER ______________ COMPARTMENT ______________

LOCATION ______________ STAND # ______________

______________ Working Group(FRI) ______________

TOWNSHIP ______________ FOREST UNIT ______________

AERIAL PHOTO NUMBER ______________ SITE CLASS ______________

STAND ACCESS ______________

OBJECTIVES

LONG TERM: ______________

SHORT TERM: ______________

STAND INFORMATION: (Based on Stand Analysis Cruise)

SPECIES COMPOSITION: ______________ STAND AREA (ha:) ______________

AGE CLASS: ______________ HEIGHT (m): ______________ STOCKING (%): ______________

REGENERATION NOTES: ______________

STAND QUALITY NOTES: ______________

SITE & TOPOGRAPHY NOTES: ______________

BASAL AREA DISTRIBUTION (m^2/ha);

Tree Size Classes (cm)>>>:	10-24	26-36	38-48	50+	TOTAL
Actual Basal Area (m^2/ha):					

STAND PRESCRIPTION

Treatment Instructions:

____

Integrated Resource Management INSTRUCTIONS:

____

FOLLOW-UP RECOMMENDATIONS

____

YEAR OF NEXT CUT ______________

RECOMMENDED BASAL AREA DISTRIBUTION OF CUT

Tree Size (cm)	ACTUAL BA (m^2/ha)			BA TO CUT (m^2/ha)			RESIDUAL BA (m^2/ha)		
	AGS	UGS	TOTAL	AGS	UGS	TOTAL	AGS	UGS	TOTAL
10-24									
26-36									
38-48									
50+									
TOTAL									

PRESCRIPTION PREPARED BY:

DATE:

PRESCRIPTION APPROVED BY:

DATE:

(OMNR 2005)

Table 24.6. Lincoln County Prescription and Marking Guide Template.

Marking Guidelines Template

Property:		Comp #		Stand #		Acres	

Prescription :

Fill in the blank, with suggestions from below

Treatment:

(Thinnning (comm, pre-comm), single tree selection (with gaps, groups, patch), shelterwood, seed tree)

Goal density:

(Basal Area/Crown cover/Trees per acre, etc)

Retain:

AGS/Crop trees/seed trees:

(crown release, number per acre, characteristics of trees)

Wildlife trees:

(number per acre of cavity/den, mast producer)

Desirable species:

(oak, BY)

Understocked size classes:

(less strict on quality?)

Remove:

Risk trees:

(mortality risk, financially mature)

UGS:

(remove low quality to release AGS, improve spacing)

Undesirable species:

(discriminate against ash)

Overstocked size classes:

(more strict on quality)

Designated species to cut:

(Cut all A, fir, BW etc.)

Special considerations:

(Historic sites, snags, nest trees, RMZ, ephemerals, legacy trees, etc)

Gap, group, patch:

(Size and number per acre)

Table 24.7. WDNR Prescription and Marking Guide Template.

TIMBER SALE MARKING GUIDE

WDNR Draft 05_01_2017

District	Property	Code				County

Sale Name	Sale Number	Tract Number

Site Considerations

Further describe the current stand conditions and other existing site factors important to the marking crew (Items to consider are listed below). Attach WisFIRS stand printouts for further information.

- *Composition details*
- *Diameter distribution*
- *Management history*
- *Site quality*
- *Advance regeneration*
- *Roads, trails, access, landings*
- *Topography*
- *Other resources (e.g., NHI, invasive species, riparian areas, nests and dens, archeological sites)*

Desired Future Condition

Describe long term goals for the site and the desired future stand conditions (e.g., structurally diverse northern hardwood stand with a hemlock component).

Short Term Silvicultural Objectives

Describe immediate silvicultural actions to be implemented.

Marking Instructions

Treatment Method:	Target Residual Density:	Estimated Treatment Acres:

Describe marking instructions in detail (items to consider are listed below)

GENERAL MARKING -

- *Species priority, order of removal*
- *Crop tree characteristics and release requirements*
- *Target residual density(BA, TPA, crown cover)*
- *Target residual structure (e.g., single tree selection target diameter distribution)*
- *Canopy gaps*
- *Special cutting requirements*

TREE RETENTION -

- *Reserve tree species, numbers, islands*
- *Snags and CWD*

TREE & BOUNDARY DESIGNATION –

- *Paint colors and marking symbols*
- *Tree marking methods (e.g., leave tree, cut tree, row designation)*
- *Reserve area boundaries*
- *Sale boundaries*
- *Property lines*

Timber Sale Design Features and Remarks
Describe other timber sale design features (items to consider are listed below) • *Operating Requirements – equipment, season, road access, sale layout, etc.* • *Water Quality BMPs* • *Wildlife* • *Aesthetics* • *TES* • *Invasive Species* • *Cultural Resources* • *Other comments and remarks useful for the marking crew*

Prepared by:	**Title:**	**Date:**

Timber Sale Map

Chapter 31

White Pine Cover Type

WISCONSIN
DEPT. OF NATURAL RESOURCES

Last Full Revision: 9/11/2002
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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Last Full Revision: 9/11/2002
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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Last Full Revision: 9/11/2002
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand Composition
More than 50 percent of the basal area in pine with **white pine** (*Pinus strobus*) predominant.

Associated Species
White pine can be found growing in associations with most major tree species native to Wisconsin. It is a common to occasional associate in most of the major forest cover types.

Within the white pine forest type, the most common associates currently are: red pine (*Pinus resinosa*), jack pine (*Pinus banksiana*), aspen (*Populus* spp.), white birch (*Betula papyrifera*), red maple (*Acer rubrum*), red oak (*Quercus rubra*), northern pin oak (*Quercus ellipsoidalis*), black oak (*Quercus velutina*), white oak (*Quercus alba*), balsam fir (*Abies balsamea*), white spruce (*Picea glauca*), and eastern hemlock (*Tsuga canadensis*).

1.2 Silvical Characteristics

Table 31.1. Summary of selected silvical characteristics.

White pine (*Pinus strobus*)	
Pollination	May to June
Cones Mature	By late August
Seed Dispersal	Occurs within the month following cone maturity. Seed will travel 200 feet within stand, 700 feet in open areas. With an average of 27,000 seeds per pound, a 90-year old stand can produce 87 pounds of seed per acre. Dominant trees produce more seed than co-dominant trees.
Good Seed Years	Every 3 to 5 years with less seed produced in most intervening years. Crop losses to white pine cone beetle, coneborers, and squirrels can be significant. It is important to monitor cone crops throughout the summer prior to implementing site preparation operations in the fall. What appears to be a bumper cone crop in the spring can be virtually eliminated by these cone pests by mid-July.
Germination	Dormancy broken by exposure to moisture at 40-50 degrees Fahrenheit for 30 to 60 days. Seedlings develop best in 30 to 60 percent full sunlight. Moist mineral soil is the preferred seedbed. Dry mineral soil, pine litter, lichen, and grasses are unsuitable seedbeds.
Seed Viability	The number of good seeds per cone varies from 0 to 73. However, germinative capacity is high (93 to 100 percent) in tests on cold stratified seeds. The recommended cold stratification period is 60 days at 33-41 degrees Fahrenheit for both fresh and stored seed (Krugman and Jenkinson, 1974).
Seedling	Light intensity is critical for survival and growth of seedlings. At

Development	least 20 percent of full sunlight is required. Growth at a given light intensity is better in the absence of root competition.
Growth	Early growth is slow; open grown trees are 5 inches in height at age 3, 12 inches at age 5, and 4.5 feet after 8 to 10 years. Between 10 and 20 years, growth in open-grown trees can be as much as 4.5 feet per year, but average growth is only 16 inches per year. Dominant trees ordinarily grow at a rate of 5 to 10 rings per inch, with diameter increasing one inch every 5-6 years in fully stocked stands on average sites. White pine yields will vary depending on site conditions and stocking density. Sawtimber averages 300 - 800 board feet per acre per year, with yields on the best sites as high as 1,200 - 1,600 board feet per acre per year (Lancaster and Leak 1978). White pine yields exceed by far all native species found in the Lake States with studies showing 100-year old stands with in excess of 80,000 board feet per acre of growing stock (Leak *et. al*. 1970). White pine is a long-lived species. Individual trees often reach 200+ years. Maximum age can exceed 450 years. Recent observations by Menominee Tribal Enterprises (MTE) indicate that stands decline rapidly after age 200 even on a very rich site. However, fully stocked stands of 160-year old white pine are common.
Shade Tolerance	Intermediate. White pines less than 30 years old, with one-third of height in live crown, will respond well to release from suppression.

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

Landowner goals and ecological potentials determine management alternatives and objectives. An ecosystem management framework gives consideration to a variety of goals and opportunities within the local and regional landscape. The silvicultural system described below is designed to promote the optimum vigor of white pine, with white pine sawlogs as the management objective. This system can be adapted to satisfy other management objectives, but white pine vigor and sawlog quality and quantity could be reduced. The habitat type is the preferred indicator of site potential.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.2 Site and Stand Considerations

3.2.1 Soils

White pine will grow on almost all soils within its range. It is often found on excessively drained sands. Although the relative growth potential is only moderate, it is one of the most productive and competitive species capable of growing on these droughty sites. Loamy sands and sandy loams (somewhat excessively to somewhat poorly drained) present the best opportunities for white pine management. Growth potentials are very good, and competition by mesic hardwoods is limited. White pine is very productive on well drained to somewhat poorly drained loams and silts, however hardwood competition on these sites makes regeneration difficult.

3.2.2 Site Quality

3.2.2.1 Range of Habitat Types

White pine, as a cover type and an associated species, was a more common component of northern and central Wisconsin forested landscapes in the pre-European settlement era than at present. Natural disturbance regimes, which created conditions conducive to white pine, have been severely altered. The historical cutover and fires that followed significantly reduced white pine occurrence. This resulted in a limited seed source, which has further restricted re-establishment. White pine was, and could become, a more important component on some habitat types than is suggested by current occurrence.

In northern Wisconsin, white pine currently is:

- A minor associate and minor cover type, exhibits moderate to good growth potential, and is competitive on the very dry to dry (VD-D) habitat type group. Occurrence and growth potentials improve as available moisture and nutrients increase (*Pinus-Acer* series). Management opportunities are good.
- A common associate and minor cover type, exhibits very good growth potential, and is competitive on the dry to dry-mesic (D-DM) habitat type group. Management opportunities are excellent.
- A minor associate and minor cover type, exhibits very good growth potential, and is somewhat competitive on the dry-mesic (DM) habitat type group. Management opportunities are good.
- A minor associate and rare cover type, exhibits excellent growth potential, but generally is not competitive on the mesic (M) habitat type group. Competition intensity from mesic hardwoods increases from moderate to severe as soil moisture and nutrients improve.
- A minor associate and rare cover type, exhibits very good growth potential, but generally is not competitive on nutrient medium to rich sites (loamy and silty soils) within the mesic to wet-mesic (M-WM) habitat type group.
- A common associate and minor cover type, exhibits very good growth potential, and is somewhat competitive on nutrient poor to medium sites (sandy and loamy soils) within the mesic to wet-mesic (M-WM) habitat type group. Example habitat types are ArAbVC and TMC. Management opportunities are good to excellent.

In central and southern Wisconsin, white pine currently is:

- A common associate and minor cover type, exhibits good to very good growth potential, and is competitive on the dry (D) habitat type group. Management opportunities are excellent.

- A minor associate and minor cover type, exhibits very good growth potential, and is somewhat competitive on the dry-mesic (DM) habitat type group. Management opportunities are good.

Most of the other upland habitat type groups in central and southern Wisconsin can provide very good to excellent growth potentials for white pine, but competition is severe and/or white pine occurrence is rare.

In general, on most upland habitat type groups, white pine offers the highest potential productivity (volume growth) compared to other naturally occurring native tree species.

Within forested lowlands (wet-mesic to wet), white pine occurs as a minor associate and a rare cover type.

Terms used above to describe frequency of occurrence:
- common: >10%
- minor: 1-10%
- rare: <1%

3.2.3 Forest Health

Major pests include white pine blister rust (*Cronartium ribicola*) and white pine tip weevil (*Pissodes strobi* Peck). Due to past concerns with these pests, additional discussion has been included below. See additional information in the Pest Management Guidelines section at the end of the chapter.

3.2.3.1 White Pine Blister Rust

The incidence of white pine blister rust varies between stands, and risk factors relating to the diseases are poorly understood. Generally, tree losses attributable to blister rust appear to be manageable on most sites. While individual trees will succumb to blister rust, survivors most often fully stock the stands at rotation. Pruning of the lower branches appears to help reduce the risk of infection. Early sanitation pruning of infected limbs prior to entry into the main stem can reduce losses. This can be accomplished by annually surveying stands in the summer to identify flagging branches. Those branches containing blister rust cankers should be immediately pruned to restrict the translocation of the disease into the main stem, which often results in mortality. White pine should not be planted in areas of heavy blister rust incidence without consulting a forest pathologist and plans for future pathological pruning. Areas where cool moist air collects appear to be more conducive to blister rust infection. Expect highest disease incidence on, or avoid, sites that have **both** of these high risk factors: 1) *Ribes spp.* (gooseberries) on or in close proximity to the site, **and** 2) site conditions that enhance lasting dew formation during cool windless nights [such as a) kettle holes or depressions, b) northerly aspect, c) small openings (diameter less than the height of surrounding trees), particularly at the bases of slopes and in low areas, d) ridge tops and shoulders in close proximity to any body of water or lowlands, and e) on the Bayfield Peninsula, sites on aspects which face Lake Superior].

3.2.3.2 White Pine Tip Weevil

The white pine tip weevil can cause stem deformity. Eggs are deposited in the terminal leaders, and larvae feeding under the bark girdle the leader and kill it. Lateral branches then compete to replace the dead leader and cause crook, forking, and sweep. Repeated hits by the weevil can cause the tree to lose its commercial value for sawtimber. The insect prefers to utilize white pine that have larger terminal leader diameters (0.2 inches), and a warm and dry environment seems to increase weevil activity. Therefore, open- grown pine tend to be injured by the weevil more frequently than understory pine. A study conducted on the Black River State Forest (Katovich, 1992) indicated increased tip weevil hits in open-grown -vs.- pine grown under a canopy. Recommendations were made to grow white pine in the understory under a 40 - 50 percent crown closure to prevent tip weevil injury.

Studies conducted by Menominee Tribal Enterprises (MTE) indicated both radial and height growth rates suffered substantially under more than twenty percent crown closure (Pubanz, 1995). Trees grown in the open had better color, denser foliage, better crown position, and greater height and radial growth. It does appear that stands which were poorly stocked (total stems of all species) may run the risk of not being well stocked in white pine crop trees in the sawtimber size classes. Stocking is important in that the adjacent trees serve as trainers (to correct stem form and keep branches small) and provide more choices for removal in intermediate thinnings. The recommendation is to grow pine unsuppressed to promote optimum vigor while maintaining high stem densities (700+ trees per acre) until crowns close.

Additional studies conducted by MTE (Pubanz, 1995) looked at the effects of tip weevil injury on well stocked, open grown white pine plantations across the northern two-thirds of Wisconsin. This study found that well stocked plantations had adequate numbers of crop trees 77 percent of the time even though these trees were attacked by the tip weevil an average of over 2 times in the first log position. The mere presence of tip weevil attack did not preclude crop tree development. Pine grown in an unsuppressed condition are substantially more vigorous. More vigorous pine have the ability to correct stem deformity associated with weevil injury. In this study, over 88 percent of the crop trees had identifiable tip weevil injury.

Stem analysis in 150-year old codominant pine indicated that these trees, which had developed in full sunlight, had been attacked by the weevil at a rate similar to that observed throughout northern Wisconsin. They had also outgrown virtually all of the stem offset and exhibited crop tree form. The sample trees in this study represented those removed in the seeding cut of a pine shelterwood. The residual trees were dominant, well-formed trees that should have been the most attractive to the tip weevil, yet these trees were generally of better quality than the sample trees. Volume losses attributable to weevil attack were insignificant and lower than losses due to felling breakage.

White Pine Pest Management Guidelines are included at the end of this chapter.

3.2.4 Wildlife

White pine is an important tree for a number of wildlife species. Total numbers of wildlife species tend to be higher in mixed white pine types (e.g. pine-oak, pine-aspen) than in pure dense stands of old field or pine plantation. Numbers of species are high in regenerating stands, then drop off in pole stands due to the decline of the herb and shrub layers which are important for many songbirds, voles, and long-tailed weasels. Numbers of species then rise in mature and overmature stands, mainly due to the increasing number of tree bole users.

Retaining wildlife trees in thinnings results in habitats with potential species numbers similar to those in the later stages of stand development. Timber thinning without reserved wildlife trees eliminates high exposed perches, medium and large diameter cavity trees, and larger crowned mast-producing individuals, and also reduces deciduous/coniferous overstory inclusions; these features are important to many wildlife species. The presence of large white pine in the supracanopy of many stands provides favorable nesting and perching sites for various hawks. Great blue herons, osprey, and bald eagles can also use the supracanopy features where white pine occurs near water bodies and other wetlands. Other wildlife attributes of white pine include the use of large individual trees by black bear cubs for escape cover, and the use of white pine stands by white-tailed deer in winter as thermal cover. Standing dead and fallen pine provide many benefits. White pine can achieve large size and deteriorates slowly so it provides very good coarse woody debris.

4 STAND MANAGEMENT DECISION SUPPORT

4.2 Key/ Checklist for Evaluating Cover Type Stand Management Options

Key to recommendations (NOTE – the following silvicultural system assumes that the management objective is to manage for optimum quantity and quality of white pine sawlogs).

Table 31.2. Management options based on stand conditions.

1. Stand approaching or past rotation age	Go to 4.
1. Stand not yet at rotation age	Go to 2.
2. Understocked stands	Evaluate stand condition. If adequate numbers of crop trees are present, schedule thinnings according to the appropriate even-aged stocking guides based on species mix and stand conditions. Identify and prune crop trees leaving one-half to one-third live crown. If adequate numbers of crop trees are not present, regenerate the stand. Go to 4.
2. Fully stocked stands	Utilize appropriate stocking guides to schedule thinnings. Prune crop trees after first thinning.

	Go to 3 for additional information.
3. Distinct rows	Do the first thinning at the earliest opportunity (normally about age 20-25 years). Apply mechanical selection of rows if possible. The basic mechanical method to apply for the initial thinning is every other row removal. In stands where thinning has been delayed (30+ years old) or diameter or tree quality variation is high, mechanically thin every third row and selectively thin (follow standard order of removal) the remaining rows to reduce stocking to not less than the "B" level from the stocking guides. Stands where thinning has been delayed will appear spindly and have a live crown ration of twenty-five percent or less of the tree's height. These plantations pose significant risk to wind and snow damage after thinning if thinned too heavily in the initial thinning. Reschedule next thinning in five years. Subsequent selection thinnings should occur at eight to ten-year intervals and follow the guidelines below for “3. Indistinct rows.”
3. Indistinct rows	Mark out skid trails for access and mark between trails to obtain not less than "B level" stocking from the stocking guides described in Figure 31.2. Thinning should favor the retention of crop trees following the standard order of removal. Subsequent thinnings should occur at eight to ten year intervals and stocking should be reduced to not less than "B level" stocking from the stocking guides. Thinning should be from below and follow the standard order of removal. **Never remove more than fifty percent of the stocking in any one thinning operation to reduce the risk of wind or snow damage.** **STANDARD ORDER OF REMOVAL FOR SELECTION THINNING IN WHITE PINE** **1. HIGH RISK TREES** **2. RELEASE CROP TREES** **3. CULL TREES** **4. LOW VIGOR** **5. UNWANTED SPECIES (REMOVE SEED SOURCE)** **6. IMPROVE SPACING** Continue periodic thinnings until the stand

	approaches rotation age. Then go to 4.
4. Adequate seed source present. Conduct natural regeneration harvest. The following assumes that the objective for regeneration is white pine and its associated species, that the stand has adequate seed source, and is approaching rotation. The recommended steps for using the shelterwood and seedtree systems are as follows:	a. Evaluate the existing reproduction. If inadequate numbers of desired species are present, go to step b. If adequate reproduction is already present, release the understory by reducing overstory to no more than twenty percent crown closure. b. Conduct the regeneration harvest. For a shelterwood, reduce overstory to 50 percent crown closure. For a seed tree, harvest all trees not desired as seed trees. All regeneration harvests should be from below and all unnecessary competing stems should be cut. The trees exhibiting the best vigor, form, and crowns should be retained as seed trees. A minimum of 4 well distributed seed trees per acre is required for adequate seed dispersal. Marking these harvests as "leave tree" is often the most effective. This cut can be made irrespective of seed crop. c. Allow the site to develop for two years or more. This allows slash to break down, stump sprouts to form, and the seedbank to germinate. d. After two years monitor white pine seed crop. Site preparation should be tied to a year with a good seed crop for white pine. The seed crop can be evaluated in the spring but its adequacy must be monitored throughout the summer to assure that it is not lost to insects. If the seed crop is adequate, begin site preparation in the late summer. e. Control the understory competition using chemical or mechanical means or fire. f. Scarify the area to create a favorable seedbed of exposed mineral soil. Expose a minimum of fifty percent of the area.
4. Inadequate seed source present. Conduct artificial regeneration.	Evaluate site potential. If white pine is suited to the site and the objective of management, conduct site preparation in the summer/fall of the year prior to planting to control competition. In the spring of the following year, plant 900 or more white pine seedlings per acre.

Management Recommendations

- To optimize vigor, white pine should be grown in full sunlight in a fully stocked condition. Underplanting is generally discouraged, and more than twenty percent overstory significantly reduces pine development. In natural regeneration systems, once pine seedlings are established on the site (within 3 - 5 years), retain no more than twenty percent crown closure over the pine to promote vigor. Maintain stands at 700 or more total stems per acre until crown closure and lower branch mortality occurs. High stem density will promote correcting of tip weevil damage and ensure adequate numbers of crop trees in sawtimber at rotation. All stems need not be white pine.
- White pine is capable of producing veneer and grade lumber. Pruning is essential in the management of white pine for quality sawtimber products as white pine does not self-prune well. Pruning offers the benefits of increasing sawlog grade (substantially increasing value), reducing infection courts for blister rust, removing blister rust infected branches, and helping to confine the spread of red rot within the tree. A recent study (Pubanz, 1995) found that pruning pole sized white pine plantations could increase the number of crop trees by 33 percent by removing competing leaders resulting from terminal damage. These competing leaders often developed into forks and/or branches too large to heal over properly. Poorly formed or diseased trees, including those resulting from tip weevil damage, should be removed in intermediate thinnings consistent with recommended stocking levels.
- Open-grown white pine stands irreparably deformed by tip weevil should be treated as any other stand understocked with crop trees. Based on site quality, an evaluation should be made whether white pine is consistent with management objectives for the site. If so, regenerate the stand to white pine using natural or artificial regeneration methods described below. It is important to completely evaluate crop tree stocking prior to considering any stand a failure and harvesting it prior to its rotation age. Keep in mind that weeviled pine often will correct, if vigor and stocking are maintained. All stems do not need to be crop tree quality, as most stems will be removed in intermediate thinnings.
- Pine stands on most habitat types will eventually convert to hardwood species unless competition is controlled and regeneration requirements for white pine are met.
- White pine regenerates best on exposed mineral soil with minimum understory competition. Delay site preparation efforts in natural regeneration systems until after the stand has had an opportunity to respond to cutting, i.e. stump sprouts and seed banks flush. This will provide for better control of competition. Natural regeneration should be started at least 10 years prior to rotation of the stand. Maintaining overstory with the intent of reducing competition is ineffective as the shade tolerant competition develops more aggressively in low light conditions than does the white pine. Allowing established white pine seedlings adequate light appears to be the best way to allow them to gain dominance over competing hardwoods. The overstory should be reduced to no greater than twenty percent crown closure as soon as the pine seedlings are established and entering the period of rapid growth, usually in 3-5 years.
- Where white pine is a desirable associate in mixed stands, several scenarios may help encourage white pine composition. In stands which have existing pine reproduction, release will allow the pine to develop within the stand. Where advanced reproduction is

not present but a seed source exists, patch clearcutting near the seed source may result in the establishment of a pine component, especially if measures are taken to scarify the site or control competition through logging or other means. Timing such operations to a good pine seed year should increase their effectiveness. Foresters should watch for opportunities to take advantage of local situations to enhance the representation of white pine.

5 SILVICULTURAL SYSTEMS

5.1 Seedling / Sapling Stands

Maintain pine in an unsuppressed condition. Understory pine should be released at the earliest opportunity. Stand should be maintained at 700 stems per acre or greater until the canopy closes. Utilize stump sprouts and root suckers of other tree species to augment pine stocking. If desired, conduct crown release on 150 crop trees per acre at about age 15 by cutting all trees touching or overtopping crop tree crowns.

5.2 Intermediate Treatments

5.2.1 Thinning

Stands are overstocked when stocking exceeds "A" level on the stocking guides or it is determined that radial growth is slowing down. Overstocked stands should be thinned from below to not less than "B" level stocking on the stocking guides in trees making up the overstory canopy. Thinnings should be conducted at roughly seven- to ten-year intervals and never remove more than fifty percent of the stand stocking.

White pine appears to exhibit a higher degree of genetic diversity in relation to growth characteristics than red pine. Selection thinnings will allow the forester to retain the best stems in the stand consistent with recommended stocking levels. Row thinning should be restricted to providing access to the stand for equipment. Where mechanical thinning may yield questionable results, a small sample area can be marked using mechanical thinning criteria and the residual basal area checked to predetermine the resulting residual density level. Field studies conducted at the Wild Rose Demonstration Forest indicate that white pine development was best in stands thinned every other row at age 20 with a subsequent selection thinning done in a timely manner and stocking reduced to prescribed levels using the stocking guides. This study also indicates that stands in which initial thinnings are delayed should be thinned every third row initially to prevent substantial potential loss to snowload and/or windthrow.

5.3 Natural Regeneration Methods

5.3.1 Even-Age Regeneration Methods

Even-age management will be applied with periodic thinnings based on basal area control. Pruning is recommended. White pine can be naturally regenerated using the seed tree and/or shelterwood regeneration methods. The primary purpose of the seed tree/shelterwood overstory is to provide an abundant source of seed rather than modifying understory environmental conditions. Where natural regeneration is not feasible, artificial regeneration may provide an alternative. Site preparation and competition control are important considerations for regeneration and establishment.

5.5 Rotation Lengths and Cutting Cycles

Ideally, the rotation length range would be defined by the maximization of mean annual increment (MAI) at the lower end and the average stand life expectancy at the upper end. But very little objective data exists identifying these endpoints in general, and even less by site type. The numbers provided are based on general data, empirical evidence, and the best estimations of the authors. Within each habitat type group, a range of conditions do exist, therefore the lower end should represent maximum MAI on the poorer sites and the upper end should represent the average stand life expectancy on the better sites. Individual trees and stands may live longer or decline earlier than these rotation length guidelines indicate. In application, foresters will need to regularly review stands in the field and exercise professional judgment concerning growth and mortality.

Table 31.3. Rotation length recommendations for cover type.

HABITAT TYPE GROUP	ROTATION LENGTH (YRS)
N. Very Dry to Dry	80-160
N. Dry to Dry-mesic	110-180
N. Dry-mesic	120-180
N. Mesic	140-200
N. Mesic to Wet-mesic	120-180
N. Wet-mesic to Wet	
S. Dry	80-160
S. Dry-mesic	110-180
S. Dry-mesic to Mesic	140-200
S. Dry-mesic to Mesic (Phase)	140-200
S. Mesic	140-200
S. Mesic (Phase)	140-200
S. Mesic to Wet-mesic	120-180
S. Wet-mesic to Wet	

8 APPENDICES

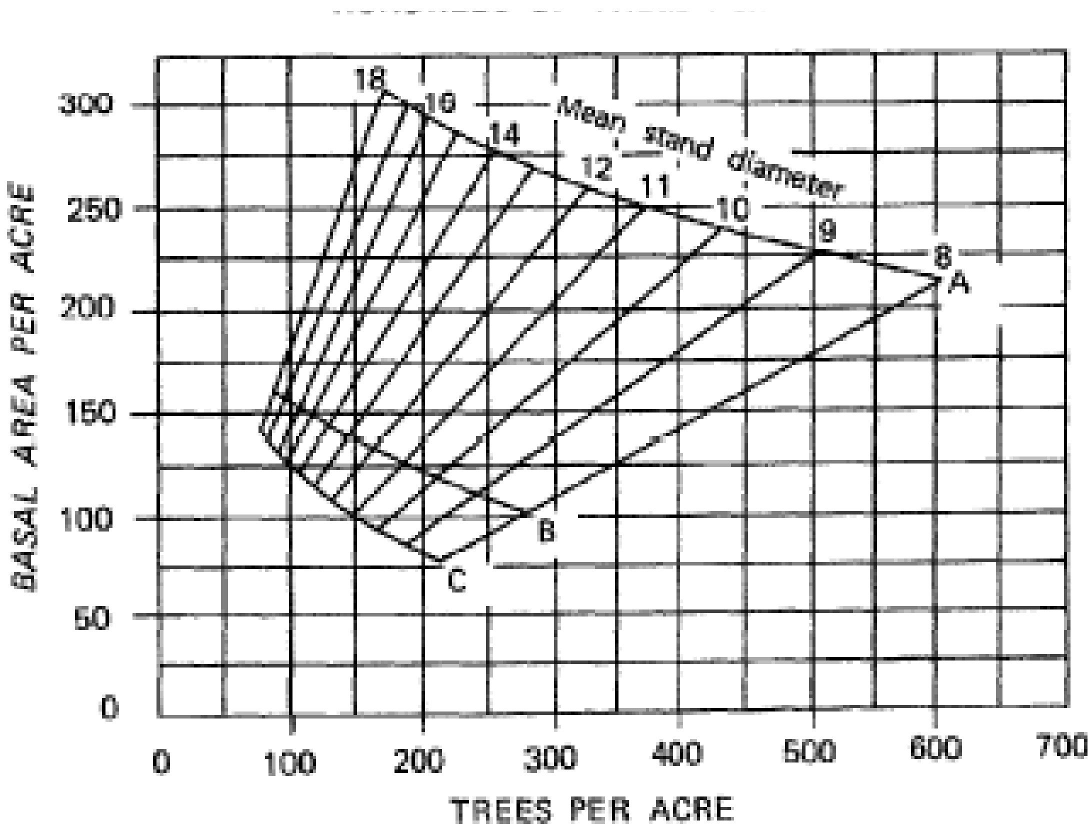


Figure 31.1a. Stocking chart for white pine, average diameter 8-18 inches (Philbrook et al. 1973, Lancaster and Leak 1978).

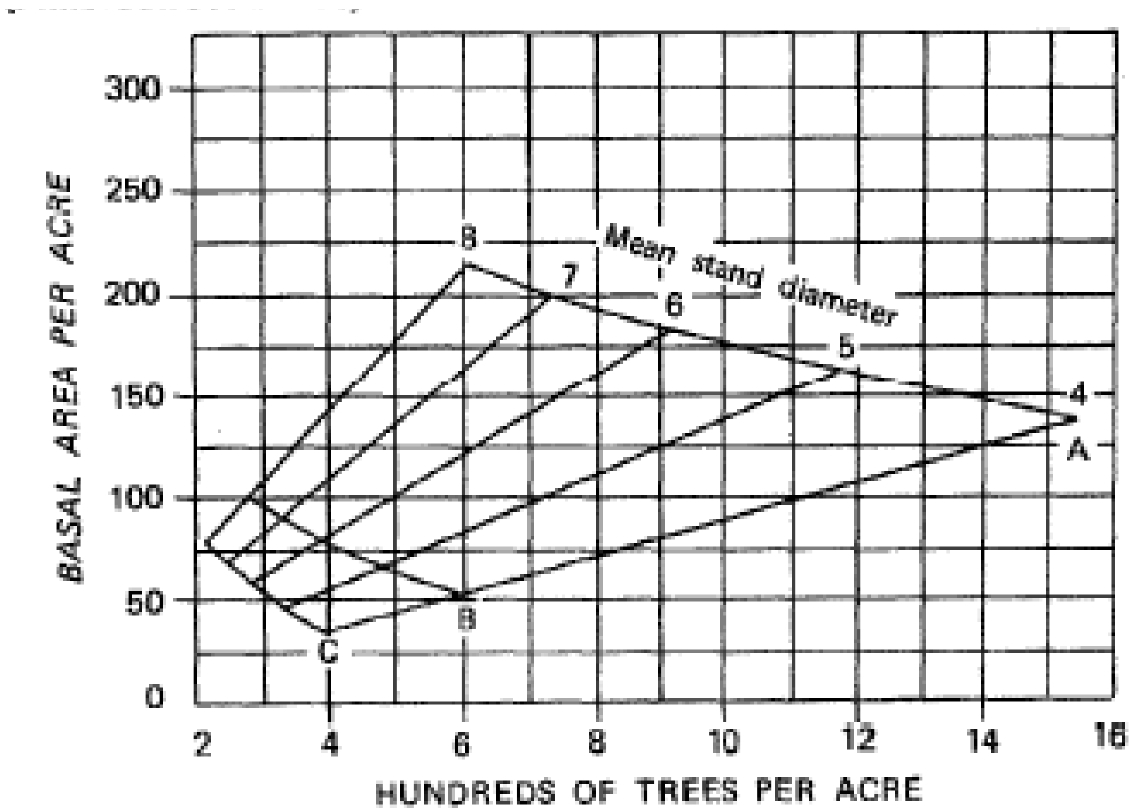


Figure 31.2b. Stocking chart for white pine, average diameter 4-8 inches (Philbrook et al. 1973, Lancaster and Leak 1978).

Stocking chart for white pine, displaying the relationship between basal area, number of trees, and mean stand diameter. The area between the A-line and B-line indicates the range of stocking where trees can fully occupy and utilize the site (fully stocked stand). The C-line shows the limit of stocking necessary to reach the B-line level in 10 years on average sites.

The stocking chart provides a statistical approach to guide stand density management (see Chapter 23).

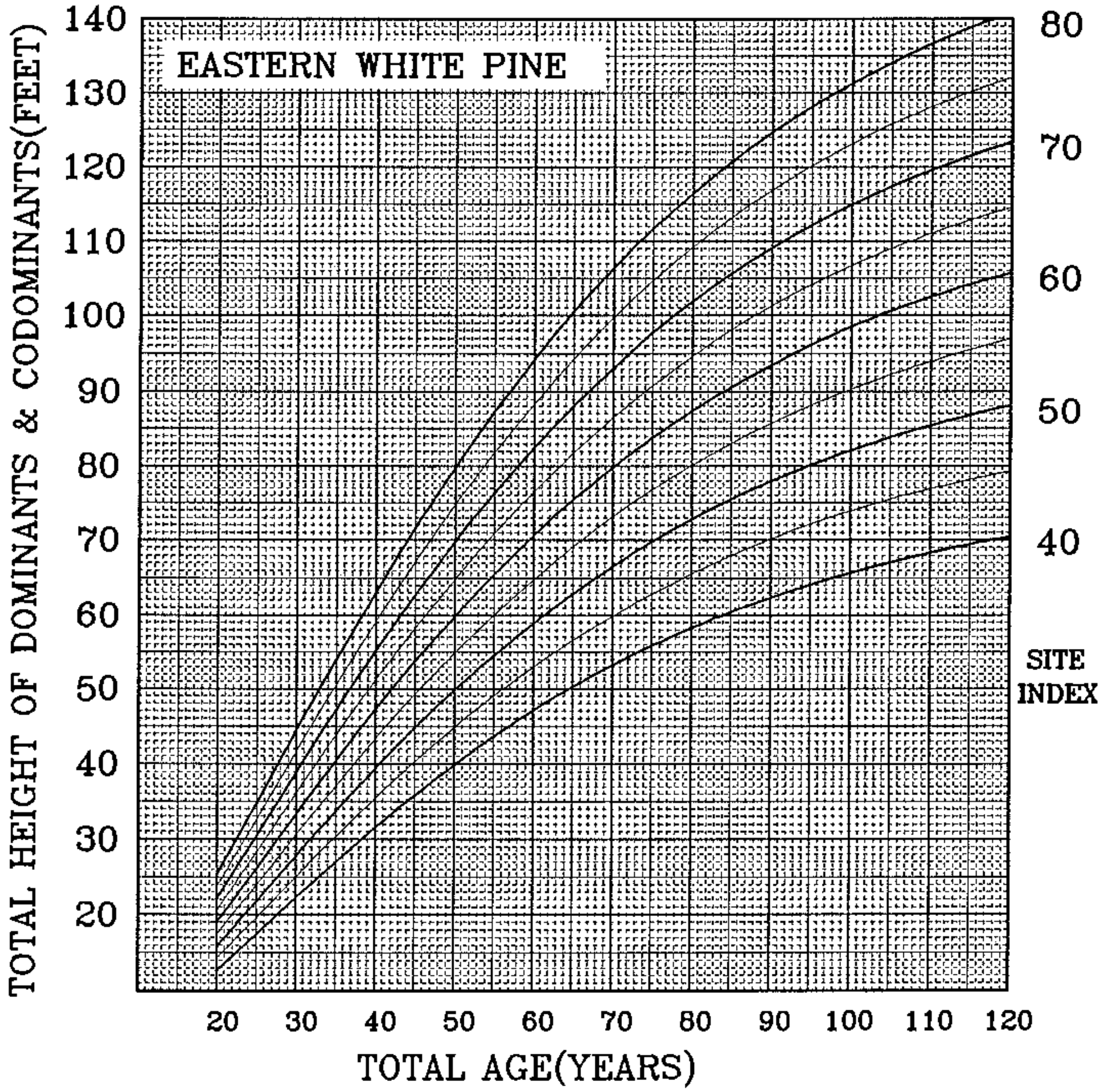
- To utilize the stocking guide, statistically accurate estimates of at least two stand variables must be obtained, including basal area per acre, number of trees per acre, and/or mean stand diameter. For the white pine stocking guide, these variables are measured only for canopy trees.
- The area between the A-line and B-line indicates the range of stocking where optimum stand growth and volume yield can be maintained.
    - o The A-line represents maximum stocking. Maintaining stocking levels near (but below) the A-line will produce comparatively more trees, but of smaller diameter.
    - o The B-line represents minimum stocking. Maintaining stocking levels near (but above) the B-line will produce larger diameter trees faster, but comparatively fewer trees.
- When designing and implementing a thinning regime for a stand, do not reduce stand density to below the B-line or allow it to surpass the A-line. For white pine, it is

suggested that 80% of A-line stocking is actually the upper limit for practical management.

- Thinning can occur at any time as long as stand density is maintained between the A-line and B-line. The A-line is not a thinning "trigger." When to thin depends on management objectives, stand conditions, and feasibility.

Typically, thinning is implemented when average stand stocking is halfway or more between the B-line and A-line. Stocking is reduced to slightly above the B-line. Crop tree concepts are applied to retain and focus growth on desirable trees, and order of removal concepts are applied to select which trees will be cut to achieve stand management objectives.

In overstocked stands, thin lightly and frequently, with increasing intensity, for the first several thinnings, to safely develop tree crown vigor and stem strength, and until target residual densities (near the B-line) are achieved. A general rule of thumb is do not remove >50% of the basal area in any one thinning operation.



-Eastern white pine (Gevorkiantz 1957f, derived from Gevorkiantz and Zon 1930)
Northern Wisconsin
92 plots, number of dominant and codominant trees not given
Total height and total age, anamorphic, equation not given
Convert d.b.h. age to total aga by adding years according to site index (BH = 0.0):

SI:	40	50	60	70	80
Years:	12	12	10	8	6

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	1.9660	1.0000	-0.0240	1.8942	0.0000	0.99	0.66	1.7
SI	0.5086	1.0000	-0.0240	-1.8942	0.0000	0.99	0.66	1.7

Figure 31.3. Site index curves for white pine in northern Wisconsin (Carmean et al., 1989).

8.1 Forest Health Guidelines - Forest Health Protection (FHP)

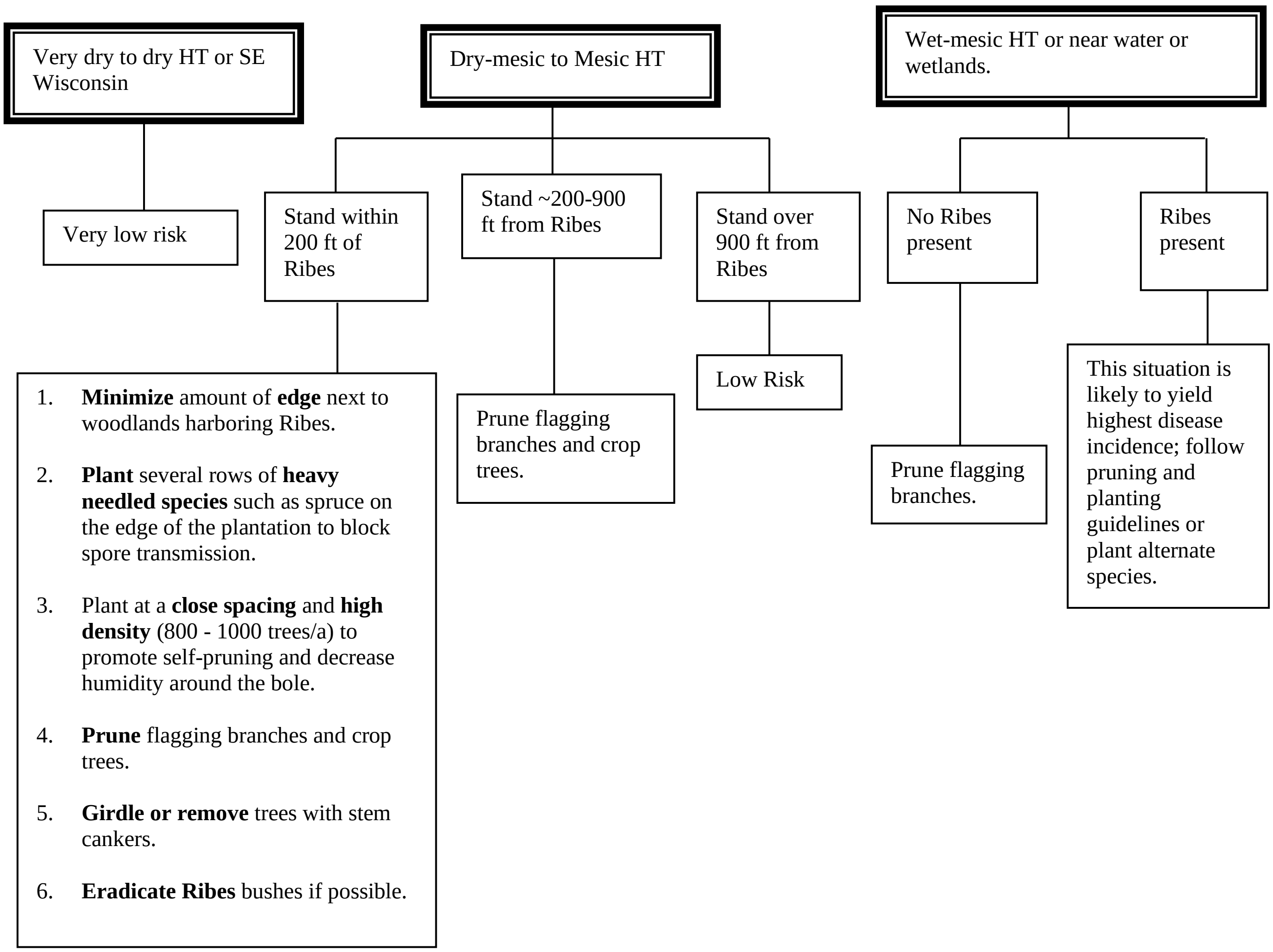
PEST MANAGEMENT GUIDELINES FOR WHITE PINE - WI DNR FOREST HEALTH PROTECTION

Disturbance Agent and Expected Mortality or Damage	Options for Minimizing Mortality or Preventing Disease	References
White Pine Blister Rust – *Cronartium ribicola* 1. Infected seedlings usually die. 2. Infected saplings and poles may have one or several cankers on branches and the main stem, within 10-15 feet of the ground. Branch cankers cause branch mortality. Stem cankers cause treetop or whole tree mortality. 3. Sawlog-sized trees will occasionally be infected. Branch and stem cankers will be located high in the crown. Cankers will cause branch and treetop mortality. 4. Disease incidence and tree mortality are highest in areas where 100% relative humidity and a temperature of <68°F is maintained for a minimum of 48 hours in late summer and fall. 5. Several factors influence disease incidence. Localized areas of high disease incidence (>25% of trees infected) can be observed in areas generally considered to be at low risk, and low disease incidence (<5%) can also be common in high risk areas. Thus, generalized statements regarding high and low risk zones within the state are not useful for local management decisions. Each site should be evaluated based on several factors (see management options). 6. Recent surveys (1998–'01) have shown proximity to the alternate host, *Ribes* spp., is still an important factor to consider, yet long range transport of the spore that infects white pine complicates Ribes eradication recommendations.	**Expect highest disease incidence on sites with both:** **1. Ribes spp. on or in close proximity to the site, and** **2. Site conditions that enhance lasting dew formation during cool windless nights:** • kettle holes or depressions, • sites with a northerly aspect, • small openings (diameter less than the height of surrounding trees), particularly at the bases of slopes and in low areas, • ridge tops or shoulders in close proximity to any body of water or close proximity to any lowlands, • on the Bayfield Peninsula, sites on aspects which face Lake Superior. **Management Options - Also see flow chart** **1. Established understory white pine regeneration.** • Recent (1998-'01) surveys have supported the known benefits of a hardwood overstory: interception of rust spores and prevention of dew formation on white pine needles. A 40-50% crown closure will reduce infection when trees are young. • To promote growth and vigor of white pine, no more than 20% overstory crown closure should be maintained. Substantial growth and vigor losses occur at higher crown densities. Stands which are well stocked (>700 trees/a) and free to grow (<20% crown closure) will exhibit higher vigor, faster growth, and earlier self-pruning of the lower branches. Losses due to blister rust normally are manageable. **Release pine from hardwood overstory at the earliest opportunity.** Prune all crop trees. 2. **Established white pine plantations.** Selectively remove trees with stem cankers. Prune all crop trees. 3. **New white pine plantations.** Habitat type and proximity to Ribes significantly influence disease incidence. **See flow chart for specific recommendations related to site. Also, follow these general guidelines:** • avoid planting in small openings (diameter less than the height of surrounding trees), • plant seedlings at a high density (800 - 1000 trees/a), • follow the pruning guidelines when trees reach 5-7 years of age, • keep grass cut when the trees are young (to reduce the humidity in the lower crown). 4. **Pruning Guidelines.** Begin pruning lower branches when trees are approximately 5-years-old. Pruned branches can be left on site. Attempt to maintain 2/3 of the tree's height in live branches. At no time should branches be pruned from more than ½ the height of the tree. Continue pruning until a minimum of 9' of the main stem is clear of branches. Pruning to 17' is ideal. Aim to	1. How To Manage Eastern White Pine to Minimize Damage from Blister Rust and White Pine Weevil. S. Katovich et. al. 1993. USDA Forest Service. NA-FR-01-93. 2. How To Identify White Pine blister rust and Remove Cankers. T. Nicholls et al. 1977. USDA Forest Service NC For. Exp. Sta. Paper. 3. Incidence of White Pine Blister Rust in a High-Hazard Region of Wisconsin. S. Dahir et al. 2001. No. JAF, 18:3 pp 81-86.

	prune 100-200 trees per acre in natural stands and 350 per acre in pure white pine plantations.	

Recommendations for White Pine Blister Rust Management based on Habitat Type (HT)

WI DNR Forest Health Protection



Disturbance Agent and Expected Mortality or Damage	Options for Minimizing Mortality or Preventing Disease	References
Ozone and Sulfur Dioxide as Air Pollutants Individual trees that are genetically susceptible will show chlorosis and necrosis of the tips of current year's needles in July and August. Highly susceptible trees will be stunted and chlorotic. These trees are referred to as chlorotic dwarfs. Susceptible trees are usually scattered throughout plantations or natural stands. Mortality is rare.	Highly susceptible trees will not "grow out" of symptoms and are likely to always be stunted. Stunted trees can be removed yet this is not necessary.	Wisconsin Woodlands: Identifying and Managing Pine Pests in Wisconsin. H. Goulding et al. 1988. U. of WI Ext. G3428. Regional Effects of Sulfur Dioxide and Ozone on Eastern White Pine in Eastern WI. C. Rezabek et al. 1989. Plant Disease Vo. 73. No. 1
White Pine Root Decline – *Verticicladiella procera* Causes a resinous, girdling canker at the root collar and on the main roots. Infected trees turn yellow and die. All ages may be affected. In Wisconsin, this pathogen appears to be most active on white pine stressed by standing water in heavy, clay soils.	Do not plant white pine on heavy clayey sites where drainage is impeded and water stands for more than 24 hours following a rain.	How To Identify and Control White Pine Root Decline. R. Anderson et al. 1979. USDA Forest Service SA-FR/P6
White Pine Root Disease – *Armillaria spp.* The fungus, Armillaria, decays dead and dying hardwood or conifer roots and stumps. It can also infect seemingly healthy white pine roots and root collars. It can cause decline and mortality of trees of all sizes. It is often found in association with other disturbance agents such as bark beetles and poor soil drainage. It can also be a problem on very droughty sites. New plantings of white pine on sites that harbor stumps and roots of hardwoods or conifers are likely to suffer some mortality of seedlings (10-30% mortality over 15 years has been observed.)	Expect some losses if planting on sites where hardwood and/or coniferous stumps and roots are decaying. Delay planting until 5-7 years after cutting a stand. This will avoid the peak productive time for Armillaria.	Armillaria Root Disease. C. Shaw III et al. 1991. USDA Forest Service Ag. Handbook No. 691.
Annosum Root Rot – *Heterobasidion annosum* Annosum root rot is a very important disease of conifers, only recently observed in Wisconsin. This fungus decays the roots of white pine and moves both overland, through basidiospores and underground through root contact. Overland infection usually occurs through freshly cut stumps. *H. annosum* causes mortality of infected trees. Its underground movement generally produces an ever-widening circle of dead trees.	As of 10/1/01, *H. annosum* had been observed in red pine plantations in Adams, Iowa, Richland and Sauk counties. Scattered white pines within the Iowa County stand have been killed by *H. annosum*. This disease is likely to be present in other areas of the state, yet surveys have not located additional infection centers. 1. To be highly cautious, treat stumps of white and red pine during thinnings with a registered product such as SPORAX. Cut stumps must be treated within 24 hours of felling. SPORAX creates an unfavorable environment for colonization of stumps by *H. annosum*. 2. If *H. annosum* is already established in a stand, consider converting or regenerating to less susceptible species such as hardwoods.	1. Protect Pine Forest Productivity by Preventing Annosum Root Rot. G. Stanosz. 1997. Dept. of Plant Pathology, UW – Madison. 2. Annosus Root Rot in Eastern Conifers. K. Robbins. 1984. USDA Forest Service I&D Leaflet 76.

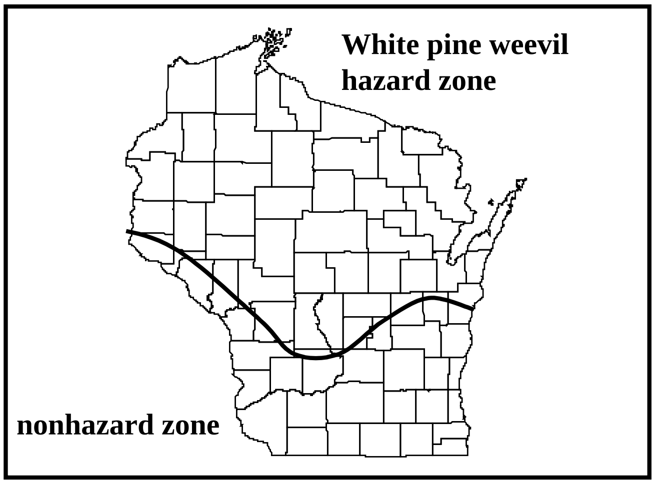
PEST MANAGEMENT GUIDELINES FOR WHITE PINE – WISCONSIN DNR FOREST HEALTH PROTECTION

HAZARD	LOSS OR DAMAGE	PREVENTION, MINIMIZING LOSSES, AND CONTROL ALTERNATIVES- The following alternatives assume that the management objective is optimum quantity and quality of sawlogs.	REFERENCES
White Pine Weevil	Destruction of current year and previous year's terminal growth allows lateral branch to assume terminal dominance resulting in deformity of main stem of sapling to pole-sized trees. IN HAZARD ZONE : (see map) Five to 30 percent of open growing white pines are likely to be attacked annually.	In existing infestations, local population and damage can be reduced by removing and destroying infested terminals before new adults emerge in mid July. IN HAZARD ZONE : (see map) In plantations and open grown seedling/sapling stands: In open areas, plant 900 - 1,000 trees per acre in mixed or pure plantations and maintain at least 700 trees per acre until canopy closes. Alternatives: Accept stem deformity and remove damaged stems during thinning. Accept stem deformity up to limit (until 200-300 acceptable crop trees per acre remain) and apply corrective pruning or insecticidal application to prevent attack by adult beetles. If less than 150 acceptable crop trees per acre remain, consider different objective. In Understory Situations:	White Pine Weevil. A. Hamid, et al. 1995. USDA Forest Service, Forest Insect & Disease Leaflet 21. How to Manage Eastern White Pine to Minimize Damage from Blister Rust and White Pine Weevil. 1993. S. Katovich, et al. USDA-Forest Service, NA-FR-01-93. Wisconsin Woodlands: Identifying and Managing Pine Pests in Wisconsin. H. Goulding, et al. 1988. Univ. Wis. Ext. G3428. The White Pine Weevil and Eastern White Pine in Wisconsin. 1995. D.M. Pubanz. Menominee Tribal Enterprises Research Report. Evaluating and Scheduling White Pine Weevil Control in the Northeast. R. Marty. 1964. USDA Forest Service, NEFES Res. Pap. 19. Effects of the White Pine Weevil in Well-Stocked Eastern White Pine Stands in Wisconsin. 1999. Pubanz, D. M., R. L. Williams, D. L. Congas,

	OUTSIDE HAZARD ZONE Little or no white pine weevil problem. Annual attacks not expected to exceed 5% of terminals in open growing white pine stands.	Reduce hardwood overstory to no more than 20 percent crown cover. OUTSIDE HAZARD ZONE No prevention or control required.	and M. Pecore. Northern Journal of Applied Forestry 16(4), pp185-190.
Spongy Moth (formerly known as gypsy moth)	Defoliation of reproduction under oak, aspen or birch overstory during outbreaks may cause up to 10% mortality. If defoliation occurs during drought, mortality could be greater. Solid stands of white pine are defoliated only along the edges.	Alternatives: If reproduction is sufficient, accept loss of up to 10%. If 10% loss of reproduction is not acceptable, remove overstory.	Gypsy Moth Silvicultural Guidelines for Wisconsin. C. Brooks and D. Hall. 1997. WDNR PUB-FR-123 97. Silvicultural Guidelines for Forest Stands Threatened by the Gypsy Moth. K. W. Gottschalk. 1993. U. S. Forest Service Gen. Tech Rep. NE-171. Gypsy moth: forest Influence. R. W. Campbell. 1979. USDA-Forest Service. Ag. Info. Bull. No. 423. Wisconsin Woodlands: Identifying and Managing Pine Pests in Wisconsin. H. Goulding, et al. 1988. Univ. Wis. Ext. G3428
Introduced Pine Sawfly	Summer defoliation, growth loss and mortality of sapling-sawlog trees usually in open grown situations.	Promote early crown closure; accept some growth loss and/or tree mortality or spray with insecticide.	Wisconsin Woodlands: Identifying and Managing Pine Pests in Wisconsin. H. Goulding, et al. 1988. Univ. Wis. Ext. G3428
White Pine Sawfly	Summer defoliation, growth loss and mortality of saplings in southern 1/3 of state.	Promote early crown closure; accept some growth loss and/or tree mortality or spray with insecticide.	Wisconsin Woodlands: Identifying and Managing Pine Pests in Wisconsin. H. Goulding, et al. 1988. Univ. Wis. Ext. G3428
Pine Spittlebug	Sapsucking may cause flagging and mortality of saplings. Seldom serious.	Direct control seldom necessary. Apply insecticide, if necessary.	A Guide to Insect Injury of Conifers in the Lake States. L.F. Wilson. 1976.

			USDA Forest Service, Agr. Handbook 501.
White Pine Aphid	Sapsucking and sooty mold may cause flagging and mortality of saplings in localized pockets during extended dry weather. Local ant populations may protect aphids from natural enemies and lead to further aphid population increase.	Direct control is seldom necessary. If high populations occur, direct insecticide application on aphid and ant mounds may be necessary.	A Guide to Insect Injury of Conifers in the Lake States. L.F. Wilson. 1976. USDA Forest Service, Agr. Handbook 501.
Mound Ants	Ants cause fatal canker at base of saplings that shade mounds. Ants protect white pine aphids from natural enemies but also protect trees by eating many sawfly larvae.	ALTERNATIVES: Accept loss of a few saplings. If numbers of mounds become excessive, treat some or all mounds with insecticide.	A Guide to Insect Injury of Conifers in the Lake States. L.F. Wilson. 1976. USDA Forest Service, Agr. Handbook 501.
Pales weevil	Populations build up in fresh cut conifer stumps. Adult weevils emerge in late summer. Bark feeding by adults causes twig and seedling mortality.	Avoid planting in areas with fresh pine stumps or treat seedlings with insecticide.	Wisconsin Woodlands: Identifying and Managing Pine Pests in Wisconsin. H. Goulding, et al. 1988. Univ. Wis. Ext. G3428
Pine Engraver Beetle (bark beetles)	Tunneling in inner bark of weakened trees may cause mortality in pole and sawlog sized trees. Seldom serious, in white pine.	Treatment seldom necessary.	Wisconsin Woodlands: Identifying and Managing Pine Pests in Wisconsin. H. Goulding, et al. 1988. Univ. Wis. Ext. G3428
White tail deer	Browsing kills and causes deformity of seedlings and saplings.	Alternatives: Deer population control by intensive hunting Remove heavily damaged stems during thinning Repellents (variable success) Bud caps Shelters Fencing	Deer. Scott Craven. 1983. IN: Prevention and Control of Wildlife Damage. Univ. Neb. Ext. Publ.

Meadow Vole (meadow mouse)	Gnawing on bark causes mortality of seedlings and saplings.	Control grass and heavy weed growth in plantations during first five years.	Meadow Mouse Control. Scott Craven. 1983. Univ. Wisc. Ext. Leaflet A2148.


White pine weevil
hazard zone
nonhazard zone

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Chapter 32

Red Pine Cover Type

WISCONSIN
DEPT. OF NATURAL RESOURCES

Last Full Revision: 1/3/2019
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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Last Full Revision: 1/3/2019
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1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand Composition
Red pine (*Pinus resinosa*) comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands. In mixed pine stands, red pine is predominant.

Associated Species
Many red pine stands are fairly pure with few associates. Pure natural stands typically originate following catastrophic fire. Red pine plantations often are established as monocultures. The most common associate within the red pine cover type is white pine (*Pinus strobus*). Other major associates are jack pine (*Pinus banksiana*), aspen (*Populus* spp.), and oak (*Quercus* spp.).

1.2 Silvical Characteristics[1]

Red pine is a native species adapted to a disturbance regime characterized by periodic ground fires and infrequent crown fires. It most commonly occurs on dry sands in historically fire-prone landscapes.

Red pine is considered genetically uniform, exhibiting relatively limited genetic variation throughout its geographic range.

Flowering and Fruiting
Red pine is monoecious; female flowers are borne mostly in the middle third of the crown (in the upper third of the crown in older trees), and the purple male flowers are borne in the lower crown. Flowers are borne April to June, and pollination occurs May to June. Fertilization occurs in July the following year when cone growth is completed, and the fully developed seed coats have hardened. Cones are about 0.5 inches long by late summer of the first year, and about 1.5-2 inches long when growth is completed. Cones are completely brown when they ripen late summer to early fall of the second year.

Seed Production and Dissemination
Good seed crops are produced every 3-7 years, with bumper crops only every 10-12 years. Seed production can be reduced by prolonged rainy weather at the time of . Almost complete cone crop failure can occur due to insects, extreme weather, and other damaging agents between the first and second year of development. Cone production is stimulated by high temperatures during the spring and summer two years before cone maturation. The production of cones can be most prolific on branches that are thick, long, and young, and on the south side of the tree. Cone production per tree generally improves as stand density decreases; thinning can help increase cone production per tree.

[1] Mainly from Rudolph (1990).

Seed dispersal begins when the cones ripen. Cones open best on hot, still autumn days when there is little wind to carry the seeds far. During the first month, the heaviest most viable seeds fall. Most seeds are dispersed between September and November, but seed dispersal can continue throughout the winter and into the following summer. Most seeds fall to the ground within 40 feet but can be disseminated up to 900 feet from the parent tree.

Seedling Development

The ideal seedbed to facilitate germination is bare mineral soil, but light pine litter is acceptable. Germination occurs spring to early summer and requires adequate moisture and warm temperatures (mostly 70-86°F). Factors facilitating the maintenance of moist seed include finer textured soils (e.g., loamy sand), thin moss, water table within 4 feet of the surface, light cover over the seed, and some shade. Germination can occur under dense brush, in heavy sod or litter, and in heavy ash, but seedlings generally do not develop or grow well. Other conditions known to inhibit germination include soil pH ≥8.5 and full sunlight for ≥4 hours per day. Both germination and early seedling survival are hindered by summer drought and high surface soil temperatures.

Growth and Development

Red pine is shade intolerant. Seedlings can become established with 35% full sun and grow well under 45% of full sun until age 5. Established seedlings grow best in (near) full sunlight, if other requirements are met. Red pine seedlings grow slowly, usually requiring 4-10 years to reach breast height. Height growth usually increases once seedlings/saplings are 5-10 years old, and dominance in dense stands is often expressed by age 12. Radial growth is related to precipitation in the current season.

During the first summer following germination, seedlings develop a taproot usually 6-18 inches long. After the first year, lateral root growth tends to be greater than vertical growth. A water table within four feet of the soil surface along with a loose soil encourages early rooting depth. The uptake of soil moisture and mineral nutrients is improved by the formation of symbiotic mycorrhizae on seedling roots.

Most root elongation occurs in the spring and early summer. Root systems typically are moderately deep and wide spreading. Vertical roots (taproot and sinkers) typically descend 5-15 feet. Lateral roots mostly occur within 4-18 inches of the surface and can extend up to 40 feet beyond the crown (depending on competition from neighboring trees). Root grafts among neighboring red pine trees older than 15 years are common. Thinning apparently stimulates grafting. Grafting among trees can enhance tree health and wind firmness, but can also transmit damaging agents, including annosum. Soil conditions, including moisture, temperature, texture, and density, can influence the timing, intensity, and pattern of root growth. Root systems become stunted in poorly drained soils and some dense soils (e.g. hardpan and compacted soils).

Red pine trees often grow to 70-80 feet tall, and up to 36 inches dbh. Maximum size is nearly 150 feet tall and 60 inches dbh. Height growth rate is strongly influenced by site quality. Other factors that can impact height growth are overhead shade and damage to terminal growth (e.g.

insects). The rate of height growth tends to decrease as trees get older, and often becomes negligible as trees approach 150 years old. Diameter growth rates tend to be the greatest in vigorous, dominant trees with large, well developed crowns. Crown size and diameter growth are strongly influenced by stand density. Basal area growth rates range from <1 to >8 square feet per acre per year, but most commonly range 2-5 ft^2/ac/yr. Factors influencing variability in basal area growth include site quality, stand age, and density extremes (<60 and >200 ft^2/ac). Greatest growth rates generally are demonstrated by young stands on good sites, and slowest growth rates by old stands on poor sites.

Table 32.1. Summary of selected silvical characteristics.

Red pine (*Pinus resinosa*)	
Flowers	Monoecious. Flowers appear between April and June.
Pollination and Fertilization	Pollination by wind, during May to June. Fertilization occurs in July of the second year (1 year following pollination).
Cone Development and Maturation	Cones are about 0.5 inches long by late summer of the first year. Cones are about 1.5-2 inches long and completely brown when they ripen mid-August to October of the second year.
No. of seeds/lb	Seeds are light. Cleaned seed averages about 52,000/lb.
Seed Dispersal	Mostly September to November. Most seeds fall to the ground within 40 feet but can be disseminated up to 900 feet from the parent tree.
Good Seed Years	Every 3 to 7 years. Bumper crop every 10 to 12 years.
Seed Bearing Age	Best production 50 to 150 years.
Cone Production	Range 0-725 cones/tree.
Seed Viability	14-86%, usually best during good or better seed years.
Germination	Epigeal. Spring to early summer. Moist spring and summer essential to germination and establishment.
Seedbed Requirements	Mineral soil preferred.
Vegetative Reproduction	None.
Seedling development	Moist spring and summer essential to germination and establishment. 35% of full sunlight satisfactory for establishment, >45% full sunlight maximizes early growth, and near full sunlight maximizes growth once established.
Shade Tolerance	Intolerant.
Maximum Tree Longevity	Expected lifespan approximately 200 years. Maximum lifespan 350-400 years.

Red pine is a long-lived species. Individual trees can reach 350-400 years of age. Fully stocked stands can persist for at least 200 years, but may exhibit declining tree vigor, increasing mortality rates, and declining stand yield.

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

Stand management objectives should be identified in accordance with landowner property goals, and within a sustainable forest management framework which gives consideration to a variety of goals within the local and regional landscape. The silvicultural systems described herein are designed to maximize tree vigor and stand growth to facilitate optimized productivity (quantity and quality) of a variety of timber products (e.g. sawtimber, pulpwood, utility poles, and cabin logs). These silvicultural systems may be modified to satisfy other management objectives, but vigor, growth, and stem quality could potentially be reduced.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.1 Landscape Considerations

The red pine forest type provides significant economic and social benefits, but there are concerns about the ecological effects of red pine plantation management at landscape and regional scales. Past management has led to altered ecological complexity through development of single cohort, monotypic stands; decrease in older age classes; lack of within stand structural variability; interruption of natural processes; and placement on the landscape, fragmenting other systems. Landscape considerations for red pine are intended to address some of the ecological effects by recognizing management strategies that can be incorporated into management plans and prescriptions.

3.1.1 Historical Context

When the General Land Office (GLO) Public Lands Surveys (PLS) were conducted in Wisconsin (1832-1866), forests of white and red pine comprised about 2 million acres (Frelich, 1995); this represented about 9% of forest vegetation, making white pine – red pine the third most abundant forest type. Species composition and successional stage varied depending on soil type and disturbance regime. Red pine was historically a component of the northern dry forest, present along with white and jack pine, and northern dry mesic forest, existing with white pine, red maple, red oak, birch and aspen (Curtis, 1959). The most extensive blocks of white pine – red pine dominated forest were in Vilas and Oneida counties (WDNR 1995). Figure 32.1 displays red pine occurrence from the PLS; red pine forests were most abundant in the sandy landscapes of northwest, northcentral, northeast and central sands areas of the state. Within the Great Lakes region both Michigan and Minnesota contained considerably more pine forests than Wisconsin (Frelich 1995).

Red pine dominated forests mostly occurred within dry, sandy landscapes where fire was the principle disturbance agent; severe blowdowns occurred infrequently. Severe fires causing mortality of most overstory trees and initiating red pine stand development typically occurred every 100-250 years (return interval); both old and young stands could be decimated by catastrophic fires. As stand development progressed, highly irregular (frequency, severity, pattern) periodic surface fires altered understory composition and structure, and sometimes caused mortality of scattered individuals or groups/patches of overstory trees. Older trees often were well represented as patches, groups, and individuals. Age class structure within forest patches ranged from mostly even-aged to complex uneven-aged distributions.

Large pines were especially sought after early in the Euro-settlement period. By the late 1800s, the red and white pine forests were being removed at the rate of 3.4 billion board feet per year. (Curtis 1959). The pine slash burned easily and intense fires spread over large areas for several decades until the fire suppression program was developed. Much of the pine forest converted to aspen-birch and oak following the Cutover (WDNR 2005) or eventually was planted.

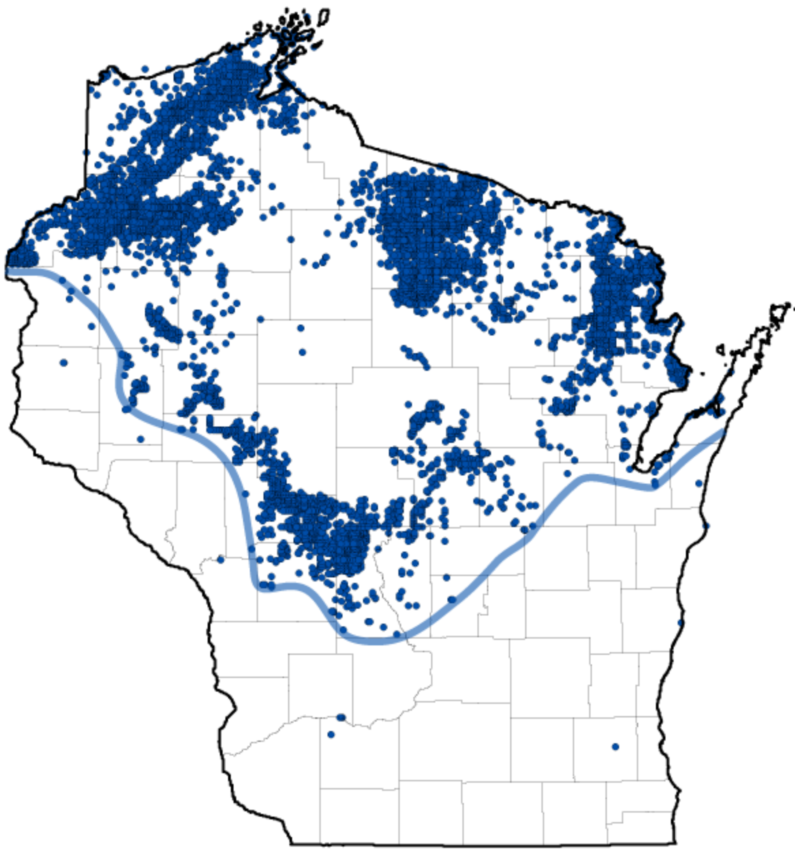

Figure 32.1. Map of red pine distribution from the GLO PLS data. A general range line for red pine in Wisconsin in the mid-1800's has been estimated and inserted to delimit the common occurrence of red pine; community outliers did sporadically occur beyond these range limits.

3.1.2 Current Context

Red pine is a common cover type, occurring on 4% of forest land in Wisconsin. Most stands are 1-60 years old and of plantation origin. Some of Wisconsin's existing red pine resource was planted on areas devoid of trees, often tax reverted agricultural land, during the 1930s by the Civilian Conservation Corps. On dry sites, where red pine is often cultivated, stands of jack pine, aspen, and oak are sometimes harvested and converted to red pine. The FIA records show that the red pine cover type has been increasing while jack pine has been decreasing since 1983 (Figure 32.2). Between 1983 and 2006 red pine acreage increased from 478,200 acres to 686,167 acres, an increase of 207,967 acres. However, jack pine acres have decreased about 191,000 acres during the same period. Management decisions to convert some jack pine stands to red pine were because of insect/disease issues, particularly jack pine budworm infestations. In some cases, jack pine stands have converted to oak or aspen. On richer, dry-mesic to mesic sites, mixed hardwood stands (e.g. oak, maple) are sometimes converted to red pine plantations. Currently, red pine is often planted as part of afforestation projects to reestablish trees on fallow agricultural lands.

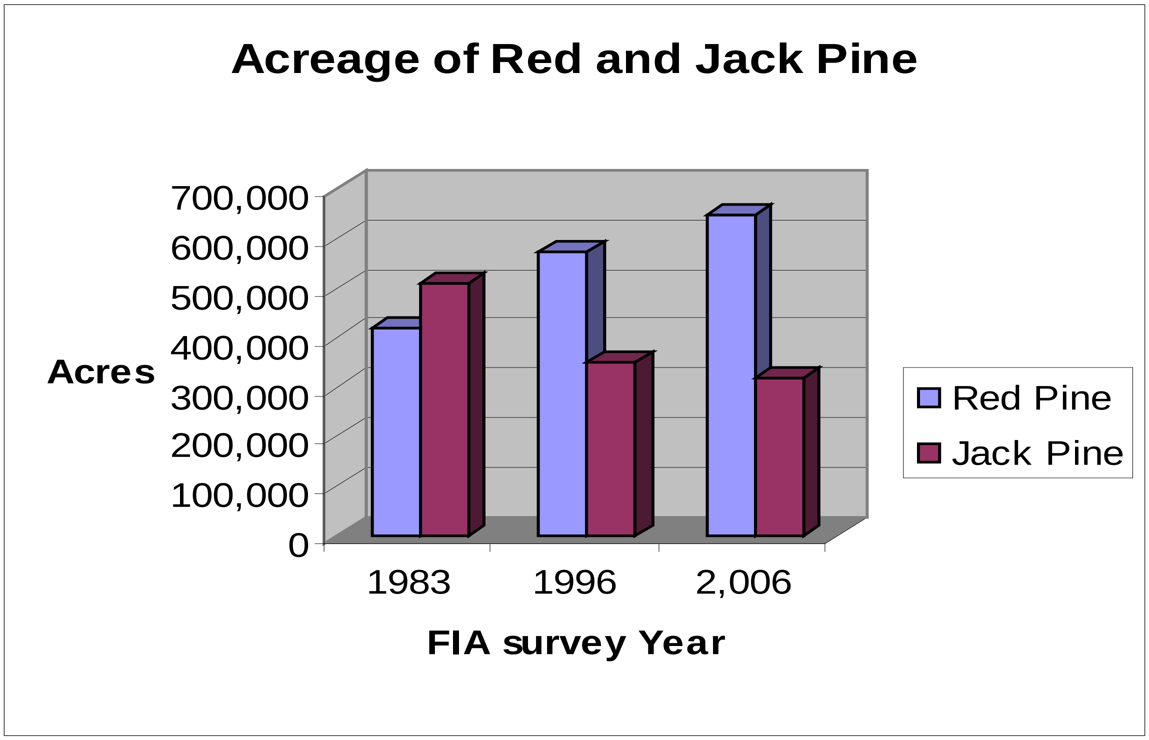

Figure 32.2. Acreage of red pine and jack pine over 3 FIA inventory periods, 1983-2006.

Most stands of red pine in Wisconsin are even-aged plantations from 1-60 years old (Figure 32.3). Some older stands from 80-100 years old also occur. Although red pine is a long-lived native species, there are few current stands that are older than 100 years. Older trees and stands provide unique ecological and social benefits but are poorly represented within modern forest landscapes.

Table 32.2 shows the distribution of red pine acreage by ecological landscape (EL) and stand origin (plantation or natural) based on FIA data from 2007 and Figure 32.4 displays a map of natural and plantation red pine in Wisconsin. Of the 697,000 acres of red pine, there were 143,000 acres that were apparently natural stands, and the vast majority, 554,000 acres, were plantations. Of the 14 Els listed in the table, the Northwest Sands had the largest acreage of red pine forests. Eight ELs contained significant red pine acreage. Nearly half of the natural origin red pine acres occurred in two ELs – the Northwest Sands and the Northern Highland.

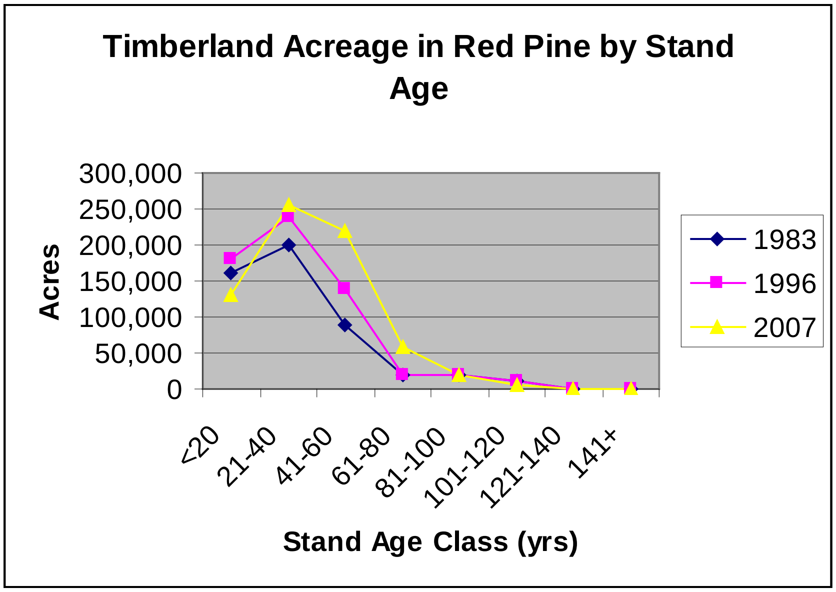

Figure 32.3. Forest age-class distribution for the red pine forest type in Wisconsin, over 3 FIA inventory periods, 1983-2006.

Table 32.2. Red pine – acres of forestland by ecological landscape and stand origin with sampling error (acreages with over 25% error are shaded) (data from FIA 2007).

	Acreage of timberland			Sampling error		
	Natural	**Plantation**	**Total**	**Natural**	**Plantation**	**Total**
Northwest Sands	34,854	88,363	123,217	12%	8%	7%
Central Sand Plains	12,310	97,133	109,444	21%	7%	7%
North Central Forest	17,936	70,339	88,275	17%	9%	8%
Forest Transition	10,314	68,269	78,583	22%	9%	8%
Northern Highland	30,219	37,835	68,053	13%	12%	9%
Central Sand Hills	5,668	60,773	66,440	30%	9%	9%
Northeast Sands	12,735	47,414	60,149	20%	10%	9%
Western Coulees and Ridges	7,413	40,782	48,195	26%	11%	10%
Northern Lake Michigan Coastal	2,540	13,770	16,311	45%	19%	18%
Western Prairie	564	11,520	12,084	96%	21%	21%
Superior Coastal Plain	4,200	6,332	10,533	35%	29%	22%
Southeast Glacial Plains	967	7,717	8,685	73%	26%	24%
Northwest Lowlands	3,175	3,175	6,349	40%	40%	29%
Central Lake Michigan Coastal		212	212	-	157%	157%
Grand Total	**142,895**	**553,634**	**696,528**	6%	3%	3%

Natural stands of red pine are uncommon. Severely altered fire regimes and stand developmental processes have forestalled natural regeneration processes. Historically, fire severity, timing, and pattern significantly influenced red pine regeneration processes across landscapes. Reductions in the frequency, extent, and variability of ground fires have been shown to change dominant successional pathways (Frelich and Reich 1995), influencing understory compositional and structural development.

A few old-growth patches are extant, and there are several relict stands that show no evidence of past harvest. Where found, these are small, and typically mixed with white pine and various hardwoods. Many of these also have not experienced fire for over a century, thus understory composition is increasingly dominated by hardwoods and shrubs rather than natural red and white pine regeneration.

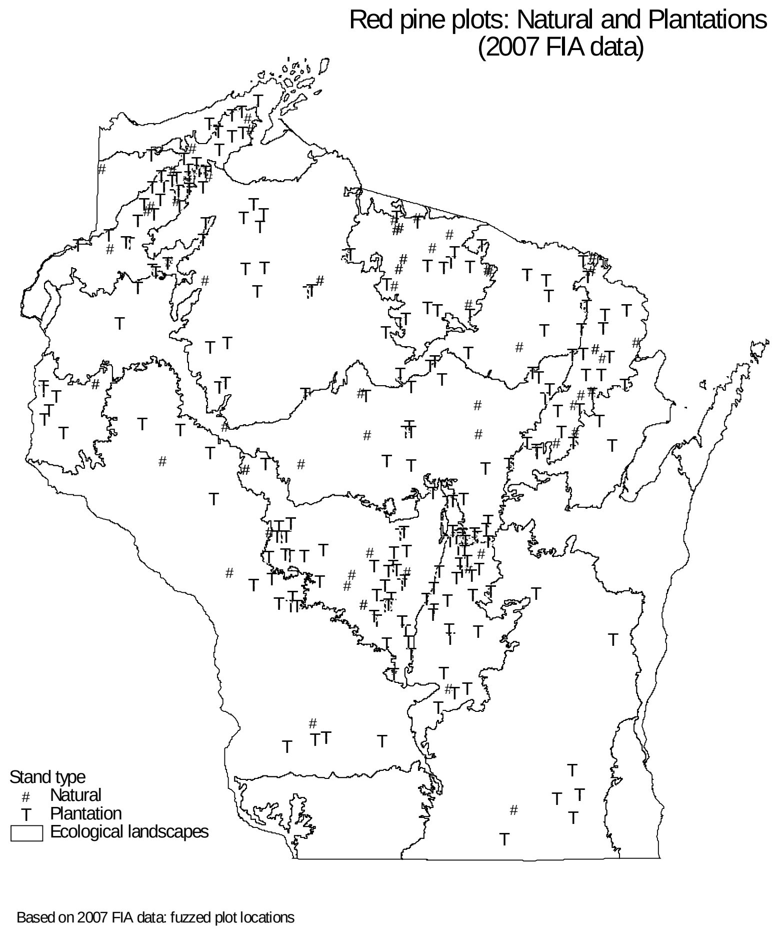

Figure 32.4. Map of red pine plantations and natural stands from FIA 2007.

3.1.4 Forest Simplification

Forest simplification refers to a reduction of species diversity and structural diversity. Human disturbances (e.g. fire suppression, fire ignition, tree cutting, artificial regeneration, and land conversion) have simplified the composition and structure of red pine forests and altered processes compared to historic conditions (Palik and Zasada, 2003). Management systems that manipulate vegetation and natural processes to encourage natural regeneration are rarely applied. Practices that cause simplification in red pine forests include:

- Application of standardized, homogenized management regimes (disturbance practices), including planting, thinning, and even-aged rotations
- Maintenance of single species, single cohort (even-aged) plantations
- Maintenance of relatively young stands lacking complex structural development
- Harvesting of the majority of older and old-growth stands
- Fire suppression

3.1.5 Landscape Pattern

Wisconsin's forested landscapes are made up of patches of different land uses, forest types, and age classes. The relative abundance and spatial arrangement of different patches forms a "landscape pattern" that can affect species' productivity, metapopulation dynamics, and ecological processes. A landscape made up of natural forest cover often has fewer and larger patches, with subtle and gradual transitional areas between them. Management for red pine can alter this pattern, creating patches of contrasting composition and structure that are typically smaller with abrupt boundaries. This change in landscape pattern breaks up a block of contiguous forest habitat and negatively affects landscape connectivity. Species that are area-sensitive (more likely to thrive in larger forest patches) or disturbance-sensitive may not find suitable habitat in a landscape that contains multiple blocks of red pine, particularly if rotations are short. Plant and animal dispersal mechanisms can be affected if species or their propagules have difficulty crossing or circumventing the red pine block, cannot find suitable habitat within it, or do not compete successfully with species that may be attracted to red pine or to the disturbance associated with an even-aged rotation.

3.1.6 Incorporating Ecological Complexity into Management

Ecological complexity in forest stands refers to compositional, structural, and functional variability across space and time. Variability can be interpreted at different scales; the range of natural variability can provide a realistic benchmark.

Prior to Euro-American settlement, variable natural processes guided the development of red pine forests and resulted in a range of conditions from relatively simple, homogeneous stands to very complex compositional and structural patterns. Currently, managed red pine stands by comparison tend to be relatively homogeneous and simplified. To increase diversity within and among red pine stands, management techniques need to be variable. Management practices and ecological conditions that could enable increased ecological complexity and benefits include:

- Develop and maintain large trees, cavity trees, snags, and coarse woody debris to provide structural diversity and habitat. These structures can be developed in current stands and can provide biological legacies at stand rotation (see Chapter 24). Retention of patches (aggregate retention) can provide unique structure.
- Improve species diversity. Create and manage some gaps within the stand during intermediate treatments and at rotation/regeneration; gaps can be managed using artificial regeneration, natural regeneration, or maintained as openings. Retain other species during intermediate treatments. Retain other species at rotation, especially white pine, to serve as seed sources. When establishing plantations, include other species.

- Apply variable density thinning (VDT). In traditional red pine prescriptions, stands are thinned uniformly. In contrast, most unmanaged forests have varying stand density and size. To emulate the natural variation, foresters can apply different thinning regimes throughout the stand, i.e. some areas heavily thinned and some lightly thinned (Franklin et al. 2007).
- Reintroduce fire. Ground fires can influence understory composition and structure and stand successional and developmental processes. Prescribed surface fire in older (>50 years old) red pine stands can be an effective management tool for eliminating shrub and hardwood competition, reducing thick duff layers, and preparing mineral seedbeds.
- Apply natural regeneration practices (see section on natural regeneration under Management Alternatives).
- Develop and maintain older forests across landscapes. Extended rotations offer the opportunity to produce significant timber yields while also producing other social and ecological benefits. Managed old growth focuses on unique ecological benefits. Maintain old-growth and relict stands; they are very rare.

3.1.7 Summary of Landscape Considerations

When deciding whether to actively manage for red pine, assuming the Habitat Type is suitable, consider the following factors:

- Evaluate landscape composition and structure, including species composition; successional and developmental stage; age structure; stand/patch size; type, intensity, and pattern of fragmentation; habitat diversity; NTMB populations and habitat needs; and common/uncommon management techniques.
- Apply landscape scale management by recognizing appropriate placement/location of red pine species in the landscape and the variety, age and size of stands.
- Match stand boundaries with large-scale, enduring physiographic and edaphic features not the present age structure or species
- Encourage connectivity of forest patches where it is possible to coalesce adjacent red pine stands.
- Promote species diversity within stands during planting, intermediate treatments, and rotation.
- Maintain reserve trees and increase structural diversity within stands through the development and maintenance of supercanopy trees, large trees, large cavity trees, large snags, and coarse woody debris.
- Increase structural diversity within stands through variable density management. Consider the development of gaps and patches of different ages and composition.
- Apply extended rotation and managed old-growth techniques.
- Protect old-growth and relict stands.
- Apply natural regeneration methods and prescribed fire.

3.2 Site and Stand Considerations

3.2.1 Soils

The red pine cover type is most common on dry (excessively to somewhat excessively drained), nutrient poor to medium sands in historically fire-prone landscapes dominated by sandy outwash, lacustrine, or washed till deposits. Productivity can be good to excellent on many of these soils, but is only fair on the driest, most nutrient poor sands. Examples of soil characteristics that improve productivity (increase moisture and nutrient availability) are finer textures (loamy sands), the presence of finer textured lenses or layers, underlying deposits (e.g. sand outwash over sandy loam till), and the presence of a water table at a depth of 4-9 feet. Red pine stands also occur on moist (moderately well to somewhat poorly drained) sands; productivity is generally good (to excellent) but decreases as soils become wetter.

Red pine plantations have been managed successfully on well drained to somewhat poorly drained loams and clays. On these moister and richer soils, natural stands sometimes occurred (historically) within landscapes where the fire regime was conducive to the regeneration and maintenance of red pine. Well drained (sandy) loams offer the greatest potential productivity.

Red pine generally does not grow well where the surface soil is alkaline (pH >6.5).

Red pine stands generally do not survive and grow on poorly drained soils.

Red pine occurs on a relatively wide range of soil types, with textures that include sand, loamy sand, and sandy loam. In some cases, red pine has been planted on heavier soils, including loams and clays. Because red pine typically grows on sandy sites, soil compaction is less of a management concern than in most other forest types. Soil displacement on roads and skid trails can be a concern in red pine stands, particularly for the sandiest sites. When the mat of ground vegetation is removed or worn away, bare mineral soil is exposed, and new vegetation is often slow to establish. Erosion by wind and water can keep these areas open, and bank slumping can prevent roadcuts from stabilizing; these impacts make parts of the stand non-productive. Roads and other travel routes have been implicated in the spread of non-native invasive plants. They can also act as barriers to the movement of some species, create habitat fragmentation and edge, and attract continuing human disturbances that prevent revegetation. Use travel routes and landing areas designed to meet the needs of the harvest while minimizing the portion of the stand impacted and maintain the ground vegetation mat wherever possible. As a general rule, less than 15 percent of a harvest area should be devoted to haul roads, skid trails, and landings (WDNR 2003).

Another area of concern for red pine sites is the potential for nutrient depletion over repeated rotations. Sites accrue nutrients through mineral weathering and atmospheric deposition. Nutrients can be lost from a site through leaching, volatilization (in the case of nitrogen), and removals in harvested wood. If losses are greater than inputs over the course of a rotation, nutrient depletion occurs. If losses are relatively small and the site is “rich”, or has a large amount of nutrient capital, then concerns are minimal. However, if the site is sandy and has little nutrient capital, losses may be significant. There is uncertainty in predicting the exact amount of potential nutrient losses, and more research is needed in this area.

Tree species vary in the amount of nutrients they take up, and a large proportion of nutrients are held in the small branches, twigs, and foliage. Perala and Alban (1982) studied nutrient removals in red pine for two sites at Pike Bay, MN (Table 32.3). These red pine plantations were on two different soil types. One soil was a Warba very fine sandy loam with sandy clay loam at a 24-inch depth, and calcareous at 41 inches. The other was an unnamed soil, dominantly loamy fine sand with clay loam and sandy clay loam between 33 and 43 inches, underlain by sand. The red pine stands were 39 and 41 years old, respectively. Compared with other tree species in this study, red pine had a lower nutrient demand than trembling aspen and white spruce, but a higher nutrient demand than jack pine. Nutrient uptake was greater on the richer site.

Table 32.3. Nutrient content of red pine foliage, branches, bark, and bole wood, for two soil types in Minnesota.

Nutrient content of red pine components, lb/ac (Perala and Alban, 1982)						
Foliage	*Branches (includes dead)*	*Bole bark*	*Bole wood*	*Bole wood + bark*	*Above-ground total*	*Soil type*
Nitrogen (lbs/acre)						
117	56	39	105	145	318	Warba vfsl, calcareous
98	31	37	95	132	261	lfs, scl, s
Phosphorus (lbs/acre)						
16.7	7.2	6.0	8.3	14.3	38.2	Warba vfsl, calcareous
11.2	3.8	5.0	7.4	12.4	27.4	lfs, scl, s
Potassium (lbs/acre)						
53	29	15	63	78	161	Warba vfsl, calcareous
53	17	18	40	58	127	lfs, scl, s
Calcium (lbs/acre)						
37	60	65	107	172	269	Warba vfsl, calcareous
29	46	62	105	168	244	lfs, scl, s
Magnesium (lbs/acre)						
12.8	8.3	7.8	24.1	31.8	53.0	Warba vfsl, calcareous
10.3	6.3	8.4	21.2	29.6	46.2	lfs, scl, s

Potassium (K) appears to be a mineral nutrient of concern for red pine. Nutrient balances for a rotation can be estimated by subtracting harvest removals from atmospheric and mineral weathering inputs. An estimate of the amount of K inputs from atmospheric deposition on average sites is 0.36 lbs/acre/year, based on data from the five Wisconsin stations of the National Atmospheric Deposition Program (NADP), for the time period 1997-2006. Mineral weathering inputs of K on average sites are estimated at 1.5 lbs/acre/year, and on nutrient-poor sites at 0.7 lbs/acre/year (Kolka et al., 1996).

Estimates of biomass and K removals for thinnings and final harvest of a 120-year old plantation are shown in Table 32.4. Inputs over 120 years are estimated to total 223 lbs K per acre on average sites, and 127 lbs K per acre on nutrient-poor sites. Removals of bole and bark wood, with 5% green tree retention at final harvest, represent 139 lbs K per acre. In this case, given uncertainty in the estimates, inputs of K over the rotation are approximately equal to harvest removals on nutrient-poor sites. However, if 80% of foliage and branches were also removed at each thinning, with 5% green tree retention at final harvest, another 243 lbs K per acre would be removed for a net loss of 254 lbs K per acre on nutrient-poor sites. Nutrient capital data for K in Wisconsin soils is not readily available, but figures have been reported for similar soils in adjacent states. The K capital of an average Minnesota soil, to a depth of 40 inches, is around 908 lbs/acre (Grigal 2004). Measurements of K capital for 24 Michigan sites showed values ranging from 106 to 1247 lbs/acre, with averages of 120 lbs/acre for a group of outwash sands, 338 lbs/acre for outwash sands with loamy inclusions, and 810 lbs/acre for loamy glacial till soils (Padley 1989).

This analysis indicates that if red pine foliage and branches are removed from the sandiest sites at thinnings and final harvest, K could be depleted before the end of the first rotation. On outwash sands with loamy inclusions, which are typical red pine sites, K depletion could occur during the second rotation. These calculations are estimates based on limited data but indicate that caution is warranted in nutrient management of red pine sites.

Table 32.4. Biomass of red pine plantation thinnings and final harvest, and estimated potassium (K) in harvested trees. Plantation yield data are from Bassett (1984), biomass equations are from Ter-Mikaelian and Korzukhin (1997), and K concentration data are from Perala and Alban (1982).

Age at thinning and final harvest	Biomass of harvested trees: bole + bark	Biomass of harvested trees: branches + foliage	K in bole + bark of harvested trees (5% green tree retention at final harvest)	K in branches + foliage of harvested trees (5% green tree retention at final harvest)	80% of K in branches + foliage of harvested trees (5% green tree retention at final harvest)
	tons/acre		*lbs/acre*		
30	15.3	4.6	15.5	20.1	16.0
40	14.9	4.9	14.9	22.5	18.0
50	6.0	2.1	5.9	10.2	8.2
60	13.4	5.1	13.2	25.3	20.2
70	12.5	4.9	12.2	25.3	20.3
90	11.4	4.8	11.1	26.2	21.0
120	71.6	32.0	65.7	173.9	139.2
Totals	**145.0**	**58.5**	**138.5**	**303.6**	**242.9**

3.2.2 Site Quality

3.2.2.1 Range of Habitat Types

See Chapter 12 – Forest Habitat Type Classification System for information summarizing the system and the habitat type groups.

The red pine cover type occupies about 4% of statewide forest land acres (1996 FIA). It currently is more common in northern than in southern Wisconsin (Figure 32.5 and Figure 32.6). Within the state, about 65% of red pine cover type acres and 73% of red pine net growing stock volume occur on northern habitat types. Southern Wisconsin habitat types contain about 35% of statewide red pine acres and 27% of the volume.

Previous View

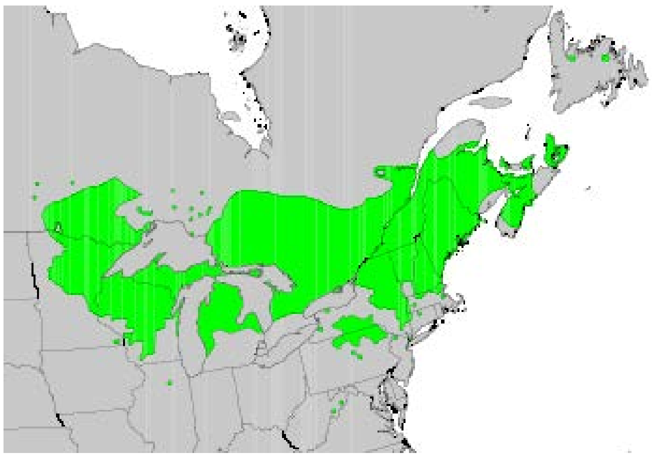

Figure 32.5. Range map for red pine.

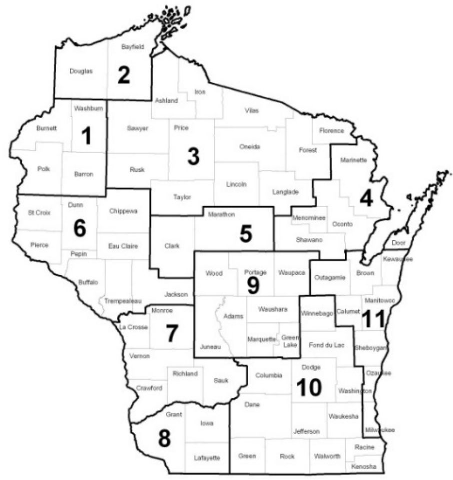

Figure 32.6. Forest habitat type regions. Regions 1-5 generally represent northern and 6-11 southern Wisconsin.

Northern Wisconsin Habitat Types

In northern Wisconsin, the occurrence and relative growth potential of the red pine cover type varies by habitat type groups and habitat types (Table 32.5 and Figure 32.7). Red pine is a common cover type on very dry to dry and dry to dry-mesic sites (habitat type groups); about 70% of the red pine cover type acres and 64% of the red pine volume in northern Wisconsin occur on these two groups. Red pine is a minor cover type on the dry-mesic, mesic, and mesic to wet-mesic habitat type groups. It generally does not occur on wet-mesic to wet sites.

Southern Wisconsin Habitat Types

In southern Wisconsin, the occurrence and relative growth potential of the red pine cover type varies by habitat type groups and habitat types (Table 32.6 and Figure 32.8). Red pine is a common cover type on dry sites; this habitat type group contains about 73% of the red pine cover type acres and 63% of the red pine volume in southern Wisconsin. Red pine plantations occur, but are uncommon, on most other habitat type groups in southern Wisconsin.

Red pine reaches its native range limit in southern Wisconsin (Figure 32.1 and Figure 32.5). The only southern habitat type region entirely within the native range of red pine is region 9 (Figure 32.6); in this region, the dry and dry-mesic habitat type groups are predominant. Habitat type regions 6, 7 and 8 in the western Driftless region, occur at the historic western and southern limits of the natural range of red pine. Habitat type regions 10 and 11, in southeastern Wisconsin, are mostly out of range.

Plantations have been established in southern Wisconsin, outside of or near the natural range limits for red pine, on dry-mesic to mesic, nutrient rich, loamy soils. Long-term growth, productivity, and tree health are uncertain. Observations of plantation performance typically indicate excellent early growth. However, at comparatively young ages, anywhere between 20 and 60 years old, tree health and mortality problems often develop and stand growth slows or stagnates.

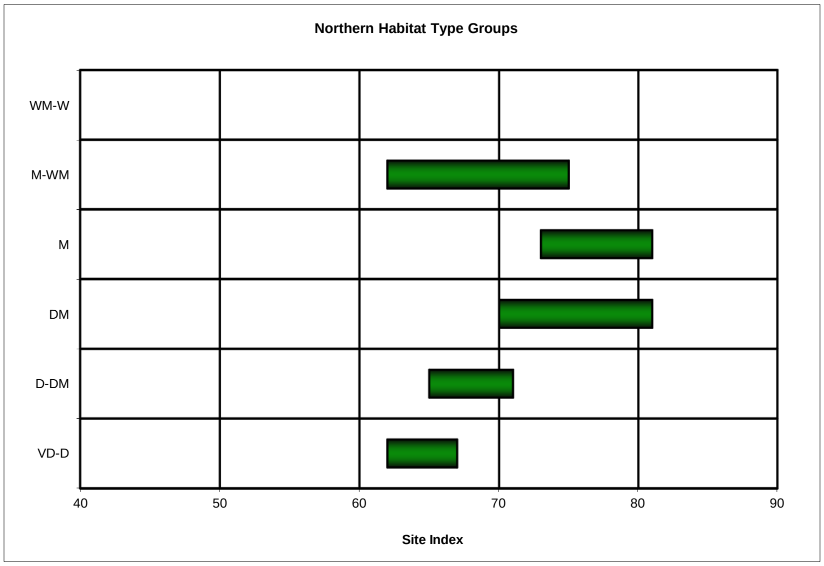

Figure 32.7. Site index for red pine by northern habitat type groups (from 1996 FIA). Bars indicate the 95% confidence limits for the mean. FIA data was insufficient to develop site index values for all habitat type groups.

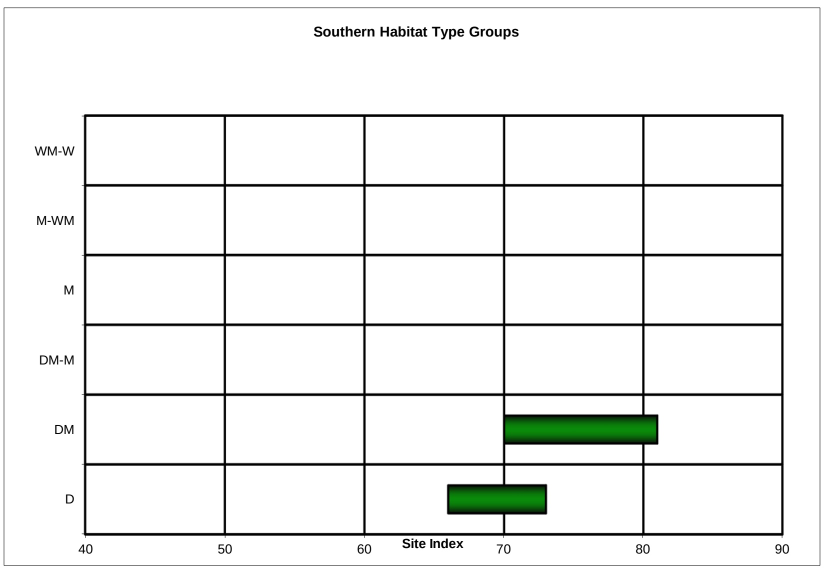

Figure 32.8. Site index for red pine by southern habitat type groups (from 1996 FIA). Bars indicate the 95% confidence limits for the mean. FIA data was insufficient to develop site index values for all habitat type groups.

Table 32.5. Red pine cover type – estimated relative growth potential by northern habitat type group and habitat type.

Northern Habitat Type Groups	Estimated Relative Growth Potential for Red Pine Cover Type[1]				
	Fair	Good	Good to Excellent	Excellent	Excellent[2]
Very Dry to Dry	PQE PQG PQGCe	PArV PArV-U PArVAo QAp			
Dry to Dry-mesic			PArVHa PArVAm PArVAa PArVAa-Vb PArVAa-Po PArVPo		
Dry-mesic				AVVb AVDe AVCI AVb-V AVb	TFAa ACl AAt ATFPo
Mesic					AFVb ATM ATFD ATFSt AAs ATD ATDH AHVb AFAd AFAl ACaCi AOCa AH
Mesic to Wet-mesic, and nutrient poor		PArVRh ArVRp ArAbVCo ArAbVC			
Mesic to Wet-mesic, and nutrient medium to rich	The red pine cover type generally does not naturally occur on these sites. Once established, growth potentials are generally good. Habitat types: ArAbSn, ArAbCo, TMC, ASnMi, AAtRp, ATAtOn, ASaI, ACaI, AHI				
Wet-mesic to Wet	Red pine will not survive and grow in most lowlands, and does not naturally occur. All sites – no habitat types – nutrient poor organics, to mineral swamps, to rich alluvial bottomlands.				

1 – Estimation of relative growth potential for red pine cover type based on:
red pine cover type average volume/acre, red pine site index, and potential tree vigor and form.
2 – Excellent growth potential once established, however the cover type generally does not naturally occur on these sites.

Table 32.6. Red pine cover type – estimated relative growth potential by southern habitat type group and habitat type.

Southern Habitat Type Groups	Estimated Relative Growth Potential for Red Pine Cover Type[1]		
	Good	Excellent	Excellent[2]
Dry	PEu PVGy PVCr PVG PVHa		
Dry-mesic		ArDe-V ArDe ArCi ArCi-Ph AArVb AQVb-Gr	AArL
Dry-mesic to Mesic			AFrDe AFrDeO ATiFrCi ATiFrVb ATiDe ATiDe-Ha ATiDe-As
Dry-mesic to Mesic (phase)			AFrDe(Vb) ATiFrVb(Cr) ATiCr(O) ATiCr(As) ATiDe(Pr)
Mesic (phase)			ATiFrCa(O) ATiAs(De)
Mesic			ATiSa-De ATiSa ATTr AFTD AFH ATiFrCa ATiCa-La ATiCa-Al ATiCa ATiH AFAs-O AFAs
Mesic to Wet-mesic	PVRh		
Mesic to Wet-mesic	No habitat types defined. The red pine type generally does not naturally occur on these sites. Once established, growth potentials are generally good.		
Wet-mesic to Wet	Red pine will not survive and grow in most lowlands, and does not naturally occur. All sites – no habitat types – nutrient poor organics, to mineral swamps, to rich alluvial bottomlands		

1 – Estimation of relative growth potential for red pine cover type based on:
red pine cover type average volume/acre, red pine site index, and potential tree vigor and form.
2 – Excellent early growth potential once established, however the cover type generally does not naturally occur on these sites. Many of these sites occur outside of or near the natural range limits of red pine. Long-term growth, productivity, and tree health are uncertain.

3.2.5 Wildlife

Red pine provides habitat and shelter for wildlife. Young stands are used primarily for shelter. Older stands with closed canopies provide thermal cover. Seeds of red pine can be an important food source for some mammals and birds. Because red pine is a long-lived tree it can serve as a legacy during either natural or artificial stand regeneration. Individual trees or small groups can be important to many wildlife species as nesting platforms or as cavity producers.

Red pine generally grows with associates in natural stands. Wildlife species will benefit from management practices that attempt to simulate natural conditions. Management of natural stands of red pine should recognize the contribution to wildlife of the associated species while maintaining vigor and health of the red pine in the stand.

Plantation management of red pine has often been conducted on open sites and the resulting stands have been relatively simple. Encouraging the development of structural complexity in red pine plantations will benefit wildlife. The presence of ground and shrub layer vegetation in red pine stands in central Wisconsin increased the use of this habitat type by deer, ruffed grouse, and songbirds. Both vertical and horizontal structure can be increased during planting and subsequent treatments. Variable density thinnings with gap establishment will encourage recruitment of multiple layers of vegetation within the plantation. Retention of individuals or small clumps of mature red pine at the time of stand regeneration will increase the value of the plantation to wildlife species; however, disease problems (i.e. *Sirococcus* and *Diplodia*) can occur when red pine seedlings are establishing under mature red pine.

Tree species diversity within red pine plantations is desirable for wildlife. This species diversity can be planned during plantation establishment or encouraged during subsequent thinnings. A mix of species including hardwoods can be planted at the time of stand establishment. In many cases, other species of trees or shrubs can be allowed to remain after establishment of a new stand. Regardless of the source, favoring mast producing shrubs and trees will have the highest value to wildlife dependent on this food source.

<u>Recommendations:</u>

- Increase compositional (species) diversity within stands
    - When establishing plantations include a component of other species either directly or through allowing tree species already present to remain.
        - New plantations should have some areas of different vegetation, either openings allowed to regenerate naturally or intentionally planted clumps of different appropriate species.
        - Large plantations should maximize the amount of interface between the plantation and other vegetation types.

    - During intermediate treatments, maintain species diversity. In homogeneous plantations, consider creating some gaps or patches to recruit natural regeneration of other species. Variable density thinning can facilitate the variable recruitment of understory species.

- Increase structural diversity within stands
    - Develop and maintain large trees, cavity trees, snags, and coarse woody debris
        - Retain both living and dead legacies during stand rotations.
        - Retain wildlife trees during intermediate treatments.
    - Employ variable density thinning to establish structural complexity within planted stands.
- Manage some stands on extended rotations to develop both stand and landscape compositional and structural diversity.
- Develop and successfully apply methods to naturally regenerate red pine, either in natural stands or in plantations nearing rotation age.

3.2.6 Endangered, Threatened and Special Concern (ETS) Species

Several uncommon species are associated with pine and mixed pine forests (e.g. see northern dry-mesic forest community in the Wisconsin Wildlife Action Plan (https://dnr.wi.gov/topic/wildlifehabitat/actionplan.html). Maintaining a conifer component in the landscape is important for biodiversity. However, pine plantations are ecologically deficient in numerous ways compared to native forest communities.

The most important rare species-related consideration for this type is whether or not to establish or re-establish a plantation on a given site. Planting pine will reduce or eliminate habitat, at least temporarily, for the vast majority of the species comprising Wisconsin's biological diversity, as few species utilize plantation habitats compared to other forest types. Therefore, consideration should be given to biological hotspots, rare community types such as prairie/barrens remnants, and other ecologically important areas when locating and designing plantations. In general, barrens and prairie communities should be avoided whenever possible when establishing plantations, as there are numerous rare species associated with these types (see "Landscape Considerations" for more information regarding plantation siting). Where plantations already exist, there are some techniques can increase community diversity and improve habitat for certain species.

In both natural and planted stands, various stand and landscape-level considerations are important for maintaining habitat for rare species. The "Landscape Considerations" and the "Wildlife Management Considerations" sections outline numerous opportunities to enhance forest diversity and improve species habitat; these include retaining structural legacies, improving forest structural and species diversity, using fire as a management tool, managing for patches of older forest, and considering the stand in the broader landscape context. In addition, rare species can sometimes be accommodated by protecting special habitats such as cliffs, rockslides, prairie/savanna openings, and vernal features.

Considering a broad suite of ecological factors for a site, including its relationship to the surrounding landscape, can enrich the overall forest for many species and improve their chances for survival. In certain cases, however, managers may need to consider accommodating a single rare species known from an area. For example, certain rare plants associated with barrens and prairie habitats may be found in areas where plantations have already been established. By providing adequate sunlight and avoiding herbicide or other treatments that might eliminate these plants, these species can be accommodated, at least for the short term. The table at the end of this section provides some examples, but other sources should be referenced. Usually modifications designed to accommodate a species can be designed to achieve multiple benefits.

Rare animals occupying red pine forest are mostly found in young (1 to 10 years) and older (> 50 years) forests. Pine-dominated forests in the oldest age classes are currently lacking across most of the state. Rare plants associated with red pine are generally found in stands of natural origin with certain characteristics. Special consideration related to the amount of shade, soil disturbance, and use of herbicides may be needed to maintain habitat for these plants.

Structural Retention at the Time of Regeneration Harvest

Retaining structural features from the original red pine stand, such as large vigorous trees, cavity trees, snags, and coarse woody debris can enhance structural complexity. Structural retention is modeled on the biological legacies that remained after natural forest disturbances. Even under the most intense historical fires many individual trees and groves survived. Consider retaining reserve trees and snags in even aged prescriptions to provide habitat.

Little quantifiable data exists on how much structure to retain. Developing standard prescriptions would require thorough analyses of species-specific requirements and response to various treatments. In general, retention of old trees can provide benefits such as distinctive architecture with large branches that are used as movement corridors or the foundation for large nests, cavities (both present and future), diverse habitats for insects and spiders which provide the prey base for vertebrates, and maintenance of diverse fine root and fungi systems in the soil.

Identify Special Habitats

Many rare species are limited in their distribution to microhabitats within larger blocks of forest. Habitats such as cliffs, vernal or ephemeral pools, seeps or springs, rock outcrops, or prairie/savanna remnants may harbor rare species. As only a portion of Wisconsin’s rare species populations have been documented to date, management of these habitats is important to allow undocumented species to persist or for future species to colonize these areas. Often special habitats can be protected while achieving other silvicultural goals such as the retention of biological legacies (see Chapter 24 for more information).

Cliffs may require one of two different approaches, depending on their physical characteristics and the species present. For moist cliffs, sometimes exhibiting seepage flow, modify harvests near the feature to maintain shading and moisture for species requiring those characteristics. For dry cliffs with species requiring more open conditions the removal of shade, especially by removing trees from the base of the cliff, may greatly improve microhabitats.

Vernal features such as ephemeral ponds are uncommon on the sandy sites where natural red pine stands are typically found. Shade should be retained on pools found within forests, – e.g., see the Northern Hardwoods chapter for a discussion. In many cases, pine plantations have been established on former prairie/barrens sites that were regularly affected by fire such as those found in the Northwest Sands. In these areas, there may be benefits to greatly reducing shade around vernal pools, as they may contain species adapted to more open conditions.

Biological hotspots such as bird rookeries, bat hibernacula, herptile hibernacula, and migratory bird concentration areas can harbor many rare species. These hotspots can be permanent as with hibernacula, or ephemeral in the case of rookeries. Different strategies may apply, depending on the situation. In any situation when these hotspots are encountered, consultation and advice from wildlife or endangered resources specialists should be sought.

Historically, natural and anthropogenic fires occurred across Wisconsin's landscapes for at least a few thousand years. Fire disturbance of low to moderate intensity and frequency was key to maintaining the northern dry-mesic forest type in the past. Prescribed Fire may reduce competition from broadleaf trees and shrubs while improving habitat for other plant species associated with these forests. These species populations can be greatly enhanced by use of fire, often in combination with understory removal.

Adaptive management is important, because many aspects of endangered and threatened species management are not precisely known, and managers need to rely on the best available information for species life history or ecological disturbance patterns. Information on rare species' responses to silvicultural techniques in working forests is notably lacking. Documenting the different approaches used by foresters across the state can benefit other managers and biologists and to help to better inform conservation efforts in the future.

Table 32.7. Select rare species that can be associated with red pine stands, their general habitat preferences, and sample management considerations for which they may benefit. These are meant as broad considerations for planning purposes, rather than avoidance measures; please consult additional sources for life history information. The species list is not meant to be exhaustive.

Rare Species	Habitat	Mgmt Considerations
	Plant Species	
Large Round-leaved Orchid- *Platanthera orbiculata - SC*	Acid soils areas with little competition such as heavy pine duff. Most often seen in older pine forests.	Extended rotation or old-growth management.
Hooker's Orchid – *Platanthera hookerii -SC*	Acid soils areas with little competition such as heavy pine duff. Most often seen in older pine forests.	Extended rotation or old-growth management
Dwarf Milkweed – *Ascelpias ovalifolia - T*	A barrens species occasionally also found in older native red pine forest in Jackson County. Sometimes uses brushy openings, roadsides, and rights-of-way.	No landings on populations. Provide open patches for sunlight.
Crinkled Hairgrass (*Deschampsia flexuosa*)	Pine forests and barrens, mostly near the Great Lakes	Provide open patches or manage near minimum stocking levels.
Giant Rattlesnake Plantain – *Goodyera oblongifolia – SC*	Scattered locations under Apostle Islands red pines.	Park rules guide management where it has been found.

Rare Species	Habitat	Mgmt Considerations
Purple Clematis - *Clematis occidentalis* - SC	Cool forests (usually mixed conifer-hardwoods), often on cliffs and ravines with igneous rock (basalt, quartzite).	Seems to occur in less dense areas within known habitat; open patches may be beneficial.
Giant Pinedrops - *Pterospora andromedea* – E	Known only from white pine stands in WI, but has been found in dry forests with other conifers in MI.	Extended rotation or old-growth management
Animal Species		
Northern Prairie Skink - *Eumeces septentrionalis – SC*	Barrens in Northwest Sands. Will inhabit 1 to 10 year old red pine plantations.	Maintain diverse ground layer composition.
Bullsnake – *Pituophis catenifer – SC*	Barrens in Northwest Sands, Central Sand Plains and Western Coulee and Ridges. Will inhabit 1 to 10 year old red pine plantations.	Maintain diverse ground layer composition.
Sharp-tailed Grouse – *Tympanuchus phasianellus – SC*	Barrens in Northwest Sands. Will inhabit 1 to 10 year old red pine plantations.	Maintain diverse ground layer composition.
Northern Goshawk – *Accipiter gentilis – SC*	Occasionally nest in old red pines	Follow forest raptor protocols.
Bald Eagle – *Haliaeetus leucocephalus – SC*	Occasionally nest in old red pines	Follow Bald Eagle management guidelines
Whip-poor-will – *ECaprimulgas vociferous - SC*	Mature pine and oak woods.	Extended rotation and landscape planning
Insect Species		
Rocky Mountain Sprinkled Grasshopper – *Chloealtis abdominalis - SC*	Dry pine forests and barrens. Will inhabit 1 to 10 year old red pine plantations.	Maintain diverse ground layer composition.
Huckleberry Spur-throat Grasshopper – *Melanoplus fasciatus - SC*	Dry pine forests and barrens. Will inhabit 1 to 10 year old red pine plantations.	Maintain diverse ground layer composition.

4 STAND MANAGEMENT DECISION SUPPORT

4.1 Stand Inventory

Prior to development and implementation of silvicultural prescriptions, landowner property management goals need to be clearly defined and articulated, management units (stands) must be accurately assessed, and landowner stand management objectives should be detailed. In-depth and accurate stand assessment will facilitate discussion of stand management options and objectives within the context of realistic and sustainable property management goals.

Red pine stand assessment should include quantifying variables such as:

- Present species composition

- Canopy, shrub, and ground layers
- Sources of regeneration
- Potential growth and competition

- Stand structure
  - Size class distribution and density
  - Age class distribution

- Stand and tree quality
- Site quality - The habitat type is the preferred indicator of site potential. Other indicators of site potential include site index, soil characteristics, and topographical characteristics. Site has a strong influence on volume growth and potential yield.
- Stand and site variability

4.2 Key to Recommendations

Note: The following recommendations assume the management objective is to maximize tree vigor and stand growth to optimize productivity (quantity and quality) of a variety of timber products.

Table 32.8. Management options based on stand conditions.

A. Seedling/Sapling Stands (<5" DBH)

1. Fully stocked stands (400-1000 TPA) or overstocked stands	Maintain 400 to 1000 TPA that are vigorous and free-to-grow. When needed, release operations are recommended to control competition and maintain tree vigor.
1. Understocked stands (<400 TPA)	Interplanting will be necessary and should be implemented within the first two years of initial planting. Control competing vegetation, and interplant red or white pine seedlings. If beyond two years in the ground, then site prep and replant.

B. Poletimber and Sawtimber Stands (≥5" DBH)

1. Fully stocked stands or overstocked stands	**2**
1. Understocked stands	**5**
2. Poletimber – first thinning	**3**
1. Poletimber – previously thinned, or Sawtimber	**4**
3. Distinct rows	Review thinning guidelines. Determine if a thinning could be recommended. If a thinning will not be recommended, then determine a date for future reassessment of growth and thinning opportunity.

	If a thinning will be prescribed, then determine target residual basal area. Follow guidelines for "**Mechanical Row Thinning** or **Mechanical Row and Low Thinning**"
3. Indistinct rows or natural stands	Review thinning guidelines. Determine if a thinning could be recommended. If a thinning will not be recommended, then determine a date for future reassessment of growth and thinning opportunity. If a thinning will be prescribed, then determine target residual basal area. Follow guidelines for "**Mechanical Strip and Low Thinning**"
4. Poletimber – previously thinned	Review thinning guidelines. Determine if a thinning could be recommended. If a thinning will not be recommended, then determine a date for future reassessment of growth and thinning opportunity. If a thinning will be prescribed, then determine target residual basal area. Apply **crop tree selection** and **standard order of removal** criteria.
4. Sawtimber	Review thinning guidelines. Determine if a thinning could be recommended. If a thinning will not be recommended, then determine a date for future reassessment of growth and thinning opportunity. If a thinning will be prescribed, then determine target residual basal area. Apply **crop tree selection** and **standard order of removal** criteria. If first thinning, consider adaptations for equipment access. Harvest at rotation age.
5. Landowner objectives include red pine management, and the site is suitable for red pine management.	Cut overstory, prepare site, and replant to red pine. When harvesting and replanting red pine, consider waiting two years before replanting to reduce risk of seedling damage from insect infestations
5. Landowner objectives indicate a preference for other feasible cover types, or the site is not suitable for red pine management.	Convert to another cover type; apply artificial or natural regeneration methods. If planting to other pine, consider waiting two years before replanting to reduce risk of seedling damage from insect infestations

5 SILVICULTURAL SYSTEMS

A silvicultural system is a planned program of vegetation treatment during the entire life of a stand. All silvicultural systems include three basic components: intermediate treatments (tending), harvesting, and regeneration. For red pine stand management, even-age management is recommended.

- Periodic thinnings based on basal area control are recommended.
- Artificial regeneration is the most reliable and most commonly practiced method to regenerate stands. Proper site selection, site preparation, and competition control are important for artificial regeneration to be successful.

5.1 Seedling / Sapling Stands

Efficient and successful stand establishment, and maintenance of early growth and productivity have a disproportionate effect (as compared to later intermediate treatments) on timber productivity over the rotation.

Stocking should be maintained between 400 and 1000 well distributed trees per acre. Sapling crop trees may be most productive with ≥50 ft^2 of growing space.

If mortality becomes excessive and minimum stocking levels are not maintained, then reinforcement planting will be necessary and should be implemented within the first two years of initial planting. Control competing vegetation, and interplant red or white pine seedlings. If beyond two years in the ground, then site prep and replant.

Once established, red pine seedlings and saplings generally exhibit optimal vigor (growth and health) when exposed to (near) full sunlight. Crop trees that are maintained in free-to-grow conditions have the greatest potential to maximize growth and productivity. When needed (before seedlings become overtopped), release operations are recommended to control competition and maintain tree vigor.

- Cleaning (sometimes termed precommercial thinning) overstocked stands will maintain crown development and diameter growth rates.
- Liberation can reduce shade cast by older, overtopping trees; however, retaining reserve trees of other species is recommended (see Chapter 24).
- Weeding can control undesirable vegetation (e.g. exotic species or competing shrubs and herbs)

5.2 Intermediate Treatments

5.2.2 Thinning

<u>Basic Concepts</u>

Intermediate treatments generally are designed to enhance tree growth, health, and quality, and stand composition, structure, and value. Thinning is a cultural treatment conducted in stands past the sapling stage to reduce stand density. It entails the removal of trees to temporarily reduce stocking to concentrate growth on the more desirable trees. Thinning can impact stand growth, compositional and structural development, and economic yield. It provides the main method, implemented between regeneration and final harvest, to increase the economic productivity of stands. Normal thinning does not significantly alter the gross production of wood volume.

Objectives of thinning include any of the following:

- Enhance the vigorous growth of selected trees through the removal of competitors. Larger diameter, more valuable trees can be grown in a shorter period of time.
- Enhance tree health. Thinning maintains tree vigor and strength and anticipates losses.
- Harvest most merchantable material produced by the stand during the rotation. Trees that would die from competition are harvested and utilized for timber products.

Application of thinnings can increase economic yields:

- Harvest anticipated losses of merchantable volume.
- Yield of income and control of growing stock during rotation.
- Increased value from rapidly growing larger diameter trees.
- Increased value from improvements in product quality.

A schedule of thinning for a stand should identify the thinning methods to be used, the intensity of application, and when thinnings will occur. Thinning schedules should be systematically and carefully developed because the effects of these cultural practices will be manifested in future growth and development and will influence future management options.

Stocking charts (Figure 32.10 Figure 32.9) generally guide density management during intermediate thinning treatments. In managed red pine stands, maintain stocking between the A-line and B-line on the stocking chart. Do not allow stand density to surpass the A-line, and do not reduce stand density to below the B-line. Within this range (between A- and B-lines), trees fully utilize (occupy) the site, and stand growth and merchantable board-foot volume yield are optimized. Thinning can occur at any time and stocking managed at any level as long as stand density is maintained between the A- and B-lines.

Advantages of higher residual thinning densities in red pine stands:

- Increased options for crop tree selection.
- Potential to reduce size and persistence of branches on lower bole.
- Potential to reduce stem taper. Taper is self-correcting over time, as the crown moves upwards and height growth declines.
- Greater flexibility for responding to mortality and pest problems.
- Products – increased yields of smaller diameter products and poles.
- Increased cubic foot volume growth rates of young stands.

Advantages of lower residual thinning densities in red pine stands:

- Increased crown vigor and tree diameter growth rates.
- Concentrates growth on best quality trees.
- Products – increased sawtimber production at younger ages.
- Better development of shrub and herb layers and increased within stand compositional and structural diversity.

The effects of thinnings are temporary. After each thinning, the remaining trees grow taller, diameters increase, crowns expand, and canopy gaps close; stand density increases. Periodic thinnings can maintain crown vigor and accelerated diameter growth rates of crop trees. Factors to consider in determining when to conduct further thinning operations include: stocking, diameter distribution and growth rates, crown development and vigor, timber yields and economics, landowner goals and stand management objectives.

Thinnings – Timing and Intensity

Refer to stocking chart (Figure 32.10). Maintain stocking between the A-line and B-line. Thinning can occur at any time as long as stand density is maintained between the A- and B-lines. The A-line is not a thinning “trigger.” When to thin depends on management objectives, stand conditions, and operability.

Typically, thinning is implemented when basal area stocking is at or above the midpoint between the A- and B-lines, but before stand density reaches the A-line. Reduce stocking to a density near the B-line, choosing a residual basal area that will accommodate landowner objectives. A general rule of thumb is do not remove >50% of the basal area in any one thinning operation.

Overstocked stands (greater than A-line stocking), where thinnings have been delayed, may be comprised of tall, thin, small-crowned trees that are susceptible to wind, snow, and ice damage following heavy thinning. In these stands, to develop tree vigor and strength, thin lightly and frequently, with increasing intensity, for the first several thinnings, until target residual densities are achieved. A general rule of thumb is do not remove >33% of the basal area during the initial thinning.

Standardized thinning regimes (simplified, general guidelines) aim to sustain consistent growth and productivity throughout the rotation, and to produce a variety of timber products from thinnings and final rotational harvest.

- Poletimber (5-9 inches dbh)
  - Typically operable when basal area is 100-180 sq. ft. per acre
  - As a general guide, reduce basal area to slightly above the B-line, to 70-110 sq. ft. per acre; 90 sq. ft. per acre can provide a standard target residual basal area.

- Small sawtimber (10-15 inches dbh)
  - Typically operable when basal area is 140-200 sq. ft. per acre
  - As a general guide, reduce basal area to slightly above the B-line, to 100-140 sq. ft. per acre; 120 sq. ft. per acre can provide a standard target residual basal area.

- Large sawtimber (>15 inches dbh)
  - Typically operable when basal area is 160-220 sq. ft. per acre
  - As a general guide, reduce basal area to slightly above the B-line, to 110-160 sq. ft. per acre; 140 sq. ft. per acre can provide a standard target residual basal area.

Thinnings are usually implemented every 8-12 years in young pole-sized stands and every 10-20 years in older sawtimber stands.

An important consideration when thinning red pine stands is the identification and control of Annosum root rot and red pine pocket mortality. For Annosum root rot, prevention is key. A new infection site primarily originates when spores land on freshly cut stumps; the fungus also spreads through root contact and root grafting. If Annosum is not present in the stand, consider treating freshly cut stumps with a fungicide (e.g. “Sporax,” “Cellu-Treat”) to prevent new infections. If Annosum is present in the stand, follow detailed Forest Health Protection guidelines.

Red pine pocket mortality is apparently caused by a complex of insects and the fungi *Leptographium*. Pockets typically start small with one to a few dead trees surrounded by trees that have reduced shoot growth and thin crowns. Each year, a few trees on the pocket edge may die and the edge of the pocket expands. *Leptographium* spp. move below ground through root contact and the pocket expands about 1 chain every 10 – 15 years. Cut dead trees and trees that are showing dieback and/or yellowing of the foliage within and adjacent to the pocket; consider cutting a buffer area of healthy trees around the pocket. As long as total pocket area is not excessive, pockets can be treated as natural openings to provide habitat diversity. See the following section, Forest Tree Health Management Guidelines for Red Pine, for additional information and references.

<u>First Thinning – Methods</u>
At least 400 trees per acre are required to provide minimum recommended stocking when stands reach poletimber size (B-line stocking when average dbh of trees in stand is 5 inches). Most red pine stands reach the poletimber size class in 15-30 years following planting; the first thinning generally occurs at the age of 20-25 years, when the trees are poletimber sized and merchantable products can be harvested.

- Plantations with distinct rows
    - Mechanical row thinning
        - Mechanical row thinning is an efficient method for the first thinning. Every other row or every third row is mechanically removed. The space created within the cut rows should be wide enough to accommodate processors and forwarders. Maintain stocking between the A-line and B-line, as recommended in the preceding discussion of thinning intensity.

    - Mechanical row and low thinning
        - Mechanical row and low thinning methods can be integrated for the first thinning. Every fifth row is mechanically removed, and a low thinning is applied within the remaining rows. The space created within the cut rows should be wide enough to accommodate processors and forwarders. Maintain stocking between the A-line and B-line, as recommended in the preceding discussion of thinning intensity.

- In very dense plantations where removal of individual rows will not provide access strips of sufficient width to accommodate equipment (processors and forwarders), then alternatives are:
  - Mechanical row thinning, removing two adjacent rows and retaining two adjacent rows.
  - Mechanical row thinning and low thinning, removing two adjacent rows and retaining five rows. To achieve target residual basal area stocking, a low thinning is conducted within the retained rows.

Maintain stocking between the A-line and B-line, as recommended in the preceding discussion of thinning intensity.

On steep topography with equipment limitations, where rows were planted on the contour, follow guidelines for "Plantations with Indistinct Rows," running the access strips up and down the slope.

Plantations with Indistinct Rows and Natural Stands – Mechanical Strip and Low Thinning

In plantations where rows are indistinct and in natural stands, mechanical strip thinning combined with low thinning is recommended. Access strips of sufficient width for mechanized access are systematically designated and cut throughout the stand. Depending on equipment needs and expectations, cut access strips generally are 10-15 feet wide. Typical spacing of cut access strips is every 50-60 feet. To achieve target residual basal area stocking, a low thinning is usually conducted within the leave strips. Maintain stocking between the A-line and B-line, as recommended in the preceding discussion of thinning intensity.

Subsequent Thinnings - Methods

Free thinnings that integrate low and crown thinning techniques are recommended (see Chapters 23 and 24).

Select crop trees for retention based on retention criteria:

- Low risk of mortality or failure (main stem breakage)
- Good crown vigor
  - Dominant or codominant trees
  - Good silhouette and healthy needles
  - Good crown/length ratio – live crown ratio >30% will provide best response to thinning

- Good stem quality
- Desirable species

Trees may also be selected for retention to achieve other objectives, such as aesthetics or wildlife management.

Select trees to cut, following the standard order of removal:

- High risk of mortality or failure (unless retained as a wildlife tree)
- Release crop trees

- Low (lower) crown vigor
- Poor (poorer) stem form and qualit
- Less desirable species
- Improve spacing

Alternatively, thinnings can be either low thinnings or crown thinnings, depending on assessment of tree and stand growth and mortality. Low thinnings are most applicable in early thinnings, particularly poletimber stands. Low thinnings mostly remove slower growing and higher risk trees (suppressed, intermediate, and poor codominants); heavy low thinning is recommended in order to provide some release to the crowns of crop trees. Crown thinnings mostly remove lower vigor, poorer quality canopy trees in order to favor (release crowns of) the best trees in the dominant and codominant crown classes.

5.2.3 Prescribed Fire

Prescribed surface fire in mature red pine stands can be an effective management tool for eliminating shrub competition, reducing thick duff layers, and preparing mineral seedbeds. Young stands of red pine 1-49 years, are susceptible to damage and mortality, however, once the tree reaches 60 feet tall (roughly 50 yrs old), the bark is thick enough to protect the cambium and crown from extreme fire damage (Rouse 1988). Burning is a less expensive alternative to other site preparation techniques, however, due to the risk and related liability issues it may not always be the best method. Depending on the type and intensity of the burn, some very intense burns may cause some damage to the tree and affect its merchantability. Burning, soon after timber harvest with available slash fuel, can be an effective tool to reduce competition from undesirable trees and shrubs. Growing season fires, conducted repeatedly over several (2-4 years) growing seasons, have been effective at controlling dense shrub (hazel) competition and exposing mineral soil (Buckman 1964). The reduction in hazel abundance in stands receiving several growing season burns can last many decades. Burning can also be an effective at exposing the mineral soil and nutrient availability for an adequate seedbed. Slow-burning, cool fires can reduce slash and needle duff, expose soil providing better seedbed conditions for germination.

5.2.4 Pruning

Pruning is a silvicultural practice that can be applied to improve log quality and value; it is implemented to promote the growth of clear, knot free wood on the first log. It is a relatively labor intensive and costly practice, implemented in young stands, and economic returns are not realized until (near) the end of the rotation. The financial efficacy of pruning is questionable.

Knots are created by branches and can degrade log quality. Factors related to log quality and branching include the number of branches, the size of branches, and the persistence of dead branches. In red pine, the size and persistence of branches is somewhat influenced by stand density.

In dense stands, red pine self-prunes comparatively well. In open stands, trees retain lower branches longer, branches grow larger in diameter, and dead branches persist longer. Pruning can be applied to improve log quality, particularly in stands that are managed at lower density to accelerate diameter growth rates. Combining pruning and aggressive thinning can facilitate the production of increased value in a shorter period of time.

If pruning red pine trees, prune only 50-150 potential crop trees per acre, and only on good to excellent sites. Generally, trees are pruned to 17 feet (the first log) in 2-3 pruning operations. Often, the first pruning is to 9 feet when trees are 18-20 feet tall. Always maintain a crown/stem ratio of at least 50% (at least 50% of total height occupied by crown).

Chapter 23 provides further guidance on pruning.

5.2.5 Planting Density

Chapter 22 provides guidelines for artificial regeneration and includes species specific considerations. Efficient and successful stand establishment is critical to long-term growth and productivity. Sites must be properly prepared before planting to facilitate operations and control competition. When harvesting and replanting red pine, consider waiting two years before replanting to reduce risk of seedling damage from insect infestations. Planting density (spacing) recommendations depend on many factors, including management objectives, silvicultural practices planned, and planting conditions.

Recommended planting densities range from 500-1000 trees per acre (TPA). At least 400 well distributed TPA are required to provide minimum recommended stocking when stands reach poletimber size (≥5 inches dbh); in general, most stands reach the poletimber size class in 15-30 years following planting. Commonly, production-oriented planting densities range from 700-900 TPA.

Advantages of higher planting densities (e.g. 750-1000 TPA):

- Partial mortality less likely to result in understocked conditions.
- Increased options for crop tree selection.
- Potential to reduce size and persistence of branches on lower bole.
- Increased cubic foot volume growth rates of young stands.
- Release – less competition from other species (less weeding)

Advantages of lower planting densities (e.g. 500-750 TPA):

- Lower planting costs.
- Increased tree diameter growth rates.
- Longer retention of abundant shrub and herb layers to enhance plant diversity
- Release – less intra-stem pine competition [less cleaning (precommercial thinning)]

When planting, consider including some species diversity to expand future management options and to provide sustainable forestry benefits. Other species can be included through integrated planting (e.g. white pine), planting patches (e.g. white pine, oak), or natural regeneration in patches (e.g. white pine, oak, birch, aspen) (see following section Managing Mixed Stands).

5.3 Natural Regeneration Methods

Silvicultural methods to regenerate red pine by natural regeneration (seed) are rarely applied. Successful natural regeneration requires a suite of coinciding factors which can be difficult to coordinate. Significant silvicultural considerations that can limit the successful establishment of natural regeneration include seed production, seedbed conditions, moisture availability during the first two growing seasons, sunlight (shade), and competing vegetation.

Shelterwood and seed tree are potential natural regeneration methods for the red pine type. However, they have been poorly studied, and success has been highly irregular. Significant silvicultural considerations include management of overstory seed sources and shade, timing to coordinate site prep and seed production, and competition control. Drought during seedling establishment can be a limiting factor. Rapid brush invasion has been one of the most important causes of failure of red pine reproduction. In addition, disease problems (i.e. *Sirococcus* and *Diplodia*) can occur when red pine seedlings are establishing under mature red pine.

Key Requirements

- Good Seed Crop
  - Very irregular, occurring on average every 3-7 years, with bumper crops every 10-12 years
  - Most seed is dispersed within 40’ during September to November
  - Seed germinates spring to early summer

- Soil Moisture
  - Moist soil throughout spring and summer is essential to germination, survival, and growth. Seedlings are very susceptible to dessication during the first growing season, and somewhat so during the second season.

- Site Preparation
  - Seedbed – bare mineral soil preferred (light pine litter acceptable)
  - Competition control

- Sunlight and Shade
  - >80% crown closure limits establishment
  - Approximately 65% crown closure recommended for initial establishment (shade facilitates moisture retention and may limit competition)
  - <60% crown closure provides best seedling growth and development for establishment (if moisture and competition are not limiting)
  - <20% crown closure provides best growth once established

- Competition Control
  - To ensure seedling survival and vigor

5.3.1 Even-Age Regeneration Methods

Shelterwood/Seed Tree Regeneration Methods

- Seeding cut alternatives
  - Strip Cut (seed tree/shelterwood hybrid)
    - Cut strips 50' wide and leave uncut strips 15'-20' wide (removes 70-80% of the overstory)
  - Shelterwood / Seed Tree
    - Recommended cut: 60% crown closure to provide seed and shading
    - Minimum cut: retain up to 70% crown closure
    - Maximum cut: retain 20-30 trees per acre to provide adequate seed coverage with a good seed crop
  - Seed trees retained are desirable species of good vigor and quality
  - Scattered seed trees and strips may be susceptible to windthrow on some sites
- Final overstory removal cut
  - When a well-stocked stand of desirable, vigorous seedlings is well established, ideally in 3-8 years
    - Well-stocked is >500 well distributed seedlings/acre remaining following overstory removal. Stocking requirements prior to overstory removal will depend on overstory density and distribution, and logging methods.
    - Well-established is 2-4 feet tall
  - Remove overstory to ≤15% crown closure to optimize growth of seedlings and saplings.
    - Retention of reserve trees is recommended
    - In general, red pine should not be retained as a reserve tree (over red pine regeneration), because of potential disease incidence (i.e. *Sirococcus* and *Diplodia*)

Recommended Natural Regeneration Process

- Overstory seeding cut, either:
  - Shelterwood cut to 60% crown closure
  - Strip cut
- Wait two or more years for crown development and understory development (sprouts and germinants of competitors)
- Monitor potential red pine seed crops
- Implement site preparation (prepare seedbed and control competition) during late summer before a good or better seed crop
- Monitor regeneration and release as needed to control competing vegetation
- Overstory removal cut
- Release as needed

Overstory Removal
In red pine stands, conditions required to implement overstory removal rarely develop. Overstory removal is an even-aged natural regeneration method implemented in stands at rotation age that removes all trees in one cut to fully release desirable advance regeneration that is well stocked and well established.

- Well stocked is >500 well distributed vigorous seedlings/acre remaining following overstory removal.
- 1000-3000 seedlings/acre prior to logging would facilitate maintenance of adequate stocking following logging damage. Logging damage to regeneration should be minimized to the extent feasible.
- Well established is 2-4 feet tall.

Retention of reserve trees is recommended. In general, red pine should not be retained as a reserve tree (over red pine regeneration), because of potential disease incidence (i.e. *Sirococcus* and *Diplodia*)

Following overstory removal, release may be needed in 1-10 years to maintain seedlings and saplings free-to grow and vigorous.

Reserve Tree Retention
At rotation, when a red pine stand is harvested, retain reserve trees (see Chapter 24).

If red pine will be regenerated, consider disease issues. *Sirococcus* and *Diplodia* can occur when red pine seedlings are establishing under mature red pine. If these diseases are a threat locally, then do not retain red pine reserve trees; do retain reserves of other species if available. Consider creating some species diversity when regenerating the stand to expand future management options.

5.5 Rotation Lengths and Cutting Cycles

Rotation Definition
In even-aged silvicultural systems a rotation is defined as the period between regeneration establishment and final cutting. The length of rotation may be based on many criteria, including culmination of mean annual increment (CMAI), target size, attainment of a physical or value growth rate, and biological condition.

Choosing an Appropriate Rotation Age
Selecting when to rotate a stand is based on multiple considerations, including landowner goals, stand condition, and expected future growth. The rotation ages provided are guidelines based on literature, empirical data, and professional experience. In application, foresters will need to regularly review stands in the field and exercise professional judgment concerning tree vigor and mortality and stand growth and productivity. Different rotation lengths can result in increased production of some benefits and reduced production of others, and landowner goals will help inform the evaluation of the benefits and costs (ecological, economic, social) associated with different forest management strategies. Below are rotation length guidelines based on three different management emphases to accommodate a variety of landowner goals.

Previous View

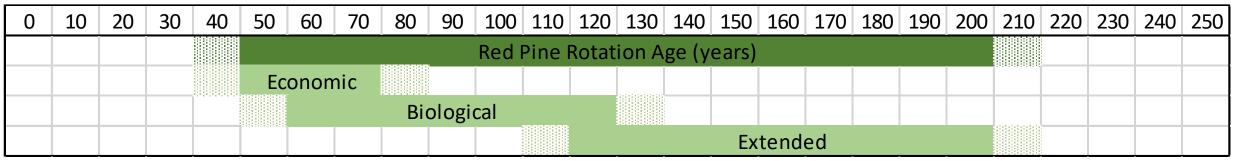

Figure 32.9. Economic, biological, and extended rotation length recommendations for red pine.

5.5.1 Economic Rotation

The economic rotation age seeks to maximize the net present value of the stand. It may only include financial (monetary) aspects but could also include non-timber benefits. The inclusion of non-timber benefits may shorten or lengthen the rotation age depending on the non-timber benefits included. Landowners who choose economic rotation ages generally want to maximize the financial performance of the stand. Economic rotations will vary depending on the target discount rate, frequency of thinnings and other factors including estimated costs and revenues. For more details on the factors that affect economic rotation age, please refer to the Economics Chapter (Chapter 62). Another consideration for plantation red pine in Wisconsin is the optimal diameter and an accurate estimate of time required to achieve it. Generally, once a red pine stand has reached its highest value product class, from a financial perspective net present value is often maximized and it is better to harvest since waiting will not add volume fast enough to compensate for the time value of money. For example, at the time this chapter was published, utility pole markets in Wisconsin were generally the highest value product class for red pines. Research on red pine in the Lake States, as well as actual stands modelled in Wisconsin, indicate that current economic rotations for well managed red pine stands are most commonly maximized between 50-70 years (Grossman and Potter-Witter 1991; Lothner and Bradley 1984; Minnesota DNR 2013; Naurois and Buongiorno 1986; Steigerwaldt 2016). Intensively managed plantations on high quality sites may reach economic rotation prior to 50 years, while unmanaged plantations and/or poor-quality sites may have longer economic rotations. Red pine markets can change and new markets, changing mill standards, or supply chain constraints may affect economic rotation ages.

5.5.2 Biological Rotation

The biological rotation seeks to maximize long-term sustained yield, or volume production. In this guideline, the range in rotation ages is defined at the lower end by the age at which maximization or culmination of mean annual increment (CMAI) growth occurs and at the upper end by the average stand life expectancy. Little objective data exists identifying these endpoints in general and even less by site type. The recommended rotations provided are our best estimates of these endpoints based on the literature and empirical data. The biological rotation range is suitable for a variety of landowner goals. Shorter rotations of 60-90 years tend to maximize cubic foot production, whereas longer rotations of 80-120 years tend to increase board foot production and may accommodate other landowner goals.

5.5.3 Extended Rotation

Extended rotation involves growing stands beyond typical biological rotation ages yet younger than average tree life expectancy, with the objective of managing for both commodity production and the development of some ecological and social benefits associated with older forests. Ecological benefits of extended rotations can include an abundance of large trees, more diverse vertical structure, and greater levels of standing snags and coarse woody debris that support organisms associated with these structures. Most natural origin stands in Wisconsin fall within this age range and are often managed on extended rotation due to their ecological importance and rarity on the landscape.

5.5.4 Flexibility in Rotation Length Guidelines

The recommended rotation ages presented here are appropriate for most stand conditions and landowner goals encountered in plantation and natural origin red pine stands. Foresters may modify these guidelines to accommodate specific stand conditions and management objectives. Modifications to these guidelines should always be scientifically sound. Some of the more common modifications include early rotations due to significant stand health concerns, modifications to regulate a species' age class distribution at the property/landscape level, and accommodations due to operability challenges. In addition, some intensively managed plantations on high quality sites may reach economic rotation and their highest value product class sooner than expected.

5.5.5 Red Pine Plantations Cultivated Outside of the Natural Range

Part of southern Wisconsin is outside of the native geographical range of red pine. On some sites, early growth can be excellent, but stand growth and tree health often decline at relatively young ages. Foresters should monitor tree vigor and mortality; as well as stand growth and productivity on these sites early. As long as vigor and productivity are maintained, continue to manage the stand following standard red pine silvicultural guidelines (i.e., intermediate treatments). If tree vigor declines significantly, stand-level mortality becomes significant, and/or productivity declines (CMAI), then rotate and convert the stand to species more suitable to the site.

5.6 Other Silvicultural Considerations

5.6.1 Managing Mixed Stands

Stands of mixed species composition, but predominantly red pine, can develop through artificial or natural regeneration. Maintaining species diversity within stands provides many potential benefits (compared to managing monocultures), including diverse sustainable forestry benefits (e.g., improved wildlife habitat), increased resilience in response to disturbance (e.g., disease outbreaks), and increased future management options. On sites where red pine most commonly occurs, common associates are white pine, jack pine, oak, aspen, and birch; successional progression tends to be toward white pine and red maple. On richer, more mesic sites, successional progression tends to be toward mesic hardwoods (e.g., maples). Within plantations where red pine is predominant, other species can be included through integrated planting (e.g., white pine), planting patches (e.g., white pine, oak), and natural regeneration in patches (e.g., white pine, oak, birch, aspen).

Mixed pine plantations with red pine predominant will be managed by even-aged systems. Planting design should consider the silvics of each species (e.g., differential growth rates), management objectives, future silvicultural practices (e.g. thinning methods and residual stocking distribution), and planting efficiencies. Species can be planted in single or multiple rows, or in complex mixtures. In most cases, mixed pine stands should be planted at a density of 700-1000 trees per acre and maintained at this stocking level while in the seedling and sapling stages. Seedlings and saplings should be maintained free-to-grow and released as necessary. Poletimber and sawtimber stands are regularly thinned based on basal area control.

Red Pine – White Pine Mixed Stands

See Chapter 31 for guidelines on white pine management. White pine is potentially somewhat longer-lived than red pine. Recommended rotation ages are similar; red pine can be rotated at younger ages, but potential extended rotations are nearly identical. In mixed red-white pine stands, rotation age can be based on either red pine or white pine guidelines; rotation ages ≥100 years are most suited for mixed stands.

In mixed red-white pine stands, both species can be maintained as vigorous associates throughout the rotation. When thinning, consider:

- Methods: In general, free thinnings will be applied; follow guidelines for crop tree selection and order of removal. Row thinning should only be applied at the first thinning if necessary for access and/or if planned for at planting.
- Timing: Thinnings are usually implemented every 8-12 years in young pole-sized stands and every 10-20 years in older sawtimber stands.
- Intensity: Target residual basal areas can be interpreted from the stocking guides; the following thinning guideline should work well: 90-100 ft^2/ac for poletimber, 120-130 ft^2/ac for small sawtimber, and 140-150 ft^2/ac for large sawtimber

Red Pine – Jack Pine Mixed Stands

See Chapter 33 for guidelines on jack pine management. Red pine and jack pine are associates, particularly on dry, nutrient poor sites; however, mixed stands may increase the risk of insect damage to red pine (e.g. root tip weevil and jack pine budworm). Jack pine is generally shorter-lived than red pine, and recommended rotation ages are shorter. In some mixed stands, red pine and jack pine will be managed together throughout a relatively short rotation (e.g. 60-70 years); this scenario is most likely when the harvest of jack pine will leave the remaining red pine stand understocked. In most mixed stands, jack pine will be harvested over several thinnings, and stands will become increasingly dominated by red pine. When thinning mixed red and jack pine stands, follow red pine thinning guidelines; the appropriateness of an initial row thinning will depend on access issues and species spatial distributions.

5.6.2 Red Pine Plantations Cultivated Outside of the Natural Range

Red pine reaches its native geographic range limit in southern Wisconsin (Figure 32.1 and Figure 32.5). Most of southern Wisconsin, as well as the central eastern zone and much of the western coulee region harbored only a few red pine community outliers. Apparently, climate, soils, and/or disturbance regimes did not favor the establishment and maintenance of red pine dominated forests.

Plantations have been established in southern Wisconsin, outside of the natural range limits for red pine. Soils typically are dry-mesic to mesic, nutrient rich, and loamy; some soils are calcareous either near the surface or in the subsoil. Long-term growth, productivity, and tree health are uncertain, but observations indicate that red pine is not well adapted to the environment, and that stands often decline at young ages.

Observations of plantation performance typically indicate excellent early growth. However, at comparatively young ages, anywhere between 20 and 60 years old, tree health and mortality problems often develop and stand growth slows or stagnates. In southwestern Wisconsin, red pine plantations often show signs of stress and decline very early, around 20-30 years old, and often by age 40-50 years growth has stagnated and significant mortality can result in understocked stands. Similar patterns of decline have been observed in southeastern Wisconsin, but signs of tree stress and stand decline generally occur in somewhat older stands. Stressed trees lack vigor, crowns may be small and thin, and the tips of branches may appear tufted (lion's tail); stressed trees may not respond to thinning. In general, many red pine stands do not remain productive (volume/acre/year) until or beyond 60 years of age, and rotation age guidelines developed for red pine in northern and central Wisconsin (within red pine's native geographic range) do not apply to the management of these stands.

All of the environmental factors causing early decline of red pine stands in southern Wisconsin have not been determined with certainty. Fine textured calcareous soils probably are a major factor. Interactions between climate, insects and diseases, and red pine growth patterns probably also contribute to declines.

<u>Management Recommendations</u>
For established red pine plantations:
- Monitor tree vigor and mortality, and stand growth and productivity
- As long as vigor and productivity are maintained, continue to manage the stand following standard red pine silvicultural guidelines (i.e. intermediate treatments).
- If tree vigor declines significantly, stand-level mortality becomes significant, and/or productivity declines (MAI), then rotate and convert the stand to species more suitable to the site. Early decline is common in red pine plantations cultivated outside of the natural range of red pine in southern Wisconsin.

If considering planting red pine (afforestation or reforestation):
- Evaluate the site and experience with red pine management on similar sites in the area.
- Evaluate the potential to regenerate other species (artificial or natural regeneration) suited to the site and native to the area.

- In general, it is not recommended to establish plantations dominated by red pine outside of the natural geographic range of red pine in Wisconsin.

8 APPENDICES

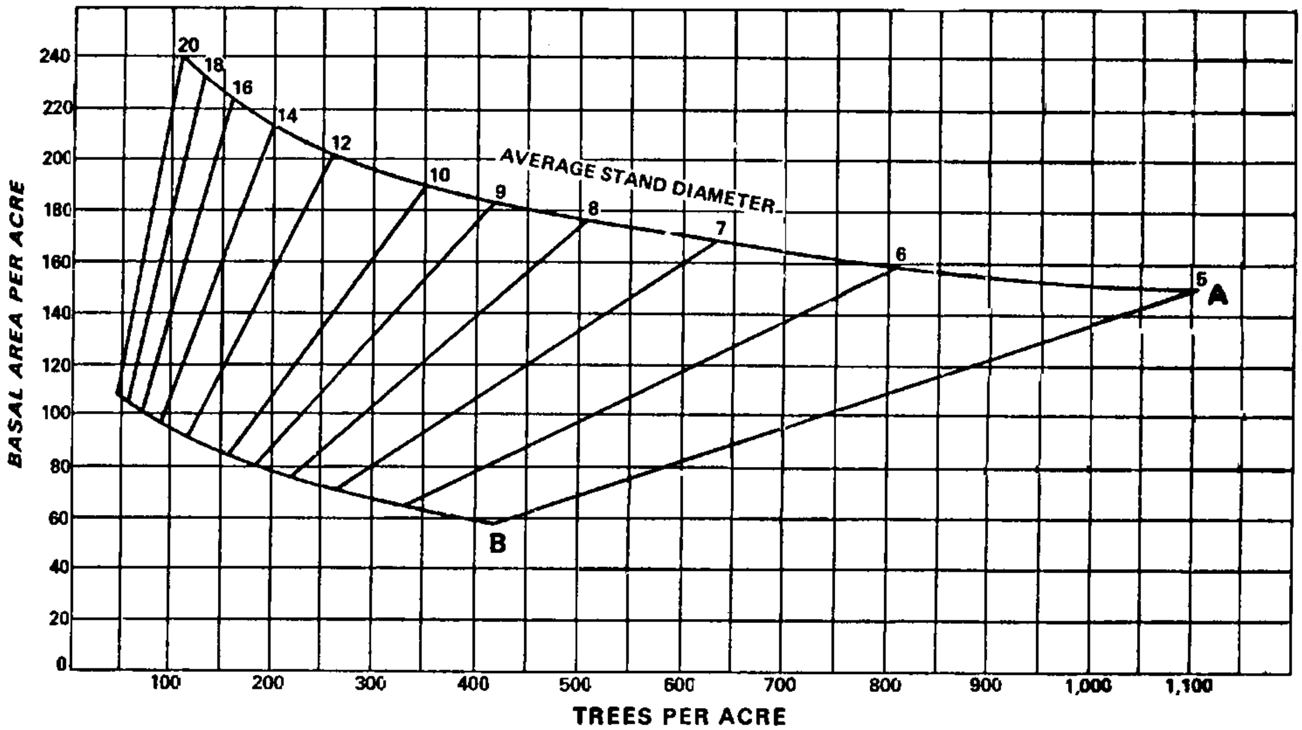

Figure 32.10. Stocking chart for red pine (Benzie 1977).

Stocking chart for red pine, displaying the relationship between basal area, number of trees, and mean stand diameter. The area between the A-line and B-line indicates the range of stocking where trees can fully occupy and utilize the site (fully stocked stand).

The stocking chart provides a statistical approach to guide stand density management (see Chapter 23).

- To utilize the stocking guide, statistically accurate estimates of at least two stand variables must be obtained, including basal area per acre, number of trees per acre, and/or mean stand diameter.
- The area between the A-line and B-line indicates the range of stocking where optimum stand growth and volume yield can be maintained.
  - The A-line represents maximum stocking. Maintaining stocking levels near (but below) the A-line will produce comparatively more trees, but of smaller diameter.
  - The B-line represents minimum stocking. Maintaining stocking levels near (but above) the B-line will produce larger diameter trees faster, but comparatively fewer trees.

- When designing and implementing a thinning regime for a stand, do not reduce stand density to below the B-line or allow it to surpass the A-line.
- Thinning can occur at any time as long as stand density is maintained between the A-line and B-line. The A-line is not a thinning “trigger.” When to thin depends on management objectives, stand conditions, and feasibility.

Typically, thinning is implemented when average stand stocking is halfway or more between the B-line and A-line. Stocking is reduced to near but above the B-line. A general rule of thumb is do not remove >50% of the basal area in any one thinning operation. Crop tree concepts are applied to retain and focus growth on desirable trees, and order of removal concepts are applied to select which trees will be cut to achieve stand management objectives.

In overstocked stands, thin lightly and frequently, with increasing intensity, for the first several thinnings, to safely develop tree crown vigor and stem strength, and until target residual densities (near the B-line) are achieved.

Previous View

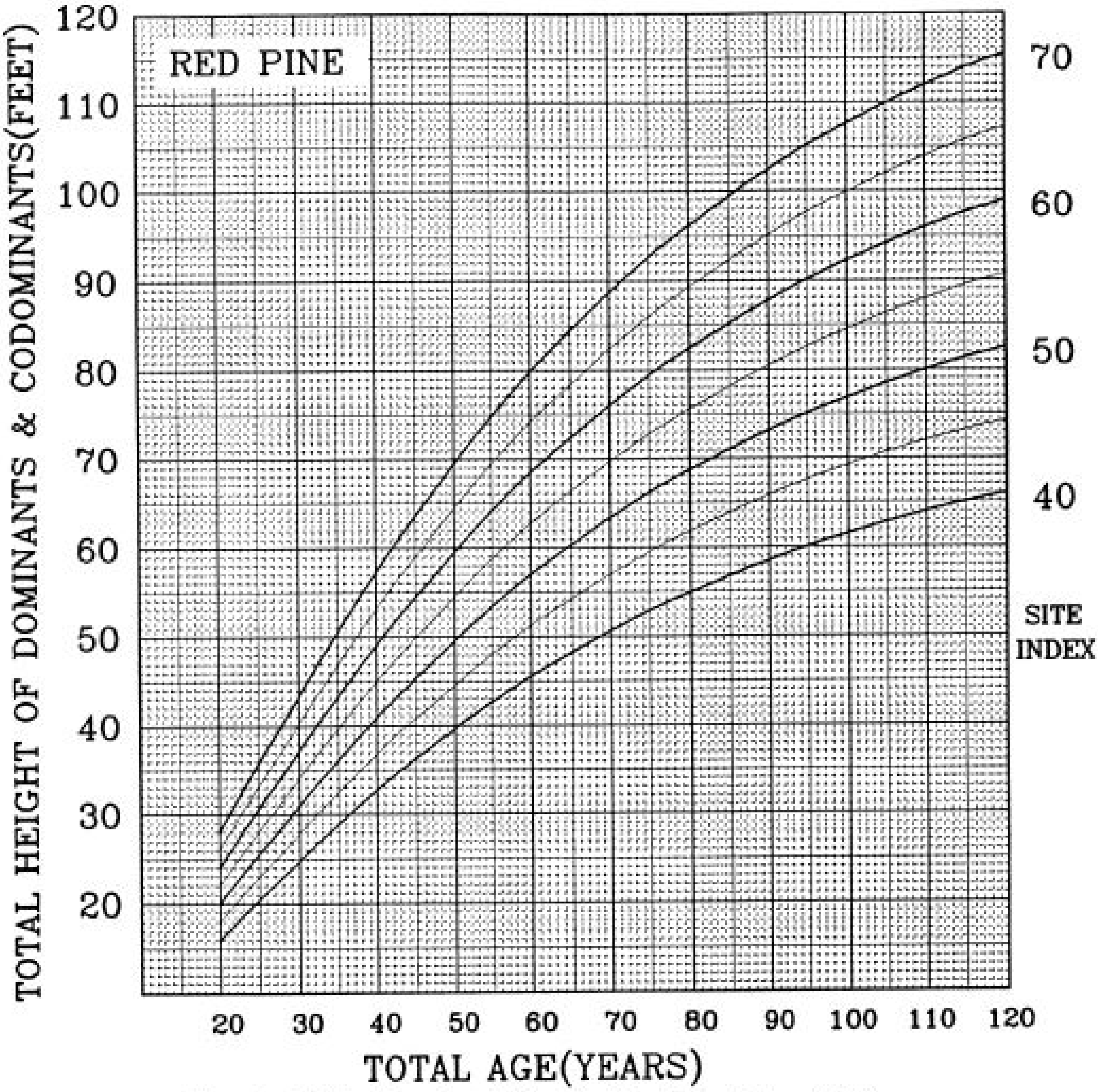

Figure 95.—Red pine (Gevorkiantz 1957c, derived from Eyre and Zehngraff 1948, and Brown and Gevorkiantz 1934)

Minnesota

Number of plots and number of dominant and codominant trees not given

Total height and total age, anamorphic, equation not given

Convert d.b.h. age to total age by adding years according to site index (BH = 0.0):

SI:	40	50	60	70+
Years:	8	6	5	4

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	1.8900	1.0000	-0.0198	1.3892	0.0000	0.99	0.64	1.4
SI	0.5291	1.0000	-0.0198	-1.3892	0.0000	0.99	0.64	1.4

Figure 32.11. Site index curves for red pine (Gevorkiantz 1957, Carmean et al. 1989).

8.1 Forest Health Guidelines - Forest Health Protection (FHP)

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
DEFOLIATING INSECTS		
Pine Tussock Moth – *Dasychira pinicola* Within the hazard zone (Douglas and Bayfield Counties), outbreaks occur every 12-15 years. During outbreaks sapling and pole sized stands can be severely defoliated in spring and early summer. Heavy defoliation of red pine is usually associated with presence of jack pine. Defoliation may cause growth loss, top kill and tree mortality.	Remove adjacent open-grown jack pine. Apply insecticides in spring. Accept defoliation and monitor for tree mortality; harvest if necessary.	
European Pine Sawfly – *Neodiprion sertifer* **Red Pine Sawfly** – *Neodiprion nanulus nanulus* Periodic outbreaks cause spring defoliation of sapling and small pole sized stands. Outbreaks are more severe prior to crown closure and in open-grown stands. Since larvae feed early in the season before new needles develop, current year's	Promote early stand closure. Apply insecticides in spring. Accept defoliation and growth loss.	

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
needles are not defoliated. Heavy defoliation for several years may cause height and radial growth reductions of 80%, but tree mortality is uncommon on healthy trees.		
Redheaded Pine Sawfly – *Neodiprion lecontei* Periodic outbreaks cause severe defoliation of sapling and small pole sized stands in summer. Larvae prefer old needles, however they move to new needles once old needles are consumed. Hazardous conditions: Excessively shallow or disturbed soil Red pine plantation adjacent to hardwood edge Excessive competition from grass or bracken fern Open stand caused by poor initial plantation survival	Prevention Avoid planting on hazardous conditions or monitor plantations closely. Maintain distance (50 feet) from hardwood edge. Control weed and grass competition. If initial survival is poor, replant or interplant. Control of current or impending outbreaks Apply an insecticide to rising populations to prevent major outbreaks. Allow population to increase and apply an insecticide to protect needles.	Redheaded Pine Sawfly-Its Ecology and Management. L.F. Wilson and R.C. Wilkinson. 1992. USDA Forest Service Agriculture Handbook 694. Redheaded Pine Sawfly. L.F. Wilson and R.D. Averill. 1978. USDA Forest Service, Forest Insect and Disease Leaflet 14.
Red Pine Needle Midge – *Thecodiplosis piniresinosae* Occasional widespread outbreaks cause needle browning in late summer. The insect attacks trees of	Control is not necessary.	

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
all sizes. However it prefers open-grown saplings of low vigor. Repeated years of heavy attacks may reduce growth and prevent shoot development.		
Jack Pine Budworm - *Choristoneura pinus pinus* Occasional widespread outbreaks cause heavy defoliation. Repeated years of defoliation leads to top dieback and tree mortality. Historically, feeding on red pine was observed only in a mixed stand of jack pine and red pine. However, recently, severe infestations of red pine stands have been observed in central and northern WI.	Accept some loss and monitor stand for budworm population build-up. Cut stands in shapes that minimize the stands' edge areas. Harvest heavily defoliated stands. Apply insecticide, if practical (see on-line manual at right). (The above management options were developed for jack pine. No specific guidelines are currently available for red pine)	How to Manage Jack Pine to Reduce Damage From Jack Pine Budworm. 1994. USDA Forest Service. NA-FR-01-94.
NEEDLE DISEASES		
Pine Needle Rust – *Coleosporium asterum (syn. C. solidaginis)* The fungus requires an alternate host (aster, goldenrod) to complete its life cycle. Occasionally, it causes needle loss on lower 5 feet of branches during spring. The disease is most prevalent on trees up to sapling size.	Accept some disease occurrence. Do not plant seedlings at close spacing. Remove alternate hosts of the fungus (Aster, Goldenrod) within 300 m of red pines manually or by applying herbicides before August when spores are released.	How to Identify and Control Pine Needle Rust Disease. T.H. Nicholls, et al. 1976. USDA Forest Service.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
Defoliation may cause growth reduction, although mortality is uncommon.		
Brown Spot Needle Blight - *Mycosphaerella dearnessii* The fungus initially causes brown bands with yellowish margins on needles. Infected needles will later turn brown and prematurely fall in late spring and early summer.	Control is usually unnecessary. Do not plant seedlings at close spacing	Brown Spot Needle Blight of Pines. W.R. Phelps et al. 1978. USDA Forest Service, Forest Insect and Disease Leaflet 44. Brown Spot Needle Blight of Eastern White Pine. 1991. USDA Forest Service NA-PR-03-91.
Needle Droop - caused by drought Drooping and/or browning of needles occur occasionally in drought years. Sandy soil, dense sod and competition for water from other plants increase the risk.	Control weed competition for the first 5-10 years. Plant seedlings properly. Avoid damage to roots such as jamming, and J-rooting.	
BUD, SHOOT AND TWIG INSECTS		
Red Pine Shoot Moth – *Dioryctria resinosella* (see hazard map in FHP Figure 1) Larvae feed on new shoots and kill shoots of trees that are 20 years old and older. Attacks by this insect lead to deformed branches and main	No direct control is available. Remove severely deformed trees during thinning. Consider planting species other than red pine on hazardous sites.	How to identify and minimize red pine shoot moth damage. 1992. USDA Forest Service. NA-FR-02-92.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
stems. Trees older than 30 years on dry, sandy soils are most vulnerable to attack.		
European Pine Shoot Moth - *Rhyacionia buoliana* (see hazard map in FHP Figure 1) Larvae feed on buds and shoots. Repeated attacks result in crooked or forked branches and stems. Infestation could last until lowest live branches are above snow line. Open stands are more susceptible to attacks by this insect than closed stands.	No direct control is available. Consider planting species other than red pine on hazardous sites. Prune lower branches.	
Common Pine Shoot Beetle - *Tomicus piniperda* Adult beetles feed on the central portion of the lateral shoots and destroy shoots. Damaged shoots droop, turn yellow to red, and fall. The insect is under federal quarantine (see control column for details).	The insect is native in Eurasia and north Africa and was first discovered in North America in 1992. As of 2008, part or all of 18 states are under federal quarantine for this insect, including the entire state of Wisconsin. For information about quarantine regulations when pine materials are shipped from Wisconsin to non-quarantined states, visit http://www.aphis.usda.gov.	Pest alert: New Introduction - Common Pine Shoot Beetle. USDA Forest Service NA-TP-05-93.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
Saratoga Spittlebug - *Aphrophora saratogensis* Sapsucking injury causes twig flagging, reduced tree growth, stem deformity, and branch mortality. Tree mortality occurs when severely infested. Trees up to 15 feet tall are more susceptible to attacks. When population is high, plantation failure could occur.	Avoid planting red pine in frost pockets, swales, and any other low lying areas. Remove alternate hosts of Saratoga spittlebug (sweet fern, young willow, berry bushes, etc.) when they occupy 20% or more of the ground cover. Monitor for Saratoga spittlebug populations and treat with insecticides if necessary. Monitor for the existence of flagged volunteer jack pine in a stand as flagging symptoms often begins one year ahead of red pine during outbreaks.	Saratoga Spittlebug-Its Ecology and Management. L.F. Wilson. 1987. USDA Forest Service Agriculture Handbook No. 657. Saratoga Spittlebug. L.F. Wilson. 1978. USDA Forest Service. Forest Insect & Disease Leaflet 3.
SHOOT DISEASES/CANKERS		
Diplodia Shoot Blight - *Diplodia pinea* Current year's shoots become stunted with short, brown needles. Cankers on branches cause branch flagging and dieback. Severe canker development and subsequent branch dieback are occasionally observed after a hail storm. The fungus also attacks root collar areas of seedlings and causes seedling mortality. Understory red	Maintain tree vigor. Do not prune trees during wet periods. Avoid two-story or uneven-aged stands in areas with a history of serious Diplodia infection. Remove infected overstory and windbreak pines. Avoid planting red pine on dry sites or sites that have a history of serious Diplodia infection. If more than 50% of the crown is affected, consider salvage harvesting.	Diplodia Blight of Pines. G.W. Peterson. 1981. USDA Forest Service. Forest Insect & Disease Leaflet 161. How to Identify and Control Diplodia Shoot Blight, Collar Rot, and Canker of Conifers. 1983. USDA Forest Service.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
pine near older diseased red pine or windbreak pines are likely to be infected by falling spores.		
Sirococcus Shoot Blight (Red pine shoot blight) - *Sirococcus conigenus* (see FHP Figure 1 for the county distribution of this disease) Current year's shoots droop or become stunted and die. The fungus causes shoot dieback and stem and branch cankers on the current year's growth. A single year of infection could kill seedlings and repeated infections could kill saplings. Understory red pine near older diseased red pine or windbreak pines are likely to be infected by falling spores.	Do not prune trees during wet periods. Avoid two-story or uneven-aged stands in areas with a history of serious Sirococcus infection. Remove infected overstory and windbreak pines.	Sirococcus Shoot Blight. T.H. Nicholls. 1984. USDA Forest Service. Forest Insect & Disease Leaflet 166.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
Scleroderris Canker - *Gremmeniella abietina* (see FHP Figure 1 for the county distribution of this disease) Infected needles turn orange at the base in spring and later turn brown and fall off. The fungus moves to branches and main stems to develop a canker. Cankers girdle and kill seedlings and small trees. Damage is minor on trees over 6 feet tall. Lower branch mortality of larger trees occurs in frost pockets.	Within hazard zone, avoid planting red pine and jack pine in frost pockets, areas of depressed ground where frost conditions are greater earlier and later in the season. Remove all infected red and jack pine.	How to Identify Scleroderris Canker. D. D. Skilling and J.T. Obrien. 1979. USDA Forest Service. Scleroderris Canker of Northern Conifers. D.D. Skilling et. al. 1979. Forest Service. Forest Insect & Disease Leaflet 730. Biology and Control of Scleroderris Canker in North America. D. D. Skilling et. al. 1986. USDA Forest Service. Research Paper NC-275.
CANKER ROT DISEASE		
Red Ring Rot - *Phellinus pini* The fungus causes a white pocket rot in the trunk of infected trees. The fruiting bodies often appear at branch stubs or knots. They are annual or perennial, hard, and bracket or hoof shape with irregular margins. Upper surface is dark grayish to dark brown.	Remove infected trees during thinning. Minimize injuries during logging operations.	Canker-rot fungi and cankers of Northern Hardwoods. 2004. Wisconsin DNR. Division of Forestry.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
MAIN STEM/ROOT INSECTS		
Northern Pine Weevil - *Pissodes approximates* Severe feeding by the adults may kill some shoots. This insect could cause considerable mortality in 1-5 year-old red pine plantations.	Delay planting seedlings for 2 years after harvesting pines. Remove freshly cut pine stumps before planting seedlings, if practical (rarely practical). Treat freshly cut stumps with an insecticide if practical (rarely practical).	A guide to Insect Injury of Conifers in the Lake States. USDA FS Agriculture Handbook No. 501
Pales Weevil - *Hylobius pales* Weevils kill seedling stems and young shoots of older trees by removing a complete ring of bark around stems or twigs. It kills first-year seedlings during moderate infestations. It can kill seedlings up to 3 years of age during heavy infestations. Though it also attacks older trees, the damage is minimal.	Delay planting seedlings for 2 years after harvesting pines. Remove freshly cut pine stumps before planting seedlings, if practical (rarely practical). Treat freshly cut stumps with an insecticide if practical (rarely practical).	A guide to Insect Injury of Conifers in the Lake States. USDA FS Agriculture Handbook No. 501 Pales Weevil. J.C. Nord, I. Ragenovich, and C.A. Doggett. 1984. USDA For. Serv. Forest Insect and Disease Leaflet 104.
Pine Root Collar Weevil - *Hylobius radices* Feeding under bark at root collar areas causes mortality of sapling and small pole-sized trees. Trees may tilt or break off at the root collar. Trees	On sandy soils, plant with root collar no more than one inch deep. Encourage early crown closure by planting 800 or more trees per acre and increase the seedling survival rate by controlling weeds and rodents for 5 years after planting.	See Red Pine Pocket Mortality below

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
planted on nutrient-deficient, sandy soils, trees with their root collars 3 inches or more below the soil surface, and red pine stands within a half mile of heavily infested Scotch pine are more prone to weevil infestation. Trees growing in open stands are more vulnerable to weevil attacks than closed stands. The insect is considered to be one of the vectors that transmits Leptographium spp. (see Red Pine Pocket Mortality) Infestation is suspected by the existence of black pitch-encrusted areas around the bole right below the ground line. Infested trees may have declining upper crowns and excessive taper.	Avoid planting red pine within one mile of infested Scotch pine stands. Liquidate nearby abandoned Scotch pine Christmas tree plantations.	
Pine root tip weevil - *Hylobius rhizophagus* Feeding on roots causes flagging, top kill and tree mortality in pole-size pines. Moderate weevil damage reduces tree growth. Red pine stands that are near Scotch pine are more vulnerable to weevil attacks. Infestation is often associated with	Accept some damage and loss. Remove jack pine from infested red pine stands. Harvest merchantable trees when branches start to die. Liquidate nearby abandoned Scotch pine Christmas tree plantations.	Life History and Damage of the Pine Root Tip Weevil, Hylobius rhizophagus in Wisconsin. W.H.Kearby and D. M. Benjamin. Annals of the Entomological Society of America. 1969. Vol. 62, No. 4, p838-843.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
presence of jack pine and/or nutrient-deficient, sandy soil.		
White Grubs - *Phyllophaga spp*. Feeding on roots kills seedlings established for 1-3 years on sandy soils. White grub densities above 0.2 per square foot may cause heavy seedling mortality and stunting of surviving seedlings. They are common on grassy or weedy sites.	Survey stands for white grub population before planting. If the population density is high, delay planting for one to two years. Currently, there is no insecticide clearly labeled for forestry use against this insect.	White Grubs, Phyllophaga spp. D. Hall. Wisconsin DNR, Division of Forestry.
GALL DISEASES		
Eastern Gall Rust (pine-oak gall rust) - *Cronartium quercuum f.sp. banksianae* **Western Gall Rust (pine-pine gall rust)** - *Peridermium harknessii* Eastern gall rust requires oak as an alternate host to complete its life cycle and it is considered to be widespread in Wisconsin. Western gall rust infects pine without an alternate host. Based on the survey in the 1960's, the distribution of western gall rust is limited to north-central Wisconsin (Vilas, Oneida, Lincoln Cos.). The	Remove severely infected trees and branches during thinning. Examine seedlings for galls or swelling on main stems, branches, and root collar areas before planting. Do not plant symptomatic seedlings.	The Range of Western Gall Rust in Wisconsin. W.T. McGrath and R. F. Patton. 1969. Plant Disease Reporter Vol. 53 No. 5 p357-359.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
fungus causes swollen spherical galls on pine twigs, branches and main stems. Galls kill seedlings and branches of older trees. The disease is very common on jack pine near oaks.		
ROOT DISEASE		
Armillaria Root Disease (Shoestring root rot) – *Armillaria spp.* Girdles roots and lower trunks, causing cankers as well as stringy white rot. Growth reduction and yellowing needles are symptoms, and dieback and mortality can occur, especially during drought years or following two or more years of defoliation (all ages). White mycelial fans and dark-colored rhizomorphs can be found in the cambial zone. Armillaria spp. produce fall mushrooms.	Maintain stand in healthy condition. Harvest declining trees before bark beetle infestation, mortality, and decay take place.	Armillaria Root Disease. R. Williams, et al. 1986 USDA Forest Service, Forest Insect and Disease Leaflet 78.
ROOT DISEASES/DISEASE COMPLEX		
Annosum Root Rot - *Heterobasidion annosum*	Expect tree mortality in pockets and growth loss in trees around the pocket margin.	Annosum Root Rot and Red Pine Pocket Mortality in Wisconsin; Biology and Management. 2008. Wisconsin DNR, Division of Forestry.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
In Wisconsin, the disease was first confirmed in Adams Co. in 1993. As of July 2009, the disease is confirmed in 20 Counties (see FHP Figure 1 for the county distribution of this disease). Infection causes pockets of trees to develop thin crowns, reduced growth, and tree mortality. Crown symptoms typically appear 2-3 years after thinning. Pockets expand at about ½ to 1 chain every 10 – 15 years. Fruiting bodies develop at the base of infected trees. They are white and look like popcorn at an early stage, and under favorable conditions, they develop into a perennial bracket-shaped conk. A new infection site usually originates at cut stumps by spores landing on them. The fungus also spreads through root contact.	Dead trees and the bottom 8 feet of trees that are showing dieback should be left on site during thinning to avoid inadvertent disease spread. Pre-salvage healthy trees 1/2 to 1 chain outside pocket perimeters to utilize the wood before the trees die. Prevention During thinning and harvesting, start in healthy stands or areas and work in diseased areas last. Apply a registered fungicide on fresh cut stumps as soon as possible after cutting or by the end of each day. Currently the use of fungicide is recommended year round throughout the state of Wisconsin. Clean logging equipment with pressurized water before leaving diseased stands.	Annosus Root Rot in Eastern Conifers. K. Robbins. 1984. USDA Forest Service Forest Insect & Disease Leaflet 76.
Red Pine Pocket Mortality Caused by a complex of insects, fungi (*Leptographium spp.)* and insect fungal vectors. Trees weakened by root insects and fungi are later killed by bark beetles (Ips spp.) This complex was first identified in	Leave the pocket as a natural opening. Cut dead trees and trees that are showing dieback and/or yellowing of the foliage within and adjacent to the pocket. Cut dead trees and trees that are showing dieback and/or yellowing of	Annosum Root Rot and Red Pine Pocket Mortality in Wisconsin; Biology and Management. 2008. Wisconsin DNR , Division of Forestry

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
Wisconsin in 1975. Infected trees have reduced growth and thin crowns with yellowing, tufted needles. Pockets typically start small with one to a few dead trees surrounded by trees that have reduced shoot growth and thin crowns. Each year, a few trees on the pocket edge may die and the edge of the pocket expands. *Leptographium spp*. moves below ground through root contact and the pocket expands about 1 chain every 10 – 15 years.	the foliage, and also cut a buffer area of healthy trees around the pocket to utilize the wood before they die. There are some experimental management options. For the experimental options, please refer to the referenced management guide.	
ANIMAL DAMAGE		
Meadow Mouse (Meadow Vole, Field Mouse) Gnawing on bark at the base of trees during winter results in mortality of trees up to 8 years old. Dense grass supports population build-ups which may cause heavy mortality.	Remove grass before planting. Control grass within 3 feet of young trees. Keep grass mowed. Practice green, cavity, and snag tree retention.	Meadow Mouse Control. Scott Craven. 1981. Univ. Wisc. Ext. Leaflet A2148.
Pocket Gophers In western Wisconsin, feeding on roots, results in mortality of seedlings and saplings. Significant mortality occurs where two or more gopher	Accept the risk of some mortality. Eliminate gophers with rodenticide, trapping, or shooting. Practice green, cavity, and snag tree retention.	Pocket Gophers. R. M. Case. 1983. Univ. Nebraska Ex. Pocket Gophers in Forest Ecosystems. C. L. Teipner, et. al. 1983. USDA Forest Service Gen. Tech. Rep. INT-154.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
mounds per acre are present. Look for trees tilting at odd angles in 3-8 year-old plantings. Such trees can be pulled up with almost no efforts as they have been rendered rootless by gopher feeding.		
Rabbits/Hares Mortality through stem girdling due to feeding on the bark.	Control is usually unnecessary.	Rabbit Damage to Tree Plantings.

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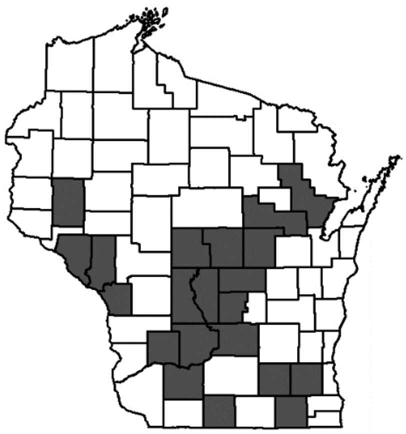
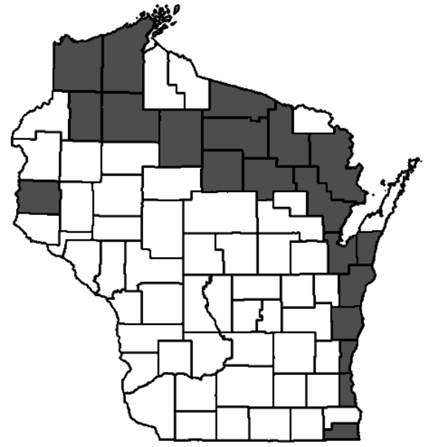
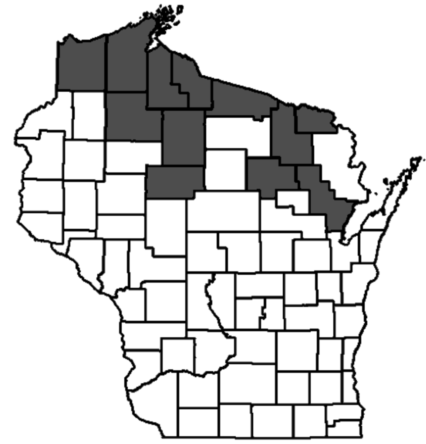


Counties confirmed with Annosum root rot

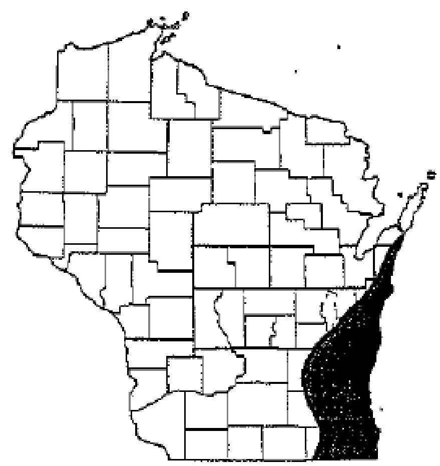


Counties where *Sirococcus* sp. was reported on conifers (Hosts include pines, spruces, and firs)



Counties confirmed with Scleroderris canker

Red pine shoot moth
Hazard zone in Wisconsin



European pine shoot moth
Hazard zone in Wisconsin

Figure 32.12. County distribution/hazard maps for several pests on red pine

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Chapter 33

Jack Pine Cover Type

WISCONSIN
DEPT. OF NATURAL RESOURCES

Last Full Revision: 2/9/2016
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter

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1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand Composition
Jack pine (*Pinus banksiana*) comprises 50% or more of the basal area in poletimber or sawtimber stands, or 50% or more of the stems in seedling and sapling stands.

Associated Species
Jack pine frequently occurs in dense, even-aged stands that originate from major disturbances, such as fire or logging. In stands dominated by jack pine, the most common associates are oak (*Quercus spp.*), red pine (*Pinus resinosa*), white pine (*Pinus strobus*), aspen (*Populus spp.*), and white birch (*Betula papyrifera*). Occasional associates include red maple (*Acer rubrum*), black cherry (*Prunus serotina*), balsam fir (*Abies balsamea*), and white spruce (*Picea glauca*).

1.2 Silvical Characteristics

Note: The primary source for the following descriptions and tabular summary is from Silvics of North America – Jack Pine (94). Visit Silvics of North America website for additional information:
https://www.srs.fs.usda.gov/pubs/misc/ag_654/volume_1/pinus/banksiana.htm

Flowering and Fruiting
Jack pine is a monoecious species; meaning an individual has both male and female strobili (cones). The female (ovulate) cones are usually borne on primary and secondary branches in the upper tree crown. Male (staminate) cones are usually borne on the lower crown. Jack pine trees, particularly under good early growing conditions, begin to flower at a younger age than most other pine species. In the Lakes States, flowers become visible in mid to late May and pollination occurs shortly thereafter. Fertilization occurs about 13 months after pollination when the female cone is approaching its maximum size of 1 to 2 inches. Jack pine is normally a wind-pollinated, cross-fertilizing species, but natural self-fertilization can occur (rarely more than 25 percent). Under natural conditions survival of self-fertilized seedlings is severely reduced by natural selection, as a result of inbreeding depression.

Once cone production in jack pine begins (typically 5-10 years), it is fairly regular and increases until crown competition becomes a factor. Jack pine cones take two growing seasons to mature. Cones are approximately ¼ inch long by the end of the first season and reach a mature size of 1 to 2 inches by the end of the second growing season. Moisture content of cones and viability of seed decrease as cones age, with cone color changing from green to brown to gray. Some cones fall to the ground each year but some cones remain on the tree for 20 years or longer.

Based on a cone study of Lake States jack pine provenances, the best indicators of cone and seed ripeness are cone color; 75 percent brown and insides of the cone scales, reddish brown; seed coat color, dark brown or black; and cone moisture content, less than 45 percent of fresh weight. These indicators of cone and seed ripeness coincide with the beginning of cone harvesting by squirrels in September (19).

Over much of its natural range jack pine bears predominantly serotinous cones, but along the southern range limit cones are sometimes non-serotinous. A survey of serotiny in jack pine across Wisconsin's Northwest Sands showed the highest levels of serotiny in the northeast portion and lowest in the southwest portion. A possible explanation for the gradient in serotiny levels may be the difference in forest density and corresponding fire regimes across this landscape. Historical vegetation patterns indicate forest density to have been highest in the northeast and lowest in the southwest portions. The savanna-type landscape of the southwest Pine Barrens experienced frequent, non-lethal surface fires that may have favored trees with non-serotinous cones. High density tree cover in the northeast portion of the Pine Barrens would have allowed for stand replacing crown fires that may have favored trees with serotinous cones (87).

Serotinous cones may remain closed for 10 to 25 years until they are exposed to fire or high temperatures near the ground after wind breakage or logging. Some serotinous cones open during hot, dry weather (temperatures of at least 80°F). Up to 50 percent of cones may open on the sun-exposed portion of the crown. The resin of serotinous cones melts at temperatures of 122-140° F or higher, but it is likely that the bonding resin softens at lower temperatures in the non-serotinous types. The mechanism of cone opening in both serotinous and non-serotinous cones is hygroscopic. Once the bonding material of the cone scales is broken, the quantity of water in the scales is the limiting factor in scale movement and flexing outward under drying condition.

<u>Seed Production and Dissemination</u>
In naturally regenerated stands, seed production begins at 5 to 10 years in open-grown stands and at 10 to 25 years in closed stands. Best seed production is from trees between 40 and 50 years old. A well-stocked stand can produce 13 pounds of seed per acre with seed numbers averaging 131,000 seeds per pound. Good seed years occur every 3 to 4 years with light crops in most intervening years. Crop failures are rare.

Seeds retained in cones maintain high viability for at least 5 years and sometimes for more than 15 years. However, because viability after 5 to 10 years may be significantly reduced, only cones 6 years old or less should be collected. Cone and seed crops in jack pine may be reduced by numerous agents, including insects and rainy weather at time of pollination.

In the Lake States, where non-serotinous or partially serotinous cones may be present, seed can be disseminated during any season. The winged seeds are the smallest of the native pines and are dispersed by gravity and wind. The range of seed dispersal is about two tree-heights (110-130 feet). Birds and rodents can consume up to 75 percent of dispersed seed.

Seed yields per cone range from about 15 to 75. Strongly curved cones yield less seed than straight ones. Well-stocked, mature stands in the Lake States dispersed an annual average of 2,700 to 10,500 seeds per acre over 5 years, but much of the total crop remained in the unopened cones. Seed viability is not markedly affected by heating, unless the cone ignites, which kills the seed. Crown torching does not ignite cones because the high temperatures are unlikely to last more than 3 minutes.

In cones exposed to fire, seeds are uninjured by temperatures that do not cause actual cone ignition (e.g., 60 sec at 700°F, 30 sec at 900°F, 2 sec at 1200°F). Seed can be shed for 3 years after a fire event.

Seedling Development

Light, moisture, air temperature and seedbed conditions influence germination and seedling survival. Optimum conditions for jack pine seedling establishment and survival are provided by exposed mineral soil and burned seedbeds where competition from other vegetation is not severe, the water table is high (within 6 feet), and there is light partial shade.

Seeds germinate within 15 to 60 days when conditions are favorable. Germination rates are reduced if seed is exposed to direct sunlight more than four hours per day or in full shade conditions. The shade cast by slash and snags on burned-over or cut-over areas reduces surface temperatures and drying, contributing substantially to the good germination often observed on such areas. Jack pine seedlings are most abundant in the understory when light intensity is 11 to 30 percent of full sunlight, but height growth is greatest in light intensities of 52 percent or more.

Highest germination and seedling survival rates are observed for seeds that fall in April, May, June, and November. Numerous factors hinder seedling survival: drought, high soil surface temperatures, vegetative competition, prolonged flooding, insects, diseases, deer browse, ice damage, and nipping and girdling by snowshoe hares.

Under forest conditions, seedling growth is slow in the first 3 years but increases rapidly beginning in the fourth and fifth years. During the first season the root system penetrates to a depth of 5 to 10 inches. By the end of the second season, on typical sandy soils, seedlings are 3 to 4 inches tall, and roots are 11 to 13 inches deep with a lateral spread of 18 to 24 inches. By the fourth year, wild seedlings are usually 1 to 3 feet in height. Early growth of 2-0 seedlings in plantations is more rapid, amounting to 12 to 18 inches per year on medium quality sites.

Although jack pine seeds usually germinate following fire, most of the seedlings die unless the organic matter left on the soil is less than 0.5 inch thick. Most germination occurs the first and second season following fire, with most mortality between the first and second growing season. Unless conditions for germination and early survival are favorable, good regeneration does not necessarily follow burns.

Growth and Development

In well-stocked stands, jack pine is short to medium tall, slender, with a narrow open crown covering 30 to 45 percent of stem. In open growth, it tends to be stocky, with poor form and a wide spreading crown with persistent branches, often to the ground. Overstocked stands produce weak, spindly stems that are susceptible to breakage by wind, ice, and snow. Normally, mature trees are 55 to 65 feet tall and 8 to 10 inches DBH, although some trees have attained greater than 100 feet in height and 25 inches DBH.

During the first 20 years, jack pine is one of the fastest growing conifers, being second only to tamarack. Seedlings reach breast height in 5 to 8 years. On average sites, growth averages about one foot a year to 50 years of age. Annual height growth on medium sites averages from 13 inches at age 30 to 9 inches at age 50. At age 80 years, annual height growth is only 5 inches. On the best sites stands begin to decline in growth and vigor after 80 to 100 years; on poor sites after 60 years. Vigorous trees 185 years old have been found in northeastern Minnesota. Most older jack pine stands in the Lake States were established following fires.

Reaction to Competition

Jack pine is one of the most shade-intolerant trees in its native range. It is ranked as less tolerant than red pine and is slightly more tolerant than aspen, birch, and tamarack. Jack pine may be more tolerant in the seedling stage and often requires some shade on dry sites to reduce surface temperatures and evapotranspiration. Soon after seedlings are established, however, they should receive full sunlight to assure survival. Overall, jack pine can be classed as intolerant of shade.

Overstocked jack pine seedling and sapling stands with 2,000 or more trees per acre may be thinned to improve growth and development. Otherwise, such stands may stagnate because natural thinning in jack pine stands is slow except on the best sites. Planting, direct seeding, and precommercial thinning should have a goal of 600 to 1,200 trees per acre (plantations 400-1200).

Jack pine is a pioneer species on burns or exposed sandy sites. In the absence of fire or other disturbances, jack pine is succeeded by more tolerant species, but on the poorest, driest sites it may persist and form a localized climax community.

Damaging Agents

Jack pine is subject to many agents that cause damage or mortality. Young jack pines are especially susceptible to early spring fires. Severe drought may kill many seedlings, particularly on coarse soils. High populations of white-tailed deer can kill young jack pines up to 7 feet tall, retard total height growth to half its potential, and deform most trees so they have little future value for timber products. Snowshoe hares can severely damage jack pine reproduction, particularly in dense stands of trees. Meadow voles cause occasional damage and mortality by gnawing the bark off main stems and lower branches. Porcupines can cause extensive damage in older stands. Jack pine budworm can be a severe defoliator, with outbreaks occurring approximately every 10 years. Wind throw is not a serious problem in jack pine stands except on shallow soils or when more than one-third of the stand basal area is removed in thinnings. Stem breakage from wind, ice, and snow is more common.

Disease can impact both survival and growth of jack pine. Diplodia (Diplodia pinea) and Sirococcus shoot blight (Serococcus conigenus) can cause significant losses in natural and artificial regeneration. Rust fungi, such as pine-oak gall rust (Cronartium quercum), can result in morality when galls form on the main stem.

Cone and seed production can be decreased by numerous factors. Seed and cone insects may limit seed production. Red squirrels and other rodents destroy cones and consume seeds.

Birds may be important consumers of jack pine seeds that fall to the ground or are directly sown. See Forest Health Guidelines section for more detailed information on jack pine damaging agents.

Table 33.1. Summary of selected silvical characteristics

Jack pine (*Pinus banksiana*)	
Flowers	Monoecious spp; mostly wind-pollinated and cross-fertilizing; some natural selfing occurs; pollination occurs mid-May to early June
Fruit	Cones 1 to 2 inches at maturity; 2 years to mature; color changes from green to brown to gray as cones age; varying degrees of serotiny
Seed	Trees can produce seeds early (5 to 10 years) in open grown stands; in closed stands seeds are produced at 10-25 years; good seed crops occur every 3 to 4 years; fully stocked stands can produce 13 pounds of seed per acre with 131,000 seeds per pound; seed yields per cone range from 15 to 75; crop failures are rare; seeds can remain viable in the canopy for many years
Seedlings	Optimum conditions for seedling establishment and survival are provided by exposed mineral soil and burned seedbeds where competition from other vegetation is not severe, the water table is high (within 6 feet), and there is light partial shade. Seeds germinate within 15 to 60 days when conditions are favorable; potential for delayed germination in first two years after seed sown
Growth	Fast growing conifer during the first 20 years. Seedlings reach breast height in 5 to 8 years. On the best sites, stands begin to break down after 80 to 100 years; after 60 years on poor sites.
Tolerance	Shade-intolerant, although in the seedling stage often requires some shade on dry sites to reduce surface temperatures and evapotranspiration. Soon after seedlings are established, however, they should receive full sunlight to assure survival.
Damaging agents	Birds, rodents, deer, snowshoes hares, porcupines, wind, fire, drought, ice, snow, insects and disease.

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

Management objectives should be identified in accordance with landowner goals and within a sustainable forest management framework, which gives consideration to a variety of goals and objectives within the local and regional landscape. The silvicultural systems described herein are designed to promote the optimum quality and quantity of timber products. These silvicultural systems may be modified to satisfy other management objectives, but vigor, growth, and stem quality could potentially be reduced.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.1 Landscape Considerations

Jack pine requires disturbance to regenerate and is found in areas that historically experienced frequent and extensive fires, most notably the Pine Barrens and Northern Dry Forest natural communities that were once widespread in Wisconsin's sand-dominated ecological landscapes. Numerous factors including fire suppression, natural succession, land-use changes, ownership patterns, and economic considerations have led to major declines in jack pine dominance and shifts in in the distribution of these natural communities. Pine Barrens in particular are now geographically restricted and considered globally imperiled (128), with the best remaining examples located in the upper Midwest states of Wisconsin, Michigan, and Minnesota.

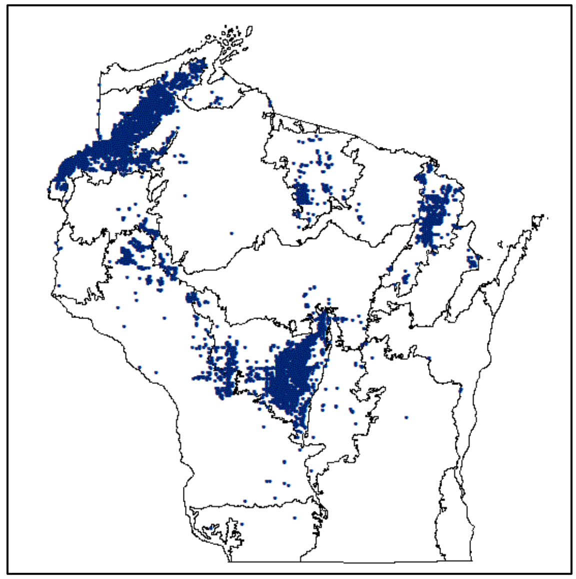

Figure 33.1. Location of jack pine "witness trees" documented during GLO Surveys (from the WDNR GIS coverage Pre-European Settlement Vegetation Database of Wisconsin: Differentiated Section and Quarter Section Corners prepared by the University of Wisconsin – Madison Forest Landscape Ecology Lab).

3.1.1 Historical Context

Jack pine was a major cover type at the time of Euro-American settlement, particularly in the Northwest Sands ecological landscape where "jack pine, scrub oak, and Barrens" made up almost two-thirds of the landscape (32). It was also a major type in the Northeast Sands and the Central Sand Plains with smaller amounts scattered throughout various other landscapes. Figure 33.1 illustrates the locations where jack pine "witness trees" were documented during the General Land Office surveys of the mid-1800s (106).

Relative Importance Value (RIV) is a metric that combines relative basal area and relative density to determine the "importance" of a particular species relative to others in a given area (43). The RIV of jack pine in the Northwest Sands was over 30% at the time of General Land Office surveys in the mid-1880s[1]. Its RIV in the Northwest Sands now, based on 2013 FIA data, is less than half of that amount (Figure 33.2). The RIV decrease is less pronounced in

[1] *Tree data from the General Land Office surveys are from a particular point in time and can be biased for a number of reasons, including due to limitations in the data collection methods. However, as the only statewide source for pre-Euro-American settlement vegetation data, they can be useful for exploring vegetation patterns at large scales, such as ecological landscapes. These data are used here to better understand the ecological capabilities of these areas and not to imply that conditions should be returned to any particular point in Wisconsin's history.*

the Central Sand Plains, but many areas there have also been converted to other forest types and land uses.

In more recent decades, jack pine acreage has been consistently declining in Wisconsin since 1983 based on FIA data (see Figure 33.10), and this change has been concurrent with an increase in red pine (121). Between 2004 and 2014 it is estimated that roughly 40,000 acres of jack pine were converted to red pine in Wisconsin (64).

Disturbance Regime

Fire was historically the primary disturbance throughout the jack pine range in Wisconsin. Crown fires were historically frequent in the Great Lakes with a rotation period of 50-70 years (36). However, fire return intervals and intensities varied across sites creating a diversity of landscape patterns and stand conditions (84). There was likely also a very wide range of fire sizes ranging from 1000 ha to 180,000 ha (36).

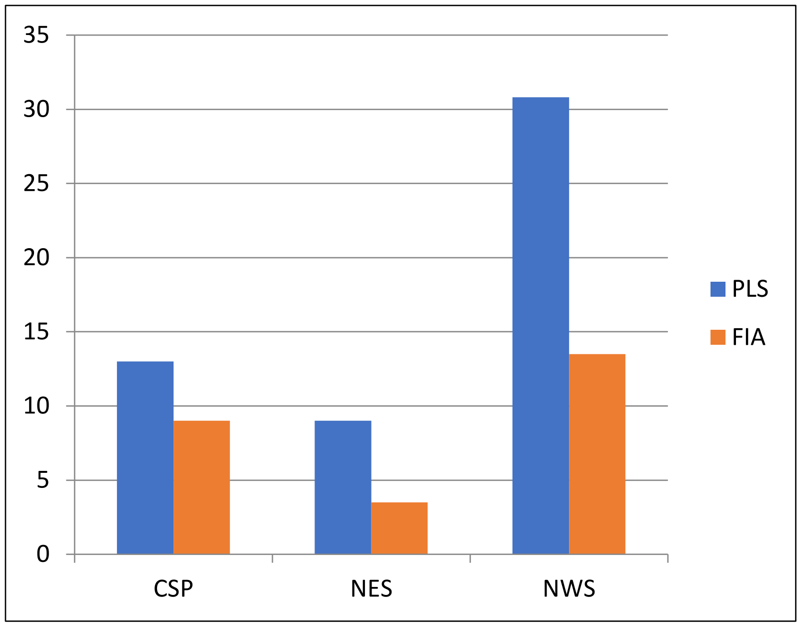

Figure 33.2. Relative importance values from the witness tree data collected in the mid-1800s (PLS) and 2013 Forest Inventory Analysis (FIA) data. The amount shown is the importance of jack pine relative to other tree species during the two time periods for the Central Sand Plains (CSP), Northeast Sands (NES), and Northwest Sands (NWS) ecological landscapes.

The fires were important not only for jack pine regeneration but developing a varied landscape with conditions ranging from dense, mature jack pine to large expanses of treeless or near treeless habitat. For example, at least three distinct subregions were defined in the Northwest Sands that exhibited different levels of fire frequency and intensity (86). Fire suppression efforts formally began in the Northwest Sands in the 1920s, but large areas were still burning as late as the 1930s (85).

The 2013 Germann Road Fire, covering over 7,000 acres, was Wisconsin's largest forest fire in recent years. An earlier fire, the 2005 Cottonville Fire, covered 3,400 acres in the Central Sand Plains. Several fires this size and larger previously occurred in the 1970s and 1980s (85). These events are reminders of the disturbance history of these sand-dominated ecological landscapes, as well as the potential for large fires to occur when an ignition source combines with extreme weather, dry soils, and abundant fuel.

Jack pine budworm, a native needle-feeding caterpillar, can also cause large-scale mortality of mature jack pine, especially during periods of drought (see "Forest Health Guidelines" section).

Historically, large fires would have followed major budworm outbreaks. Huge budworm outbreaks have occurred in the past in Wisconsin when large acreages of jack pine shared the same or similar age classes. An outbreak in 1992 and 1993 resulted in defoliation in 90% of the jack pine forests in the Northwest Sands, and salvage harvests occurred on 27% of the mature forest in the landscape at that time (74, 85).

Salvage harvests and other clearcuts differ from fires in many ways, including the size and shape of the remaining patches, as well as the resulting structure and species composition. Wildfires often result in a patchy, discontinuous landscape with burned and unburned "legacy" structures (25, 48). These structures change light conditions and provide nesting and foraging habitat for certain species. For example, some of the larger snags following a fire provide foraging opportunities for black-backed Woodpecker, a WI Special Concern species (68), especially recently dead trees (69). Fire also makes nutrients available to plants that were bound in organic matter.

Figure 33.3. Photos of the Germann Road Fire of 2013 by (top) Colin Nowaczyk, WDNR and (bottom) Phil Miller, WDNR.

Role in Pine Barrens

Pine Barrens once covered seven percent of Wisconsin's landscape (116) but are now quite rare. The Pine Barrens community is now ranked as "G2" by NatureServe, the umbrella organization for an international group of Heritage programs including the Wisconsin Natural Heritage Inventory (128). This rank indicates that they are globally imperiled because of rarity.

Pine Barrens is an open community type with trees occurring in low density and either scattered individually or in groups. Prior to Euro-American settlement, there was also a "pine savanna" Barrens type that included large-diameter scattered red pine, but these areas are considered to have since been eliminated (131) (Figure 33.4).

Much of the original Pine Barrens acreage has succeeded to forest or has been converted to other land uses. Of the remnants, many are too small to ensure viability of species that require Barrens habitat (116). However, certain high-quality remnants have been kept open through intensive efforts and connecting and expanding these has been identified as a major conservation priority. This is especially important since there are area-sensitive species associated with Barrens communities such as sharp-tailed grouse (124) that require very large open patches.

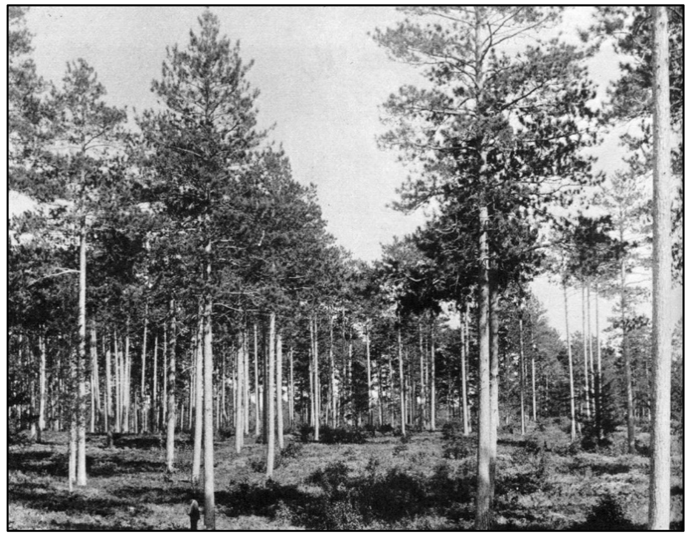

Figure 33.4. Red pine savanna, circa 1890, Bayfield County. Note the individual standing next to the tree in the left side of the image illustrating tree size. From St. Croix Trail Country: Recollections of Wisconsin by William Gray Purcell (University of Minnesota Press, 1967). Copyright 1967 by the University of Minnesota. Used by permission.

There can be major benefits to maintaining open areas within working forest landscapes. Open patches could be located in areas with rare plants and/or floristic diversity, and even small openings placed in these areas can have ecological benefits. These habitats could be incorporated into planning efforts on stands, properties, or regions. Although small patches can provide habitat for rare plants and certain animals, other species are area-sensitive and need much larger openings or very young forest. For example, Kirtland’s warbler has been found in patches of 75-100 acres or more of young jack pine, and sharp-tailed grouse need even larger areas (38, 103). However, managing large patches is typically only possible on public lands or large, industrial forest landholdings.

Ideally, jack pine stands could be managed as a “shifting mosaic” that would benefit a number of species while allowing for timber management as a primary objective. The pre-Euro-American settlement Pine Barrens included frequent large openings that would have shifted locations over time (84). Figure 33.5 (122) shows an idealized, hypothetical example of how an area could be managed in a similar way through planning. The jack pine stands are harvested on a rotating schedule, so each stand periodically provides an early seral stage “temporary Barrens” connected to the core Barrens unit. Thus, an area with very low tree density is always available for species requiring open habitats. This would also provide habitat for species using young and older jack pine at all times. Shifting clearcuts in this manner would provide very little savanna structure since that would require higher numbers of trees to be retained than a typical clearcut harvest. However, clearcuts can provide some of the open habitat for Barrens species that would otherwise be lost from many areas (40).

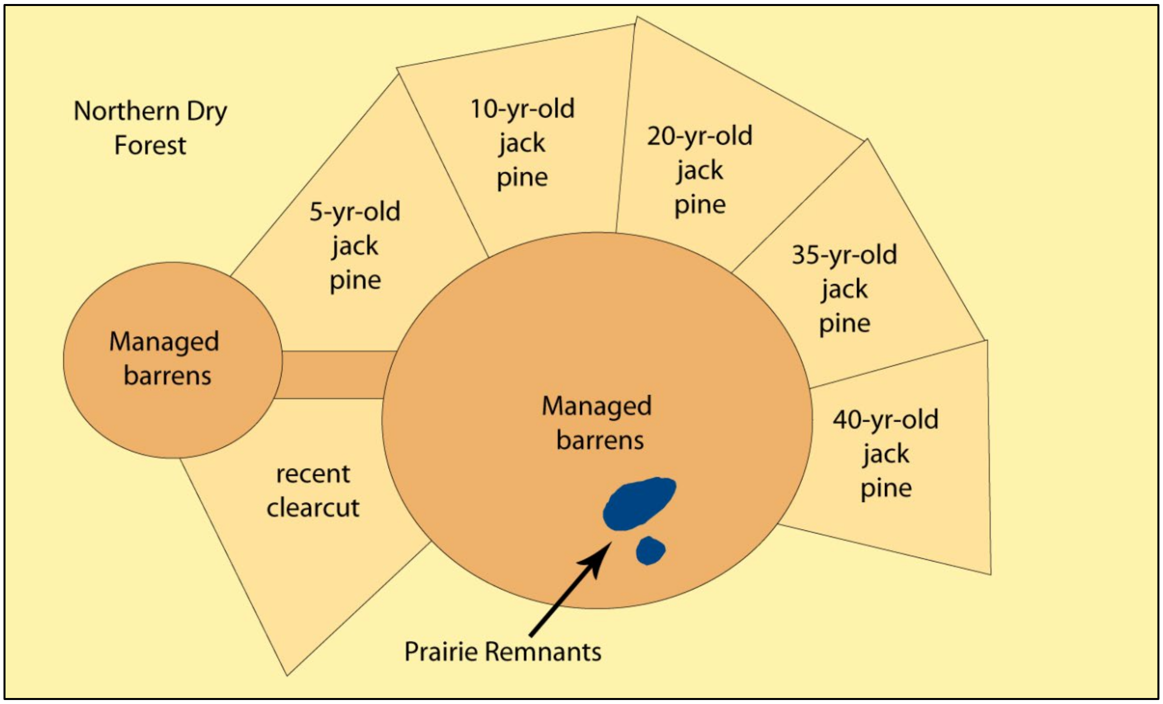

Figure 33.5. Figure adapted from the Ecological Landscapes of Wisconsin, Chapter 1: Principles of Ecosystem and Landscape-Scale Management

3.1.2 Current Context

Jack pine is found mostly in three states (Wisconsin, Minnesota, and Michigan), as well as large areas of Canada. Within Wisconsin, jack pine is more localized than many other tree species. Over 90% of Wisconsin's jack pine acreage is found in five ecological landscapes with large areas of sandy soils. Nearly two-thirds of the acreage is in the Central Sand Plains and Northwest Sands ecological landscapes.

The ecological landscapes with the greatest acreages in jack pine are Central Sand Plains, Northwest Sands, Western Coulees and Ridges, Northeast Sands, and Northern Highlands (Figure 33.6). These are generally the same landscapes where jack pine was dominant historically, but its abundance is reduced, and it continues to decline for a variety of reasons. Modern fire suppression has clearly resulted in a natural conversion to other forest cover types. In addition, land use changes and the decision to plant other species, such as red pine have also reduced jack pine acreage in many cases.

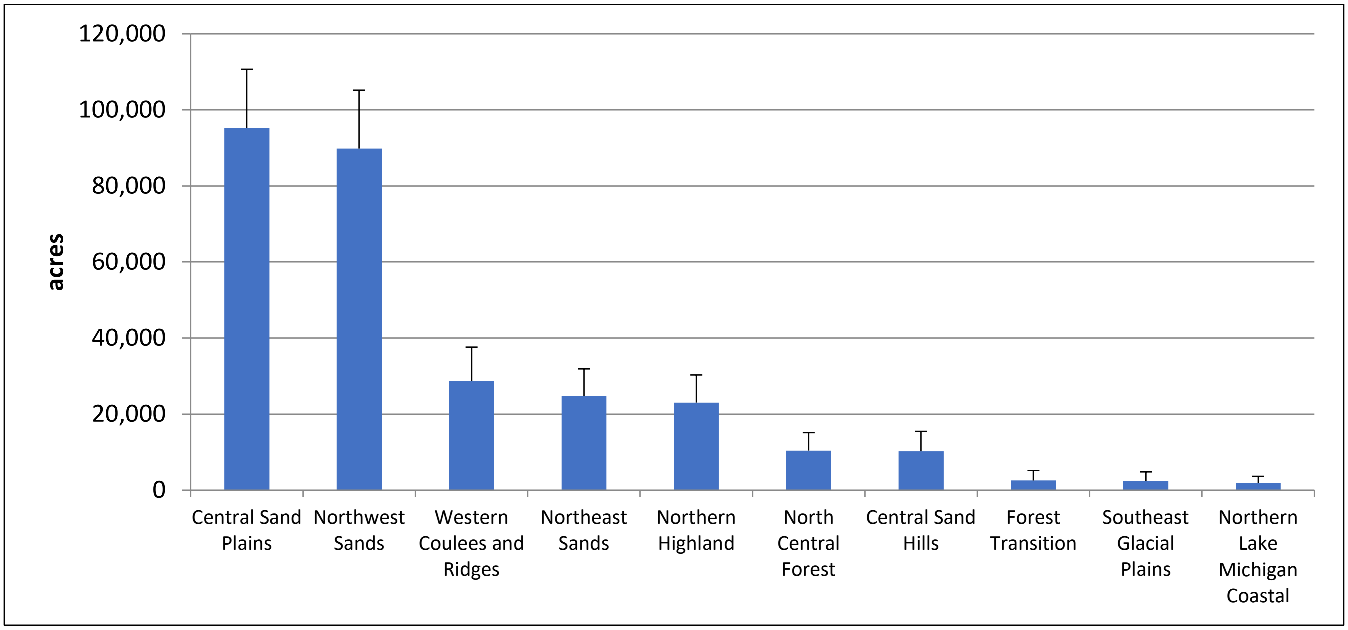

Figure 33.6. Acres (with standard errors) of jack pine by Ecological Landscape in 2013. Data are from the U.S. Forest Service Forest Inventory and Analysis (64).

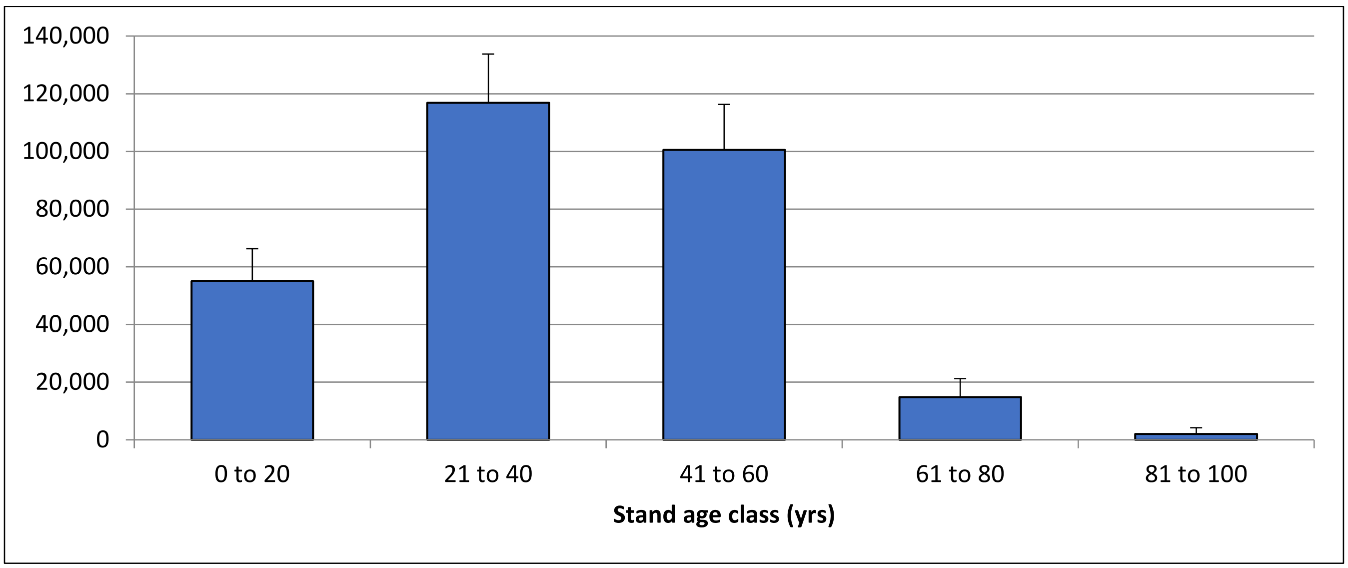

Figure 33.7. Jack pine age classes by volume in Wisconsin from the U.S. Forest Service's Forest Inventory and Analysis data (64).

Age-Class Distribution

There are both ecological and economic benefits to having a full range of age classes of a particular cover type across the landscape. Jack pine currently exhibits an unbalanced age class distribution with less acreage in the youngest and oldest age classes (64) (Figure 33.7). This reflects a decreased emphasis on reproducing jack pine in Wisconsin which is a concern for the future of the jack pine resource in Wisconsin. Moreover, the animal species associated with jack pine vary by stand age (107), and this age class imbalance is a problem for species requiring young jack pine such as Kirtland's Warbler (see Endangered Threatened and Special Concern Species section).

3.1.3 Climate Change

Jack pine was ranked as moderately vulnerable to climate change in a recent vulnerability assessment (45). The report noted the species ability to compete on poor-quality sites, withstand disturbance, and persist with drought conditions. However, the species is at the southern extent of its range in Wisconsin, and it may be less able to persist and regenerate under substantial warming. USFS (45) hypothesizes that regeneration failure could occur more frequently in drought conditions, and pests and diseases could become more damaging.

Recommendations for Management

- Increase jack pine in the youngest age classes
- Use variety of techniques to naturally regenerate jack pine
- Provide openings, ideally focused on areas with better herbaceous plant diversity
- Limit conversion to other cover types in areas best suited for jack pine
- Create large block management areas of jack pine dominant forests, working to reduce fragmentation effects.
- Participate in rolling Barrens habitat projects, ideally at the landscape scale appropriate for the site. For example, in the Northwest Sands there would be a temporarily open core Barrens surrounded by 500-1000 acres of jack pine regeneration resulting in approximately 1000-2000 acres open at any given time where possible. However, this will be difficult in many areas, depending on ownership patterns.
- Plan rolling Barrens over the long term to create a landscape scale shifting mosaic.
- Modifications to timber management objectives and forest management guidelines (e.g., tree retention, biomass harvesting) may be appropriate to achieve site specific and landscape level objectives, such as Pine Barrens restoration.
- Consider landscape level management efforts that promote jack pine habitats, such as the Northwest Sands Habitat Corridor Plan (123), the Kirtland's Warbler Plan, and other related Conservation Opportunity Areas (COAs) as identified in the Wisconsin Wildlife Action Plan 2005 (118).

3.2 Site and Stand Considerations

3.2.1 Soils

Jack pine grows most commonly on level to gently rolling sand plains, usually of glacial outwash, fluvial, or lacustrine origin. These sandy soils are typically of the Spodosol or Entisol soil orders. Best growth occurs on well-drained loamy sands where the midsummer water table is within 4 to 6 feet of the soil surface. Jack pine will persist on very dry sandy or gravelly soils where other species can scarcely survive. It also grows on loamy soils, thin soils over bedrock, and peats.

Jack pine has been managed successfully on moist sands and peats, where seasonally-high water tables can provide suitable conditions for seed germination and seedling development.

Soil productivity considerations are important when managing the jack pine cover type for several reasons; jack pine commonly occurs on excessively drained/nutrient poor soils, rotations are relatively short, and whole-tree or biomass harvesting is common. These factors influence the availability of nutrients in the soil and thereby may alter the long-term stand productivity.

Wisconsin's Forestland Woody Biomass Guidelines (10) allow for biomass harvesting of jack pine on dry nutrient poor sandy soils as long as rotations are 40 years or longer. This exception for jack pine is based on the lower nutrient content of jack pine needles, twigs, and bark, as compared to other tree species. A Minnesota study found 765 lbs/acre calcium in above ground parts of aspen compared to only 181 lbs/acre calcium in jack pine (78). Based on nutrient budget calculations for these dry nutrient poor sandy soils, the soil nutrient pool is maintained with jack pine biomass harvests on rotations of 40 years or longer. Biomass rotations shorter than 40 years indicated depletion of the soil nutrient pool for certain nutrients, even in jack pine forests. Retention of fine woody material and rotation age determination are important considerations to maintain long-term site productivity in the jack pine cover type.

3.2.2 Site Quality

3.2.2.1 Range of Habitat Type

The range of jack pine is primarily located in Canada, extending from the Northwest Territories east to Nova Scotia, and then south into the New England and Great Lake states (Figure 33.8). At the northwest extremities of the range in Alberta, jack pine hybridizes with lodgepole pine (*Pinus contorta*) (93). In the United States, the largest acreages of jack pine are located on sandy soils in Minnesota, Wisconsin, and Michigan.

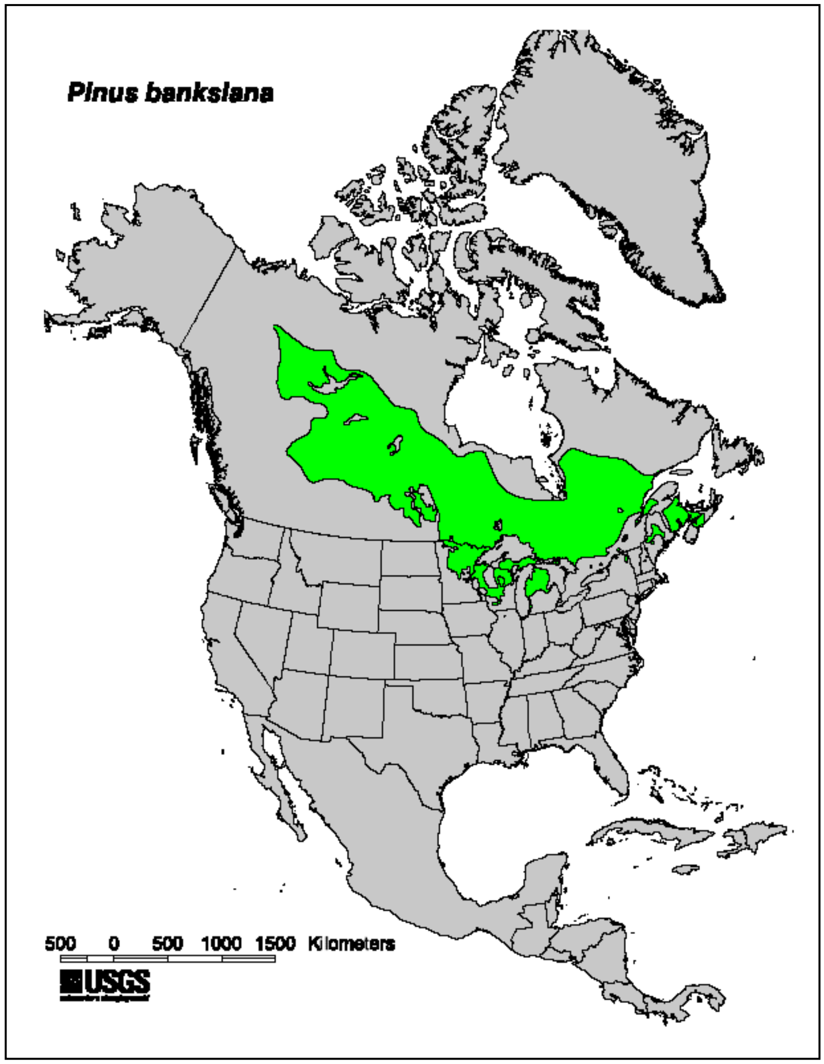

Figure 33.8. Native range of jack pine (57).

The jack pine cover type occupies approximately two percent (i.e. 307,500 acres) of the forestland acres in Wisconsin (64). Jack pine's statewide distribution is concentrated in the

Northwest Sands, Central Sand Plains, Northeast Sands, and Northern Highlands ecological landscapes (Figure 33.9). Approximately three-quarters of the jack pine volume is found on the sandy soils of northwest and central Wisconsin, with lesser amounts in the northeast, north-central and on other suitable habitats.

Jack pine is a pioneer tree species that historically regenerated almost exclusively after forest fires. Fire regimes of varying intensity and frequency resulted in pine-dominated ecosystems ranging from open Pine Barrens to very dense jack pine stands (83). Still today over three-quarters of all jack pine in Wisconsin is naturally occurring (i.e., not planted), a result of fire or scarification treatments and logging disturbance. However, with the advent of modern fire suppression practices, conditions for successful jack pine regeneration have been greatly diminished, resulting in a decline of the jack pine cover type. In the Northwest Sands, for example, the area of jack pine has decreased by 30% since pre-European settlement (83).

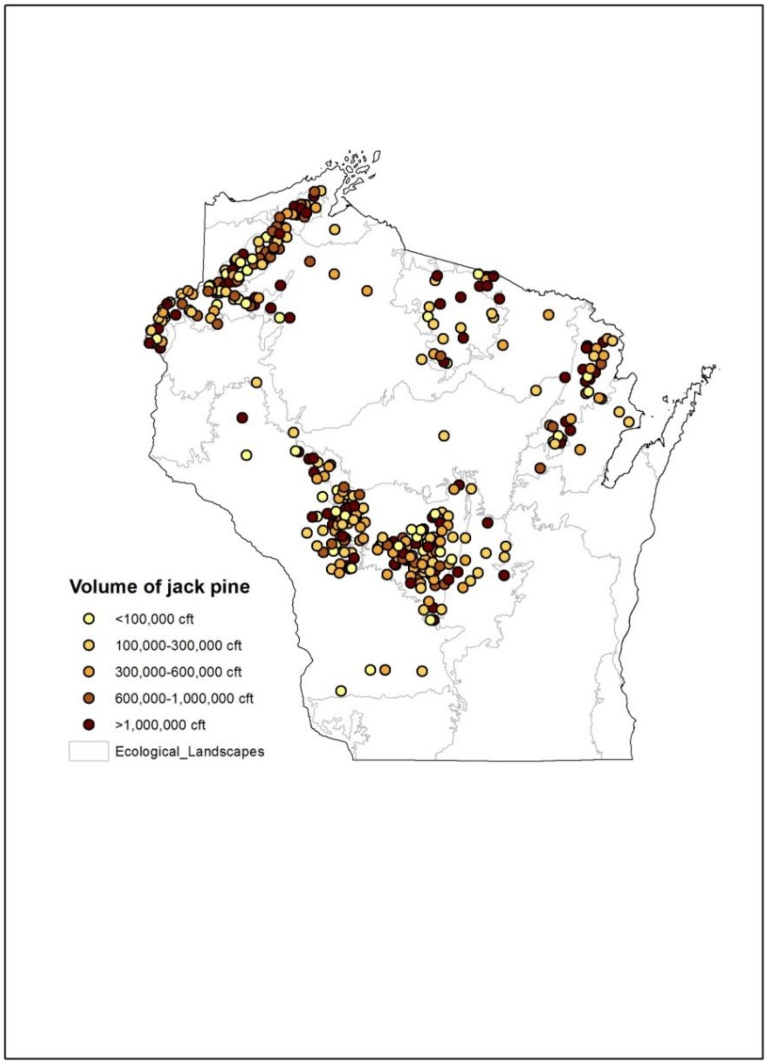

Figure 33.9. Volume of jack pine (cubic feet) by Ecological Landscape in Wisconsin from USDA FIA (64).

The volume of jack pine growing stock has been steadily decreasing in Wisconsin for poletimber and sawtimber (Figure 33.10). The ratio of removals to growth has more than doubled since 1983 and currently stands at 213% (64), meaning that harvesting removes twice as much volume as is being replaced by growth (Figure 33.11). The loss of jack pine acres and volume in Wisconsin is a result of high removals and high natural mortality (e.g., insects, disease, wind), coupled with poor regeneration and conversion to other species, such as red pine.

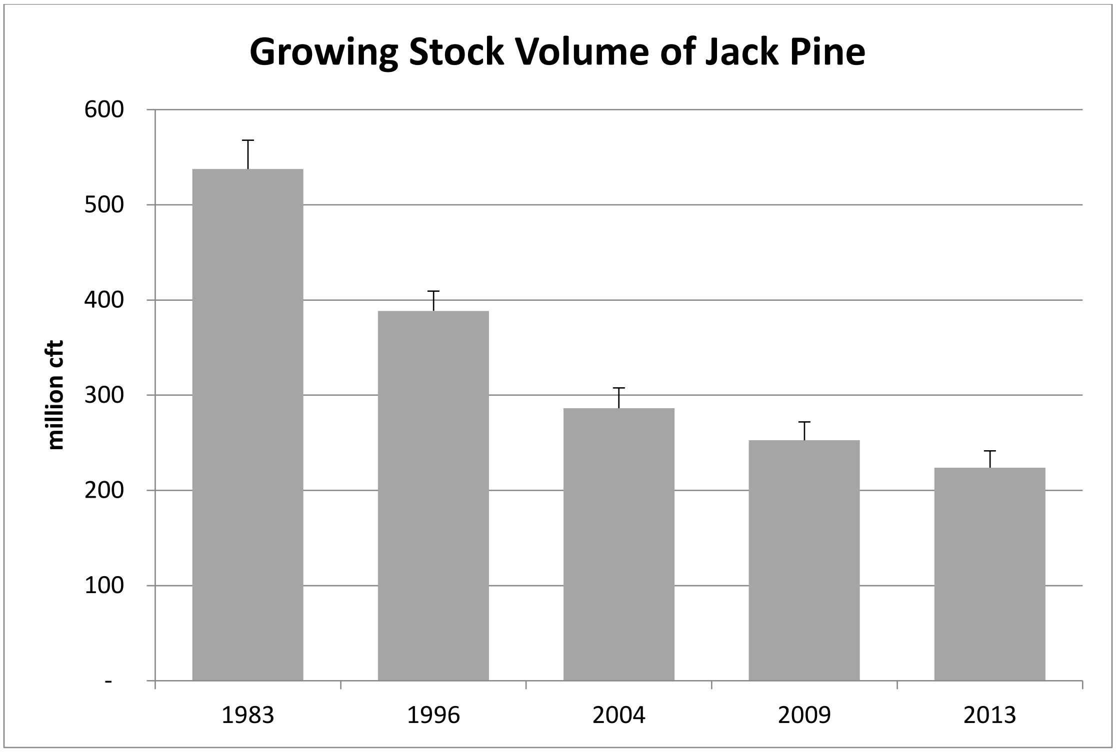

Figure 33.10. Growing stock volumes (million cubic feet) by inventory year from USDA FIA (64).

Northern Habitat Type Groups

Approximately 48% of the statewide jack pine volume occurs on northern habitat type groups, with most of that volume occurring on the northern very dry to dry (36%) and northern dry to dry mesic groups (7%). A small percentage occurs on the northern mesic to wet mesic group (4%), often associated with poorly drained sandy soils with ground water influences and low nutrients (Figure 33.12).

The northern very dry to dry habitat types are often associated with glacial outwash deposits of deep, excessively drained sands and include the driest and most nutrient poor ecosystems in northern Wisconsin. Jack pine is a common cover type on many of the habitat types in this group, but can also occur in mixed stands with pin, red, and bur oak, as well as with red and white pine. Jack pine and jack pine-oak mixtures are common on the PQE, PQG, PQGCe, PArV, PArV-U, PArVAo, and QAp habitat types (53). Jack pine ecosystems are dependent on fire or logging for regeneration and in the absence of these disturbances oak, white pine, and red maple become more abundant on this habitat type group.

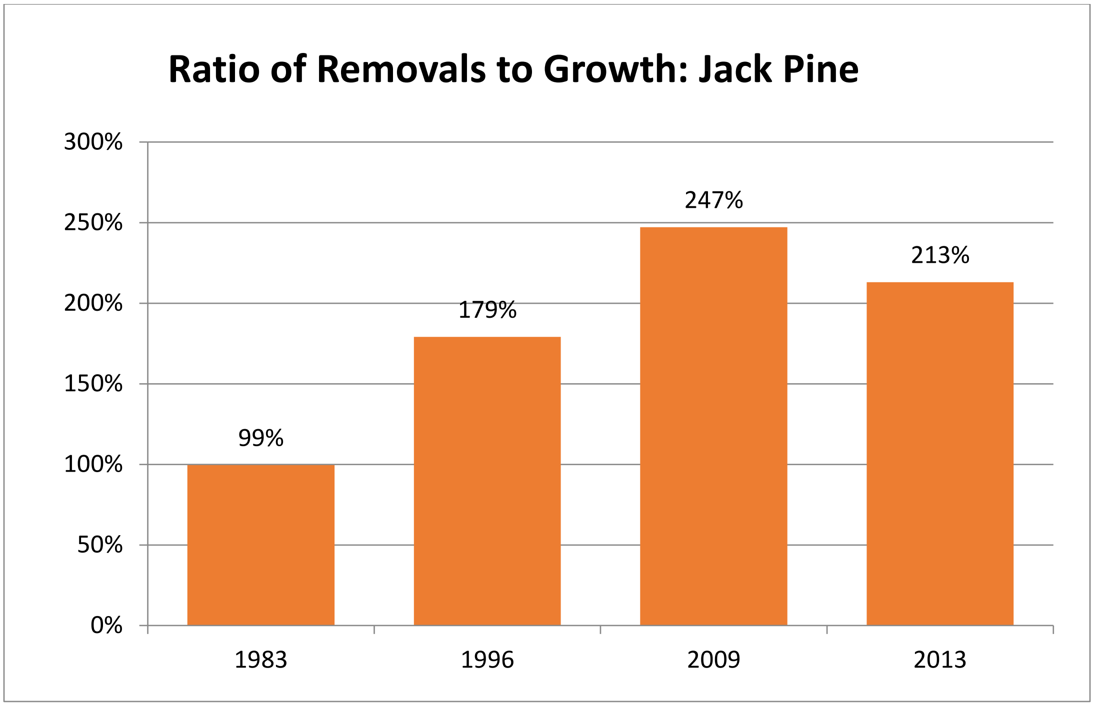

Figure 33.11. Ratio of volume harvested annually to net growth from USDA FIA (64).

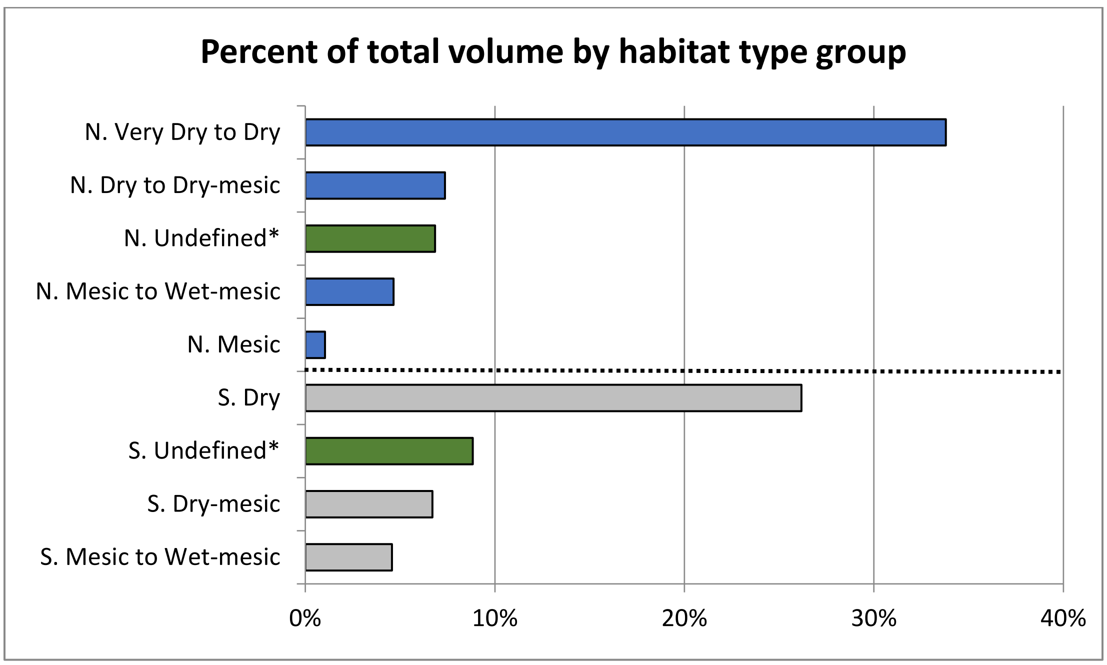

Figure 33.12. Percent jack pine volume by habitat type group from USDA FIA (64).

**Undefined groups contain FIA plots where no habitat type could be determined. Note: See Chapter 12 – Forest Habitat Type Classification System for information summarizing the system and the habitat type groups.*

The dry to dry-mesic habitat types have somewhat improved moisture and nutrient levels and therefore better growth potential for jack pine. This habitat type group includes glacial outwash sands, as well as moraines and lake plains with excessively to moderately well drained loamy sands and sands. Jack pine can be found on the PArVAm, PArVHa, PArVAa, PArVAa-Po, PArVAa-Vb, and PArVPo habitat types, but often in mixtures with competing associated species due to the improved growing conditions (53). All the habitat types in this group have the potential to grow large diameter, high quality jack pine. In the absence of disturbance, competition can be moderate to strong from red maple, white pine, and oak, contributing to continued losses in jack pine acreage due to natural conversion. In addition, jack pine stands are sometimes converted to red pine plantations due to its growth potential on these habitat types.

The northern mesic to wet-mesic habitat types where jack pine is found include poorly drained, sandy soils with high or perched water tables and poor nutrient regimes. Some habitat types in this group include ArVRp and PArVRh. Red maple and white pine usually develop in these stands in the absence of fire.

Southern Habitat Type Groups

Approximately 39% of the statewide jack pine volume occurs on southern habitat type groups, with most of that volume occurring on the southern dry (25%), southern mesic to wet-mesic (8%), and southern dry mesic groups (6%) (Figure 33.12).

The southern dry habitat types are located on nutrient poor sandy soils, often associated with glacial outwash deposits or residual material over sandstone. Topography is level to gently rolling, but these habitat types can also occur on steep slopes and narrow ridges. Jack pine in south-central Wisconsin exhibits less growth potential along the southern edge of its range, and is commonly associated with pin oak, white oak, black oak, aspen, red maple, red pine and white pine. Common habitat types in this group where jack pine are found include PVGy, PEu, PVCr, and PVG (52). In the absence of fire disturbance, white pine has become increasingly abundant on this habitat type group, especially in the central sands.

Jack pine occurs as an associate on the southern dry mesic habitat type, PVRh. This habitat type is similar to the dry types, except for ground water influences within 1-3 feet of the surface. White pine and red maple usually develop in these stands in the absence of fire.

Red Pine vs. Jack Pine Productivity

Red and jack pine grow on similar habitat types throughout the Lake States, including in mixed natural stands. However, forest managers have traditionally debated between either growing jack pine or red pine, typically favoring jack pine on the very dry sites and red pine on the somewhat more mesic sites. A Lake States study comparing volume productivity between red and jack pine plantations found that red pine mean annual increment averaged 29 cubic feet per acre greater than jack pine regardless of site index (1). These higher yields were primarily attributed to red pine's ability to carry greater basal area per acre and to a lesser extent related to differences in site quality. This potential for increased yields has historically led to management decisions to convert natural jack pine stands to red pine plantations, especially on the dry to dry-mesic habitat types. However other studies have found that jack pine performance is generally greater in terms of average height growth and survival when compared to red pine, especially on dry outwash sands and when utilizing well-adapted or improved seed sources (67, 93). Sustaining jack pine forests for economic (e.g., fiber supply) and ecological reasons (e.g., pine barrens, Kirtland's warbler), as well as recent forest health concerns with red pine plantations (e.g., annosum, pocket decline, climate adaptations), have led to renewed interest in jack pine reforestation. The decision to manage for jack pine, red pine, or mixed stands should be based on careful consideration of overall management objectives and site conditions.

3.2.5 Wildlife

Jack pine habitats in Wisconsin are concentrated into four main ecological landscapes; Northwest Sands, Central Sand Plains, Northeast Sands and Northern Highlands. Each of these landscapes supports a somewhat different suite of wildlife species. All of these landscapes were strongly influenced by fire disturbance, resulting in fire adapted vegetation and wildlife species that depend on frequent disturbance to provide suitable habitat. The Northwest Sands and Central Sand Plains contain the largest areas of jack pine forests, including many large blocks of public land which provide opportunities to manage for area-sensitive species, such as sharp-tailed grouse. The Northern Highlands contains a greater variety of landforms, soils, and forest types, and its abundant lakes, streams, and wetlands likely resulted in a somewhat less fire-prone landscape with less area of open conditions.

Jack pine stands provide an important habitat component for many wildlife species, depending on regeneration methods, stand development stage and stand size. Deer especially favor young stands of jack pine, or jack pine mixed with aspen and oak. A dense shrub layer in jack pine provides bedding and escape cover. As a browse, jack pine ranks as a secondary choice similar to white pine, less favored than hemlock or cedar, but preferred over red pine or balsam fir (29). Deer browse has still been a significant problem in some locations, especially on planted jack pine. A 2003 deer repellent trial on the Governor Knowles State Forest documented heavy browsing on jack pine seedlings, but application of deer repellents offered moderate protection (126). Research conducted at Sandhill Wildlife Area (Wood County) in oak/jack pine habitats found dewberry, blueberry, blackberry, and wintergreen were the most abundant perennial ground-layer plants that provided non-woody forage for deer in winter (54). The thermal protection provided by jack pine forests increases use by deer and other wildlife during the winter months.

Bear use all jack pine age classes for cover but prefer regenerating stands for summer and fall foraging areas, especially for berries. For many wildlife species, small openings within a regenerating stand are important for life history requirements including; nesting, foraging, mating, and rearing young. Ruffed grouse use middle-aged jack pine more commonly if mixed with a dense shrub understory and especially if associated with young or middle-aged aspen. Spruce Grouse use young to middle-age jack pine when associated with black spruce-tamarack bogs (3). Jack pine associated with conifer swamps are also preferred habitats for bobcat and fisher. Turkeys use mature jack pine as roost trees and forage in open stands of middle-age and mature jack pine. Small mammals, such as red squirrel, utilize the stored seed supply available from jack pine's serotinous cones.

Similar to game species, Species of Greatest Conservation Need (SGCN) use jack pine habitats according to the seral stages. Initially, if regenerating stands are open and large, vesper sparrows and upland sandpipers use the new openings. Young dense stands with small openings are critical for Kirtland's warbler, as well as the more common brown thrasher and northern flicker. Limiting tall snags and perches may be a consideration in certain situations to reduce cow bird nest parasitism, such as within Kirtland's restoration areas. However, other wildlife species, such as black-backed and red-headed woodpeckers, will require snags. As jack pine stands mature and if a deciduous understory remains, Connecticut warblers find the habitat favorable. Mature stands will supply whip-poor-will habitat, especially near edges.

Thirty-one vertebrate SGCN were reported as being associated with Northern Dry Forest, a natural community type often dominated by jack pine (118). In addition, 33 SGCN were reported to be associated with the Pine Barrens community (118). Table 33.2 and Table 33.3 list the major jack pine-associated Species of Greatest Conservation Need. This list includes two WI Endangered species (Kirtland's warbler and slender glass lizard), and four WI Threatened species (spruce grouse, upland sandpiper, northern long-eared bat, and wood turtle). The Kirtland's warbler is also federally listed as endangered and the northern long-eared bat is federally listed as threatened. At least 21 invertebrate species designated as SGCN appear to use jack pine forests, including Pine Barrens (Table 33.3). The list includes one US Endangered species (Karner blue butterfly), three WI Endangered species (northern blue butterfly, phlox moth, and warpaint emerald dragonfly), and one WI Threatened species (frosted elfin).

<u>Pine Barrens and Wildlife</u>

Figure 33.13. A male sharp-tailed grouse displays among jack pine stumps and new growth. Photo by WDNR.

The Pine Barrens is a community characterized by variable densities of pine and oak, ranging from completely open areas to scattered trees to dense groves interspersed with openings. These communities are commonly associated with the dry nutrient poor sands and more fire prone landscapes, such as the Northwest Sands or Central Sand Plains, and support a unique mix of fire adapted flora. Wildlife species associated with the Pine Barrens range from the very common generalists (e.g., deer, snowshoe hare, turkey) to many rare and special concern species that are in decline due to loss of barrens habitat (see Landscape Considerations). Several species associated with the barrens are area-sensitive, meaning they require large, contiguous habitats to fulfill life history requirements. These large areas must have a component of open habitat, at least temporarily, for many of the rarest barrens-dependent species. In the Northwest Sands, sharp-tailed grouse are considered an indicator species for quality barrens communities. Sharp-tailed grouse make use of jack pine stands mainly in early regeneration stages, especially in areas of large block management and rolling barrens (see Landscape Considerations). Landscape level planning and implementing large scale cooperative projects is critical to restoring landscape function in the barrens community. Forest management and working forests, particularly jack pine harvesting and regeneration, play a key part in successful barrens management.

<u>Wildlife Recommendations</u>

- Consider regenerating jack pine stands in order to offset declines in this forest cover type.
- Consider landscape context; adjust stand size and placement where appropriate in order to achieve large blocks of jack pine habitat, including blocks of various age classes. The age class blocks can be rotated over time, as in rolling barrens management (Figure 33.5).
- Allow for variable densities during the regeneration stage, creating dense patches and small openings (i.e., generally less than ½ acre in size).
- Consult with local biologists to determine where tree retention is appropriate to meet stand-level and landscape-level objectives.
- Use the least intensive site preparation methods possible to maintain ground flora, while achieving regeneration objectives. Consider not treating small areas where rare species occur (i.e., refugia).

3.2.6 Endangered, Threatened and Special Concern (ETS) Species

Jack pine can be the dominant species in two major natural community types: Northern Dry Forests and Pine Barrens. These closely related, disturbance-dependent community types support a number of rare species and often form a continuum from very open to more closed-canopy forest. Maintaining both of these communities on the landscape is important for conserving rare species, and there can be ecological benefits to managing them together, even within the context of timber production.

Pine Barrens are not just recently logged or otherwise treeless areas, and they can vary greatly in structure and species composition. These areas can contain a unique flora, including species associated with dry prairie habitats. The Pine Barrens community found in Wisconsin is considered globally imperiled because there are so few high-quality examples remaining (128). Wisconsin’s barrens are different from the “barrens” of the eastern U.S. which lack much of the floristic diversity present in this type in the Lake States (127). The structure of the barrens can range from almost completely open to partially open with patches of larger trees.

Some of Wisconsin’s rarest plants and animals are associated with Pine Barrens communities. These include numerous WI Threatened species, as well as WI Endangered species such as slender glass lizard (*Ophisaurus attenuatus*), phox moth (*Schinia indiana*), and dwarf huckleberry (*Vaccinium cespitosum*), the only known host plant for the northern blue butterfly (*Lycaeides idas*) which is also WI Endangered. The US Endangered Karner blue butterfly

(*Lycaeides melissa samuelis*) uses Pine Barrens, as well as other open to semi-open habitats in sandy ecological landscapes if they contain its host plant, lupine (*Lupinus perennis*). Frosted elfin (*Callophrys irus*), a much rarer butterfly in Wisconsin that is found only in the Central Sand Plains ecological landscape, also relies on lupine as its host plant.

Some barrens species are area-sensitive including Sharp-tailed Grouse (*Tympanuchus phasianellus*), a WI Special Concern species that requires very large, contiguous habitats to support viable populations. Its best Wisconsin populations are located in large managed areas in the Northwest Sands. Connecting scattered openings and pockets into larger blocks could benefit a number of species, and these open areas could be managed in conjunction with the surrounding forests (see Landscape Considerations).

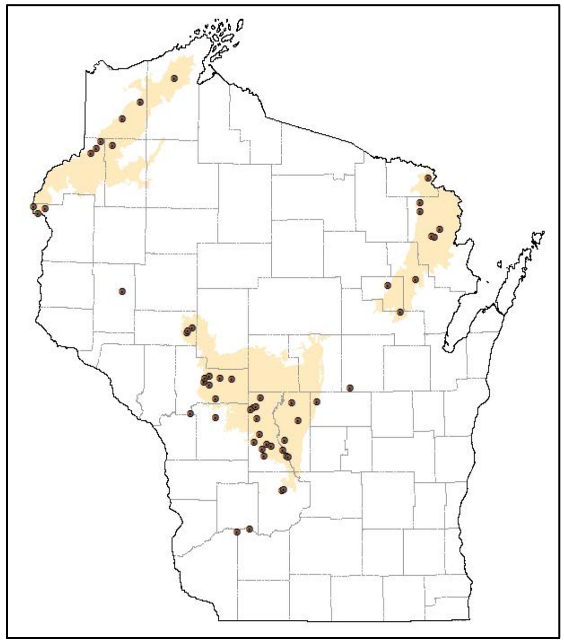

Figure 33.14. Location of Pine Barrens remnants documented in the NHI database (dots) in the Northwest Sands, Northeast Sands, and Central Sand Plains ecological landscapes. Many of the species described in this section are found in these landscapes.

Most of the rare plants associated with the more closed-canopy jack pine forests (Northern Dry Forest community) are barrens associates that have survived where light and other conditions have remained favorable. Sometimes these species can be present in the seed bank and return following logging, burning, or a combination of the two. Whether a stand can support some of the flora associated with barrens will depend on the stand's location, its disturbance history, and the amount of light reaching the understory.

Maintaining pockets of open barrens within jack pine plantations can be important for increasing species diversity since a normal timber rotation may be too long to support some of the light-demanding plants associated with barrens communities. Providing openings in jack pine plantations has been described as vital for the maintenance of barrens species (44). Ideally, planted sites would include permanent or semi-permanent open areas, where feasible, and these would be located where high-quality barrens remnants exist. Sometimes these pockets can support additional animal species such as certain butterflies and moths which usually rely on specific plant species to complete their life cycle.

More closed-canopy forests dominated by jack pine can support several animal species such as Connecticut warbler (*Oporornis agilis*) and spruce grouse (*Falcipennis canadensis*). The jack pine forests of northwest Wisconsin are an important stronghold for Connecticut warbler where it uses dense stands of older jack pine (131). Spruce grouse has been found in jack pine forests near lowland conifer swamps, especially in winter (4, 124), and these lowland areas provide critical nesting habitat. Table 33.2 lists additional rare vertebrate species associated with jack pine communities.

Kirtland's Warbler

Kirtland's warbler (*Setophaga kirtlandii*), a US Endangered species since 1967, is probably the most well-known animal species associated with jack pine. In its core breeding range in the northern part of Lower Michigan, there is evidence that populations were at their highest in recorded history at the same time jack pine habitat was most abundant during the 1880s and 1890s . It has been the focus of major recovery efforts, formerly mostly in Michigan, for several decades (75).

Figure 33.15. Planting pattern in a Kirtland's Warbler management area, Huron-Manistee National Forest, Michigan. Photo by Linda Haugen, USDA Forest Service Bugwood.org.

In Wisconsin, Kirtland's warbler has been documented in several ecological landscapes but is known to breed in just two locations, as of this writing. Its habitats are highly specialized; it generally breeds in jack pine stands from 6-23 years old, with tree heights ranging from 5.5 to 16.5 feet tall, and in stands of 75 to 100 acres or larger (82).

In Lower Michigan, intensive management techniques conducted through state and federal agencies have proven highly successful for increasing numbers of Kirtland's warbler. Populations increased from about 400 individuals in 1971 to 3600 by 2012 (48). Approximately 2,000-2,500 acres of jack pine are established annually using a wave planting pattern in order to create small openings (75), and it also provides habitat for a number of other wildlife species (24). The trapping of cowbirds, a parasitic songbird that often prevents successful nesting by Kirtland's warbler, has been critical to the success of these efforts in recent years (75). However, this approach differs greatly from natural disturbance (27, 24) and does not provide the level of diversity that would be found in most barrens. The impacts of this approach on plant and animal diversity have become important research questions (25, 66, 101) and the focus of recent efforts in the Upper Great Lakes. One concern is that this intensive approach leads to a homogenous landscape if applied over very large scales. Recent efforts in Michigan have focused on examining similarities and differences between this type of management and natural fire disturbance, as well as ways to incorporate burning, patch retention, and other barrens management into the management for Kirtland's warbler (25). Wisconsin, being recently colonized by Kirtland's warbler, may have the opportunity to incorporate a broad range of considerations into management for this species.

The first documented breeding location for Kirtland's warbler in Wisconsin was dominated by red pine, but most red pine plantations would not be able to support this species. A high degree of red pine mortality combined with abundant natural jack pine recruitment created the conditions that allowed Kirtland's warbler to utilize this central Wisconsin site (3). There may be opportunities to grow red pine in coordination with jack pine in an attempt to mimic the conditions of this site while making it more economically attractive to manage for jack pine in certain areas (3). See the USFWS Kirtland's warbler website (105) for more information.

Other considerations for jack pine communities include the impact of chemical and mechanical site preparation techniques on the flora and fauna of the barrens and dry forests. These communities clearly require disturbance to persist, and there are several aggressive invasives that need control. Moreover, some rare plants have been shown to respond favorably to disturbances such as scarification. However, the impacts of some techniques on many rare species are not completely clear at this time. A careful approach is warranted where rare species occur, including consideration for not treating certain areas or limiting certain areas to spot-treatments when using herbicides. A biologist can help with planning these decisions.

Table 33.2, Table 33.3 and Table 33.4 list many of the species known to use habitats dominated by jack pine. For more information and guidance on these and other rare species, as well as information on natural communities, and ecological landscapes, see the following resources:

- Wisconsin DNR's rare plant, animal, and natural community web pages: *https://dnr.wisconsin.gov/topic/endangeredresources/biodiversity*
- Ecological Landscapes of Wisconsin: https://dnr.wisconsin.gov/topic/lands/EcologicalLandscapes
- Wisconsin DNR's Natural Heritage Working List: https://dnr.wisconsin.gov/topic/NHI/WList

Figure 33.16. Photos: (Left) Karner Blue habitat. Pine Barrens in Adams County, Photo by WDNR. (Right) Pine Barrens understory with wild lupine, cylindrical blazing-star, lance-leaved loosestrife, prairie grasses, Eau Claire County. Photo by Eric Epstein.

Table 33.2. Wisconsin Vertebrate Species of Greatest Conservation Need (SGCN, 2005) that use jack pine forests. See also dnr.wi.gov keyword "biodiversity."

Common Name	Scientific Name	State Status[1]	Federal Status[2]	Forest Stage [3]				Season [4]			Locations[5]	Comments
				R	Y	M	O	YR	W	S		
Birds												
American Woodcock	*Scolopax minor*	SC		xx	xx	xx				xx	Nearly statewide	Not primarily associated with jack pine but may use it.
Black-backed Woodpecker	*Picoides arcticus*	SC				xx	xx	xx			Northernmost ecological landscapes	Retain cavities and dead trees for nesting. Often nests where tree density is higher.
Black-billed Cuckoo	*Coccyzus erythropthalmus*	SC			xx	x				xx	Nearly statewide	Found most in extensive tracts of forest. Uses several forest types.
Boreal Chickadee	*Poecile hudsonicus*	SC				xx		xx			Northernmost ecological landscapes	Not primarily associated with jack pine. Uses lowland conifers in WI.
Brown Thrasher	*Toxostoma rufum*	SC			xx	xx				xx	Nearly statewide	Brushy habitats; edge species. More associated with barrens / prairies.
Connecticut Warbler	*Oporornis agilis*	SC				xx	xx			xx	Northernmost ecological landscapes and CSP	Prefers mature, multi-layered stands.
Field Sparrow	*Spizella forsteri*	SC		xx						xx	Nearly statewide except the most forested northern landscapes.	Early successional species that could be in barrens or very young forest following disturbance.
Grasshopper Sparrow	*Ammodramus savannarum*	SC		x						x	Nearly statewide except the most forested northern landscapes but mostly found in the south.	Grassland / barrens species that avoids tall, dense vegetation.
Kirtland's Warbler	*Setophaga kirtlandii*	END	LE	xx	xx					xx	NWS, NH, NES, CSP	Requires jack pine of a certain size class and in larger blocks; see text.
Lark Sparrow	*Chondestes grammacus*	SC		xx	x					xx	Southern and western ecological landscapes	Early successional species that could be in barrens or very young forest following disturbance.
Least Flycatcher	*Empidonax minimus*	SC				x	x			xx	Nearly statewide	Can be found in a variety of forested habitats.
Northern Harrier	*Circus cyaneus*	SC		xx						xx	Nearly statewide	Species of very open habitats that nests on the ground. Does not use forests.

Previous View

Common Name	Scientific Name	State Status[1]	Federal Status[2]	Forest Stage [3]				Season [4]			Locations[5]	Comments
				R	Y	M	O	YR	W	S		
Red Crossbill	*Loxia curvirostra*	SC					xx		xx	x	Mostly northernmost ecological landscapes but could be found in almost any EL.	Mature coniferous forests and relies on seed cones. Breeding locations change based on locations of good seed crops.
Red-headed Woodpecker	*Melanderpes erythrocephalus*	SC					xx		x	xx	Nearly statewide except the most forested northern landscapes.	Savanna / barrens species that uses various species of oaks. Not directly tied to jack pine.
Sharp-tailed Grouse	*Tympanuchus phasianellus*	SC		xx				xx			Northern WI and CSP Best habitats are in the NWS	Uses large areas with dense. herbaceous cover and shrubs.
Spruce Grouse	*Falcipennis canadensis*	THR				xx	xx		xx	x	Northernmost ecological landscapes	Prefers dense stands. Jack pine stands adjacent to lowland conifers appear to be important in WI. Seems to avoid stands with high component of deciduous trees.
Upland Sandpiper	*Bartramia longicauda*	THR		xx	xx					xx	Nearly statewide except the most forested northern landscapes.	Grassland / barrens species that avoids tall, dense vegetation.
Vesper Sparrow	*Pooecetes gramineus*	SC		xx	xx					xx	Nearly statewide except the most forested northern landscapes.	Grassland / barrens species that avoids tall, dense vegetation.
Whip-poor-will	*Caprimulgus vocifeus*	SC				xx				xx	Nearly statewide	Prefers forest with little underbrush that is close to foraging areas (open areas).
Mammals												
Gray Wolf	*Canis lupus*	SC		x	x	x	x	xx			Northern and central WI	Not primarily associated with jack pine but may use it along with many other forest types.
Hoary Bat	*Lasiurus cinereus*	SC				x	xx			xx	Statewide	Roost in large, mature trees.
Moose	*Alces alces*	--		x	xx				xx		Rarely move into WI from MI - usually only the northernmost counties	Can be found in a variety of forests and wetlands.
Northern Flying Squirrel	*Glaucomys sabrinus*	SC				x	xx	xx		xx	Northernmost ecological landscapes	Conifer or mixed forests with standing dead trees, coarse

Common Name	Scientific Name	State Status[1]	Federal Status[2]	Forest Stage [3]				Season [4]			Locations[5]	Comments
				R	Y	M	O	YR	W	S		
												woody debris and diverse understory.
Northern Long-Eared Bat	*Myotis septentrionalis*	THR				xx	xx			xx	Statewide	Roosts in a wide variety of tree species in intact forests.
Herptiles												
Blanding's Turtle	*Emydoidea blandingii*	SC		xx	x	x				xx	Nearly statewide, except far north-central counties	Species is primarily aquatic but will traverse a variety of terrestrial habitats in the active season. Nests in open sandy areas within 900 ft. of a wetland or waterbody. This is a consideration for siting landings or roads.
Gophersnake	*Pituophis catenatus*	SC		xx						xx	Western and southwestern 1/3 of the state	Prairie/savanna/barrens species. Needs open habitat.
Prairie skink	*Plestiodon septentrionalis*	SC		xx						xx	Northwestern WI	Sandy barrens, savannas, prairies, and dry forests. Active from May – September.
Slender Glass Lizard	*Ophisaurus attenuatus*	END		xx						xx	CSH, CSP, and WCR ecological landscapes	Barrens, prairies, and savannas. Needs sandy soils but will use forest edges.
Wood Turtle	*Glyptemys insculpta*	THR		x	x	x	x			xx	Northern 2/3 of the state	Species is very terrestrial during the active season and utilizes a mosaic of forest and open habitats. Nests in open sandy areas, often within 200 ft. of a wetland or waterbody, but individuals can be found much farther from their overwintering streams. This is a consideration for timber harvests, as well as siting of landings or roads.

1. END = Endangered, SC = Special Concern, THR = Threatened. Note some SC species are protected by other laws; see WDNR 2014b for more information.
2. LE = Listed Endangered by the US Fish and Wildlife Service
3. Forest Stage: R=regenerating, Y=young forest, M=Mid-age forest, O=older forest; xx= major use; x= minor use
4. Season: YR=year-round, W=Winter, S=Summer season; xx= major use; x= minor use
5. Ecological Landscape abbreviations: CSP = Central Sand Plains, NH = Northern Highlands, NES = Northeast Sands, NWS = Northwest Sands (see *dnr.wi.gov* keyword "landscapes" for more information).

Table 33.3. Select Wisconsin invertebrate SGCN that use jack pine forests. See also dnr.wi.gov keyword "biodiversity." For grasshopper guidance, see Kirk and Bomar (48), the source of some of this information.

Species	Scientific Name	State[1] Status	Federal Status[2]	Ecological Landscape(s)[3]
Speckled Rangeland Grasshopper	*Arphia conspersa*	SC		Sandy gravel soils in dry prairie settings such as open sand in Pine Barrens and Lake Superior sand spits.
Frosted Elfin	*Callophrys irus*	THR		Pine barrens, oak savanna, and edges of sandy oak/pine forest.. Needs lupine (*Lupinus perennis*), its larval host plant. (CSP only).
Rocky Mountain Sprinkled Locust	*Chloealtis abdominalis*	SC		Jack pine barrens, pine forest openings.
Tiger Beetle	*Cicindela longilabris*	SC		Sandy areas in coniferous forest with jack pine, blueberries, reindeer moss. Sandy roads, gaps in northern forest.
Tiger Beetle	*Cicindela patruela huberi*	SC		Dry, sandy soils within mixed jack pine-oak forest and pine barrens, usually along forest roads and sand quarries.
Tiger Beetle	*Cicindela patruela patruela*	SC		Dry, sandy soils within mixed jack pine-oak forest and pine barrens, usually along forest roads and sand quarries.
Wild Indigo Dusty Wing	*Erynnis baptisiae*	SC		Dry open woods, prairie including wet prairie, pine/oak barrens, and along highways and railroad right-of-ways.
Mottled Dusty Wing	*Erynnis martialis*	SC		Scrub forest, pine/oak barrens and oak savanna.
Persius Dusky Wing	*Erynnis persius*	SC		Pine/oak barrens, sand barrens. Microhabitat includes open sandy ground and small scrub oaks may be required components of the habitat.
Slender Clearwing	*Hemaris gracilis*	SC		Jack pine/oak barrens and open trails through northern dry forests (NWS only).
Cobweb Skipper	*Hesperia metea*	SC		Pine barrens and oak savanna.
Northern Blue Butterfly	*Lycaeides idas*	END		Only found in association with the larval host plant, dwarf bilberry (*Vaccinium caespitosum*), which is also State endangered. (NES only).
Karner Blue Butterfly	*Lycaeides melissa samuelis*	SC	LE	Found in pine barrens and oak savanna, as well as a number of other open or partially-open sandy habitats with its larval host plant lupine (*Lupinus perennis*).
Huckleberry Spur-throat Grasshopper	*Melanoplus fasciatus*	SC		Sandy woods and pine/oak barrens with jack pine, blueberry, sweet fern, and lupine.

Species	Scientific Name	State[1] Status	Federal Status[2]	Ecological Landscape(s)[3]
Stone's Locust	*Melanoplus stonei*	SC		Pine/oak barrens and northern dry-mesic forest (in CSP), high quality sand dunes on Lk. Michigan shore.
Chryxus Arctic	*Oeneis chryxus*	SC		Dry grass habitats, cutovers, jack pine barrens, rocky and grassy openings in forest especially along ridges.
Pink Sallow Moth	*Psectraglaea carnosa*	SC		Usually in unburned sandy pine or oak barrens. Apparently absent from many barrens less than 2000 acres.
Sprague Pygarctica Moth	*Pygarctia spraguei*	SC		Pine barrens and oak savanna in Wisconsin.
Bina Flower Moth	*Schinia bina*	SC		Pine barrens supporting native hawkweeds.
Phlox Moth	*Schinia indiana*	END		Sandy dry to dry-mesic savannas (black/Hill's oak or jack pine barrens) and small dry-mesic prairie openings with an abundance of downy phlox (*Phlox pilosa*), its host plant.
Warpaint Emerald Dragonfly	*Somatochlora incurvata*	END		Large wetlands often adjacent to sandy uplands (old beach ridges) consisting of jack pine, red pine, and northern pin oak.

1. END = Endangered, SC = Special Concern, THR = Threatened. Note some SC species are protected by other laws; see WDNR 2014b for more information.
2. LE = Listed Endangered by the US Fish and Wildlife Service
3. CSP = Central Sand Plains, NES = Northeast Sands, NWS = Northwest Sands (see *dnr.wi.gov* keyword "landscapes" for more information).

Table 33.4. Select Wisconsin rare plants known from Northern Dry Forest and Pine Barrens. See also *dnr.wi.gov* keyword "biodiversity."

Common Name	Scientific Name	Community Type [1]	State Status [2]	Documented Habitat
Prairie Sagebrush	*Artemisia frigida*	PB	SC	Very dry dolomite bluff prairies and sand terraces along the upper Mississippi River; adventive elsewhere.
Wooly Milkweed	*Asclepias lanuginosa*	PB	THR	Dry, sandy or gravelly hillside prairies.
Dwarf Milkweed	*Asclepias ovalifolia*	PB	THR	Oak barrens, open pockets within pine barrens, periodically brushed areas, and rights-of-way.
Fernald's Sedge	*Carex merritt-fernaldii*	PB, NDF	SC	Dry sandy soils and rocky outcrops in central, north-central, and northeastern Wisconsin. It is usually found in recently burned barrens, and occasionally in low, moist sandy areas along lake margins or roadsides.
Grassleaf Rush	*Juncus marginatus*	PB	SC	Acidic, peaty ditches and depressions in pine and oak barrens.
Large-Flowered Ground-Cherry	*Leucophysalis grandiflora*	PB, NDF	SC	Mostly in recently burned or disturbed moist to dry forests, as well as on gravel bars of large rivers.
Brittle Prickly-Pear	*Opuntia fragilis*	PB	THR	Thin, dry soil over rock, as well as sand prairies.
Hairy Beardtongue	*Penstemon hirsutus*	PB	SC	Dry gravelly and sandy prairies, or in hillside oak woodlands. It is also naturalized on roadsides.
Pale Beardtongue	*Penstemon pallidus*	PB	SC	Dry, often calcareous prairies, as well as hillside oak or jack pine woodlands. It is naturalized on roadsides and in pine plantations.
Hooker's Orchis	*Platanthera hookeri*	NDF	SC	Variety of dry to moist, mostly mixed coniferous-hardwood forests.
Catfoot	*Pseudognaphalium micradenium*	PB, NDF	SC	Dry, commonly sandy soil, often in open oak and pine woods and barrens.
Prairie Fame-Flower	*Phemeranthus rugospermus*	PB	SC	Open, sandy prairies, barrens and in moss on exposed bedrock outcrops, often where there is little competition from other forbs.
Dwarf Huckleberry	*Vaccinium cespitosum*	PB, NDF	END	Pine barren openings and can often be located by searching for the WI Endangered northern blue butterfly whose larvae feed exclusively on this shrub.
Blue Ridge Blueberry	*Vaccinium pallidum*	PB	SC	Dry, upland woods and old fields. Known only from northeastern counties in WI.
Sand Violet	*Viola sagittata var. ovata*	PB	END	Dry, sandstone road cuts or trailside with little competition other than jack pine.

1. PB = Pine Barrens, NDF = Northern Dry Forest
2. None of these species were federally-listed at the time of this writing.

3.2.7 Economic Issues

<u>Primary Wood Using Industries</u>

Jack pine is utilized by primary wood using industries as pulpwood, biomass, posts, and sawlogs. In 2009, jack pine accounted for 13 million cubic feet or 3.6% of Wisconsin's total roundwood production, with approximately 56% used for pulpwood and 33% for sawlogs (125). Jack pine is a desirable pulpwood species because of its long fiber length, making it ideal for producing strong paper. Wisconsin paper mills generally lump jack pine with other conifer species and process softwood and hardwood pulpwood separately. Jack pine lumber is generally knottier than other hard pine species, such as red pine, and is often grouped with other softwoods like spruce, pine, and fir and stamped with the abbreviation “SPF” (132). A few Wisconsin sawmills have developed good markets for jack pine dimensional lumber (e.g., SPF lumber, pallet stock, fence pickets), specifically targeting 8’to 12’ sawlog lengths.

Current Statewide Inventories
The statewide growing stock volume of jack pine in 2013 was approximately 224 million cubic feet. This represents a decrease of 57% since 1983 (Figure 33.10). Jack pine growing stock volume has been decreasing steadily due to high removals and natural mortality, coupled with poor regeneration and conversion to other species. The ratio of removals to growth has more than doubled since 1983 and currently stands at 213% (Figure 33.11). The number and volume of pole and sawtimber trees has decreased significantly since 1996, but the number of saplings has increased by about 10%, suggesting some level of successful regeneration for this forest type (125).

Wisconsin paper mills report concern for limited supplies of jack pine, as well as other softwood species. Jack pine has become a smaller portion of their softwood volumes, due to the decreasing supply and diversion of larger trees to sawtimber markets. Wisconsin mills that utilize jack pine also indicate they would purchase more volume if it was available, but even at small volumes jack pine is still an important component of their overall product mix (Joseph Kies, personal communication).

General Product Specifications:
Pulpwood
- Length – 100”
- Minimum Diameter (small end) – 3” or 4”
- All softwoods scaled by weight
- No charred wood

Sawtimber
- Length – 8’, 10’, or 12’ sawlogs (plus 6” trim)
- Minimum Diameter (small end) – 8”

3.2.8 Wildfire Protection

Fuel Management for Reducing Wildfire Hazards
Fuel management considerations should be made in jack pine communities, prioritizing areas adjacent to developed residential areas. There are two main types of fuel management options to consider: fuelbreaks and firebreaks.

Fuelbreaks: A fuelbreak is a natural or man-made change in fuel characteristics which affects fire behavior so that fires burning into them can be more readily controlled (73). Strategically locating fuelbreaks near developments and within larger blocks of pine will reduce the risk of crown fire and create tactical opportunities for fire suppression personnel and equipment if a forest fire should occur. A fuelbreak will lower the fuel volume and reduce fire intensity by using techniques such as thinnings, harvest and species conversion. A fuelbreak does not stop a wildland fire; rather the focus is on interrupting the contiguous fuel arrangement so that the canopies will not sustain fire.

Jack pine thinnings and harvest will reduce the amount of fuel that sustains crown fire, causing a fire to drop to or remain on the forest floor where suppression crews are better able to control or narrow the fire. Post-harvest slash near houses should be mitigated. Mechanically treating fuels (e.g., roller chopping) to create a fuelbreak can also serve as a wildlife opening.

During species conversion, less hazardous associated species are favored as determined by location and habitat type. Scrub oak, aspen and white birch are common associates that should be considered for conversion as well as opportunities for oak savanna or Pine Barrens. Aspen can actually slow a fire once they have greened-up. Widths can be delineated by features in the area (e.g., from road to road or lake to lake).

Another consideration is floating fuelbreaks. Use progressive clearcut methods by maintaining separate harvest areas in strips, so there is always one strip of low vegetation that can be considered a fuelbreak and access point for fire suppression equipment.

Firebreaks: A firebreak is a natural or constructed barrier used to stop or check fires that may occur, or to provide a control line from which to work (73). The objective of a firebreak is to remove all burnable material from an area. Two considerations are the placement of roadside mineral soil firebreaks and logging or access roads. Mineral soil firebreaks on the sides of plantations next to roads can provide suppression opportunity. They can also prevent a roadside surface fire from burning into the plantation.

Logging road locations should be designed to maximize their value as firebreaks. Include 20-foot wide fire breaks/access roads within larger plantations for suppression opportunity.

4 STAND MANAGEMENT DECISION SUPPORT

4.1 Stand Inventory

Prior to development and implementation of silvicultural prescriptions, landowner property management goals need to be clearly defined and articulated, management units (stands) must be accurately assessed, and stand management objectives should be detailed. In-depth and accurate stand assessment will facilitate discussion of stand management options and objectives in relation to realistic and sustainable management goals. Jack pine stand assessment may include quantifying variables such as those described in the following table.

Table 33.5. Jack pine stand inventory considerations.

Species Composition	• Canopy, shrub, and ground layers • Potential growth and competition • Sources of regeneration, especially non-target species that may interfere with jack pine regeneration (e.g., aspen coppice)
Stand Structure	• Size class distribution and density • Age class distribution
Stand and Tree Quality	• Overall stand health and vigor • Crown form and vigor • Stem form and quality • Potential products (fiber vs. bolt wood) • Genetic potential of current stand (Note – past improper seed source selection may have resulted in poorly adapted planting stock)
Regeneration Potential	• Cone production • Serotinous vs. non-serotinous • Seedbed condition – scarification needs • Depth to water table – available moisture • Competing vegetation (e.g., hazel, sedge)
Site Quality	• Habitat type • Site index • Soil characteristics
Damaging Agents	• Gall rust • Jack pine budworm damage • Browse
Special Considerations	• Stand history • Wildlife objectives • Rare species presence or potential habitat • Landscape context • Rare or declining natural communities (e.g., Barrens)

4.3 Cover Type Decision Model

Jack Pine Stand Assessment

Rotation Age:
- Fiber: **40-60 years**
- Sawtimber (SI>60): **50-70 years**

Pre-rotation

Seedling/Sapling Stands (see page 33-14):
- maintain stocking-
  - **natural stands:** 600-1200 seedlings/acre
  - **plantations:** 400-1200 seedlings /acre
- chemical or mechanical release at 7-10 years of age (if needed)
- overstocked stands - SI<50, >2000 stems/acre, pre-commercial thinning beneficial

Pole Stands (see page 33-15):
- SI>60 - commercial thinning optional to reduce fiber rotation or increase sawtimber output
- low or mechanical thinning
- refer to stocking chart (Figure 33.22, page 33-61)

At Rotation

Natural Regeneration Considerations:
- compatible landowner objectives
- existing stand quality good
- current stocking adequate
- seed potential good
- seedbed availability good

Artificial Regeneration Considerations:
- compatible landowner objectives
- existing stand quality poor
- current stocking poor
- seed potential limited

Artificial

Tree Planting (see page 33-24):
- planting density - 400-1200 seedlings/acre
- site preparation - mechanical (Bracke or disk trenching) and/or chemical
- limit soil disturbance around aspen
- bare root or containerized stock (generally 1-0)
- proper seed source selection critical

Direct Seeding (see page 33-24):
- 40-60% exposed mineral soil seedbed
- limit soil disturbance around aspen
- 4-6 ounces viable seed per acre
- sow late winter to spring
- proper seed source selection critical
- can be used to supplement natural seeding
- sphagnum moss seedbeds over moist sands may not require scarification

Conversion

Natural Conversion (see page 33-26):
- Aspen - 10-30 ft^2 BA healthy trees per acre
- Oak - assess oak regeneration potential (refer to Chapter 41)
- Red or White Pine - 400 seedlings/saplings per acre or 50 ft^2 BA poles or sawtimber

Natural

Cone Habit:
- **Serotinous or partially serotinous** - good numbers of closed cones in the outer portions of tree crowns
- **Non-serotinous** - most cones exhibit open scales (except immature cones)

Serotinous or Partially Serotinous

Clearcut (see page 33-16):
- harvest and scatter cone bearing slash
- apply mechanical scarification (pre-harvest, post-harvest, or during harvest)
- 40-60% exposed mineral soil seedbed
- limit soil disturbance around aspen
- sphagnum moss seedbeds over moist sands may not require scarification

Seed Tree (see page 33-17):
- retain 10 -20 well-distributed, quality seed trees per acre
- apply prescribed fire to prepare seedbed and open serotinous cones
- reduce humus layer to 0.2 inches or less

Non-serotinous

Shelterwood (see page 33-27):
- seed cut - retain 30-60 ft^2
- apply post-harvest mechanical scarification to achieve 40-60% exposed mineral soil seedbed
- limit soil disturbance around aspen
- final harvest - as soon as adequate regeneration established

5 SILVICULTURAL SYSTEMS

A silvicultural system is a planned program of vegetation treatment during the entire life of a stand. Silvicultural systems typically include three basic components: intermediate treatments (tending), harvesting, and regeneration.

5.1 Seedling / Sapling Stands

Jack pine germination and early seedling establishment is usually best on sites where there is some shade cast by slash and snags to reduce surface temperatures and drying. Subsequent early growth however is best in full sunlight with limited competition from shrubs and herbaceous vegetation (94).

Under forest conditions, seedling growth is generally slow in the first 3 years but increases rapidly beginning in the fourth and fifth years (94). Once established, seedlings and saplings exhibit optimal vigor (growth and health) when exposed to full sunlight. Delayed germination following disturbance combined with slow initial seedling growth may result in incorrect determinations of regeneration failure. Allow for a slow establishment period of 1-5 years for naturally regenerated stands. However early monitoring is still important if corrective management activities, like supplemental planting, are needed that take advantage of initial site preparation.

Density of seedling stands should be maintained between 600-1200 well distributed (i.e., at least 60% of area fully stocked) trees per acre (plantations 400-1200 trees per acre).

5.2 Intermediate Treatments

5.2.1 Release

Following establishment, jack pine seedlings and saplings can be outcompeted by other tree species resulting in jack pine mortality and reduced stocking and representation well into the poletimber stage. When aspen reproduces as an associate, it often assumes dominance. As site quality improves, aspen as well as other species (e.g. oak, white pine, red maple) can limit and out-compete jack pine.

In instances of aspen or other species competition, release operations will generally be required to control competition and maintain tree vigor. Release operations are best implemented before desirable stems are physically suppressed and while there are still many individuals to choose from. Seedlings and saplings generally respond to release with significant increases in vigor, height, and diameter growth. Release operations should be implemented early in the life of the stand, typically at 7-10 years of age. Release at an earlier or later stage will not have the same beneficial effect.

Weeding or cleaning operations are also sometimes recommended in overstocked jack pine seedling and sapling stands of more than 2000 trees per acres to prevent stagnation (8, 102). A northern Minnesota precommercial thinning study compared unthinned to thinned (4x4, 6x6, and 8x8 ft. spacings) plots and found after twenty-two years that average stand diameter increased 3.5 inches in DBH in the unthinned plots, and 4.1, 5.1, and 5.8 inches in DBH, respectively, in the thinned plots (12). Sapling stands with a site index of 50 or less and stocked in excess of 2000 stems per acre should be thinned to 600-1200 stems per acre. Higher quality stands tend to self-thin through stem competition and natural suppression. Very dense stands, like those that sometimes originate from direct seeding or fire (i.e., >10,000 trees per acre), can be mechanically thinned by clearing strips about 8 feet wide and leaving strips 2 feet wide (8).

5.2.2 Thinning

Commercial thinning of jack pine is uncommon in the Lake States since many stands are primarily managed for pulpwood. Thinning in jack pine can however reduce the length of fiber rotations and increase sawtimber output (8, 100).

Thinning is an option on better quality sites (site index of 60 or greater) to increase production of poles and small sawlogs. Low or mechanical (plantations) thinning is generally recommended. Do not remove more than one-third of the stand basal area in any one thinning operation, as jack pine can be subject to wind and snow/ice damage. Refer to the stocking chart (Figure 33.21) to help determine timing and level of thinning. On less productive sites or in stands managed for fiber, thinning is not recommended (8).

5.3 Natural Regeneration Methods

Even-aged management is the generally accepted method to obtain jack pine regeneration. Natural jack pine regeneration methods generally require some form of soil scarification or disturbance for successful germination and seedling establishment. Artificial regeneration (seeding or planting) is also a generally accepted and commonly practiced method to establish jack pine. The even-aged natural regeneration methods generally accepted and supported by literature are:

- Clearcut
- Seed tree
- Shelterwood (Conditionally Recommended)

Table 33.6. Recommended and Conditionally Recommended natural regeneration methods. A detailed discussion of these methods can be found later in this chapter.

FOREST COVER TYPE	NATURAL REGENERATION METHODS							
	Coppice	Clearcut	Seed Tree	Overstory Removal	Shelterwood	Patch Selection	Group Selection	Single-tree Selection
Jack Pine	NR	R	R	R	CR	NR	NR	NR

R - Recommended
CR – Conditionally Recommended (see Regeneration Systems for more detail)
NR – Not Recommended

5.3.1 Even-Age Regeneration Methods

5.3.1.1 Clearcut (Recommended)

The clearcut method is an even-aged regeneration system designed to naturally regenerate a stand from seed by the removal of most or all woody vegetation during the harvest. Regeneration is from natural seeding from trees cut in the harvest operation, or in some cases, natural seeding from adjacent stands. Clearcutting is a recommended method for naturally regenerating jack pine stands at rotation (8).

An important aspect for the successful application of the clearcut method in jack pine is the presence of serotinous cones. Serotinous cones persist on the tree for years and result in an accumulation of seed within these unopened cones. The unopened cones provide the primary seed source after the harvest operation. In the Lake States however, stands may contain trees with non-serotinous or partially serotinous cones. Careful cone and seed assessment is needed prior to using this regeneration method to ensure that adequate seed will be available after the harvest. Direct seeding may need to be considered if the existing seed bank is limited (see Artificial Regeneration).

If the current tree quality is desirable and there is an ample number of serotinous cones, a new seedling stand can be established naturally by scattering cone-bearing slash on bare mineral soil seedbeds. The heat near the ground surface (18 inches and less) will open the cones and release seeds. The slash will provide light beneficial shade during germination to reduce moisture stress, but care is needed to avoid too much accumulation of slash that might interfere with later seedling development (8).

Proper scarification and seedbed preparation are critical for successful germination and seedling establishment. Mineral soil seedbeds provide the best conditions for seed germination because soil moisture levels are generally more stable and vegetation competition is minimized. Scarification can be accomplished by several methods and should be tailored to the particular stand conditions. See the following Scarification section for more detail.

In stands with limited numbers of serotinous cones along with non-serotinous and/or partially serotinous cones, the clearcut regeneration method may be modified by conducting scarification 2-3 years before the harvest to establish advance jack pine seedlings. This modification is similar to the shelterwood method; however some regeneration may also originate from the limited numbers of serotinous cones present in slash after the harvest. Complete the clearcut harvest after adequate advance regeneration becomes established, anticipating post-sale regeneration in addition to advance regeneration. Adequate jack pine stocking should be between 600-1200 seedlings per acre and at least 60% milacre stocking. The harvest can be done during winter months with at least one foot of snow cover to protect the advance regeneration.

5.3.1.2 Seedtree (Recommended)

Figure 33.17. Jack pine seed tree with prescribed fire on the Northern Highlands American Legion State Forest. Photo by WDNR.

The seed tree method is an even-aged regeneration system designed to encourage seed origin regeneration by leaving enough trees singly or in groups to naturally seed the area. This method is generally used in jack pine stands with serotinous cones and is coupled with prescribed fire to open the serotinous cones and prepare a favorable seedbed. Some managers have coupled the seed tree method with pre-harvest scarification in place of fire, however seed dispersal from the seed trees may be limited with this method if the cones are mostly serotinous. The seed tree method has been used effectively in the Lakes States but is less common likely due to the additional resources and preparation required, as well as the difficulties in achieving the appropriate timing and intensity of prescribed fire (65, 2).

The jack pine seed tree method should retain at least 10 well-distributed, quality seed trees per acre (8). A Superior National Forest study determined 7-9 seed trees per acre were adequate, however this study stressed the importance of careful seed tree selection: high quality trees with an abundant supply of serotinous cones. Trees with a DBH greater than 11 inches produced the most viable seed in this study (2). Managers in Wisconsin have generally retained higher numbers of seed trees (10-20 per acre), depending on the quantity and quality of cones within the seed tree crowns. Tree selection should also consider that average jack pine seed dispersal distances are approximately twice the height of the tree.

Prescribed fire is critical with this method to both prepare a suitable seedbed and open serotinous cones. The fire needs to limit slash amounts and reduce the humus layer to less than 0.2 inches, exposing mineral soil (21). Prescribed burns are generally conducted in spring, early summer, or fall. Backfires are most effective at reducing the humus layer and still sufficiently hot to open serotinous cones (2). Burns should take place soon after the harvest to minimize the risk of wind throw prior to seed dispersal (i.e., after one warm month of drying conditions). Jack pine seed trees often are scorched and killed by the fire. If seed trees survive beyond the regeneration period they can increase the risk of insect and disease problems. If conditions for seed germination are not favorable following seed dispersal, supplemental seeding or planting may be required (8). See the Prescribed Fire section for more detailed information on the use of fire in jack pine.

5.3.1.3 Scarification

Proper site scarification is a critical element to ensure successful regeneration of jack pine. Standard logging operations often result in a disturbed forest floor, however the level of disturbance is often inadequate to create favorable seedbeds for jack pine regeneration. Prescribed fire or mechanical scarification is often required to ensure successful germination of jack pine seed (22).

Jack pine stocking is directly related to the proportion of favorable seedbed that is available (88). Favorable seedbeds for jack pine germination include exposed mineral soil and a residual humus layer of 0.2 inches or less. Excessive post-harvest slash and/or organic duff layers greater than 0.5 inches can inhibit germination, although complete removal of the humus layer from the site can also have an adverse effect on seedbeds by decreasing nutrient availability, especially on dry nutrient poor sands. Some light slash cover is desirable to provide light shade, reducing surface temperatures and drying to improve germination. Undisturbed heavy mosses, lichens, sedge, and thick, poorly decomposed organic horizons make poor seedbeds for jack pine because they dry out quickly and do not allow for the upward movement of moisture, thereby limiting seed germination and seedling survival. (18, 81, 22). Seedbeds with some silt and clay content, as well as water tables within 6 feet of the surface, also improve germination success. Some upland outwash sands may be too dry at times for good germination. Sphagnum moss seedbeds over moist sands have been a notable exception where good germination without scarification has been noted. Best management practices for water quality and biomass harvesting guidelines are important considerations for all jack pine scarification operations (refer to Wisconsin's Forestry Best Management Practices for Water Quality Field Manual and Wisconsin's Forestland Woody Biomass Harvesting Guidelines).

A successfully prepared seedbed will have at least 40-60% exposed mineral soil. Mechanical scarification and prescribed fire have both been used to expose mineral soil for jack pine regeneration. Prescribed fire emulates the natural regeneration ecology of jack pine and has been used effectively to prepare seedbeds and open serotinous cones (see following Prescribed Fire section for more information). Mechanical scarification is often the preferred method because it offers flexibility, good quality control, and a seven- to eight-month window for operation, along with effective control of competing vegetation.

When mechanically preparing a seedbed for natural jack pine regeneration where aspen is present in the stand, limit soil disturbance around the individual aspen trees to minimize aspen sprouting.

Deep scarification to expose mineral soils may provide relatively good results on drier course-textured soils. However, on wetter sites with finer-textured soils, establishment may be best on seedbeds near the mineral soil-humus interface. Seed burial due to soil sloughing and duff, as well as flooding and cold temperatures on wetter sites, are common problems with deep scarification. (97, 22, 34). Soil sloughing can be minimized by allowing the scarification to settle prior to harvesting or seeding. Depending on the scarification method and soil type, allowing loose soils to stabilize may also help reduce air pockets and improve early seedling survival.

Mechanical scarification equipment for jack pine includes blades (straight, Salmon), anchor chains, roller choppers, root rakes, drags, disks, rotary-head scarifiers, disk trenchers, plows, and patch scarifiers (Bracke, Leno).

Straight/Salmon Blades and Root Rakes

Figure 33.18. Pre-harvest blade scarification. Photo by Douglas County Forestry Dept.

Blade and rake scarification are common and successful pre-harvest methods of soil scarification in mature jack pine stands that have enough room between the trees to maneuver equipment effectively. This type of scarification is often more effective than other methods in stands with a heavy oak, hazel, and/or sedge component. The equipment operator should try to expose as much mineral soil seedbed as possible (i.e., at least 40-60% recommended). With a straight blade, the equipment operator should angle the blade, just deep enough into the sod/duff layer to ensure good seedbed exposure. Straight blade scarification is usually done in 20-40 foot segments and at the end of each segment the operator lifts the blade while still pushing forward to roll the sod layer over, running the flap of sod over with the dozer tracks. This technique shakes the accumulated soil out of the sod layer, thus keeping the disturbed piles down to two feet or less in height. The operator should make sure that there is no soil accumulation around the base of trees to be harvested. Too much soil accumulation around the base of trees makes it difficult to operate logging processors during the harvest. Creating large soil and sod piles (sometimes 3-4 feet high) is the most common mistake made by inexperienced equipment operators, resulting in very difficult harvest conditions for the logging contractor. Salmon blades and root rakes contain teeth that are designed to turn and expose soil in place, minimizing the accumulation of large piles.

Anchor Chains

Drag scarification with anchor chains is a common and successful method to prepare jack pine seedbeds and distribute cone-bearing slash after a harvest. Anchor chain scarification should be done immediately after harvest with non-frozen soil conditions, preferably in late spring or summer, before serotinous cones open and disperse their seed. If done in early summer, it can help reduce competing vegetation more effectively through greater root disturbance. Roller chopping can be done prior to chaining to reduce competing vegetation, particularly in stands with an aspen component. Jack pine slash must contain serotinous cones with viable seed to achieve successful natural regeneration (with the exception of shelterwood harvests that rely on seed rain from non-serotinous cones). Supplemental direct seeding can be done if the site does not have adequate cones. Anchor chaining is most effective on sites with a limited cover of sedge and other competing vegetation, as well as a limited humus layer. Previously dense jack pine stands with limited hardwood and brush competition that are dominated by light mosses over mineral soil are ideal. Slash should be adequately scattered during harvest operations to help distribute cones and promote the opening of serotinous cones by exposing them to the higher temperatures near the soil surface (i.e., slash heights of 18” or less). Scattering slash also allows the chains to reach the ground and not float up on heavy slash loads. Roller chopping can also be utilized to break up heavy slash loads and improve chaining effectiveness. The chain setup should consist of at least two chains spaced six feet apart, attached to a draw bar to keep them adequately separated. Adding bars on the chain ends in an “X” formation also helps keep the chains free of debris and helps limit floating up on slash. Bars or spikes should also be added to the chain links to increase scarification effectiveness. Two passes over the site at right angles will help maximize coverage and increase cone distribution; however, one pass may be sufficient on lighter slash. On formerly furrowed sites, chaining across the furrows effectively exposes more mineral soil seedbed. Rubber tire skidders are typically utilized to pull the chains but tracked dozers can be used if more power and equipment floatation are needed.

Figure 33.19. Anchor chain scarification. Photo by Vilas County Forestry Department.

Harvesting Operations

Whole tree ground skidding during non-frozen conditions may provide adequate scarification and mineral soil exposure. If natural regeneration is desired, the jack pine trees must be topped and the tops scattered before skidding to ensure as much of the seed source stays on site as possible.

5.3.1.4 Shelterwood (Conditionally Recommended)

Non-serotinous jack pines are more common along the southern edge of the species range and can be found in central and northwestern Wisconsin (87). The mature cones on these trees typically open and disperse seed in September to October. Common jack pine regeneration methods, like clearcutting, are not as successful in non-serotinous stands since there is inadequate seed within the harvest slash. The shelterwood method in combination with scarification to expose mineral soil has been successfully used in stands with predominantly non-serotinous cones (8, 13, 63).

Regeneration is usually accomplished using a two-step shelterwood. The initial harvest (seed cut) should reduce stocking levels to 30-60 square feet of basal area per acre, leaving a uniform crown cover of vigorous, high quality trees (best phenotypes) with non-serotinous cones (8). The harvest operation may provide some scarification, but it is usually insufficient to produce a consistent mineral soil seedbed. Post-sale mechanical scarification (e.g., anchor chain or blade) is recommended to produce a seedbed better suited for jack pine germination (see scarification section), as well as control competing vegetation. Harvesting and scarification operations must be timed with a good cone crop (every 3-4 years). Michigan DNR has observed success using the shelterwood method on sites with a high summer water table (within 6 feet) and limited sedge competition (63). Complete the final harvest or overstory removal as soon as adequate advance regeneration becomes established, typically 2-3 years after the seed cut. Some have noted longer establishment periods up to 10 years, but the overstory should be removed as soon as possible after adequate regeneration is established to minimize seedling losses due to suppression and logging damage, and the risk of jack pine budworm buildup in the overstory and subsequent defoliation of the newly established seedlings (17). Ideally the overstory removal should be conducted with sufficient snow cover to minimize damage to the advance regeneration.

Disadvantages to the shelterwood method may include; increased timber sale establishment costs, longer regeneration period compared to clearcut and seed tree methods, mortality of overstory trees prior to the final harvest, and potential for conversion to more tolerant associated species (17, 63).

5.4 Artificial Regeneration Methods

Tree planting and direct seeding are successful and commonly utilized methods to establish jack pine regeneration in the Lake States. Chapter 22 provides guidelines for artificial regeneration and should be referenced when developing artificial regeneration prescriptions. Some jack pine specific considerations are also discussed here to aid in jack pine tree planting and direct seeding practices.

5.4.1 Planting

Some stand conditions are not conducive to natural jack pine regeneration or direct seeding (e.g., excessive competing vegetation, unfavorable seedbed conditions, limited cone-bearing slash, poor quality growing stock) and therefore tree planting may be a preferred management option. Tree planting also provides the opportunity to introduce well adapted seed sources and improved genetic material into stands. Jack pine specific planting considerations include:

- Tree planting densities for jack pine generally range between 400-1200 seedlings per acre, with 6-8 foot spacing typically recommended (9).
- Both bare root and containerized stock are successfully used for jack pine planting operations in Wisconsin. Managers need to consider site conditions, site preparation methods, seed source, planting operations, and costs to determine the appropriate

stock type. Chapter 22 provides detailed information on advantages and disadvantages of bare root and containerized stock types.
- One-year old bare root (1-0) or containerized jack pine stock is generally recommended for hand planting on sites with good site preparation and limited competing vegetation. Two-year old seedlings are generally recommended for sites with greater competition and where machine planting will be utilized.
- Bracke scarification, disk trenching or DNR fire plows are common tree planting site preparation methods used in Wisconsin. Herbicide treatments may be used alone or in combination with these mechanical methods to control heavy competing vegetation.
- Consider delayed reforestation of sites where weevils (i.e., Northern Pine and Pales) are present
- First year regeneration monitoring is important to determine if supplemental planting is needed to improve stocking levels. Supplemental planting should be conducted by the second or third growing season while site preparation is still adequate.

5.4.2 Direct Seeding

Jack pine sites are often well suited for direct seeding operations, as long as favorable seedbeds are available. Direct seeding can be used to supplement or replace natural seeding in stands with limited cone production, non-serotinous cones, or on other poorly regenerated areas where a seed source is not naturally present. Advantages of direct seeding jack pine include introduction of well adapted seed sources, low cost, simple and rapid application, and good seedling development. Direct seeding results however are often variable and careful consideration must be given to the following:
- As with natural seeding, favorable seedbeds are required for direct seeding success. See scarification section for more information on favorable seedbed conditions.
- Scarification can be accomplished by drags, blades, disks, spot scarifiers, trenchers, or prescribed fire, with seed distributed by hand (cyclone seeder, coffee can), machine (Bracke, seed bombs), or aerial. Depending on scarification method, equipment, labor, and seed availability, sites may be spot or broadcast seeded.
- Seedbeds should be allowed time to stabilize prior to seeding.
- Seeding rates should be 20-30,000 repellent-treated, viable seeds per acre (average 131,000 seeds per pound). Seeding rates greater than 30,000 seeds per acre generally do not enhance stocking (88). In application, sowing rates are commonly 4-6 ounces per acre. Greater aerial coverage can be achieved if seeded in two directions; 2-3oz. per acre in each direction.
- Jack pine seed from Wisconsin DNR state nurseries is generally repellent-treated, using the fungicide thiram, which is also an animal repellent, and a latex paint carrier. Refer to the seed treatment SDS for more information on personal protection equipment to use while handling treated seed.
- Establishment is generally greatest when seeding is done from late winter to mid-June. Broadcast seeding is best over fresh snow or before snow melt in early spring. Sowing during this period minimizes the interval between seeding and germination, reducing the risk of seed loss to predators. Soil moisture is usually plentiful in spring due to snow melt and warming soil temperatures encourage good root development (35, 22).

- Allow at least 3-4 growing seasons before judging direct seeding results. Delayed germination can result in increases in stocking between the first and third years after sowing (88, 94). Reseeding can be successful if a favorable seedbed remains.
- Avoid direct seeding in areas with heavy competing vegetation, such as aspen, or on higher quality sites (i.e., dry mesic habitat types) where competition may limit results, unless herbicides are utilized.
- Aerial seeding can be an effective regeneration method for jack pine, as long as adequate amounts of favorable seedbed are available. Aerial seeding coverage is maximized in larger block stands of at least 25 acres in size and by limiting the number of reserve trees that may interfere with aerial applications. Islands of reserve trees interfere less with aerial applications than dispersed tree retention.

5.4.3 Seed Source Considerations

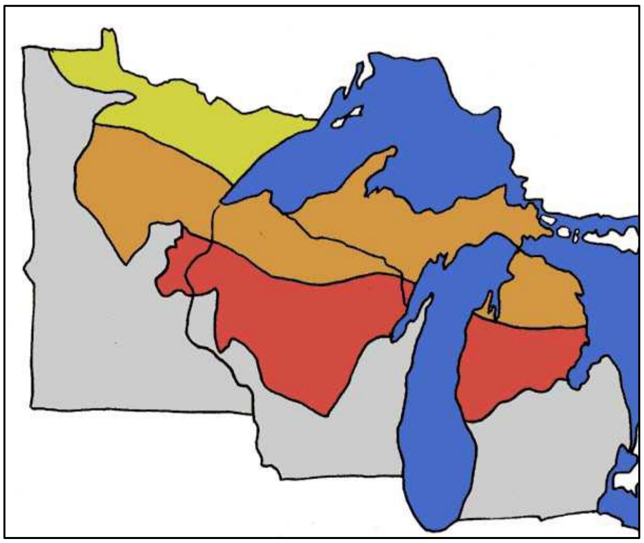

Figure 33.20. Seed zone map developed from the twenty-year results of the Lake States jack pine seed source study (45). Seed sources kept within each zone should generally perform best (i.e., each color represents a separate seed zone).

Jack pine is known for its wide genetic variation in many important characteristics, such as height growth, form, disease resistance, cone serotiny, and others. Lake States provenance studies have found that local seed sources generally grow better than the average for all provenances, but sources moved slightly northward generally grow best (93, 46). Provenance study results have been used to develop seed zone maps to guide the appropriate movement of jack pine seed sources in the Lake States (Figure 33.21)(46). Tree improvement efforts by the Division of Forestry and other agencies continue to develop jack pine seed orchards through advanced progeny testing and breeding.

Selecting appropriate seed sources is critical for maintaining stand productivity. Managers need to consider seed source appropriateness when selecting material for both tree planting and direct seeding practices. Jack pine plantations on suitable sites that exhibit poor growth and form may have originated from inappropriate seed sources and should not be naturally regenerated, but rather reforested with genetically better adapted trees.

5.5 Rotation Lengths and Cutting Cycles

In even-aged silvicultural systems the rotation is defined as the period between regeneration establishment and final cutting. The length of rotation may be based on many criteria including culmination of mean annual increment, mean size, age, attainment of particular minimum physical or value growth rate, stand history, and biological condition.

Commonly the lower end of the rotation length range is defined by the age at which maximization or culmination of mean annual increment (MAI) growth occurs. The upper end of the rotation length range would be defined by the average stand life expectancy. However, very little objective data exists identifying these endpoints in general and even less by site type. In addition, growth and mortality rates vary among stands and can be affected by many variables, including site characteristics, silvics, stocking, silvicultural methods, insect and disease, and units of measure. The rotation ages provided are based on general data, literature, empirical evidence, and professional experience. In application, foresters will need to regularly review stands in the field and exercise professional judgment concerning tree vigor and mortality and stand growth and productivity. On all sites, individual trees and stands may maintain vigor longer or decline earlier than these rotation length guidelines.

<u>Recommended Rotation Ages</u>

- 40 to 70 years is recommended for timber management
    - Fiber production is generally 40 to 60 years on most sites.
    - Sawtimber production is generally 60 to 70 years on better quality sites with site indices of 60 or greater.

- Extended rotation is not recommended for this short-lived, early successional species. However, vigorous stands and vigorous individual trees on good sites could potentially be managed to 80-100 years.
- Short rotations of less than 40 years are generally not recommended in order to maintain soil nutrient levels, especially on dry nutrient poor sandy soils with whole tree harvesting operations. Refer to Wisconsin's Forestland Woody Biomass Harvesting Guidelines for more information on dry nutrient poor sandy soils and rotation age considerations (10).

The decision to rotate stands at the lower end of the rotation length range or earlier can be based on many conditions, including very nutrient poor sites, landscape level management modifications, site competition factors, jack pine budworm defoliation, disease outbreaks, and low vigor. Documenting the site and stand conditions are important when determining a rotation age for a stand.

Different rotation lengths can result in increased production of some benefits and reduced production of others. Landowner goals and objectives will also influence rotation age determination. See the discussions under management considerations in the following sections to evaluate some benefits and costs (ecological, economic, social, and cultural) associated with different forest management strategies.

5.6 Other Silvicultural Considerations

5.6.1 Cover Type Conversion

Jack pine can be difficult to maintain on all but very dry and nutrient poor habitat types. Jack pine ecosystems are dependent on fire or logging for regeneration and in the absence of these disturbances oak, white pine, and red maple often become more abundant if a seed source is available. From an ecological and forest diversity standpoint, it may be desirable to maintain the jack pine cover type, since the acres and volume of jack pine growing stock have been steadily decreasing in Wisconsin (64). In some cases it may also be possible to manage for stands of mixed species composition. Depending on site capabilities and landowner objectives, however, conversion to other associated species may be prescribed. For example, conversion to red pine on the dry to dry mesic habitat types has been common because of the species' economic value and increased growth potential on these sites. However, jack pine may perform better than red pine on very dry to dry habitat types in terms of average height growth and survival (67, 93). Conversion to red pine and other closed canopy forest on the state's Pine Barrens, woodlands, and savanna habitats has raised concerns over loss of diversity and fragmentation of these ecosystems at the landscape level (39, 40).

Conversion will be simplest in mixed stands with adequate stocking of desirable associated species, where the jack pine can be removed through periodic thinning or overstory removal. Some common associated species that may be considered in conversion include aspen, oak, white pine, red pine, red maple, balsam fir, and white spruce. If adequate stocking of desirable species is not present, artificial conversion would be required through site preparation and planting. The following are management considerations for common jack pine natural conversions:

- Aspen – 10-30 ft^2 of basal area per acre of healthy aspen trees required for coppice regeneration to produce adequate stocking. Consideration should be given on very dry and wet-mesic habitat types, where aspen conversion may not be recommended due to poor productivity, except for wildlife purposes (53).
- Oak – Clearcut/coppice regeneration methods may encourage a mixed conifer-deciduous type for greater diversity. Jack pine – oak mixed stands can be successfully managed on very dry to dry habitat types where oak are regenerated easily by advanced regeneration/coppice and inclusions of jack pine are regenerated by creating suitable jack pine seedbed conditions. See Chapter 41 for guidelines on evaluating oak regeneration potential from advance regeneration and sprouting.
- Red and White Pine – Stocking of at least 400 seedlings/saplings per acre or sufficient overstory of red or white pine to facilitate shelterwood regeneration methods.

Refer to the individual species cover type chapters for more information on natural conversion.

5.6.2 Prescribed Fire

Many of today's jack pine stands resulted directly from wildfires of the past. These stands can provide insight into the use of fire for effective management and regeneration of the species (30). The use of prescribed fire as a tool in the management of jack pine has been relatively uncommon in the Lake States (30), due in part to the logistical challenges of safely burning in the pine fuel type. Its applications include seedbed preparation, fire hazard reduction, control of competing vegetation, insect and disease control, and Pine Barrens restoration. Prescribed fire can be an economical alternative to either mechanical or chemical site preparation (2, 30, 76, 91).

Jack pine is well suited for the use of prescribed fire because of a number of adaptations to fire including delayed seed release from serotinous cones, early reproductive maturity, fast growth rates in full sun, and preference for mineral soil seedbeds (15). Temperatures ranging between

120 and 140 degrees Fahrenheit are required to melt the resin on the cones, open the scales and release the seed (91). Heat does not markedly affect seed viability, however if cones ignite, the seed will be destroyed (15).

Most research indicates the best use of prescribed fire for jack pine is in site preparation for regeneration (94). Regeneration methods commonly used in conjunction with fire include tree planting, direct seeding, and seed tree. Note that prescribed fire in clearcut slash (i.e., without seed trees) does not usually result in adequate natural seeding, because most of the cones within the slash ignite, destroying this source of seed.

Prescribed fire for jack pine regeneration is most often used to create a favorable seedbed for germination. The most receptive seedbeds for germination are on exposed mineral soil consisting of minor amounts of post-harvest slash and a thin residual humus layer of 0.2 inches or less. Excessive post-harvest slash can shade seedbeds and organic duff layers greater than 0.5 inch in depth can inhibit germination and adversely affect establishment (7, 15, 21, 91, 94). However, complete removal of the humus layer can also have an adverse effect on seedbeds. Several case studies cited that maintaining some humus will increase nutrient availability and promote moisture retention by slowing runoff (2, 30, 76).

Planning the timing and intensity of prescribed fires is important in achieving the desired results. Multiple research trials have indicated the most effective time to burn for seedbed preparation is either spring or early summer, with both advantages and disadvantages listed below (2, 7, 91). Alternatively, early fall has been suggested as a potential burn season to disperse seed for germination the following spring, but more field evaluation in Wisconsin is likely needed (7, 63).

<u>Spring Burns</u>
Advantages:

- Most favorable time for seed germination and establishment
- Lower humidity, higher burning index

Disadvantages:

- Control of the fire can be difficult
- Operational times limited – number of days when fire weather is appropriate to burn.
- Due to higher forest floor moisture levels spring fires may not burn with enough intensity to consume organic duff layers, resulting in limited exposure of mineral soil seedbeds.

<u>Early Summer Burns</u>
Advantages:

- Drier fuel conditions result in a hotter burn and greater likelihood of reducing organic duff layers, resulting in greater exposure of mineral soil seedbeds.
- High humidity levels make fire control easier
- Better control of competing vegetation

Disadvantages:

- Establishment may be too late in the year for seedling survival

- Newly germinated seedlings are more vulnerable to heat and desiccation during drier summer months

Burning should be conducted as soon as possible after the timber harvest and after at least one warm month of drying conditions have lapsed. This ensures that fuels have adequately cured and if regeneration is to be conducted using the seed tree method, the loss of trees to wind throw will be minimized (7). Refer to the section on seed tree regeneration for more details. Other considerations regarding timing include:

- Conduct burns after mid-day when RH is lowest and winds most stable (2).
- Strive to burn when there is a high Buildup Index (moisture deficiency in fuels) and a low Burning Index (current burning conditions). This will permit maximum fuel consumption including duff with minimal control difficulty. This is considered the most important factor in removing enough of the humus layer to prepare a receptive seedbed (30).

In addition to timing, a fire must burn with sufficient intensity to ensure enough heat is generated to eliminate excessive slash, reduce the humus layer, control competing vegetation and open cones. Fuels should be cured, and uniformly distributed over 75% of the ground area. The humus layer must be dry to within 1 inch of the mineral soil. Based on previous Lake States' guidance, adequate fuel loads to ensure a hot fire are normally obtained if the pre-harvest condition of the stand contains a minimum of 100 $ft^2$of basal area per acre and achieves a minimum slash depth of 18 inches (7).

The ignition pattern chosen will also influence fire intensity. The two primary ignition patterns include headfires and backing fires. Headfires are hot, rapidly moving fires that consume slash quickly, and open serotinous cones. However, because they move rapidly, they may be harder to control and may not adequately consume enough of the humus layer as is required. In contrast, backing fires consistently consume the required amount of humus because fires burn significantly slower and longer in duration at higher temperatures, typically producing sufficient heat to open serotinous cones on seed trees as well. In addition, since these fires burn more slowly, they are easier to control (2). In either case, when burning in conjunction with a seed tree regeneration method, individual crown torching will normally not result in cone ignition because the higher temperatures are unlikely to last more than several minutes (15).

Prescribed fire has been used with varying degrees of success in controlling undesirable competition and reducing insect and disease concerns. Competition from both sedges and hazel can inhibit regeneration and subsequent establishment. Fire can temporarily impede these competitors and allow for jack pine seedlings to grow above the recovering grass and shrub layer (2, 91). However, to be effective a prescribed fire must be conducted either before or immediately after the overstory has been removed. A hot early to mid-summer burn will be most effective at limiting competing brush species, especially if the litter fuels have been adequately cured (2, 15). For example, single spring prescribed fires have been shown to have little lasting impact on hazel competition, but summer fires more effectively decrease hazel vigor and sprouting (11).

In addition to controlling competition, fire can also help to protect jack pine from pests, including damping-off fungi, *Scleroderris* canker, dwarf mistletoe (*Arceuthobium* spp.), and *Ips pini*. Elimination of newly created slash will discourage population outbreaks from *Ips* beetle (91).

Additional considerations when using prescribed fire include:

- Larger burn areas are more cost effective to administer.
- Timber harvest plans should incorporate road design that will also serve as future firebreaks.
- Harvest plans should also incorporate treatment of slash to aid in facilitating suitable burning conditions – directional felling of trees and uniform slash distribution and depth.

Monitoring and documenting prescribed fire trials is recommended during pre- and post-burn application. The intent is to assess and document fire effects on seedbed enhancement, regeneration stocking, competition, and fire conditions. Recommendations for monitoring include:

- Document pre-burn and post-burn forest conditions – density, size and vigor of regeneration, and competition
- Measure fire conditions – fuel load, fire intensity/flame length, rate of spread
- Document costs associated with the burn – equipment time and labor
- Examine the site 2-5 years post-burn – document density, size and vigor of regeneration, and competition. If the objective of the prescribed fire is for regeneration from jack pine seed, its success may not be evident for two to five years post-burn. Survival of germinants depends upon a number of factors including a good seedbed, adequate moisture, seed supply, delayed germination, seed predation and rate of recovery of competitive species.

8 APPENDICES

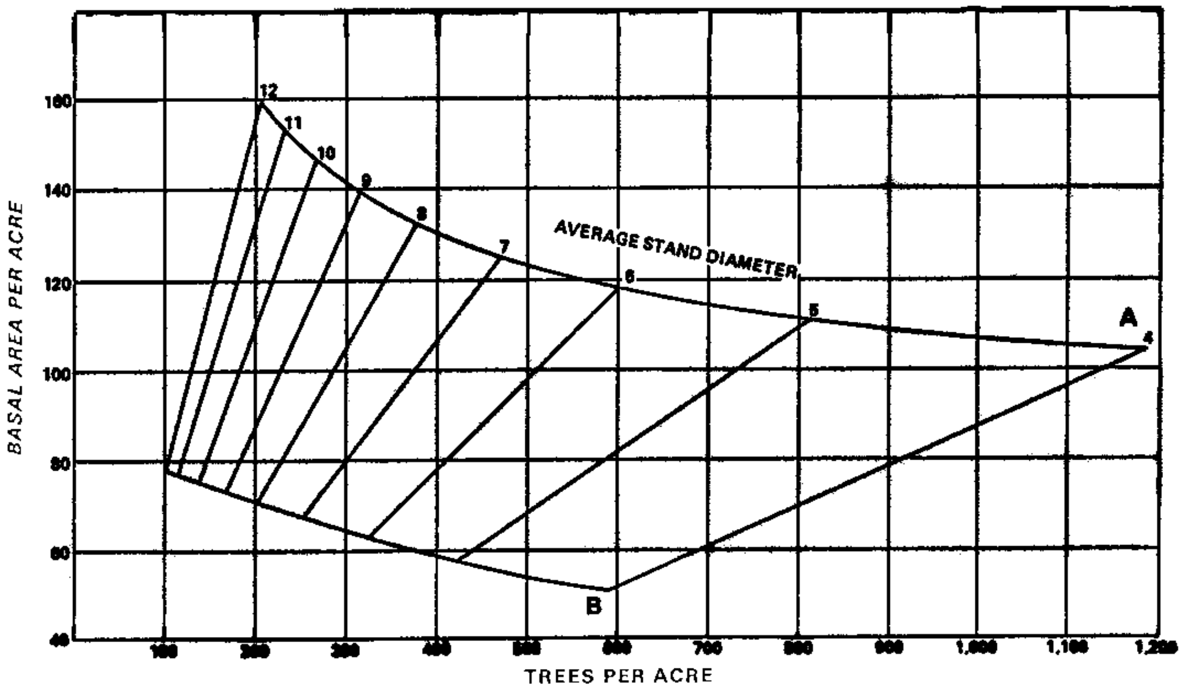

Figure 33.21. Stocking chart for jack pine stands (8).

Recommended upper limit (A-curve) is based on stand tables from Eyre and LeBarron (31) and adjusted to approximately 85 percent stocking for pole timber and 100 percent stocking for sawtimber stands. Minimum stocking (B-curve) is based on crown width for open-grown trees.

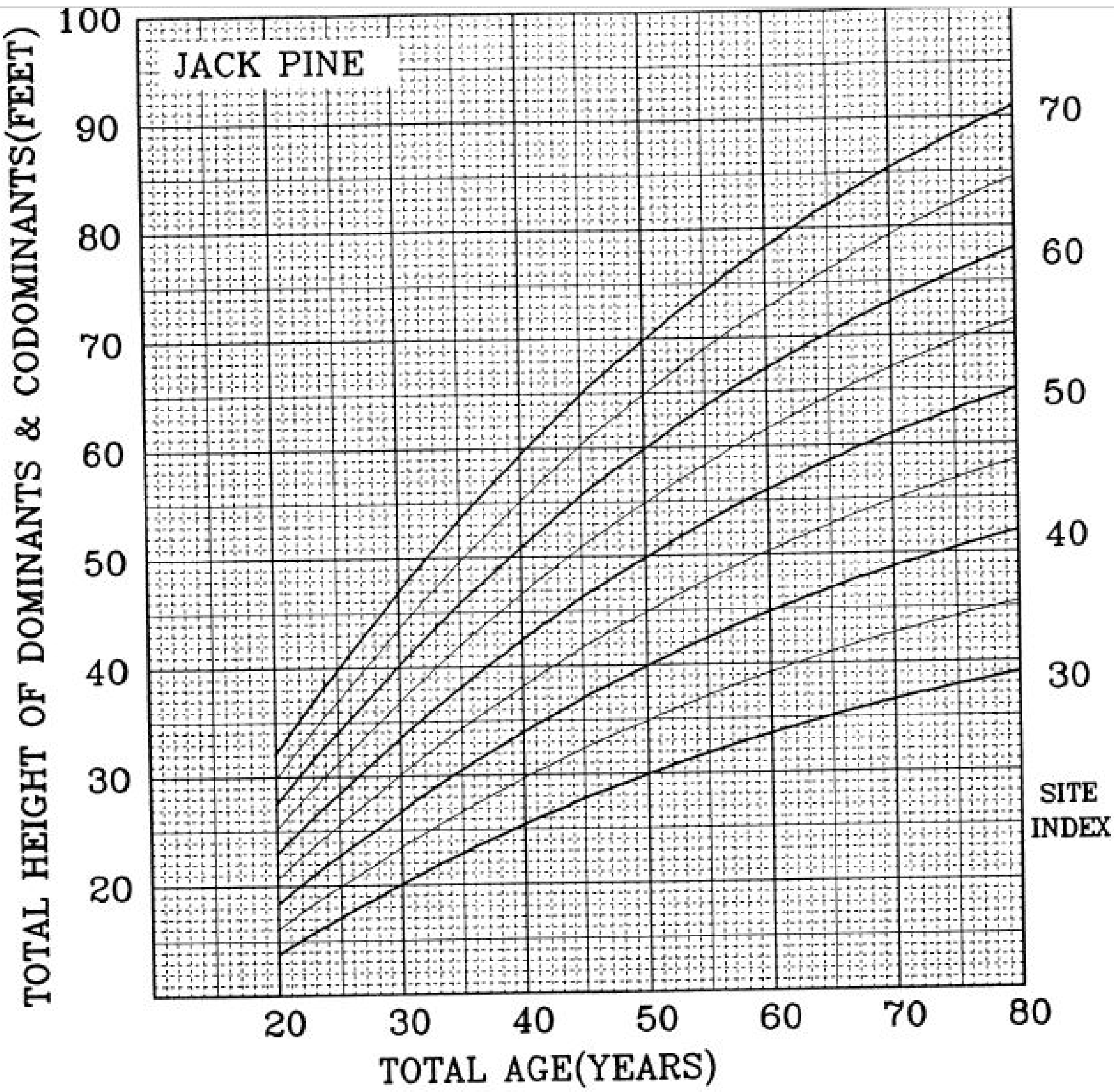

Figure 74.—Jack pine (Gevorkiantz 1956c, derived from Wackerman *et al.* 1929, and from Eyre and LeBarron 1944)

Lake States

Number of plots and number of dominant and codominant trees not given

Total height and total age, anamorphic, equation not given

Convert d.b.h. age to total age by adding years according to site index (BH = 0.0):

SI:	30	40	50	60	70	80	90
Years:	9	8	7	6	5	4	4

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	1.6330	1.0000	-0.0223	1.2419	0.0000	0.99	0.50	1.1
SI	0.6124	1.0000	-0.0223	-1.2419	0.0000	0.99	0.50	1.1

Figure 33.22. Site index curves for jack pine in the Lake States (16).

8.1 Forest Health Guidelines - Forest Health Protection (FHP)

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
DEFOLIATING INSECTS	
MOTHS **Jack pine budworm –** *Choristoneura pinus* Caterpillars from May to July. Outbreaks occur approximately every ten years and last two to four years. One heavy defoliation event causes 10-15% top kill and 5% mortality. Two heavy defoliation events cause 45-50% top kill and 20-25% mortality. Damage is most severe on poor quality sites. Stand history of defoliation events may also impact seed production and the supply of stored seed in serotinous cones.	• Do not hold stands on poor quality sites past maturity. Keep stands even aged and regenerate by appropriate regeneration methods. • Maintain basal area between 70-110 ft²/acre. Avoid widely spaced trees that produce large crowns with numerous male flowers and overstocked stands with suppressed trees. • Stand size is critical. Promote age class diversity to avoid large areas of mature and overmature trees that are all susceptible at the same time. Stands should be at least 40 acres and boundaries designed to minimize edge. • **Do not leave strips or islands of jack pine during harvesting.** • Salvage stands with severe defoliation. • Consult a forest health specialist if considering insecticide treatments to determine the economic feasibility of spraying.
Northern conifer tussock moth - *Dasychira plagiata* Overwintering larvae emerge in April and initially feed on male cones and previous year's needles. Older caterpillars move to current year's needles until pupation occurs in July. Adults emerge and lay eggs mid-summer. The next generation of larvae hatch and feed for approximately 10 days in August before overwintering under bark scales. Severe defoliation for two consecutive years has killed entire stands. Caterpillars prefer jack pine but will attack red pine under 30 years old. The last outbreak of this insect occurred in Douglas, Bayfield and Burnett Counties in the 1960s.	• Do not hold stands on poor quality sites past maturity. Keep stands even aged and regenerate by appropriate regeneration methods. • Avoid large areas of susceptible trees. Townships with greater than 40% jack pine or stands larger than 1 section may contribute to large outbreaks. • Salvage stands with severe defoliation. • Consult a forest health specialist if considering insecticide treatments to determine the economic feasibility of spraying.
Eastern pine elfin - *Callophrys niphon* Caterpillars from May to June. Typically feed on trees less than 23 ft. in height. Young larvae feed on new foliage. Older caterpillars may eat old needles.	• No control is necessary.
Washed-out zale - *Zale metatoides* Caterpillars from July to August.	
Gray spring zale - *Zale submediana* Caterpillars in June.	
Abstruse looper - *Syngrapha abstruse* Caterpillars from May to June.	
Pine pinion - *Lithophane lepida* Caterpillars from June to July.	

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
MOTHS: NEEDLE MINERS **Pine needleminer -** *Exoteleia pinifoliella* Attacks pole sized trees. Consumes old needles first, then new. **Pine needle sheathminer -** *Zelleria haimbachi* Hollows out terminal needles at the base, typically near male flowers.	• Control is rarely necessary. • If severe damage occurs, consider a salvage harvest.
MOTHS: SILK NEST BUIILDERS **Pine webworm -** *Pococera robustella* Colonies build silk tubes and feed on nearby needles. Occasional pest of seedlings or saplings.	• Control is rarely necessary as natural enemies typically keep populations in check. • If control is necessary it should be conducted while nests are small. Either remove nests by hand (crush or drown caterpillars in water) or spray branch tips in mid-June and again in early July.
SAWFLIES: SILK NEST BUIILDERS **Pine false webworm -** *Acantholyda erythrocephala* Live singly or in small colonies in silk nests up to 6 inches long. **Nesting-pine sawfly -** *Acantholyda zappei* Larvae build silk tubes where they feed on chewed off needles.	
SAWFLIES **Abbott's sawfly -** *Neodiprion abbottii* Larvae from June to July. Larvae feed in colonies during early instars then individually in later instars.	• Accept damage and monitor for population increases. • Allow control by natural enemies and disease. • Kill small groups of larvae by hand. • If control is necessary, spot treat small groups of larvae with pesticide, or broadcast treat large infestations. Success will be greater if larvae are treated when they are small. • Keep stands fully stocked and promote early canopy closure by planting 800 or more trees per acre.
Brownheaded jack pine sawfly - *Neodiprion dubiosus* Larvae from June to July. Larvae feed in colonies and prefer edge trees.	
European pine sawfly - *Neodiprion sertifer* Larvae from May to June. Larvae feed in colonies on old needles.	
Introduced pine sawfly - *Diprion similis* Larvae from May to September. Larvae feed in colonies during early instars then individually in later instars on old needles. Prefer ornamental, nursery, and plantation trees.	
Jack pine sawfly - *Neodiprion pratti banksianae* Larvae from May to June. Larvae feed on old needles in colonies and prefer open grown, even-aged stands of all ages.	
Redheaded jack pine sawfly - *Neodiprion rugifrons* Larvae from June to September. Larvae feed on old needles in colonies. When a second generation occurs new foliage is also eaten.	
Redheaded pine sawfly - *Neodiprion lecontei* Larvae from June to September. Larvae feed in colonies and prefer edge trees less than 20 feet tall. Larvae consume old needles first, then new.	
Red pine sawfly - *Neodiprion nanulus nanulus* Larvae from May to June. Larvae feed in colonies on old needles.	
Swaine jack pine sawfly - *Neodiprion swainei* Larvae from July to August. Larvae feed in colonies mostly on old needles.	

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
BEETLES **Pine chafer -** *Anomala oblivia* Adults feed in June and July preferentially on new needles. Pine chafers eat the sides of needles through the sheaths causing the needles to turn brown and droop.	• Allow control by natural enemies. • If control is necessary, apply insecticide in late June.
SUCKING INSECTS	
Scale insects and aphids Heavy infestations cause needle yellowing, premature foliage drop, and dieback of twigs and branches. These insects also produce honeydew which can lead to growth of sooty mold. Three common species are: **Black pineleaf scale -** *Nuculaspis californica* Infestations are usually confined to a cluster of stressed trees. **Pine needle scale -** *Chionaspis pinifoliae* **Pine tortoise scale -** *Toumeyella numismaticum* Pest in sapling and pole-sized plantations.	• Usually controls are not needed and not realistic. • Maintain stand vigor. • Promote early stand closure. • If control is necessary, treat scales with horticultural oil before budbreak or spray crawlers with insecticide in June or July. • Kill mound ants protecting the scales.
Saratoga Spittlebug - *Aphrophora saratogensis* Feeding causes twig flagging, reduced tree growth, stem deformity, and branch mortality. Prefers red pine under 15 feet tall. Severe infestations may cause significant mortality.	• Remove alternate hosts of Saratoga spittlebug (sweet fern, young willow, berry bushes, etc.) when they occupy 20% or more of the ground cover. • Consult a forest health specialist about the feasibility of treatment with insecticides.
Pine spittlebug - *Aphrophora cribrata* Heavy infestations (typically localized) cause branch flagging starting with new growth and progressing to the trunk, typically from the bottom of the tree up. Prefer saplings and pole-sized trees.	• Natural enemies, including a parasitic fungus, usually keep populations in check. • If insecticides are necessary, apply in July when 95% of spittle masses are empty.
PINE PITCH MIDGES **Gouty pitch midge -** *Cecidomyia piniinopis* Larvae feed in small resin filled pits between the needles on new growth. May kill needles and shoots on trees 4-16 feet tall. Two other common species are *Cecidomyia banksianae* which feed in resin filled cavities close to buds and *Cecidomyia reeksi* which feed in resin masses typically on open-grown saplings.	• Control is rarely necessary because populations are usually kept in check by natural enemies.
BARK AND WOOD INSECTS	
BARK BEETLES *Ips* spp. Tunneling in inner bark causes mortality in sapling to sawlog sized trees, singly or in pockets. Weakened or storm-damaged trees, trees that have been struck by lightning, and overmature or overstocked stands provide a breeding ground for the beetles. Mortality is usually limited to a few trees during years of normal rainfall. However, during dry summers with suitable breeding material, beetle populations quickly build up and cause large scale mortality.	• Use the pine species and spacing intervals best suited to the site. • When cutting during the growing season, remove harvested timber from the stand within 3 weeks of cutting. • If cutting stands adjacent to other pine stands during the growing season, utilize tops down to a 2” diameter. Leave branches attached to stem wood to speed drying. • Avoid overmature stands. • Promptly salvage or destroy potential breeding material, such as pines that are

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
	severely damaged by wind, lightning, fire, disease, insects, or other destructive agents. • If trees have low vigor due to drought, defoliation, or disease, consider a pre-salvage harvest. • Harvest newly infested and adjacent trees before the following spring to reduce local populations.
Mountain Pine Beetle - *Dendroctonus ponderosea* Mountain pine beetle (MPB) outbreaks occur regularly in lodgepole and other pines in Western North America but do not currently occur in Wisconsin. The recent, successful establishment of MPB in jack pine in Alberta, Canada however could allow spread through the range of jack pine to the eastern U.S. (28).	• Management guidelines are currently only available for MPB's host trees in western North America. Contact forest health staff immediately if you suspect a MPB infestation in Wisconsin.
Red Turpentine Beetle - *Dendroctonus valens* Tunneling under bark causes mortality in weakened trees of pole size and larger. Adult beetles attack dead or weak trees as well as fresh stumps, freshly cut logs, and exposed damaged roots. Although infestation by this insect itself is usually not serious, it vectors *Leptographium* fungi. Look for red boring dust and pitch tubes on the bottom six feet of attacked trees.	• Control is typically not necessary or feasible.
Pine Shoot Beetle - *Tomicus piniperda* Adult beetles feed on and kill the central portion of the lateral shoots. Attacked shoots turn red, droop, then fall to the ground. This insect is under federal quarantine as of 2015 but removal of the quarantine is being evaluated.	• Follow quarantine rules: this insect is native in Eurasia and North Africa and was first discovered in North America in 1992. All of WI, MN, and MI are quarantined. • Cut trees so stumps are as low to the ground as possible.
Jack pine tip beetle - *Conophthorus banksianae* Causes shoot tip mortality mostly of saplings. Attacked shoot tips turn red, droop, then fall to the ground. The pine flower snout beetle *Cimberis elongata* sometimes attacks buds and shoots in association with Jack pine tip beetle.	• Control is rarely necessary.
LONGHORNED BEETLES **Whitespotted sawyer -** *Monochamus scutellatus scutellatus* Attack dead and dying trees. Larvae feed beneath the bark and bore deep into the wood. Adults feed on the bark of twigs and may cause flagging.	• Avoid stacks of logs on landings from late June through August when possible. If cutting during the growing season, remove harvested timber from the stand within 3 weeks of cutting. • Cover logs with slash 1-2 feet thick. • Pile logs in the shade of standing trees. • Peel or immerse logs in water. • Allow control by natural enemies.
WEEVILS **Northern Pine Weevil -** *Pissodes approximatus* Severe feeding damage by the adults may kill some shoots.	• Delay planting seedlings for 2 years after harvesting pines. • Remove freshly cut pine stumps before planting seedlings (rarely practical). • Treat freshly cut stumps with an insecticide (rarely practical).

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
Pales weevil - *Hylobius pales* Infestations girdle and kill seedlings and damage the young shoots of older trees.	• Delay planting seedlings for 2 years after harvesting pines. • Remove freshly cut pine stumps before planting seedlings (rarely practical). • Treat freshly cut stumps with an insecticide (rarely practical).
White pine weevil - *Pissodes strobi* Feed inside the leader of sapling to pole-sized trees causing the leader to die and often resulting in lateral branches assuming dominance. Look for leaders that curl into a shepherd's crook and die.	• In existing infestations, local population and damage can be reduced by removing and destroying infested terminals before new adults emerge in mid-July. • In plantations and open grown seedling/sapling stands: In open areas, plant 900 - 1,000 trees per acre in mixed or pure plantations and maintain at least 700 trees per acre until the canopy closes. • Accept stem deformity. • If control is necessary, apply insecticidal application to prevent attack by adult beetles.
Pine root collar weevil - *Hylobius radicis* Typically attack sapling and small pole-sized trees. Damage may cause trees to tilt or break off at the root collar. Trees planted on nutrient-deficient, sandy soils, planted too deeply or spaced too widely are most vulnerable to attack. The insect is a known vector of Leptographium fungi.	• On sandy soils, plant with root collar no more than one inch deep. • Encourage early crown closure by planting 800 or more trees per acre and increase the seedling survival rate by controlling weeds and rodents for 5 years after planting. • Avoid planting within one mile of infested Scotch pine stands or liquidate nearby Scotch pine.
Pine root tip weevil - *Hylobius assimilis* Feeding on roots causes flagging, top kill and tree mortality in pole-size pines. Moderate weevil damage reduces tree growth. Stands on nutrient-deficient, sandy soil and those near Scotch pine are more vulnerable to weevil attacks.	• Liquidate nearby Scotch pine. • Do not plant jack pine and red pine together if the site index is 50 or below – keep it to one species or the other.
SCARAB BEETLES **White Grubs -** *Phyllophaga* spp. Feeding on roots kills 1-3 year old seedlings. Damage is most severe in sandy soils and on grassy or weedy sites. White grub densities above 0.2 per square foot may cause heavy seedling mortality and stunting of surviving seedlings.	• Survey stands for white grubs before planting. If the population density is high, delay planting for one to two years. • Consult a forest health specialist for current insecticide options.
MOTHS **Eastern pine shoot borer -** *Eucosoma gloriola* Open-grown trees are most susceptible to damage within 10 years of establishment. Larvae attack shoots in May and June causing them to turn red, droop, and then fall to the ground. Leaders and lateral shoots near the tops of trees are typically attacked.	• Control is rarely necessary or feasible.
Zimmerman pine moth - *Dioryctria zimmermani* Attack and feed in the base of shoots or branches or in eastern gall rust galls. Attacked branches flag and may	• Control is rarely necessary or feasible.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
break off. Damage causes white, irregular pitch blisters at the site of attack.	
Northern pitch twig moth - *Retinia albicapitana* Prefer to attack open grown saplings at the crotch of multiple twigs. Damage causes hollow, thin-walled, brownish pitch blisters. Two other closely related species, *Petrova houseri* and *Petrova pallipennis*, cause similar damage.	• Control is rarely necessary or feasible.
FOLIAGE DISEASES	
Pine Needle Rust – *Coleosporium asterum* The fungus requires an alternate host (aster, goldenrod) to complete its life cycle. Occasionally it causes needle loss on the lower 5 feet of branches during spring. The disease is most prevalent on trees up to sapling size. Defoliation may cause growth reduction, although mortality is uncommon.	• Control is rarely necessary. • Do not plant seedlings at overly dense spacing. • Remove alternate hosts of the fungus (aster, goldenrod) within 1000 ft. of jack pines manually or by applying herbicides before August when spores are released.
Brown Spot Needle Blight - *Mycosphaerella dearnessii* The fungus initially causes brown bands with yellowish margins on needles. Infected needles turn brown and prematurely fall in late spring or early summer.	• Control is rarely necessary. • Do not plant seedlings at overly dense spacing.
Tar spot needle cast – *Davisomycella ampla* Infects current year needles. Lesions become apparent by the following spring. Severe infection leads to browning and premature casting of year-old foliage.	• Control is rarely necessary.
SHOOT DISEASES/ CANKERS	
Diplodia Shoot Blight - *Diplodia pinea* Current year's shoots become stunted with short, brown needles. Cankers on branches cause branch flagging and dieback. Severe canker development and subsequent branch dieback are occasionally observed after a hail storm. The fungus also attacks seedling root collars causing mortality.	• Remove infected overstory and windbreak pines. • If more than 50% of the crowns are affected consider a salvage harvest. .
Sirococcus Shoot Blight - *Sirococcus conigenus* Current year's shoots droop or become stunted and die. The fungus causes shoot dieback and stem and branch cankers on the current year's growth. A single year of infection may kill seedlings and repeated infections may kill saplings.	• Remove infected overstory and windbreak pines.
Scleroderris Canker - *Gremmeniella abietina* Infected needles turn orange at the base in spring and later turn brown and fall off. The fungus moves to branches and main stems where cankers develop. Cankers girdle and kill seedlings and small trees. Damage is minor on trees over 6 feet tall. Lower branch mortality of larger trees occurs in frost pockets.	• Avoid planting in frost pockets. • Salvage infected pines.
CANKER ROTS	
Red Ring Rot - *Phellinus pini* The fungus causes a white pocket rot in the trunk of infected trees. The fruiting bodies often appear at branch stubs or knots. They are annual or perennial,	• Control is rarely necessary.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
hard, and bracket or hoof shape with irregular margins. Upper surface is dark grayish to dark brown.	
GALL DISEASES	
Eastern Gall Rust (pine-oak gall rust) - *Cronartium quercuum f. sp. banksianae* **Western Gall Rust (pine-pine gall rust)** - *Peridermium harknessii* Eastern gall rust requires red oaks as alternate hosts to complete its life cycle and is considered to be widespread in Wisconsin. Western gall rust infects pine without an alternate host. Based on the survey in the 1960's, the distribution of western gall rust is limited to north-central Wisconsin (Vilas, Oneida, and Lincoln Counties). The fungus causes swollen spherical galls on pine twigs, branches and main stems. Main stem galls may cause breakage at the point of the gall. Galls kill seedlings and branches of older trees. The disease is very common on jack pine near oaks.	• Examine seedlings for galls or swelling on main stems, branches, and root collar areas before planting. Do not plant symptomatic seedlings.
ROOT DISEASES	
Armillaria Root Disease (Shoestring root rot) – *Armillaria* spp. Girdles roots and lower trunks, causing cankers as well as stringy white rot. Affected trees have reduced growth and chlorotic needles. Dieback and mortality can occur, especially during drought years or following two or more years of defoliation (all ages). White mycelial fans and dark-colored rhizomorphs can be found in the cambial zone. *Armillaria* spp. produce fall mushrooms.	• Do not hold stands on poor quality sites past maturity. • Harvest declining stands before bark beetle infestation, mortality, and decay take place.
Annosum Root Rot - *Heterobasidion irregulare* Jack pine are susceptible to infection by *Heterobasidion irregulare* mainly through spores landing on freshly cut stumps as for other pines. Infection could spread to living jack pines if their roots contacted old infected roots. Annosum root rot causes pockets of trees to develop thin crowns, reduced growth, and tree mortality. Pockets expand at about ½ to 1 chain every 10 – 15 years. Fruiting bodies develop at the base of infected trees and stumps. Early fruiting bodies are white and look like popcorn. Under favorable conditions, fruiting bodies develop into perennial bracket-shaped conks.	Management • Expect tree mortality in pockets and growth loss in trees around the pocket margin. • Harvest healthy trees before harvesting diseased trees. • Leave the bottom 8 feet of infected trees on site to avoid inadvertent disease spread. • Clean logging equipment with pressurized water before leaving diseased stands. Prevention • Apply a registered fungicide on fresh cut stumps as soon as possible after cutting or by the end of each day.
ABIOTIC DAMAGE	
Drought, fire, wind and other abiotic factors may kill or significantly stress impacted trees.	• Pre-salvage or salvage dead or stressed trees to avoid insect and disease issues. Trees with more than 50% of the canopy affected are unlikely to recover and should be harvested.

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Chapter 34

Fir-Spruce Cover Type

Last Full Revision: 8/30/1995
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand Composition
More than 50 percent **balsam fir** (*Abies balsamea*) or **white spruce** (*Picea glauca*) or both.

Associated Species
Paper birch (*Betula papyrifera*), trembling aspen (*Populus tremuloides*), red maple (*Acer rubrum*), white cedar (*Thuja occidentalis*), black spruce (*Picea mariana*), hemlock (*Tsuga canadensis*), red pine (*Pinus resinosa*), white pine (*P. strobus*), jack pine (*P. banksiana*), and other species found among northern hardwoods (Chapter 40) and swamp hardwoods (Chapter 46).

1.2 Silvical Characteristics[1]

Table 34.1. Summary of selected silvical characteristics.

Species	Balsam fir	White spruce
Pollination	Strobili open the last of May through the beginning of June.	Strobili open by the end of May and stay open only 3 to 5 days.
Cones Mature	Erect cones, 2 to 4 inches long, maturing in autumn.	Pendulous cones ripening in August or September and opening in September.
Seed Dispersal	Begins in autumn and continues through spring. Cones open as they mature and seed is carried short distances by wind. Most seeds fall near base of parent tree.	Seed is quickly shed with 80 percent dispersal within five weeks of opening. Usually seed is blown about 330 feet but dispersal in excess of 1000 feet is possible from mature trees.
Good Seed Years	Every 2 to 4 years with light crops intervening. Seed production begins at 15 years of age, but best production is after 30 years. Seed numbers average 59,800 per pound.	Every 2 to 6 years with light crops in intervening years. Seed production begins at 30 years of age with optimum production when trees are 60 years old or older. White spruce cones average 140 seeds each. These seeds are extremely lightweight with about 240,000 seeds per pound.
Germination	Generally occurs from late May to early July on almost any seed bed including mineral soil, rotten wood, and shallow duff. Best under a forest cover with low light intensity (15 to 20 percent of full sunlight at midday). Summer mortality is due to high soil surface temperatures and drought. Winter mortality results from frost heaving, or from	Usually in June and July. Dry stored seed exhibits dormancy and requires stratification to induce germination. Moisture condition of seed bed is the most important factor in seedling survival as first year seedlings are small with root penetration of only three inches. In undisturbed forest settings, the majority of seedlings are found on decayed wood which offers

[1] Fowells (1965) except where indicated.

Species	Balsam fir	White spruce
	being crushed or smothered under fallen hardwood leaves, ice or snow.	more moisture, less chance of being smothered by fallen leaves, and better temperature and light conditions. However, overall survival and growth is better on mineral soils.
Seed Viability	Depends on age of parent tree. Increases through mid-life and declines as tree completes life span. Highest observed germination rate was 68 percent from a 41-year-old tree.	Germinative capacity was 70 percent in germination tests with no stratification and eight hours of daily light for 21 days (Safford, 1974).
Seedling Development	Will grow well in dense shade during first 6 to 8 years but needs nearly full light for best development.	Although tolerant, white spruce is unable to compete with dense ground cover or understory growth because of its small size during the first year. Consequently, white spruce is difficult to maintain when grown in mixture with hardwoods.
Growth	Vigorous trees with room to grow will reach 10 inches in diameter and 50 to 60 feet in height in about 50 years. At maturity, reaches 12 to 18 inches in DBH and 40 to 60 feet in height. Maximum reported height is 75 feet with a diameter of 34 inches. Maximum age is 200 years.	Grows rapidly in early years under good conditions and full sunlight. In Wisconsin a 13-year-old plantation on sandy clay loam contained dominants that were between 18.2 and 21.4 feet in height and 2.8 and 4.2 inches in diameter. White spruce, 110 feet tall and 21 inches in diameter, are not uncommon.
Shade Tolerance	Classified as very tolerant; relative tolerance varies with soil fertility and climate. Responds quickly to release.	Classified as tolerant along with black spruce. Will survive 40 to 50 years of suppression and respond to release. In mixed hardwood stands, white spruce will remain an understory tree until it is released. In mixed conifer stands, will reach dominance with balsam fir and black spruce and eventually outgrow them.
Major Pests	Spruce budworm (*Choristoneura fumiferana*), several heart rots (including red heart rot), and over 30 butt rots (including brown cubical butt rot and white stringy butt rot) affect both species. Spruce budworm outbreaks occur in open growth and in overstocked stands, causing defoliation, growth loss, and mortality. Rots generally enter the tree bole through injury to the root and root collar zone. A history of budworm attack usually indicates a higher potential for developing butt rot and heart rot within a stand. Generally, the drier the site, the higher the incidence of heart rot and butt rot in fir-spruce. Balsam fir should not be grown on dry upland sites beyond 60 years of age.	

Species	Balsam fir	White spruce
	White spruce grown on a sawlog rotation should be monitored for signs of rot; overstocked and stagnant conditions should be avoided. Fir-Spruce Pest Management Guidelines are included at the end of this chapter.	

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

The management objective should be identified within an ecosystem framework, considering a variety of objectives within the local and regional landscape. The habitat type is the preferred indicator of site potential. Possible alternatives include managing to produce the maximum quantity and quality of balsam fir pulpwood and white spruce sawtimber where it is consistent with site potential.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.2 Site and Stand Considerations

3.2.1 Soils

Loamy soils are preferred but the type also does well on sand-based soils.

Balsam fir grows on a wide variety of soils but generally does best on loams. It grows on gravelly sands and in peat swamps.

White spruce grows on a variety of soils of glacial, lacustrine, marine, or alluvial origin. Over its geographic range, soils vary from heavy clays to sandy podzols. White spruce is exacting in its nutrient requirements and tends to show symptoms of potassium deficiency on poor soils.

5 SILVICULTURAL SYSTEMS

Even-age management can be applied with periodic thinnings based on site capabilities. Fir-spruce can also be managed on an all-age basis. Development of compositional and structural diversity (within and across landscape) is encouraged.

Swamp edge or lower ridge areas are considered primary sites for fir-spruce. Upland locations tend to convert to hardwoods and are considered secondary sites for fir-spruce. On some sites aspen and fir may dominate every other rotation on a cyclical basis. The Lake Superior lowlands (glacio/acustrine clay plain) were historically associated with this type.

Balsam fir has a better developed juvenile taproot than white spruce but both are subject to windthrow if more than 50 percent of a stand is removed at one time. Cutting on a minimum tree limit of 2 or 3 pulp sticks, is usually too heavy, and results in some windthrow of remaining trees, removal of seed trees, and overexposure and excessive drying of organic matter and small seedlings. Row thinning of either every other row or every fourth row, removing the center row of the remaining three in the next thinning, provides access and encourages development in spruce plantations.

5.1 Seedling / Sapling Stands

Most pole size fir-spruce stands have 1- to 3-inch seedlings present which can be encouraged to develop by partial removal of the overstory. By the time seedlings are one foot or greater in height, their root systems are established in mineral soil and they can withstand full release.

5.2 Pole and Small Sawtimber Stands (5-9" and 9-15" DBH, respectively)

Mixed or pure stands with white spruce management potential (at least 200 dominant and co-dominant white spruce per acre):

Manage for white spruce. Reduce basal area stocking to B-level whenever stand becomes operable (see stocking chart in Figure 34.1). Remove fir as it reaches maturity but do not harvest more than 50 percent of the total stand volume at anyone thinning.

Rotate stand in accordance with site index rotation age (see Figure 34.2 and Figure 34.3). Opportunities for extended rotation management may occur. Regenerate by stripcutting stand, leaving 50 feet wide uncut strips or patches at no more than 150 feet intervals as a seed source. Bunch or windrow slash and disc cutover area to provide a mineral soil seed bed.

If adequate spruce regeneration does not occur within 5 to 6 years, plant to white spruce. Do not leave undesirable seed trees such as aspen, birch, and soft maple in the reserve strip. If hardwoods are present in the fir-spruce stand, either tolerate them as a component in the future stand or remove them during the regeneration cut.

Uneven aged management can be applied through individual tree or group selection. Development of structural diversity should be encouraged.

Pure or mixed balsam fir stands (with less than 200 dominant and co-dominant white spruce stems per acre):

Manage for balsam fir. Reduce basal area stocking to B level whenever stand becomes operable if at least 10 years prior to rotation age. Rotate stand in accordance with site index rotation age.

To regenerate, reduce basal area stocking to 60 square feet of basal area by removing no more than 50 percent of the dominant and co-dominant trees in the residual stand to provide seed. Remove hardwoods with partial harvest. Harvest shelterwood residual when 60 percent millacre stocking of regeneration taller than one foot in height will remain after removal of overstory.

Slash accumulation should be controlled to prevent covering of advance regeneration by bunching slash during felling and limbing. Tree length skidding to landing may also be used if damage to regeneration is minimal.

Understocked stands below C stocking level:
Scarify with disc or blade to expose mineral soil. Clearcut overstory when regeneration reaches one foot or greater in height and 60 percent millacre stocking will remain after harvest.

OR

Clearcut, prepare site and plant to white spruce.

White spruce plantations:
Allow stocking level to reach 160 square feet of basal area, then reduce to 90 square feet. A combination of row thinning and selective marking from below will be needed. Never remove more than 50 percent of the stocking level at one time.

Subsequent thinnings should be made from below, whenever the stand becomes operable, with a residual level of 90 square feet of basal area in poles and 120 square feet in sawtimber.

Regenerate as previously described above in subsection 4.2.

8 APPENDICES

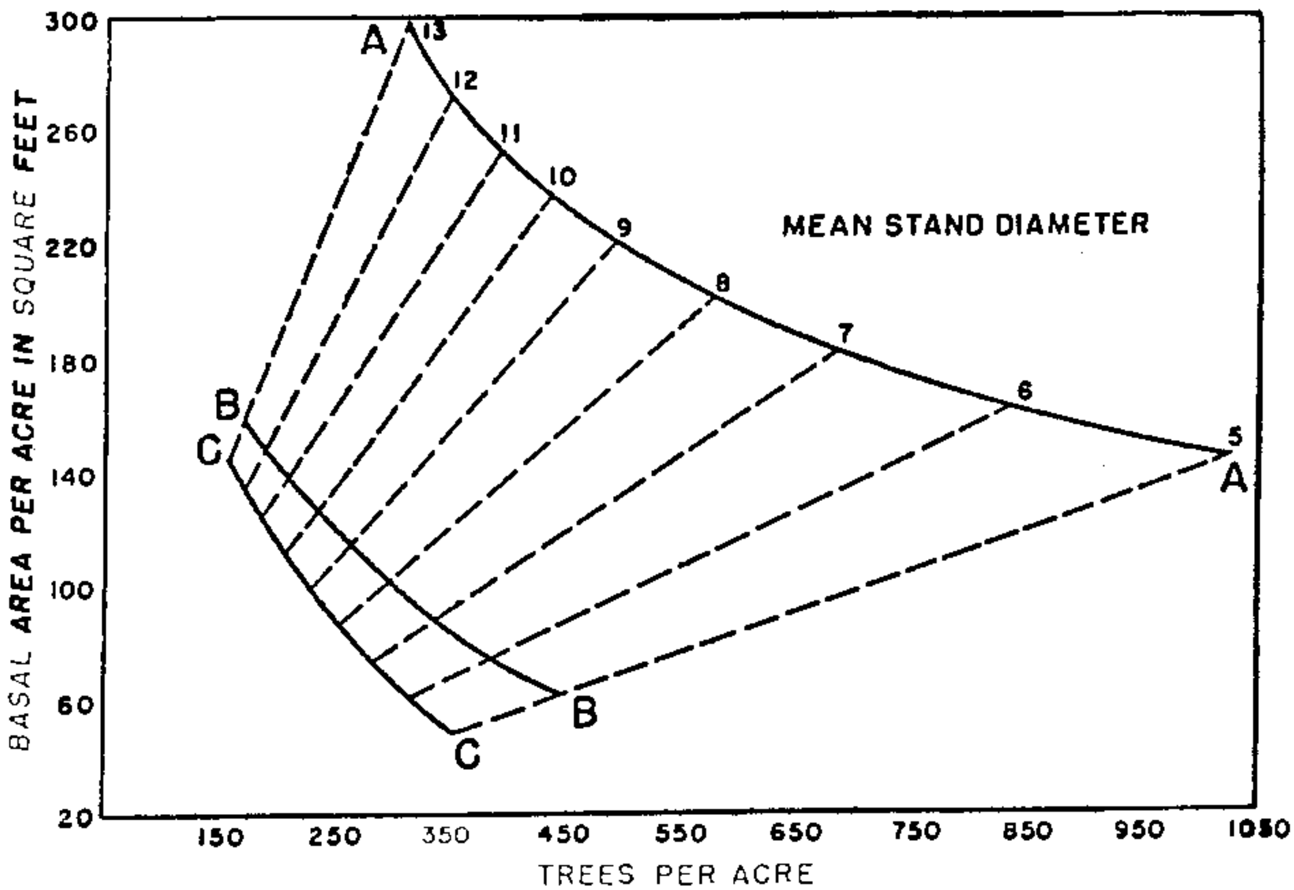
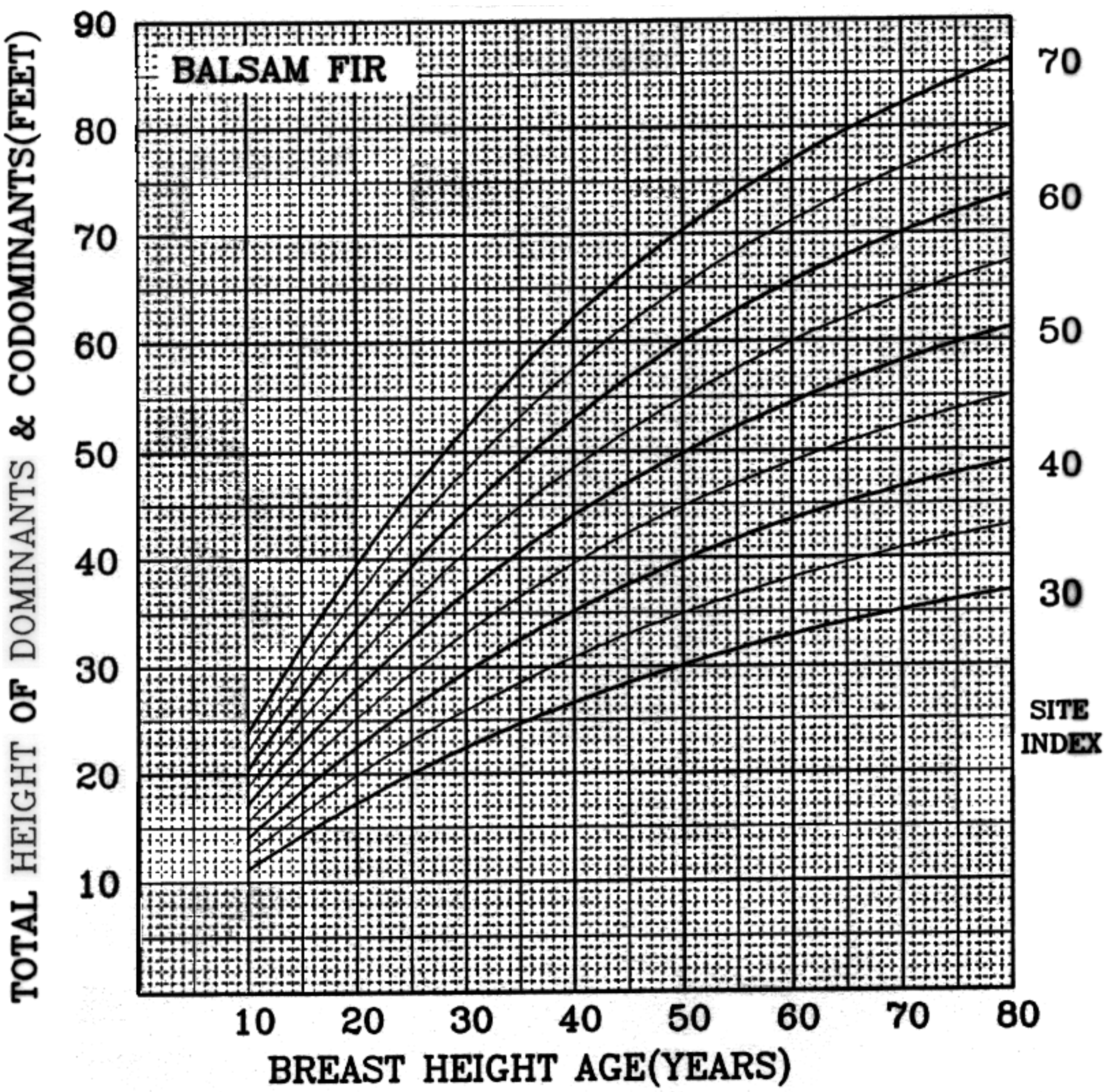


Figure 34.1. Stocking chart for even-aged spruce fir (Frank and Bjorkbom, 1973).

Based on the number of trees in the main canopy, average diameter, and basal area per acre. The area above the A-level represents overstocked stand conditions. Stands between the A- and B-levels are adequately stocked. Stands between the B- and C-levels should be adequately stocked within ten years or less. Stands below the C-level are understocked.

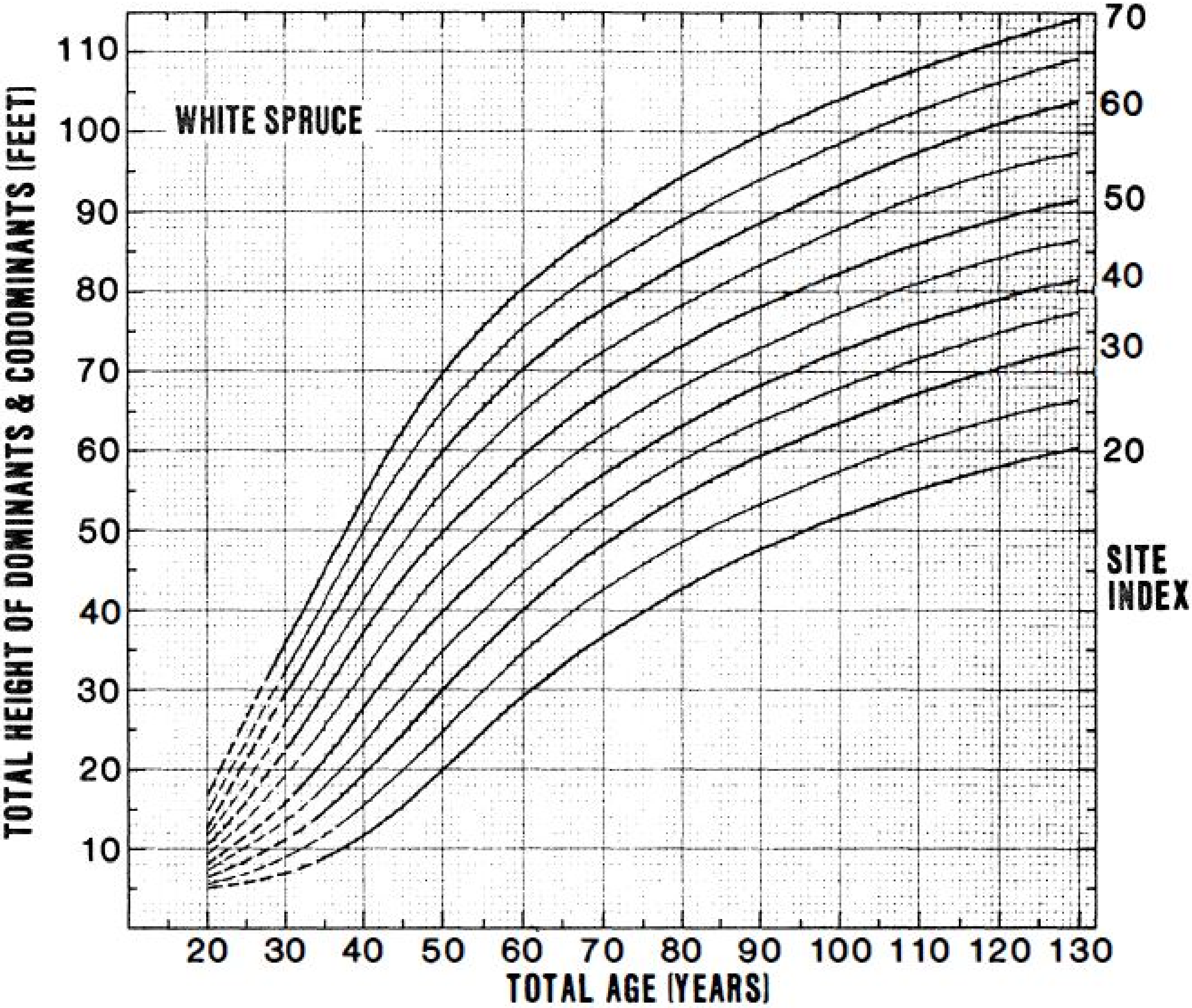


Balsam fir (Gevorkiantz 1956b)
Lake States
Number of plots and number of dominant and codominant trees not given
Total height and breast height age, anamorphic, equation not given
Site index is total height of dominant and codominant trees at 50 years breast height age (BH = 4.5)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	1.0438	1.0708	-0.0222	1.5915	-0.1068	0.99	1.08	1.6
SI	0.4358	1.0650	-0.0179	-0.7497	0.0251	0.99	1.18	2.1

Upland Sites					
Site Index	70	60	50	40	30
Rotation Age (years)	60	50	50	40	40
Rotation Age for Swamp Sites	50 years				

Figure 34.2. Site index curves for balsam fir in the Lake States (Carmean et al., 1989).



White spruce (Carmean and Hahn 1981, revision of Gevorkiantz 1957g)
Minnesota
Number of plots and number of dominant and codominant trees not given
Total height and breast height age, anamorphic, Gevorkiantz (1957g) equation not given
Convert d.b.h. age to total age by adding years according to site index (BH = 0.0):

SI:	20	30	40	50	60	70
Years:	15	13	11	10	9	8

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	11.3079	0.5419	-0.0345	34.1568	-0.6078	0.99	2.18	6.4
SI	0.0380	1.5142	-0.0124	-6.4840	-0.3550	0.99	2.29	6.4

Rotation age: All sites -- 80 to 100 years.

Figure 34.3. Site index curves for white spruce (Carmean et al. 1989).

8.1 Forest Health Guidelines - Forest Health Protection (FHP)

HAZARD	LOSS OR DAMAGE	PREVENTION, MINIMIZING LOSSES AND CONTROL ALTERNATIVES	REFERENCES
Spruce Budworm	Periodic outbreaks of spring defoliation cause growth loss and mortality of balsam fir and, to a lesser extent, white spruce.		Spruce-Fir Silviculture and Spruce Budworm in the Lake States. 1983. J.L. Flexner, et al. CANUSA Handbook 83-2.
	OUTBREAKS: 1. One severe defoliation (more than 75% new needles destroyed) causes growth loss and up to 50% top kill and some tree mortality	MINIMIZE LOSSES BY: 1. Harvest defoliated stands within two years.	
	2. Two severe defoliations cause up to 50% tree mortality on good sites and up to 90% on poor sites.	2. Harvest defoliated stands within one year on all sites.	
	HAZARDOUS STAND CONDITIONS: 1. Even aged and overmature balsam fir to 95%.	PREVENTIVE PRESCRIPTION: 1. PRIORITY 1: Clearcut as soon as feasible.	Spruce Budworm Handbook: Managing the Spruce Budworm in Eastern North America. 1984. D.M. Schmitt, et al. Agr. Handbook No. 620. USDA Forest Service.
	2. Even aged, mature to overmature balsam fir and white spruce: Balsam fir to 70%, white spruce to 10% and swam hardwoods to 20%.	2. PRIORITY 1: Clearcut as soon as feasible. Do not leave white spruce to carry budworm population to next generation.	

HAZARD	LOSS OR DAMAGE	PREVENTION, MINIMIZING LOSSES AND CONTROL ALTERNATIVES	REFERENCES
	3. Balsam fir and swamp conifers with mature balsam fir to 30% and cedar, black spruce, tamarack to 70%.	3. PRIORITY 2: Cut balsam fir within 5 years and remove older cedar and white spruce favoring younger cedar, black spruce and tamarack to rotation age.	
	4.Balsam fir and aspen in mature stands. Balsam fir to 50% and aspen to 50%.	4. PRIORITY 2: Clearcut balsam fir and aspen within 5 years of initial infestation.	
	5.Balsam fir and northern hardwoods with mature balsam fir in fringe area to 10% and northern hard-woods to 90%.	5. PRIORITY 3: Selective cut hardwoods and harvest mature balsam fir as part of the overall cutting operation.	
STEM AND ROOT DECAY			
Red Heart Rot of Balsam Fir (Haemato-stereum sanguino-lentum)	STEM DECAY OF BALSAM FIR: 1. Incipient Stage: Wood is water-soaked and reddish but firm. 2. Advanced Stage: Wood is cull; half or more of diameter is defective.	1. Limit rotation age to 50 years. Harvest. 2. Harvest.	Balsam Fir Decay and Cull on Different Sites, with Rotation Age Recommendations. Don Prielipp. 1956. Kimberly-Clark Corp.
Brown Cubical Butt Rot of Balsam Fir (Phaeolus schweinitzii)	Heartwood decay in roots and lower 4 feet of stem.	Limit rotation age to 50 years.	Balsam Fir Decay and Cull on Different Sites, with Rotation Age Recommendations. Don Prielipp. 1956. Kimberly-Clark Corp.

HAZARD	LOSS OR DAMAGE	PREVENTION, MINIMIZING LOSSES AND CONTROL ALTERNATIVES	REFERENCES
White Stringy Butt Rot (Armillaria mellea) of Balsam Fir and White Spruce	Growth loss, tree mortality, decay of lower stem wood.	Limit rotation age to 50 years.	Armillaria Root Disease. R. Williams, et al. 1986. USDA Forest Service. Forest Insect and Disease Leaflet 7p.
White Pocket Root Rot of White Spruce (Inonotus omentosus)	Decay of heartwood of roots and lower stem. Growth loss, decline, mortality of individual trees or groups.	On sites with very acid (pH 4-5) soils, low nutrient availability, and water-holding capacity, very shallow or compacted soil: 1. Discriminate against white spruce. 2. Clearcut entire stand when infected.	Polyporus Tomentosus Root Rot of Conifers. R.D. Whitney. 1977. Canadian Forestry Service GLFRC Tech. Report 18.

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Chapter 35

Swamp Conifer-Balsam Fir Cover Type

WISCONSIN
DEPT. OF NATURAL RESOURCES

Last Full Revision: 4/15/1998
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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Last Full Revision: 4/15/1998
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1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand Composition
More than 50 percent swamp conifers with balsam fir (*Abies balsamea*) predominant.

Associated Species
Northern white cedar (*Thuja occidentalis*), black spruce (*Picea mariana*), white spruce (*P. glauca*), tamarack (*Larix laricina*), hemlock (Tsuga canadensis), white pine (Pinus strobus), jack pine (*Pinus banksiana*), black ash (*Fraxinus nigra*), paper birch (*Betula papyrifera*), yellow birch (*B. allegheniensis*), red maple (*Acer rubrum*), quaking aspen (*Populus tremuloides*) and balsam poplar (*P. balsamifera*).

1.2 Silvical Characteristics

For silvical characteristics, see Chapter 34 for balsam fir and white spruce, Chapter 36 for black spruce, Chapter 37 for tamarack, and Chapter 38 for white cedar. In addition, site index curves and pest management guidelines for balsam fir are provided in Chapter 34.

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

The management objective should be identified within an ecosystem framework, giving consideration to a variety of objectives within the local and regional landscape. A possible objective is to manage for production of the maximum quantity of pulpwood where possible and permissible under wetlands protection restrictions. Management concerns of special importance for lowland forest types include Best Management Practices (BMPs) for water quality, endangered resources, biodiversity, wildlife, and aesthetics.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.2 Site and Stand Considerations

3.2.1 Soils

Located on peat or muck soils where soil pH is in the range of 4 to 6.

3.2.2 Site Quality

3.2.1.1 Range of Habitat Types

Hydric (wet) site habitat types have not been developed for Wisconsin. Habitat types for swamp conifers were determined for upper Michigan (Coffman et al., 1980) and include TTM (*Tsuga-Thuja-Mitella*), TTS (*Tsuga-Thuja-Sphagnum*), PO (*Picea-Osmunda*), and PCS (*Picea-Chamadaphne-Sphagnum*). However, these types are based on very limited sampling and have not been studied adequately to offer extensive management information.

5 SILVICULTURAL SYSTEMS

Even-age management will be applied with a set rotation length of 50 years on all sites where objectives include harvesting and regeneration.

Generally conifer species are thriftier and better producers than hardwood species on peat soils. These sites should be managed to retain, at least, or increase, if possible, the proportion of conifers in the future stand's composition. Strip cutting in swamp conifer will encourage survival of advance conifer seedlings, favor establishment of new conifer seedlings, and allow conifers to compete successfully with hardwood species.

A commercial clearcut in swamp conifer usually leaves 30 to 60 square feet of non-merchantable residual trees. These non-merchantable trees should be removed concurrent with the sale or immediately thereafter to allow full development of the future stand.

Current research indicates that it may be possible to clearcut, burn, and direct seed swamp conifer stands. Balsam fir can also be regenerated by shelterwood cutting on swamp sites. However, the limited volume present and the likelihood of difficult logging conditions usually precludes two-step stand removal.

Incidence of decay in balsam fir decreases as stand density increases. The incidence and extent of decay in balsam fir is also much greater on upland sites than on swamp sites. Natural pruning may reduce infection source by healing over limb scars.

5.1 Seedling / Sapling Stands

At this stage no treatment is necessary. Simply allow natural development. The adequate moisture of swamp conifer sites allows balsam fir to become established over a wide range of light conditions.

5.3 Natural Regeneration Methods

5.3.1 Even-Age Regeneration Methods

5.3.1.1 Stands without Cedar

Do not thin. Clearcut stand at rotation age if stand has vigorous advance regeneration that will provide 60 percent millacre stocking after harvest.

If advance regeneration is inadequate, commence strip clearcutting when stand reaches rotation age. Divide the stand into strips, 2-chains wide, at a right angle to the prevailing wind direction (generally from the southwest). Clearcut the most leeward strip and each successive third strip.

When 60 percent millacre stocking of one-foot tall seedlings has been attained, clearcut the next series of strips windward of the newly regenerated strips.

When the second series of strips has regenerated, cut the third series. Either leave seed trees at 100 ft. spacing or apply direct seeding to regenerate the last series of strips.

As each strip is cut, or shortly thereafter, most residual stems larger than 2 inches DBH should be removed to favor regeneration.

To provide adequate seed bed, bunching or windrowing of slash may be necessary if stand is very dense. In case of heavy slash, burning may be the best method of slash disposal and seed bed preparation.

5.3.1.2 Stands with Cedar Management Potential

When the balsam fir component of the stand reaches 50 years of age, harvest the stand leaving 90 square feet of residual basal area. Retain all cedar and other long-lived species such as tamarack and white spruce. Some balsam fir may also be left to bring the residual up to 90 square feet. Thereafter, manage as prescribed for white cedar.

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Chapter 36

Black Spruce Cover Type

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DEPT. OF NATURAL RESOURCES

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Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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Table 36.1. Summary of selected silvical characteristics. 1

1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand Composition
More than 50 percent swamp conifers with black spruce (*Picea mariana*) predominant.

Associated Species
Common associates include tamarack (*Larix laricina*), northern white cedar (*Thuja occidentalis*) and balsam fir (*Abies balsamea*).

Occasional associates include: white spruce (*Picea glauca*), hemlock (*Tsuga canadensis*), white pine (*Pinus strobus*), jack pine (*P. banksiana*), balsam poplar (*Populus balsamifera*), quaking aspen (*P. tremuloides*), black ash (*Fraxinus nigra*), red maple (*Acer rubrum*), paper birch (*Betula papyrifera*) and yellow birch (*B. allegheniensis*).

1.2 Silvical Characteristics*

Table 36.1. Summary of selected silvical characteristics.

Species	Black spruce
Pollination	First week of June in southern part of its range across North America.
Cones Mature	Early September. Cones are only 1/2 to 1-1/2 inches long and tend to be concentrated in upper part of the crown.
Seed Dispersal	Seed fall begins in October, but because cones are persistent and semi-serotinous, seed fall occurs throughout the year with most seed being shed within 4 years. Heavy seed falls occur when cones are opened by heat, thereby allowing dense even-aged stands to become established when stands are burned over.
Good Seed Years	Crops seldom fail and successive failures are uncommon. Heavy crops occur about every four years. Seed production averages 200,000 seeds per acre per year and can be as high as 500,000. Because black spruce has yearly seed crops and semi-serotinous cones, a seed supply is almost constantly present in stands 40 years of age and older.
Germination	Germination rates depend on type of seed bed and available moisture. Germinative capacity was 88 percent in germination tests (Safford, 1974); under field conditions germination varied from 46 percent on mineral soil, to 29 percent on burned duff, to 7 percent on undisturbed duff (Fowells, 1965). Seedling establishment requires a moist, but unsaturated seed bed, free of competing vegetation. Black spruce establishment is generally successful if the surface layer is either removed by machine or fire, compacted, or composed of living sphagnum moss.
Seed Viability	Viable seed has been found in 15-year old cones. After fire exposure, most of the seed in dense clusters of cones remains uninjured. Seeds can be exposed briefly to temperatures of 185°F, and can be stored for periods of 5 to 17 years, without loss of viability.
Seedling Development	Seedlings seldom grow more than an inch the first year. Seedlings are slow growing and are usually only 3 to 5 inches tall at 3 years of age.

	Tamarack, aspen, and jack pine seedlings grow faster than black spruce, but black spruce grows faster than white spruce. Seedlings will develop under as little as 10 percent full sunlight, but best development requires open conditions. Roots penetrate to a depth of only two inches the first season on soils, and less so on moss. Root development is characteristically shallow.
Growth	On the best sites black spruce may grow to diameters of 18 inches and heights of 90 feet and may reach 250 years of age.
Shade Tolerance	Black spruce is tolerant, but not as tolerant as two of its most common competitors, balsam fir and northern white cedar. Black spruce is a pioneer species on filled-lake bogs, although it sometimes may develop uneven-aged self-perpetuating stands.
Major Pests	**Butt rot** (several species): avoid holding stands beyond recommended rotation length. **Dwarf mistletoe** (*Arceuthobium pusillum* Peck): broadcast burn slash resulting from harvest of stands infected by mistletoe to prevent new stands from becoming infected. **Flooding:** do not install road drainage structures in a manner that will impede drainage. Remove all beaver dams that impede drainage. **Windthrow:** wind breakage is more common in stands with butt rot which becomes common at 100 years of age on organic soils and at 70 years of age on mineral soils.

* Mainly from Fowells (1965) except where indicated.

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

The management objective should be identified within an ecosystem framework, giving consideration to a variety of objectives within the local and regional landscape. Possible alternatives include managing to produce the maximum quantity and quality of pulpwood or to maintain black spruce where it now exists. Through natural succession the type may be maintained or converted, depending upon a variety of factors. Management concerns of special importance for lowland forest types include endangered resources, biodiversity, wildlife, aesthetics, and BMPs (Best Management Practices) for water quality.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.2 Site and Stand Considerations

3.2.1 Soils

Black spruce is found almost entirely on peat bogs, muck-filled seepages, and stream courses in Wisconsin. Occasionally black spruce will be found on mineral soil adjacent to a swamp that contains black spruce. A few plantations of black spruce have also been established on upland sites.

3.2.2 Site Quality

3.2.2.1 Range of Habitat Types

Hydric (wet) site habitat types have not been developed for Wisconsin. Habitat types for swamp conifers were determined for upper Michigan (Coffman et al., 1980) and include TTM (Tsuga-Thuja-Mitella), TTS (Tsuga-Thuja-Sphagnum), PO (Picea-Osmunda), and PCS (Picea-Chamadaphne-Sphagnum). However, these types are based on very limited sampling and have not been studied adequately to offer useful management information.

4 STAND MANAGEMENT DECISION SUPPORT

4.2 Key/ Checklist for Evaluating Cover Type Stand Management Options

Key to recommendations:

1. Pole timber plantation on mineral soil	Allow stocking level to reach 160 square feet of basal area then reduce to 90 square feet. A combination of row thinning and selective marking from below will be needed. Never remove more than 50 percent of the stocking level at one time. Subsequent thinnings should be made from below, whenever the stand becomes operable, with a residual basal area of 90 square feet. To regenerate, mark a shelterwood cut and leave stand with 60 square feet of residual without removing more than 50 percent of stocking in one cutting. Harvest residual stand when regeneration reaches one foot in height.
1. Not a plantation site	**2**
2. At least 6 percent millacre stocking of vigorous advance seedling reproduction	Clearcut stand at site index rotation age (Figure 36.1). Rely on existing regeneration to regeneration stock future stand.
2. Stands lacking adequate advance regeneration	**3**
3. Sphagnum seed bed is well-distributed and low volume of slash is expected or whole tree skidding to be applied	Two options are possible: a) At site index rotation age, divide the stand into strips 2 - 4 chains wide at a right angle to the prevailing wind direction. Clearcut every third strip starting with the most leeward strip. When at least 60 percent of millacre plots become stocked with 3-year old seedlings within the clearcut strip, clearcut a second series of strips.

	Clearcut the third series of strips when 60 percent millacre stocking of regeneration is attained in the second strip series. The third strip series will have to be regenerated by leaving seed trees spaced at 100 feet. or by direct seeding. **OR** b) Clearcut entire stand at site index rotation age and direct seed to establish regeneration. If 60 percent of millacre plots fail to become regenerated, a subsequent seeding will be necessary in understocked areas.
3. Stands lacking adequate sphagnum distribution, and with heavy brush, slash, or mistletoe infection	Rotate the stand by clearcutting on an entire area or strips as previously described above. Then burn slash to prepare a suitable seed bed. Direct seeding will be needed where seed source is not within four chains on windward side of area to be regenerated.

5 SILVICULTURAL SYSTEMS

Even-age management will be applied where objectives include harvesting and spruce regeneration. In sensitive areas with deep organic soils and reduced risk of windthrow, uneven-aged management through selective harvesting may provide an alternative (competition from fir and cedar should be monitored).

When the site index is less than 25 (Figure 36.1), the site should be managed for Christmas trees. Remove trees with the best form every 10 years once sufficient height has been attained. When the site index is 25 or more, manage for pulpwood.

5.1 Seedling / Sapling Stands

Allow stand to develop naturally.

5.2 Intermediate Treatments

5.2.2 Thinning

Intermediate thinnings are not recommended due to low economic returns and the risk of mortality from windthrow.

5.3 Natural Regeneration Methods

5.3.1 Even-Age Regeneration Methods

Black spruce should not be held beyond 70 years on mineral soils because of increased incidence of butt rot.

When all other stand conditions are equal, a dense black spruce stand should be harvested before a less dense stand because it will reach culmination of mean annual growth sooner. To control undesirable species and favor black spruce regeneration, all non-merchantable stems should be cut at the time of harvest or destroyed shortly thereafter.

Black spruce releases seed for up to four years after good seed years which occur frequently enough to provide almost continuous seed supply. Maximum seed dispersal is about four chains downwind along the prevailing wind direction from parent trees of normal height.

Sphagnum moss provides a good seed bed for black spruce, whereas feather mosses dry out quickly after clearcutting, resulting in a poor seed bed. On black spruce sites, feather mosses should be either removed through fire or scarification or compacted to form a good seed bed.

Slash should be broadcast burned if dwarf mistletoe is prevalent in a black spruce stand. The main requirements for setting up and conducting a successful broadcast burn on black spruce sites are as follows:

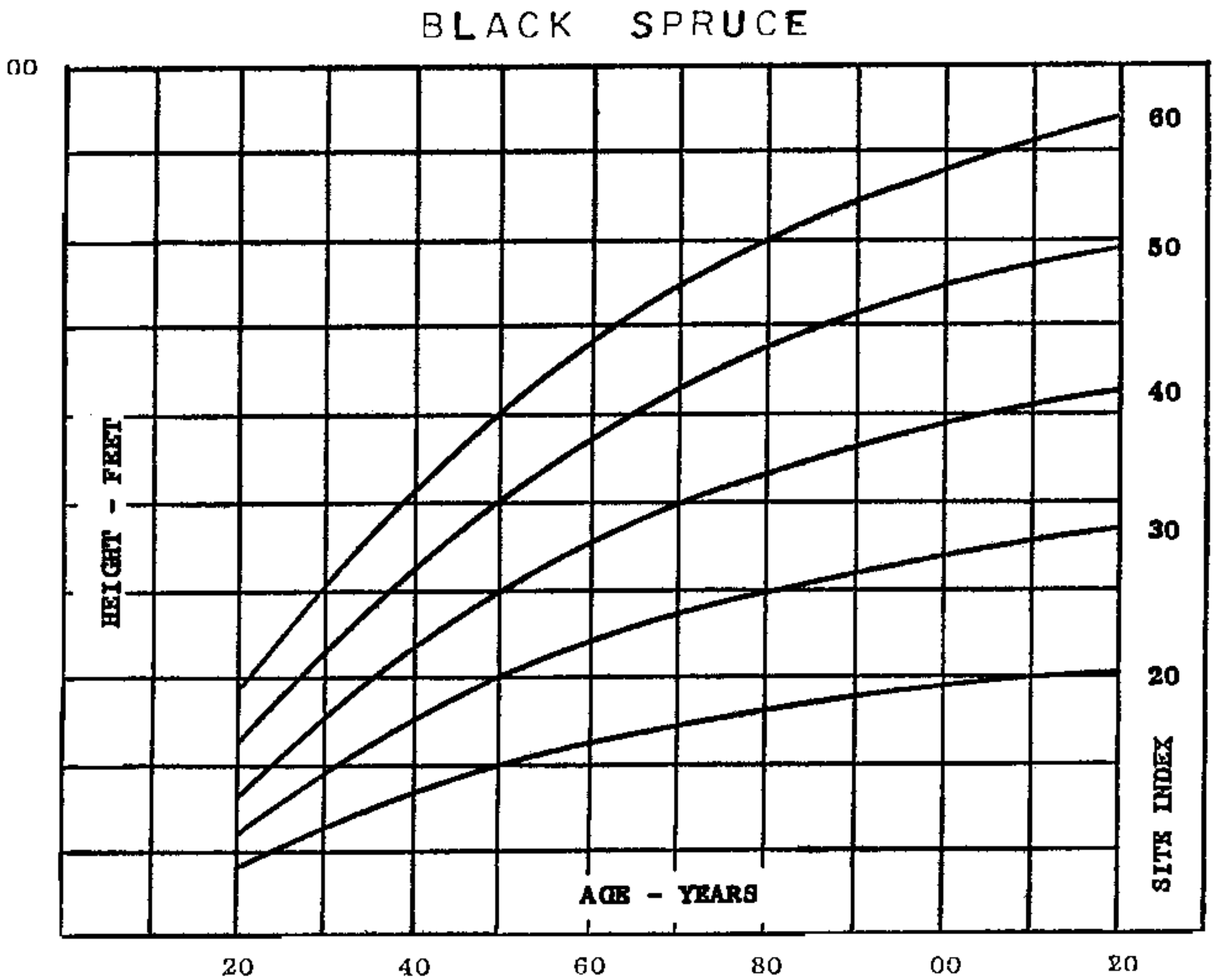
1. Locate edges of burn area on undrained organic soil. Special control measures, such as long ditches, should be taken near drained organic soils and near upland sites.
2. Make edges of burn area smooth and reasonably straight.
3. Cut all merchantable trees near the edge of the burn area.
4. Plan cutting and skidding in a manner that will distribute the slash evenly within the burn area.
5. Leave a slash-free alley about 1/2-chain wide between the burn area and the surrounding area.
6. Burn slash within a year after harvesting.
7. Burn when conditions are suitable for consuming most of the slash that is less than one inch in diameter without starting deep ground fires.
8. Burn when the wind direction is away from adjacent timber to avoid serious crown scorch or mortality. Otherwise, use center firing when the wind speed is 0 to 5 miles per hour.
9. Burn should be conducted at least three days after 0.1 inch of rainfall when the relative humidity is 30 to 60 percent and the maximum wind is 5 to 15 miles per hour.
10. Burning a non-sphagnum seed bed requires a hotter fire which is produced at least seven days after rain, when the relative humidity is less than 45 percent, and the minimum air temperature is 80°F.

Heavy brush competition can significantly reduce spruce productivity and regeneration success.

5.4 Artificial Regeneration Methods

Direct seeding of black spruce requires a seeding rate of four ounces (about 100,000 seeds) per acre for 60 percent millacre stocking. At present, seed is hard to obtain and expensive. Overstocking is a frequent problem with direct seeding. Seeding rate should be well-calibrated or seed trees should be removed as soon as 60 percent millacre stocking is achieved.

8 APPENDICES



NOTE: Total age = Breast height age + 15 years

Rotation Age					
Organic Soil Sites					
Site Index	60	50	40	30	20
Rotation Age	60	80	100	110	120
Mineral Soil Sites	70 years				

Note: Rotation ages represent minimums and can be extended to a significant degree depending on site capability and management objectives.

Figure 36.1. Site index curves for black spruce in the Lake States (Technical Note No. 473).

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Chapter 37

Tamarack Cover Type

WISCONSIN
DEPT. OF NATURAL RESOURCES

Last Full Revision: 12/5/1990
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand Composition
More than 50 percent swamp conifers with tamarack (*Larix laricina*) predominant.

Associated Species
On organic soils, the tamarack cover type includes black spruce (*Picea mariana*), white spruce (*P. glauca*), and northern white cedar (*Thuja occidentalis*).

On mineral soils, this cover type includes quaking aspen (*Populus tremuloides*), paper birch (*Betula papyrifera*), red maple (*Acer rubrum*), and white pine (*Pinus strobus*).

Tamarack is usually associated with lowland brush (Chapter 50) because it has a relatively thin crown that passes sufficient light to allow the brush layer to develop.

1.2 Silvical Characteristics*

Table 37.1. Summary of selected silvical characteristics.

Species	Tamarack
Pollination	Late April to early May, depending on location. Male and female strobili occur separately and emerge before leaves appear, with male parts on young branchlets and female parts on older branches.
Cones Mature	Cones begin to form in June and ripen in mid-August to late September. Seed mostly falls by the end of October with the empty cones remaining on the trees for 2 to 5 years.
Seed Dispersal	Seeds are light in weight (averaging 318,000 seeds per pound), have long wings, and travel up to 200 ft. from the parent tree.
Good Seed Years	Good crops occur at intervals of 3 to 6 years, with some seed produced in intervening years. Best crops are found on vigorous, open-grown trees 50 to 150 years old. A medium-stocked stand may produce as many as five million viable seeds per acre in a bumper year.
Germination	Under forest conditions, internal dormancy is broken during the first winter. Germination occurs from late May to mid-June, peaking at soil surface temperatures of 65 to 70°F. The best seed bed is moist mineral soil or organic soil free of brush but with a light cover of herbs or grass. Hummocks of slow-growing sphagnum moss are also good seed beds if they are free of Labrador tea and associated with a stable water table. Fine textured mosses are also good.
Seed Viability	As much as 50 percent of seed fall may be destroyed by rodents. Red squirrels often cut cone-bearing branchlets and cache the cones. An undetermined Lepidoptera is also known to feed on developing seeds and may sometimes destroy as much as 40 percent of the crop. Seeds are also eaten by the American red crossbill. As a result of these losses plus those due to bacteria and fungi, only 4 to 5 percent of a seed crop may germinate.
Seedling Development	Because tamarack seedlings are small, they are easily killed in the first 6 to 8 weeks following germination. Early losses are primarily caused by

Species	Tamarack
	damping-off, with mechanical injury, drought, drowning and insects (especially the larch sawfly) contributing. Drought or drowning along with insufficient light may cause appreciable losses in the second and third years. For best growth, tamarack seedlings need abundant light and a constant water level. Seedlings established under fully stocked stands are usually only an inch tall at the end of the first year and do not survive beyond the sixth year. Under little or no cover, seedlings may be as tall as 7 to 9 inches the first year and 18 to 25 inches by the third year. From then on, with adequate light and good drainage, growth is rapid.
Growth	The growth rate of tamarack saplings depends largely on moisture conditions with slowest growth on water-covered stagnant swamps, and fastest growth on well-drained sites. Average height of mature trees is 50 to 75 ft., with occasional individuals reaching 100 to 115 ft. in height. Diameters of mature trees are usually 14 to 20 inches but a few may reach 36 to 40 inches. Trees 60 to 80 feet tall with 20 to 24 inch diameters were once common in the Lake States. Maximum age is generally 150 to 180 years. Growth of pole timber stands is generally 0.3 to 0.4 cord per acre per year, with better growth rates associated with higher stocking levels. Tamarack typically has a shallow, compact root system, one to two ft. in depth. On favorable sites it may spread over a radius greater than the height of the tree.
Shade Tolerance	Tamarack is very intolerant. Although it can tolerate a little shade during the first 3 to 4 years, it must become dominant to survive. The tree is a good self-pruner, and boles of 25- to 30-year old trees may be clear for one-half to two-thirds of their heights.
Major Pests	**Larch sawfly** (*Pristiphora erichsonii* Htg.) is periodically epidemic and may defoliate tamarack stands over large areas for several successive years. Growth of infested stands is greatly reduced and mortality is severe. The suggested prevention method is to avoid sparse stands, but this is considered to be difficult to attain because of tamarack's intolerance and scattered stocking pattern. Other pests include the **larch casebearer** (*Coleophora laricella*), **eastern larch beetle** (*Dendroctonus simplex*), **needle cast disease** (*Hypodermella laricis*), **heart rot** (*Fomes pini*), **butt rot** (*Polyporus schweinitzii*), and **root rot** (*Armillaria mellea*). **Flooding or unstable water levels** often kill established tamarack stands. Stands that survive very wet conditions usually grow very slowly. Avoid

Species	Tamarack
	blocking swamp drainage by road construction or by allowing beaver dams to impede drainage. **Windthrow**: Strong winds often uproot large tamarack trees growing in swamps or other wet sites where rooting is shallow. Avoid open-grown stands and maintain wind-firm residual densities.

* Information primarily from Fowells (1965).

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

The management objective should be identified in relation to other land management objectives using the habitat type, if known, as the preferred indicator of site potential. Possible alternatives for tamarack include managing to produce the maximum quantity and quality of pulpwood and saw timber consistent with site potential and to maintain tamarack on sites where it now exists.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.2 Site and Stand Considerations

3.2.1 Soils

Tamarack can tolerate a wide range of soil moisture conditions and soil textures. It is most commonly found on moist organic soils, peats and mucks of swamps and muskegs, especially in the southern limits of its range. Best growth is observed on rich, moist, but well-drained, loamy soils along streams, lakes and swamps; in seep areas; and on shallow layers of mulch or well-decomposed peat over mineral soil.

3.2.2 Site Quality

3.2.2.1 Range of Habitat Types

Habitat types for swamp conifers were determined for upper Michigan (Coffman et al., 1980) and include TTM (Tsuga-Thuja-Mitella), TTS (Tsuga-Thuja-Sphagnum), PO (Picea-Osmunda), and PCS (Picea-Chamadaphne-Sphagnum). However, these types are based on very limited sampling and have not been adequately studied to offer useful management information.

5 SILVICULTURAL SYSTEMS

Even-age management will be applied.

5.1 Seedling / Sapling Stands

Allow stand to develop naturally.

5.2 Intermediate Treatments

In all cases, if at least 20 years prior to rotation, reduce basal area stocking level to 100 sq. ft. whenever stand becomes operable.

5.3 Natural Regeneration Methods

5.3.1 Even-Age Regeneration Methods

1. When at least 60 percent millacre stocking of vigorous advance regeneration will remain after logging, clearcut stand at site index rotation age. Rely on existing regeneration to stock future stand.

2. When there is inadequate advance regeneration, clearcut in strips when stand reaches site index rotation age. Divide the stand into strips, 3 chains wide, at a right angle to the prevailing wind (generally from the southwest). Clearcut the most leeward strip and each successive third strip. When 60 percent millacre stocking of one-foot tall seedlings has been attained, clearcut the next series of strips windward of the newly regenerated strips.

   When the second series of strips has regenerated, cut the third series leaving scattered dominant seed trees at 100-ft. spacing to regenerate the final strip. All other residual stems larger than 2 inches DBH, should be removed to favor regeneration as soon as each strip is cut or shortly thereafter.

   Dense stands will require disposal of slash to provide proper seed bed. If mixture of black spruce, cedar, or balsam fir is adequate to carry fire, slash can be burned. Otherwise whole tree skidding or bunching of slash will be necessary.

   Where alder is dense, brush should be burned, sheared, chopped or flailed off during or immediately after logging to provide sufficient seed bed for tamarack. Research indicates that tamarack seedlings can compete successfully with alder when alder is cut or otherwise killed back to ground level, due to tamarack's relatively fast growth rate.

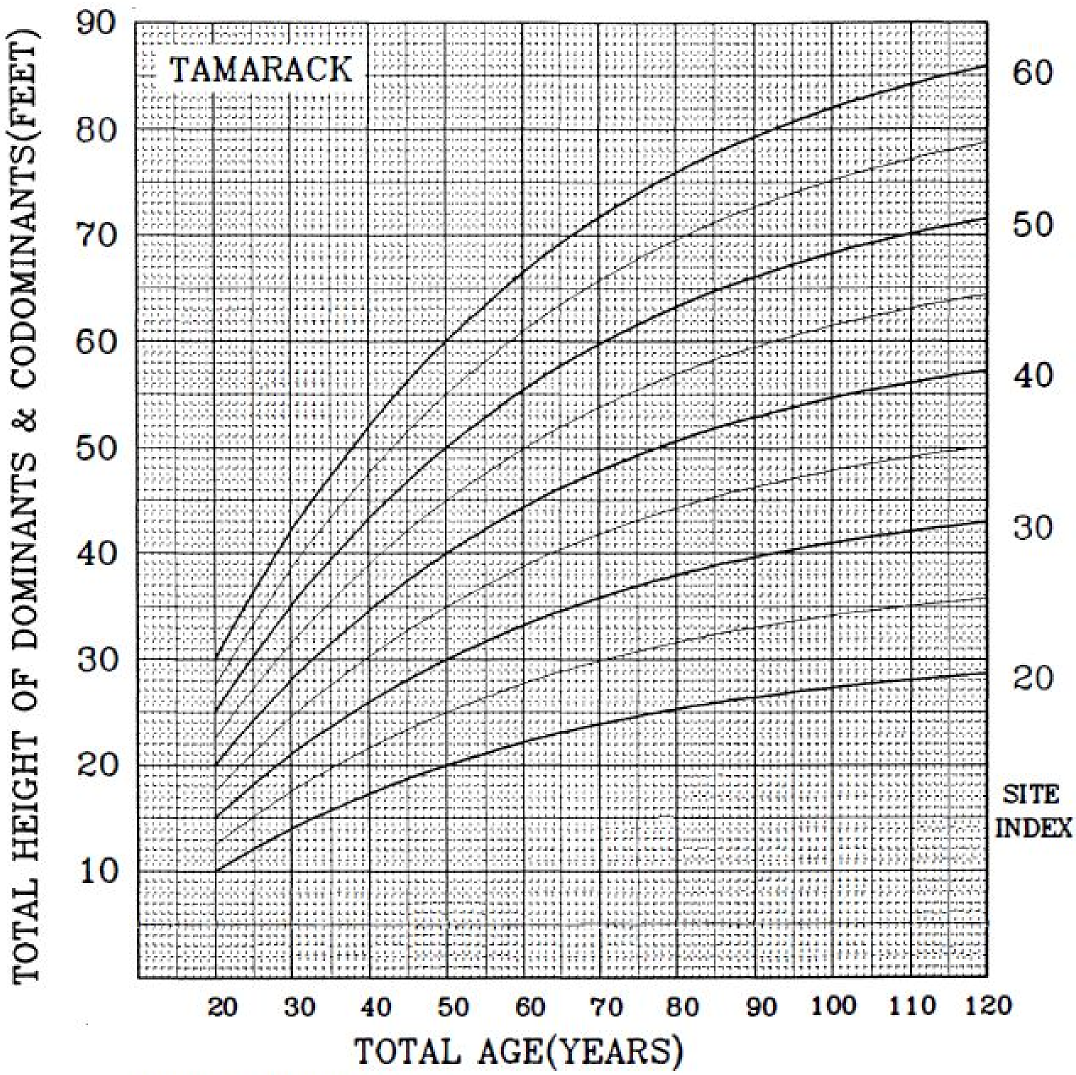
5.4 Artificial Regeneration

Tests on tamarack plantations in northern Wisconsin indicate that local seed sources give the best height growth results.

Direct seeding may become a viable alternative in regenerating tamarack if seed becomes readily available and seeding techniques are developed.

8 APPENDICES

Rotation Age					
Other Sites					
Site Index	60	50	40	30	20
Rotation Age	80	90	100	120	130+
Mineral Soil Sites	70				



Tamarack (Gevorkiantz 1957d)
Minnesota
Number of plots and number of dominant and codominant trees not given Total height and total age, anamorphic, equation not given Convert d.b.h. age to total age by adding years according to site index (BH = 0.0):

SI:	20	30	40	50-90
Years:	12	10	7	5

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	1.547	1.0000	-0.0225	1.1129	0.0000	0.99	0.52	1.4
SI	0.646	1.0000	-0.0225	-1.1129	0.0000	0.99	0.52	1.4

Figure 37.1. Site index curves for tamarack (Carmean et al. 1989).

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Chapter 38

White Cedar Cover Type

WISCONSIN
DEPT. OF NATURAL RESOURCES

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1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand Composition
More than 50 percent swamp conifers with northern white cedar (*Thuja occidentalis*) predominant.

Associated Species
Includes black spruce (*Picea mariana*), white spruce (*P. glauca*), tamarack (*Larix laricina*), balsam fir (*Abies balsamea*), eastern hemlock (*Tsuga canadensis*), black ash (*Fraxinus nigra*), red maple (*Acer rubrum*), yellow birch (*Betula alleghenensis*), paper birch (*B. papyrifera*), American elm (*Ulmus americana*), and quaking aspen (*Populus tremuloides*).

1.2 Silvical Characteristics*

Table 38.1. Summary of selected silvical characteristics.

Species	Northern white cedar
Pollination	Late April or early part of May.
Cones Mature	Cone formation begins by mid- to late June. Cone growth is complete by mid-August with cone-opening beginning anywhere from mid-September to late October. The interval between cone ripening and cone opening is short, about 7 to 10 days.
Seed Dispersal	Most seed is dispersed by November but some seed fall occurs throughout the winter. Seed is wind-disseminated, but because cedar trees are usually not very tall, the effective seeding range is 150-200 ft. except during unusually high winds.
Good Seed Years	Good seed crops occur every 3 to 5 years, with light to medium crops intervening. Seed production has been reported on stems as young as six years, but adequate seed production starts at 30 years of age and is best after 75 years of age.
Germination	Normally begins in May or June of year following seed dissemination. Cedar requires very warm germination temperatures (65 to 85°F). Seedlings usually develop on rotten wood, decayed litter, peat, or sphagnum moss, all of which provide warmer microsites with stable moisture regimes, but cedar does very well on seedbeds of exposed mineral soil. Seedlings are also aggressive on burns on both upland and swamp soils, and on skid rows where the moss has been compacted and will stay moist throughout the summer. Half to full sunlight produces the best germination and seedling establishment rates.
Seed Viability	Seed shows only a slight internal dormancy. Germinative capacity is only about 35 percent under test conditions (Schopmeyer, 1974).
Seedling Development	During the first several years, seedlings tend to develop taproots which are later replaced by fibrous root systems. Drying causes about one-third of all seedling mortality, but seedlings are resistant to damping-off fungi.
Growth	Northern white cedar generally grows more slowly than associated species, and is longer lived, reaching ages of 400 years or more on swamp or lowland sites. It is medium-sized, commonly 40 to 50 ft. tall and 2 to 3 ft. in diameter.

Species	Northern white cedar
	On average swamp sites in the Lake States it takes 80 to 100 years for cedar to grow to a 6-inch diameter.
Shade Tolerance	Northern white cedar is tolerant. On swamp sites it is generally shorter than its associates and is able to withstand extreme suppression for several years without ill-effect. It responds well to release at nearly all ages, especially on good well-drained sites.
Vegetative Reproduction	Layering is a common means of cedar regeneration in swamps. Branch layering accounted for over 60 percent of stems of cedar regeneration in northern Michigan swamps. Vertical stems from windthrown trees and layering by 5-year old seedlings also contribute to regeneration. Root or stump sprouts, and root suckers are rare, however.
Major Pests	Northern white cedar is resistant to insect pests and disease for the most part. White stringy butt rot (*Poria subacida*) and brown cubical butt rots (*Polyporus balsameus* and *P. schweinitzii*) are uncommon in young stands but do affect trees on swamp knolls or in drier portions of the swamp. To avoid, do not hold cedar stands beyond recommended rotation length. Because northern white cedar is a relatively shallow-rooted tree, it is subject to windthrow and uprooting. Threat of windthrow is greatest in overmature and over-dense stands. Apply proper management. Flooding, high water table, and slow-moving or stagnant ground water are critical conditions that reduce growth rates and in some cases kill entire stands. Keep swamp drainage patterns open by controlling beaver dam and road construction. Northern white cedar is preferred browse for white-tailed deer and snowshoe hares both in terms of palatability and nutrition. Browse damage can be extensive, retard tree growth, and eventually kill smaller trees. Snowshoe hare damage can usually be expected where alder accompanies cedar regeneration and sometimes is as great as deer browse damage. Eliminate or reduce adjacent deer and hare winter cover where browsing is a problem when regenerating cedar. According to preliminary research findings, deer tend to avoid cedar clearcuts that are 40 acres or larger, due to deeper snow and lack of protective cover.

* Mainly from Fowells (1965) except where indicated.

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

The management objective should be identified in relation to other land management objectives using the habitat type, if known, as the preferred indicator of site potential. Possible alternatives for white cedar include managing to produce high quality, sustained yield of cedar posts and poles while maintaining good winter deer cover where needed.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.2 Site and Stand Considerations

3.2.1 Soils

Best growth occurs on neutral or alkaline mineral soils of limestone origin. In swamps, the site quality for cedar increases as the internal drainage improves and the depth of peat decreases. However, the composition of the organic material is more important than its depth. Peat comprised of moderately to well decomposed woody plants or sedges is preferred by white cedar.

3.2.2 Site Quality

3.2.2.1 Range of Habitat Types

Habitat types for swamp conifers were determined for upper Michigan (Coffman et al., 1980) and include TTM (Tsuga-Thuja-Mitella), TTS (Tsuga-Thuja-Sphagnum), PO (Picea-Osmunda), and PCS (Picea-Chamadaphne-Sphagnum). However, these types are based on very limited sampling and have not been adequately studied to offer useful management information.

5 SILVICULTURAL SYSTEMS

Even-age management will be applied with thinning where stands become overstocked.

Medium quality sites of middle-aged cedar have demonstrated net growth at the rate of 4 to 5 sq. ft. per year when thinned to 90 to 150 sq. ft. of residual basal area. Site index curves for white cedar are provided in Figure 38.1.

5.1 Seedling / Sapling Stands

Allow natural development. In very dense stands, cedar may need release.

5.2 Intermediate Treatments

5.2.2 Thinning

<u>If stand is essential for deer shelter and subject to heavy browsing,</u> reduce stocking level to 150 sq. ft. of residual as stand becomes operable. A heavy canopy is essential for good deer shelter. Do not attempt to regenerate stands essential to winter deer shelter. Research is being conducted which will provide a management prescription for regeneration of these stands.

<u>If stand is not essential for deer shelter and is subject to only light browsing,</u> and if it is at least 20 years prior to rotation, reduce stocking level to 120 sq. ft. in sawtimber or 90 sq. ft. in poles as stand becomes operable. Never remove more than 35 percent of a stand's total stocking at one time. Discriminate against other species during thinning if a heavy proportion of cedar is desired in the next rotation.

5.3 Natural Regeneration Methods

Advance cedar regeneration is a reliable source for the next stand only if it is young, vigorous stock of seedling origin. Many of the cedar stems that remain after clearcutting are old and probably originated by layering. More research is needed on cedar regeneration techniques. Clearcutting, burning or skidding slash, and direct seeding have not provided conclusive results. However, shelterwood cuts have been tried on the Menominee Reservation and the Nicolet National Forest with some promising results. These shelterwood cuts were made at the 60 to 80 percent crown closure level.

Balsam fir should be removed from cedar stands by 70 years of age to avoid losses due to butt rot. Some fir may be retained to maintain proper stocking levels. However, balsam fir frequently takes over cedar sites if it is allowed to remain in the stand and to comprise a portion of the seed source for future regeneration.

Black spruce and tamarack generally produce more seed and grow faster than cedar and should be removed from the seed source if a relatively pure cedar stand is desired.

To minimize overstocking, the forest manager should survey cedar regeneration four years after site preparation and remove seed source when adequate regeneration is attained.

5.3.1 Even-Aged Regeneration Methods

5.3.1.1 Clearcut

If vigorous advance regeneration exists that will provide 60 percent millacre stocking after harvest, clearcut entire stand at rotation age.

5.3.1.2 Strip Clearcut

If advance regeneration is inadequate, apply strip clearcutting. Divide the stand into strips 2 chains wide at a right angle to the prevailing wind direction. Clearcut the most leeward strip and each successive third strip.

When 60 percent millacre stocking of one-foot tall seedlings has been attained, clearcut the next series of strips windward of the newly regenerated strips. When the second series of strips has regenerated, cut the last series of strips, leaving scattered dominant seed trees at 100-ft. spacing to regenerate the final strip. Planting or direct seeding can be undertaken in place of leaving seed trees or in the case of seed tree failure.

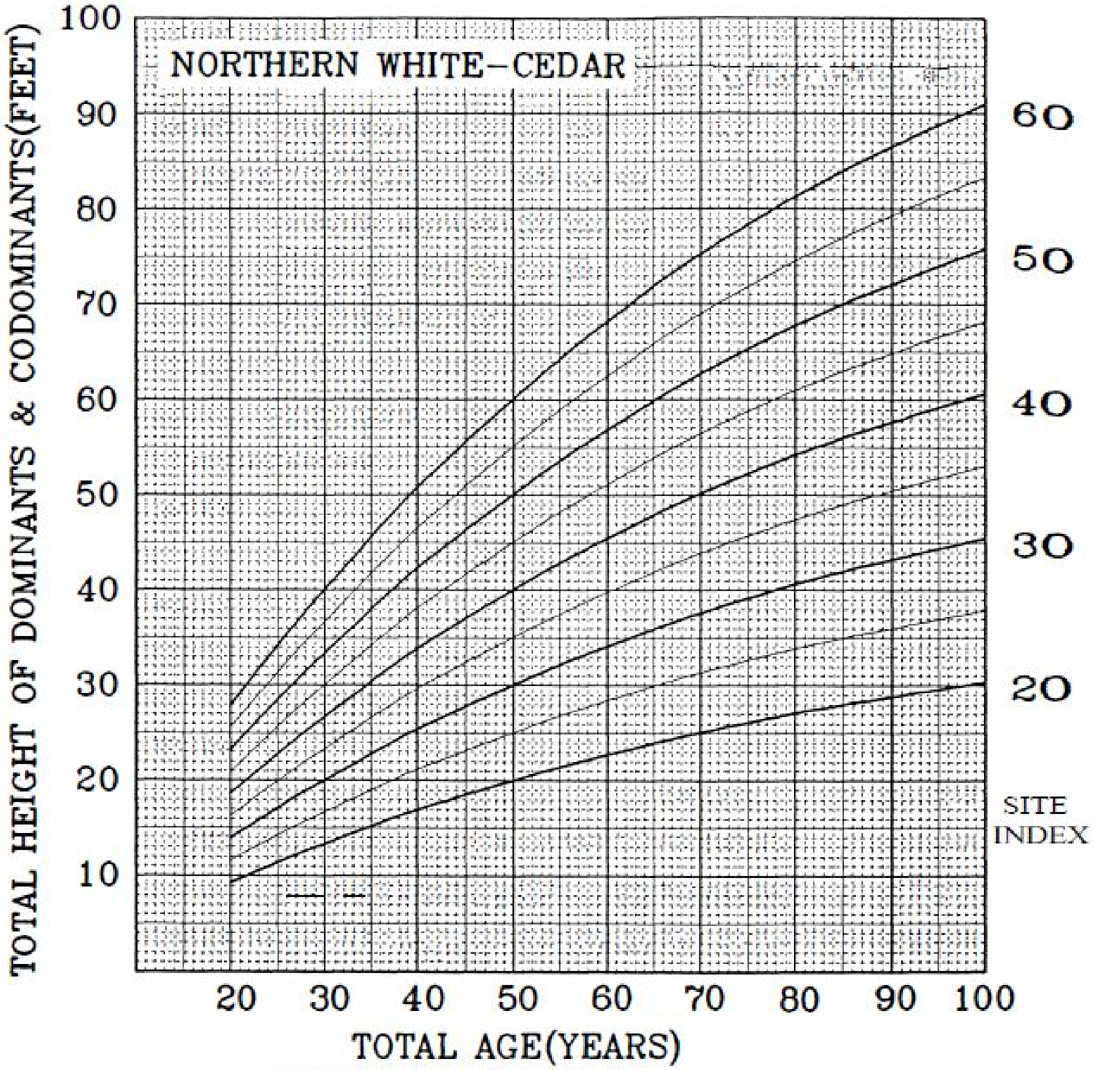
All residual stems larger than 2 inches DBH should be removed to favor regeneration as each strip is cut or shortly thereafter.

As each strip is cut, prevent heavy accumulation of slash by whole tree logging, tree length skidding with slash disposition at landing, or bunching of slash to ensure adequate seed bed. Either compaction or burning will also be necessary if the site is covered with feather mosses.

Extensive presence of alder may require shearing, chopping or flailing to reduce competition that would retard seedling growth. Tamarack should be favored as a seed source where alder is sheared because of its relatively fast growth rate.

8 APPENDICES

Rotation Age					
Site Index	60	50	40	30	20
Rotation Age	80	90	100	110	120



Northern white-cedar (Gevorkiantz 1957e)

Lake States

Number of plots and number of dominant and codominant trees not given

Total height and total age, anamorphic, equation not given

Convert d.b.h. age to total age by adding years according to site index (BH = 0.0):

SI:	20	30	40	50	60
Years:	20	15	15	10	10

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	1.9730	1.0000	-0.0154	1.0895	0.0000	0.99	0.66	1.7
SI	0.5068	1.0000	-0.0154	-1.0895	0.0000	0.99	0.66	1.7

Figure 38.1. Site index curve for northern white cedar in the Lake States (Carmean et al. 1989).

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Chapter 39

Hemlock-Hardwood Cover Type

WISCONSIN
DEPT. OF NATURAL RESOURCES

Last Full Revision: 12/5/1990
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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1 TYPE DESCRIPTION

Three major timber types with basal areas consisting of more than 50 percent hemlock occur in Wisconsin:

- White Pine-Hemlock
- Eastern Hemlock
- Hemlock-Hardwood (or Hemlock-Yellow Birch)

This chapter contains guidelines for hemlock and yellow birch.

1.1 Stand Composition and Associated Species

Stand Composition
Mainly eastern hemlock (*Tsuga canadensis*), with yellow birch (*Betula allegheniensis*), eastern white pine (*Pinus strobus*), sugar maple (*Acer saccharum*), and in the eastern part of the state, American beech (*Fagus grandifolia*).

Associated Species
Northern red oak (*Quercus rubra*), red maple (*A. rubrum*), basswood (*Tilia americana*), white ash (*Fraxinus americana*), northern white cedar (*Thuja occidentalis*), paper birch (*B. papyrifera*), and balsam fir (*Abies balsamea*).

1.2 Silvical Characteristics*

Table 39.1. Summary of selected silvical characteristics.

Species	Eastern hemlock	Yellow birch
Cones or Flowers	Late April - early June.	First three weeks in May as trees begin to leaf (monoecious).
Seed or Fruit Ripens	Cones reach full size late August to early September.	Winged nutlet in late July or August.
Seed Dispersal	Mid-October extending into early winter.	Mid-October extending into early winter.
Good Seed Years	Two out of three years.	Every one or two years.
Germination	For best germination, stratify 10 weeks at or slightly above freezing temperature. Exposure to light can break partial dormancy in unstratified seeds. Peak germinative activity when held at a constant 59°F for 45-60 days (Ruth, 1974).	Around 60°F. If not sown in autumn, seeds should be stratified in moist sand at 40°F for at least one month before sowing (Brinkman, 1974).
Seed Viability	Despite regular cone production, seed variability is less than 25 percent.	Seed viability averages 27 percent. The range is 6 to 48 percent. Seeds of highest germinative capacity are those that fall first. Seeds can remain viable for two years.

Species	Eastern hemlock	Yellow birch
Seedling Development	Very slow compared to competitors. First year seedlings develop 1 to 1.5 inches in height and 0.5 inch in root depth. New seedlings easily damaged by drying; 60 to 80 percent are damaged within 6 to 8 hours of drying.	Germination in spring after seed dispersal. Large numbers may germinate but roots may be too weak to pierce leaf litter. If seedlings are protected from sun and wind, humus soils or mineral soil become good seed beds. Survival depends on a combination of temperature, moisture and light. Seedlings cannot survive much competition particularly where moisture is limited. Unless seeds germinate on a favorable seed bed, competing vegetation will overtake and smother seedlings.
Shade Tolerance	Hemlock is one of the most tolerant of all tree species. It is capable of surviving with as little as 5 percent sunlight for many years and can respond vigorously after release.	Moderately tolerant, but 1 to 2 year old seedlings appear to be quite tolerant. As the seedlings develop and age, the amount of sunlight needed for optimal development increases.

* Mainly from Fowells (1965).

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

The management objective should be determined in relation to other land management objectives using the habitat type as the preferred indicator of site potential. Possible alternatives for hemlock-yellow birch include managing to produce the maximum quantity and quality of pulpwood and sawtimber and managing stands for aesthetic or wildlife values and for "old growth" potential.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.2 Site and Stand Considerations

3.2.1 Soils

The soil criteria for hemlock varies but typically soils are moist and well-drained. Preferred soil types include upland sandy loams, loamy sands, loams, and silt loams. Preferred soil types for yellow birch are loams and shallow silt loams.

The primary landforms associated with the above soils and habitat types include end moraines, ground moraines, drumlins, outwash, and lacustrine deposits.

3.2.2 Site Quality

3.2.2.1 Range of Habitat Types

Habitat Type		Soil Nutrient Regime
TMC	(Tsuga/Maianthemum-Coptis)	medium
ATM	(Acer-Tsuga/Maianthemum)	|
ATD	(Acer-Tsuga/Dryopteris)	|
AFD	(Acer-Fagus/Dryopteris)	|
AViO	(Acer/Viola-Osmorhiza)	|
AH	(Acer/Hydrophyllum)	rich

Hemlock does not constitute 50 percent of basal area on AOCa or AH but they are included here for comparison. Yellow birch is a constant companion of hemlock on all habitat types because the two species, despite their significantly different shade tolerance, have very similar germination requirements.

5 SILVICULTURAL SYSTEMS

The even-age (shelterwood) system can be successfully employed in managing hemlock and yellow birch. However, difficulties in securing regeneration of both species are a possible limitation of the uneven-aged selection system.

5.1 Seedling / Sapling Stands

The early growth of eastern hemlock is very slow, especially where overstory suppression occurs. Established sapling stands should be released to full sunlight to stimulate growth. Allow saplings to then develop naturally.

For increased diameter growth and crown development on yellow birch, do an early crown release prior to 16 years of age. In relatively pure stands of yellow birch, 100 released crop trees per acre -- well-spaced (21 ft. apart) -- will produce 75 final harvest trees per acre, each more than 18 inches DBH. Crown release by cutting all trees whose crowns are within 10 ft. of the crop trees.

5.2 Intermediate Treatments

5.2.2 Thinning

<u>Pole Timber Stands</u>
Growth of eastern hemlock during the pole stage also tends to be slow due to overstory suppression of faster growing species and crowding. Although pole stands can be suppressed for many years, good stem form and live crown ratio are retained. Suppressed and crowded pole stands should be released or thinned to maintain vigor. Thin from above those trees that suppress hemlock. Selectively thin from below those low vigor trees exhibiting seams, rot, many dead branches, or butt log injury. These external defects indicate internal decay and shake which are common in hemlock.

For commercial thinnings in stands of hemlock and hemlock-yellow birch, refer to Figure 39.1. This stocking chart for even-age management identifies two levels of management relating to the proportion of the hemlock component.

The lower B'-level of residual stocking applies to stands with 20 to 49 percent hemlock. The upper B-level applies to stands with more than 50 percent hemlock. Growing space requirements for stands that are predominantly hemlock are not as great as those for stands that are predominantly hardwood mixtures; consequently residual basal area levels are higher.

Sawtimber Stands

To maintain vigor and prevent overcrowding, thin to the appropriate stocking levels as indicated in Figure 39.1 (even-age stocking curves), selectively removing low-vigor trees from below to favor hemlock. In heavily stocked stands (200 sq. ft. or more per acre) not more than one-third of the total basal area should be removed at one time. In even-age management, these thinnings can be conducted before rotation age.

Favor yellow birch crop trees with a crown release. Cut all trees within 10 ft. of the crop tree crown. A crown release can double the diameter of pole-sized yellow birch in 10 years.

5.3 Natural Regeneration Methods

5.3.1 Even-Age Regeneration Methods

Even-age management is the preferred system of managing eastern hemlock. Generally, the economic rotation age is 150 years and the biological rotation age is 320 years.

Even-age management is also the preferred system of managing yellow birch. Where yellow birch is present, favor yellow birch dominants and co-dominants. Approximate rotation ages for yellow birch are similar to hemlock on most sites.

The stocking chart for yellow birch can be found in Chapter 40 (Figure 40.9).

5.3.1.1 Shelterwood

The shelterwood system is the best method of regenerating hemlock and yellow birch at rotation age, because it can provide the warm, moist environment required by hemlock-yellow birch silvics to obtain seed germination and prevent seedling desiccation. The shelterwood system can be implemented with the following sequence:

1. Thin the stand from below to 70 to 80 percent crown closure. Favor the best dominant hemlock and yellow birch trees for high shade and superior genetic seed source potential. Discriminate against tolerant, less desirable hardwood species, i.e., sugar maple or red maple. Avoid making large openings in the canopy.
2. Shallow scarification of at least 50 percent of the ground area, after leaf fall and before cutting, thoroughly mixing humus and mineral soil, provides an optimal seed bed.
3. Kill or remove advance hardwood (i.e., sugar maple, red maple) reproduction by mechanical or chemical means.

4. Directly seed one-half pound of hemlock seeds per acre. Seeding can be done in early winter to prevent rodent damage and to promote natural seed stratification.
5. When hemlock-yellow birch reproduction is established (3 to 5 ft. tall) partially or completely remove the overstory. Winter logging is preferred to provide protection for hemlock and yellow birch seedlings.
6. Hemlock reaches the western limit of its natural range in Wisconsin; consequently we should expect a certain percentage of regeneration failures when weather conditions are not favorable for seedling germination and establishment. Occasional dry years are normal in a continental climate.

8 APPENDICES

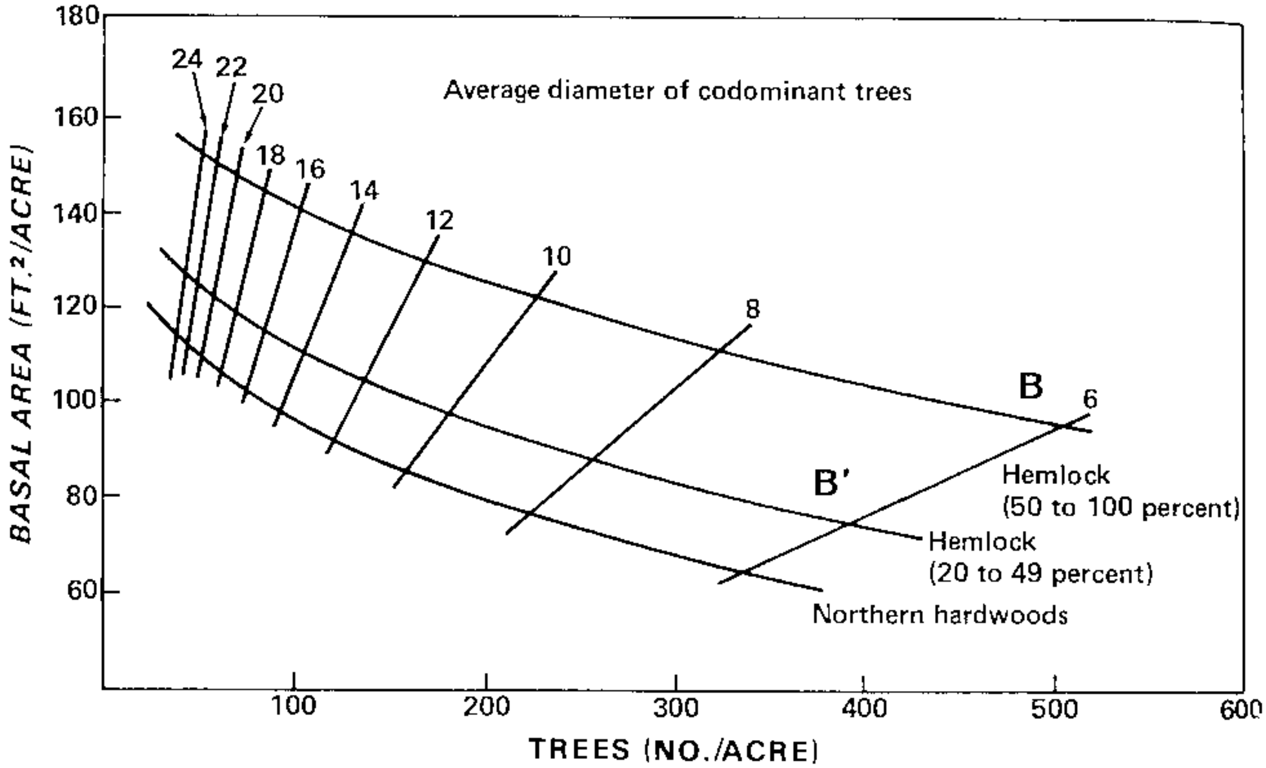

Figure 39.1. Residual stocking levels (B and B'-levels) for even-aged hemlock stands based on number of trees, mean stand diameter, and basal area per acre (Tubbs, 1977).

The lower B'-level of residual stocking applies to stands with 20 to 49 percent hemlock. The upper B-level applies to stands with more than 50 percent hemlock. Growing space requirements for stands that are predominantly hemlock are not as great as for stands that are predominantly hardwood mixtures so residual basal area levels are higher.

Table 39.2. Residual stand structure for hemlock designed for 130 sq. ft. of residual basal area, up through the 18-inch DBH class.

DBH class (inches)	Trees per acre (number)	Basal area per acre (sq. ft.)	Percentage distribution
6	58	11	
8	44	15	
10	34	19	
Subtotal:	**136**	**45**	**35 percent**
12	26	21	
14	20	21	
16	15	22	
18	12	21	
Subtotal:	**73**	**85**	**65 percent**
Total:	**209**	**130**	**100 percent**

Table 39.3. Residual stand structure for hemlock, for fully regulated uneven-aged stands, with residual basal area 130 square feet per acre (trees ≥5" dbh) and maximum diameter class 30 inches, for 2 inch diameter classes and q-factor 1.3

DBH class (inches)	No. of Trees per acre	No. of Trees by size class	Basal Area (sq. feet / acre)	Basal Area by size class
6	33	58	6	15
8	25		9	
10	19	54	11	47
12	15		12	
14	11		12	
16	9		12	
18	7	19	12	44
20	5		11	
22	4		11	
24	3		10	
26	2	5	9	24
28	2		8	
30	1		7	
Total (per acre)	136		130	

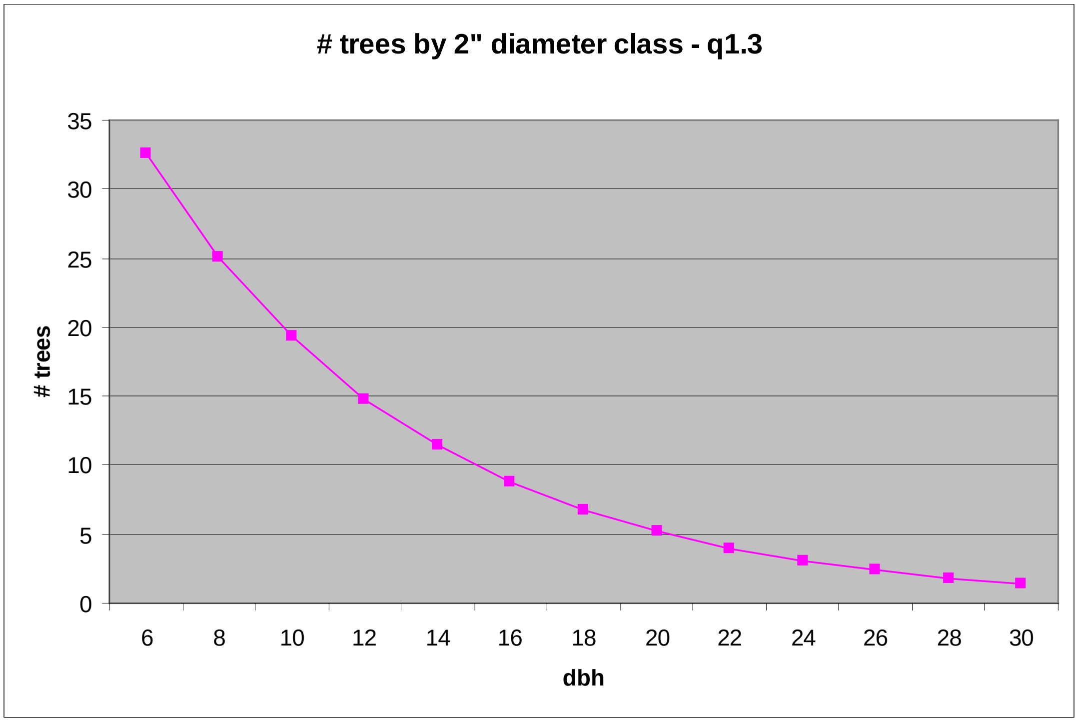

Figure 39.2. Maximum diameter class 30 inches, for 2-inch diameter classes and q-factor 1.3.

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Chapter 40

Northern Hardwood Cover Type

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Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand Composition

The northern hardwood cover type is defined as any combination of sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), basswood (*Tilia americana*), white ash (*Fraxinus americana*), and yellow birch (*Betula alleghaniensis*) that comprises more than 50% of a stand's basal area in sawtimber and pole timber stands or more than 50% of the stems in sapling and seedling stands.

Sugar maple typically is the dominant species in northern hardwood stands in Wisconsin. In eastern Wisconsin, beech sometimes is dominant. Basswood is the most common associate of sugar maple, but only occasionally dominates. White ash and yellow birch are common minor associates, but only rarely dominate stands. Red maple is also a common associate and when dominant is a separate cover type.

The northern hardwood and central hardwood upland forest cover types are differentiated as follows:

Northern hardwood type:

- Any combination of the five major species can dominate any stand, but typically sugar maple is the predominant overstory species. Though formerly not distinguished from the northern hardwood cover type, stands with more than 50% red maple are classified as the red maple cover type.
- Important associates unlikely to occur in the central hardwood type are beech, yellow birch, hemlock, and fir.
- Occurs throughout Wisconsin but is most common north of the tension zone.

Central hardwood type:

- Any combination of the five major northern hardwood species cannot be predominant.
- Tree species playing relatively greater compositional roles are oaks (especially white oaks), hickories, elms, ashes, red maple, black cherry, black walnut, butternut, hackberry, and box elder,
- In Wisconsin, it occurs within and south of the tension zone, commonly on sites submitted to long-term repeated disturbance.

Associated Species

Within the northern hardwood cover type, the predominant associates in Wisconsin currently are red maple (*Acer rubrum*), red oak (*Quercus rubra*), hemlock (*Tsuga canadensis*), white pine (*Pinus strobus*), and balsam fir (*Abies balsamea*) (Kurtz *et al.* 2017). Many other tree species occurring in Wisconsin can be found as occasional associates in northern hardwood stands.

1.2 Silvical Characteristics[1]

1.2.1 Sugar Maple

In Wisconsin, sugar maple has the greatest net growing-stock volume of all tree species with the; nearly 2.5 billion cubic feet on forest land (Kurtz *et al.* 2017). This represents about 15% of the total hardwood volume and 11% of the total (net growing stock) wood volume growing in Wisconsin's forest lands (Schmidt 1997; Kotar *et al.* 1999; Kurtz *et al.* 2017). According to the 2017 FIA, sugar maple's net growing-stock volume increased 8.6% % since 1996.

Sugar maple is one of the most shade tolerant of the major forest species in the state. Trees respond to release from extreme and prolonged suppression. It is regionally significant as a late-successional dominant on dry-mesic to wet-mesic sites.

In Wisconsin the site index (SI_{50}) mostly ranges from 40-80, but on average to better sites (suitable for growing quality sawtimber) is typically 55-70. Where site index is less than 50, quality sawtimber development generally is not a stand management option (Erdmannn 1986).

Sugar maple trees produce abundant and viable seed every 1-5 years; flower crops can be predictive of seed crops. Seeds are dispersed in the fall and early winter, lay dormant (undergoing stratification) on the forest floor during winter, and generally germinate in spring once the required temperatures are reached. The extremely low germination temperature (34^0F), high germinative capacity, and frequent good seed years facilitate abundant seedling crops. Early survival is enhanced by the vigorous development of a strong radicle (root) that has the strength and length to penetrate heavy leaf litter and reach mineral soil during the moist period in early spring (often under the snow). However, the young root system is rather shallow and fibrous, making seedlings sensitive to moisture stress and surface moisture conditions.

Seedlings are relatively slow growing. Some overstory shade (30-90% full sunlight) improves growth and survival of natural seedlings until 2-4 feet in height. Dense shade (<10% full sunlight) can result in poor growth and higher mortality. Full sunlight (>90%) also can result in poor growth and higher mortality due to moisture stress.

Sugar maple tree and stand growth rates can be expected to vary geographically and by site quality. Growth is somewhat slower than for most associated species, but relatively large sizes and old ages can be attained. Tree radial growth rates are strongly influenced by site quality, stand density, and tree age. In general, radial growth rates are greater on better sites, in less dense stands, and in younger stands. DBH growth rates can range from 1-4 inches per decade; 1 inch is typical for mature unmanaged stands, 1-2 inches is average for mature managed stands, 2-3 inches is the maximum measured for sawtimber trees, and 3-4 inches is the maximum for pole timber trees (Crow *et al.* 1981). In DBH, trees frequently reach 24 inches, older trees can reach 30-36 inches, while the maximum recorded is 84 inches. In general, throughout stand development, tree diameter growth continues at a decreasing rate

[1] Mostly from Burns and Honkala 1990 (Crow 1990; Erdmannn 1990; Godman *et al.* 1990; Schlesinger 1990; Tubbs and Houston 1990; Harlow 1991). More sylvicultural information on Table 40.1.

with increasing age and size. Height growth also slows with increasing age and becomes negligible at about 140-150 years. Trees average 12 inches/year height growth for their first 30-40 years of life. Sugar maple commonly attains 60-90 feet in height, older trees can reach 120 feet, while the maximum is 135 feet tall. Sugar maple trees can reach 300-400 years of age. In relict old growth forests the average age of canopy trees often ranges from 120-170 years, but trees 250-300 years old are common (Frelich and Lorimer 1991; Singer and Lorimer 1997; Lorimer 2001).

Stand basal area growth of 2.0-2.5 (ranges 1.5-3) ft^2/acre/year is typical for managed stands on average to better sites in the Lake States. Similarly, typical values for net volume growth are 60-90 ft^3/acre/year, and 200-300 (ranges 100-400) bdft/acre/year (Crow *et al.* 1981). Net growth equals mortality when basal area exceeds 125 sq.ft./acre in stands dominated by sugar maple (Hutchinson 1992). Example total yields from average, well-stocked stands of northern hardwood dominated by sugar maple on medium to good sites in the lake states are: 3,500 – 6,000 bdft/acre at 80 years, 7,000 – 11,000 bdft/acre at 120 years, 10,000 – 14,000 bdft/acre at 160 years, and 12,500 – 16,500 bdft/acre at 200 years.

1.2.2 Beech

In Wisconsin, beech is a minor species, representing less than 1% of the total net growing-stock volume on forest land (Schmidt 1997; Kotar *et al.* 1999; Kurtz *et al.* 2017). In Wisconsin, there are an estimated 18.5 million American beech 5 inches DBH or larger on forest land (Kurtz *et al.* 2017). Beech occurs only in the eastern quarter of the state, where it reaches its western range limit. Here, it occurs almost exclusively on mesic sites. Beech is moisture demanding, but intolerant of flooding.

Beech trees produce abundant viable seed every 2-8 years (the flowers are susceptible to damage by spring frosts). Seed are dispersed in the fall after the first heavy frosts, lie dormant (undergoing stratification) on the forest floor during winter, and generally germinate in spring to summer once the preferred temperatures are reached. Early survival is enhanced by the vigorous development of a strong radical (root) that has the strength and length to penetrate heavy leaf litter and reach mineral soil. However, seedlings are sensitive to moisture stress and surface moisture conditions.

Beech trees less than 4 inches DBH can produce vigorous and successful stump sprouts. Beech can also produce abundant root sprouts (suckers), and this can be an important mode of regeneration. Suckering is stimulated primarily by injury to the roots. Beech limbs can root when layered. Root grafting among beech trees is common.

Beech is very tolerant of shade, similar to sugar maple. Seedlings are slow growing, shallow rooted, and susceptible to desiccation. Best growth and survival are demonstrated under moderate shade (partial canopies and small, protected openings). In dense shade, seedlings can be abundant, but growth is slow (e.g., 2 feet tall at 10 years and 5 feet at 20 years). In full sunlight, growth and survival are poor. Seedlings are seldom severely browsed by deer.

Beech is a slow growing, long-lived species. Site index is lower than for any of its hardwood associates in the Lake States. Average diameter growth rates for pole and small sawtimber trees typically range from 0.8 inches/decade in unmanaged forests, to 1.7 inches/decade in managed forests, to 2.6 inches/decade in relatively open-grown conditions. Typically (within natural range), beech trees grow to 60-90 feet tall and 2 feet DBH. The maximum dimensions recorded within its range are 161 feet tall and 6 feet DBH. Trees can attain ages of 300-400 years.

1.2.3 Basswood

In Wisconsin, basswood has the seventh greatest net growing stock volume of all tree species; over 1 billion cubic feet on forest land estimated by the 2017 forest inventory and analysis (Kurtz *et al.* 2017). Since 2004, basswood sawtimber net volume has increased by 37% and growing stock by 17% since 2000-2004. Basswood is known to improve soil fertility; the leaves contain high levels of calcium, magnesium, nitrogen, and potassium.

Basswood trees produce abundant seed every 1-2 years. Seed are dispersed in the fall, and usually fall within 1-2 tree lengths of the parent tree. The seed lie dormant requiring both scarification and cold stratification to break dormancy. Seed viability is poor; common problems are parthenocarpy (production of fruit without seed), insects, rodents, and rotting of seed. In a study in northern Wisconsin, only 2 percent of the identifiable seed found in the litter were sound (Godman and Mattson 1976). In some situations, viable seed can lie on the ground for over five years (if not damaged) without germinating while still maintaining viability.

Basswood is a prolific stump sprouter. Most trees less than 4 inches DBH and more than half of sawtimber trees will produce vigorous stump sprouts. Sprout regeneration can be managed for sawtimber, but early thinning of sprouts is needed to promote rapid growth and quality development. It is recommended to thin sprout clumps to 1-2 stems before they reach 10 years of age.

Basswood is tolerant of shade, but less so than sugar maple, beech, and hemlock. Shading influences seedling growth and survival. Partial shading aids seedling establishment and early survival, but heavy shade will limit growth and development. Once established, seedlings grow most vigorously in full sunlight. Basswood is able to maintain itself as an associate in late successional forests and in managed uneven-aged forests primarily through vigorous sprouting and rapid sprout growth. This sprouting ability also facilitates maintenance under even-aged management systems.

Basswood is a large, rapidly growing tree. Within its range, it typically grows to 70-130 feet tall. It often reaches a DBH of 24-48 inches. The maximum dimensions recorded within its range are 140 feet tall and 7 feet diameter. Basswood grows faster than most of the other northern hardwood species. On a given site, basswood often exceeds sugar maple, beech, and yellow birch in site index by 5-10 feet. Tree radial growth rates are strongly influenced by site quality, stand density, and tree age. In comparison to unmanaged stands, basswood radial growth rates have been nearly doubled by applying crop tree release and moderate single-tree selection cuts. “Relatively narrow bark ridges and V-shaped fissures, with new light-colored inner bark visible in the fissures, represent a high-vigor basswood. In contrast, low-vigor trees have scaly bark with wide bark ridges and shallow, short fissures, frequently producing a rather smooth surface" (Burns and Honkala 1990). Basswood trees can reach more than 200 years of age.

1.2.4 White Ash

In Wisconsin, white and green ash together represent nearly 4% of the total net growing-stock volume on forest land (Kurtz *et al.* 2017). Since 2009, white ash has increased 12% in net volume and 78% in sawtimber volume since 2004. White ash typically grows as an associate in other forest cover types, and only rarely as a dominant. With the impacts from Emerald Ash Borer on the ash resource, it is expected that the ash representation in the state to decline.

White ash trees produce abundant and moderately viable seed every 3-5 years; flower crops can be predictive of seed crops. Seed are wind dispersed up to 460 feet in fall to early winter. The seed lay dormant (requiring moist, cool stratification) on the forest floor during winter. Germination usually occurs in spring to summer, but some seed may delay germination for 2-3 years.

White ash is shade tolerant when young, but intermediate when older. In dense shade, seedlings can survive for several years, but exhibit minimal growth. Seedlings can be abundant in the understory of northern hardwood stands, but generally do not grow into the overstory unless a canopy gap that provides increased light is created. Advanced regeneration can quickly capture newly formed canopy gaps. About 45% of full sunlight provides ideal conditions for early growth and development. Partial shade provides ideal conditions for seedling establishment, but once established increased sunlight provides for optimal development and vigorous growth.

White ash grows faster than most of the other northern hardwood species. On a given site, it often exceeds sugar maple, beech, and yellow birch in site index by 3-10 feet.

White ash is a rapidly growing tree that exhibits strong apical dominance. In height, it typically grows to 70-90 feet, but the maximum recorded within its range is 125 feet tall. In diameter, older trees can reach 24-36 inches DBH, while the maximum recorded is 84 inches.

1.2.5 Yellow Birch

In Wisconsin, yellow birch represents only about 1% of total net growing-stock volume on forest land (Kurtz *et al.* 2017). Net growing stock volume of yellow birch has decreased on timberland by 1% since 2000-2004 on forest land and by 4% since 1996 on timberland (Kurtz *et al.* 2017). It typically grows as an associate in other forest cover types, and only occasionally as a compositional dominant.

The successful germination of yellow birch seed and the establishment of abundant and vigorous seedlings depend on an adequate seed supply, favorable weather, a proper seedbed, adequate light, and control of competition. Yellow birch trees produce abundant seed every 2-3 years. Seed are wind dispersed in fall to winter. Most seed lands within 330 feet of the parent tree, but some seed can be blown across the snow up to 1300 feet or more. Seed viability is highly variable and germinative capacity generally is low. Seed problems include parthenocarpy (fruit without seed), hard frosts, insects, and disease. Pre-chilling and light can improve germination. Germination requires moisture and warm temperatures, and typically occurs around early June. Seedlings also require an adequate and consistent supply of moisture and are susceptible to moisture stress. The optimal seedbed is disturbed and moist humus or mixed humus mineral soil with minimal competition. In undisturbed stands, favorable seedbeds include decaying wood (mossy logs, rotten stumps), windthrown hummocks, and even cracks in boulders. Yellow birch also can colonize sites with moist mineral soil following disturbance by catastrophic fire, logging, and blowdowns. On undisturbed forest floors, yellow birch radicals cannot pierce the hardwood leaf litter and the seedlings become susceptible to desiccation. Yellow birch benefits from soil disturbance and requires openings in the canopy.

Yellow birch is intermediate in shade tolerance and is a gap phase species. The optimal light level for seedling development and growth is approximately 50% full sunlight. After 5 years of age, yellow birch grows and develops best in full overhead sunlight. Yellow birch cannot compete with sugar maple under dense forest canopies.

Yellow birch is a slow growing, long-lived species. Average site index at age 50 years is 55-65. Growth rates tend to decline as trees age. Diameter growth of less than 1 inch/decade is common in unmanaged stands and in managed uneven-aged single-tree selection stands. Overhead light and crown expansion space facilitate growth and vigor. Release and thinning can significantly improve growth rates. Crop tree release can improve diameter growth up to 3 inches per decade in saplings, and diameter growth of 75% in poletimber, and 45% in sawtimber. Under intensive even-aged management, 18-inch trees can be grown in less than 90 years. Typically, yellow birch trees grow to 70-100 feet tall and 24-30 inches DBH. Maximums measured within its range are 114 feet tall and 60 inches DBH. In unmanaged forests, most growth (height and diameter) is completed by 120-150 years of age. Yellow birch trees commonly reach 300 years old and can surpass 350 years.

Table 40.1. Summary of selected silvical characteristics.

	Sugar Maple	Beech	Basswood	White Ash	Yellow Birch
Flowers	March-May Polygamous	April-May Monoecious	June (May-July) Perfect	April-May Dioecious	Pistillate catkins May (Apr.-June) Monoecious
Fruit Ripens	Sept.-Oct. 1(2) seeded double samara	Sept.-Nov. 2(3) Nuts/Bur	Sept.-Oct. 1(2) seeded Nutlike drupe	Sept.-Nov. 1 seeded Samara	August-Sept. Strobile
No. of seeds/lb	7000 samaras/lb	1600 seed/lb	5000 seed/lb	10,000 seed/lb	450,000 seed/lb
Seed Dispersal	Fall to early winter. Wind dispersed up to 330 feet.	Fall. Near tree. Jays, rodents, and gravity can enhance dispersal.	Fall. Wind and gravity rarely disperse seed more than 1-2 tree lengths.	Fall to early winter. Wind dispersed up to 460 feet.	Fall to winter. Wind dispersed up to 300-1300 feet or more.
Good Seed Years	Every 1-5 years	Every 2-8 years	Every 1-2 years	Every 3-5 years	Every 2-3 years
Seed Bearing Age	20 years – minimum; 40-60 years – light crops; 70-100 years – moderate crops; >100 years – heavy crops.	Good crops by 40 years; abundant by 60 years.	Generally, 15-100 years.	20 years minimum. Good crops usually begin at about 30-40 years.	Generally, 30-40 years is minimum, and 70 years begins optimum.
Seed Viability	Prolific seeder. High viability. On forest floor doesn't remain viable beyond first year.	High viability.	Poor viability. Impermeable seed coat. Can remain viable on forest floor >5 years.	Moderate viability.	Prolific seeder. Viability highly variable; generally poor; usually best in good seed years.
Germination	Pronounced dormancy, requiring 1-3 months stratification. Spring; best at 34^0F; poor at >50^0F.	Pronounced dormancy, requiring stratification. Spring to early summer; best at 59^0F.	Pronounced dormancy, requiring 3-4 months stratification. Requires scarification. Spring to summer; best at 68^0F.	Pronounced dormancy, requiring 2-3 months stratification. Spring to summer; best at 84^0F.	Typically June; requires moisture and warm temperatures; best at 60-85^0F.
Seedbed Requirements	Moist undisturbed leaf litter, humus, or	Moist undisturbed leaf litter, humus, or	Moist with variable substrate	Moist leaf litter, humus, or mineral soil.	Disturbed and moist humus or mixed humus mineral

	Sugar Maple	Beech	Basswood	White Ash	Yellow Birch
	mineral soil; often under snow.	mineral soil; poor on wet sites.			soil with minimal competition. Also, moist mineral soil, decaying wood, and cracks in boulders.
Vegetative Reproduction	Seedlings sprout readily. Stump sprouts decrease with increasing tree size.	Seedlings and saplings produce vigorous stump sprouts. Prolific root sprouter. Also layers.	Wide range of diameter classes produce prolific and vigorous stump sprouts.	Seedlings and saplings produce vigorous stump sprouts.	Seedlings and saplings produce vigorous sprouts. Larger stems sprout poorly.
Seedling development	Best growth when light levels are 30-90% full sunlight. Dense shade or full sunlight can result in poorer growth and higher mortality. Sensitive to moisture stress.	Moderate shade facilitates best survival and growth. Dense shade slows growth. Full sunlight results in poor growth and survival. Sensitive to moisture stress.	Partial shade facilitates initial survival and establishment. Dense shade limits growth. Once established, (nearly) full sunlight facilitates vigorous growth.	Establishment and early growth best at about 50% full sunlight. Dense shade limits growth. Once established, (nearly) full sunlight facilitates vigorous growth.	Establishment, growth, and development best at about 50% full sunlight. Dense shade limits growth. Sensitive to moisture stress.
Shade Tolerance	Very tolerant. Good survival and response to release.	Very tolerant. Good survival and response to release.	Tolerant.	Tolerant when young, then becoming intermediate.	Intermediate.
Maximum Longevity	300-400 years	300-400 years	200-250 years	250-300 years	300-400 years

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

Landowner goals and management objectives should be identified in a sustainable forest management framework, with consideration to the local and regional landscape. Prior to the development and implementation of silvicultural prescriptions, landowner goals and objectives need to be clearly defined and management units (stands) must be accurately assessed.

The silvicultural systems described are designed to promote the balance of quality and quantity in northern hardwood stands. These silvicultural systems may be modified to satisfy other management objectives, but vigor, growth and stem quality could potentially be reduced.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.1 Landscape Considerations

The northern hardwood and hemlock-hardwood forest types were historically the 'matrix' communities (the most abundant and connected forest communities) of the northern Wisconsin landscape. Although northern hardwood forests are still abundant and widespread, they have undergone many changes during the past century. Considerations are related to the loss, simplification, and fragmentation of forested land, and other human-induced changes in ecosystem structure or function.

Management Recommendations at the Landscape Level

- Consider landscape composition and structure, including species composition; successional and developmental stage; age structure; stand/patch size; type, intensity, and pattern of fragmentation; habitat diversity; NTMB populations and habitat needs; and common/uncommon management techniques.
- Increase the representation of hemlock, yellow birch, basswood, and white pine.
- Increase structural diversity within stands (i.e., large trees, large cavity trees, large snags, large downed woody debris, and variable gap sizes).
- Manage larger stands where it is possible to coalesce adjacent northern hardwood or hemlock-hardwood stands.
- Increase the representation of large patches of older uneven-aged forest.
- Increase the representation of older trees and stands and later developmental stages (i.e., old forest and old-growth).
- Apply a variety of management techniques, including old-growth reserves, managed old forests, extended rotations, uneven-aged management, even-aged management, and the maintenance of reserve trees.
- Apply adaptive uneven-aged management that considers variability in application, including gap size and distribution, diameter distribution, cutting cycle, coarse woody debris management, and reserve tree management.
- Favor uneven-aged management (with even-aged patches), to increase and manage diversity within the northern hardwood forest type.
- Control deer and limit herbivory.
- Limit permanent fragmentation caused by development (e.g., roads and landings).

3.1.1 Historical Context

When the General Land Office Public Land Surveys (PLS) were conducted in Wisconsin (1832-1866), forests dominated by northern hardwood and hemlock-hardwood covered about 15.2 million acres (43.7% of the state) (Frelich 1995). Schulte *et al.* (2002) conducted a quantitative analysis of PLS data and found that these forest types were dominant on 42-46% of forested area in northern Wisconsin. Across the landscape, these forests existed with all age-classes and developmental stages represented, but older age-classes and advanced developmental stages were dominant. Frelich (1995) estimated that 89% of the northern hardwood forest was 120 years old or older. Old forests featured multi-layered canopies, large quantities of dead wood, trees with cavities and broken branches and trunks, and tip-up mounds on the forest floor.

Northern hardwood forests historically contained a large component of hemlock. Within its range in northern Wisconsin, hemlock made up about 21% of basal area (based on GLO data) and was the most common tree species in many areas. Yellow birch was typically the second-most dominant tree, with sugar maple ranking third. Basswood, ironwood, and white pine were other common associates of the historic forest. Hemlock still exists as a component of the northern hardwood forests but is greatly reduced from levels found in the 1800s. FIA data show that it currently makes up about 3% of basal area in the northern forest (Schmidt 1997).

Wind disturbance was the primary factor in regenerating northern hardwood forests. Wind disturbance occurred mostly as small and medium-sized gaps that may have impacted 5.7 to 8.5 percent of the northern hardwood and hemlock-hardwood forests during a decade (Frelich and Lorimer 1991; Dahir and Lorimer 1996). Most canopy gaps were small (<0.1 acre), created by windthrow of one to a few large trees. Moderate intensity disturbances are defined as those that removed 30-50% of the forest canopy in a decade (Craig Lorimer, pers. comm., 2006). These disturbances occurred at average return intervals of 325 to 410 years; heavier disturbances were associated with longer return intervals. Moderate intensity disturbances were likely responsible for creating much of the cohort structure observed in old growth forests (Bourdo, E. A. 1983; Loucks 1983; Frelich and Lorimer 1991). Gap expansion processes, competition for soil moisture and nutrients (Loucks 1983), and drought events may have also contributed to development of cohorts. Catastrophic windthrows may have impacted about an additional 0.7 percent of the forest each decade on average (Canham and Loucks 1984). Wind disturbance is less of an impact in today's younger and less structurally diverse forests. Small canopy gaps are now being created in some locations through adaptive silvicultural techniques but are still thought to be relatively scarce. A lack of small gaps can impact some species of concern, like the Canada warbler.

Fire is known to have occasionally followed windthrow in the historic northern hardwood forests. Fire would have been more likely to impact northern hardwood forests that bordered fire-prone conifer forests or grasslands. The interiors of northern hardwood and hemlock-hardwood forests were, and still are, quite fire-resistant due to their mesic nature. Roth and Fernow (1898) noted that on loam and clay lands, “where the heavy hard woods and Hemlock predominate... the ground and litter is usually damp. Fires run only during exceptionally dry seasons.” Fire is also a factor that historically limited northern hardwood forests from expanding onto more xeric sites, or in some cases, onto otherwise suitable sites that were frequently impacted by fires originating in adjacent areas.

There are many questions about the effects of Cutover-era fires in northern hardwood forests. Land managers have noted that some lower-quality hardwood sites appear to be degraded and have speculated that past fires played a role. There is little information on exact locations or intensity of fires in northern hardwood; however, the overall impact can be partially deduced from historic writings. Roth and Fernow (1898) describes conditions in northern counties at that time, noting that hemlock-hardwood forests suffered fire damage where pine “slashings” caught fire. White pine was a large component of many hemlock-hardwood forests. It was typically cut selectively with considerable damage to the remaining timber, much of which died and created fuel loads in addition to the pine slash, thus allowing fire to carry into the hardwood forest. Hardwood adjacent to cutover pineries were also more likely to burn. Areas that were further away from pineries, with less of a white pine component, escaped heavy fire damage. By 1900, fires were less frequent because nearly all the pines had been cut, and fire suppression programs were developing (although not fully in place until the late 1920's).

Northern hardwood was the last forest type to be heavily logged during the Cutover. Hemlock and hardwood were harvested between about 1900 and 1930, usually by clearcutting or high-grading. These forests were initially accessed for hemlock bark, which was peeled in the woods during the spring and early summer and shipped to tanneries. The hemlock logs were generally used for lumber or pulp, although some were left to rot in the woods when demand was low or were used as fill beneath railroads. After a stand was accessed for hemlock bark, removal of hardwood soon followed, often during the following winter (Corrigan 1978). Selective logging began in the 1920s, and although much of this was high-grading, some longer term sustained-yield management also emerged.

FIA records show that northern hardwood forests have been increasing in extent during the past several decades. In 1968, the maple-basswood forest type group occurred on about 3.5 million acres; in 1983 it occupied about 4.1 million acres, and by 1996 had increased to about 5.3 million acres (Schmidt 1997). Although northern hardwood forests are occupying increasingly larger areas, they are still considerably reduced in extent from historic times, and their structure and diversity have been greatly changed.

3.1.2 Current Context

Age-Class Distribution

Maintaining a desirable age-class distribution is a landscape-level consideration. A relatively stable age class structure, including all developmental stages, maximizes benefits to wildlife by providing a range of structural conditions. It also contributes to diversified economic interests by supplying different types of materials, including pulp, poles, sawlogs, and veneer. The average age of northern hardwood forests in Wisconsin increased between 1983 and 1996 because of increased acreage in the middle classes. However, acreage occupied by the oldest age classes decreased during this time period.

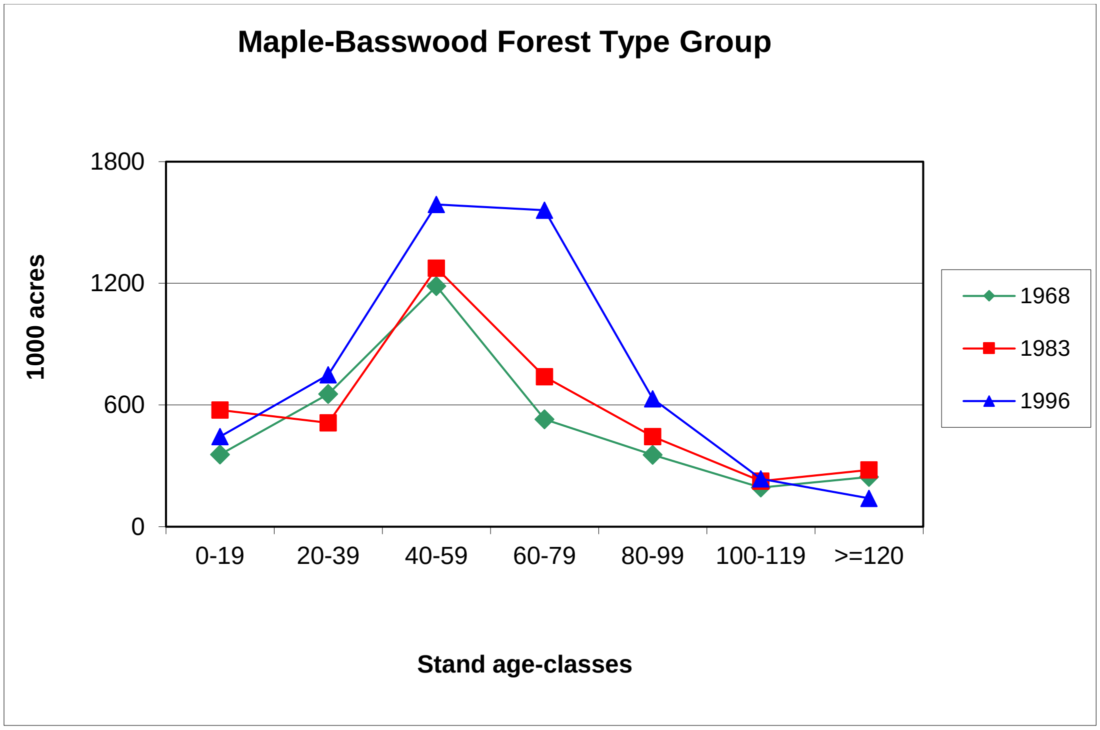


Figure 40.1. Forest age-class distribution for the maple-basswood cover type in Wisconsin, from FIA measurements taken in 1968, 1983, and 1996 (1000 acres).

3.1.3 Forest Simplification

Forest simplification refers to a loss of species diversity and structural diversity, and an increased dominance of fewer species. The increase in sugar maple dominance that is occurring in northern hardwood forests is an example of simplification, as is the lack of features like large woody debris and tip-up mounds. Sugar maple is outcompeting conifers and other species that were common in the historic forests. Regeneration of hemlock and yellow birch are problematic in many cases, and basswood is also decreasing in abundance. Strict application of the single-tree selection method is probably a factor that increases sugar maple's dominance (Crow *et al.* 2002). White-tailed deer herbivory can give sugar maple a competitive advantage (Anderson and Loucks 1979; Frelich and Lorimer 1985), contribute to declines in some native plant species, and lead to homogenization of species composition among sites (Rooney *et al.* 2004). The northern hardwood forests have lost most of their Canada yew, a formerly widespread evergreen shrub that provided structural diversity. These changes occur at the stand level but have cumulative effects at broader spatial scales.

At the landscape level, simplification and homogenization occur when forested patches become similar in size, shape, and composition. Land uses have led to homogenization and reduction of patch sizes, and creation of patch shapes that are less complex (Mladenoff *et al.* 1993). The cumulative effects of stand-level simplification make composition similar among patches. This is unlike the mosaic of forest patches found in remnant old growth hemlock-hardwood forests, where some are dominated by hemlock, some by sugar maple, and some a mixture of the two (Crow *et al*. 2002).

3.1.4 Fragmentation and Edge Effects

Fragmentation effects have been described in the Aspen Chapter and are also a landscape-level consideration in northern hardwood management. Even-aged management in northern hardwood forests has effects beyond the immediate area, bringing increased light and heat into the adjacent forest and attracting a different suite of species. Some of the species attracted to open and early successional forest patches compete with or prey upon species characteristic of interior northern hardwood forests.

Fragmentation is a term used to describe certain kinds of landscape structure. “Inherent fragmentation” describes landscapes that are naturally heterogenous due to characteristics of the physical environment, such as an area with numerous small lakes and wetlands dispersed throughout a pitted outwash plain. “Permanent fragmentation” refers to long-term conversion of forest to urban, residential, or agricultural uses. Roads can also create permanent fragmentation. “Habitat fragmentation” is defined as a disruption of habitat continuity, caused by human (e.g., tree cutting) or natural disturbance, creating a mosaic of successional stages within a forested tract. This kind of fragmentation is a shorter-term effect on species, and at a site level, impacts them during the time it takes for the forest to regrow. At a landscape scale, the aggregated amount and continuing nature of human disturbance may result in relatively high levels of habitat fragmentation.

In Wisconsin and elsewhere, the loss of forest habitat has a larger impact on species than shorter-term habitat fragmentation. Habitat loss is often correlated with measures of fragmentation (e.g., patch size, distance between patches, cumulative length of patch edges, etc.), making it difficult to quantify their separate effects. Habitat loss may result from second homes, utility or transportation corridors, and urban or industrial expansion. A drastic change in land cover, such as that which occurs after a clearcut harvest, represents a short-term loss of habitat for some species and a gain for others. Dispersal can be affected if species or their propagules cannot cross or get around the open land, find suitable habitat within it, or successfully compete with disturbance-adapted species.

Some species are "area-sensitive", requiring large patches of relatively homogenous habitat. The American marten and Northern Goshawk are examples of species that utilize larger areas of older northern hardwood forest.

3.1.5 Summary of Landscape Considerations

When deciding whether to actively manage a northern hardwood stand, and if so, which silvicultural practices to apply, consider the following factors:

- What are the characteristics of the broader-scaled ecological unit (LTA or Subsection) around the stand?
- Is the ecological unit already fragmented by either habitat or permanent fragmentation or by inherent fragmentation (a heterogenous landscape that contains a wide variety of habitat types, wetlands, and/or water bodies)?
- In even-aged management, are there opportunities to aggregate individual cuts to reduce the overall amount of edge?

- Are there NTMB's of concern in the surrounding LTA, which ones are they, and how is the proposed management likely to affect them?
- Is the area around the stand a large patch of older northern hardwood forest? Large forest patches with older age-class structure are scarce and managing for interior NTMB's may be an important consideration.
- What kinds of silvicultural techniques have been commonly applied in the surrounding LTA or Subsection in recent years, and are there techniques that may be beneficial in creating underrepresented kinds of forest structure?
- How much of the landscape has been harvested recently? Are there sufficient amounts of closed-canopy, interior forest habitat available for interior forest NTMB's and other area-sensitive species?
- Consider emulating gap-phase windthrow in selection management of uneven-aged northern hardwood.
- Are there issues with herbivory in the vicinity (e.g., lack of regeneration of hemlock, yellow birch, or Canada yew; excessive browsing of lilies and orchids)? If so, consider fencing or large block management to reduce deer impacts.
- What is the age class distribution of northern hardwood in the broader-scaled ecological unit? Are there opportunities for providing a scarce successional stage?
- Are there opportunities for fencing to help restore understory and shrub components?
- Are there opportunities for increasing components of hemlock, yellow birch, or basswood?

3.2 Site and Stand Considerations

3.2.1 Soils

The northern hardwood cover type develops and grows best on mesic sites with well drained to moderately well drained loamy soils; the very best soils are deep, well drained, silt loams. However, it occurs on a wide range of soil conditions, from well drained to somewhat poorly drained and from sands to clays. Dry, excessively drained sands and wet, poorly drained soils generally do not support the development of northern hardwood stands. Soil pH can range from 3.7 to 7.3, but a pH between 5.5 and 7.3 is most common.

Northern hardwood frequently occur on finer textured soils on which vehicle travel can result in soil compaction. Soil compaction and rutting have been shown to decrease seedling and sapling growth in many forest types although specific effects depend on soil type and moisture content (NCASI 2004). The total area devoted to landings, roads, and trails should be minimized to limit the loss of productive area. Pre-planned skidding routes and landing areas should be used to limit the total area affected by vehicle travel and skid trails should be re-used in future entries wherever possible. Road layout guidance such as that found in the Wisconsin Forest Management Guidelines (WDNR 2003) should be used to minimize impact on hydrology and limit erosion and sedimentation. Harvesting when the soil is frozen or dry can reduce compaction. Increasing the interval for re-entry into stands may partially mitigate the effects and reduce the occurrence of compaction and rutting, although soil compaction is not readily ameliorated and effects can persist for several decades (NCASI 2004).

Impacts of Equipment and Infrastructure
The cumulative effects of infrastructure development and soil compaction in forests have been studied in other parts of the country and found to be correlated with changes in hydrologic regimes, surface drainage patterns, and soil moisture. The negative ecological effects of soil compaction and rutting, and of forest roads, are well known at fine scales, but these issues have not been studied in an integrated fashion on larger landscapes in our area. Roads and utility corridors have been implicated in the spread of non-native invasive plants. They also act as barriers to the movement of some species, create fragmentation and edge, and can attract human disturbances.

3.2.2 Site Quality

Assessing site productivity can be achieved through the evaluation of the Forest Habitat Type Classification System (FHTCS), soil site analysis, or through determination of site index. The FHTCS provides qualitative site productivity assessment and limited quantitative productivity data. The use of the FHTCS is limited to the period of active understory vegetation growth. Habitat types may be estimated during non-growing seasons using correlation with soil types and landforms, but these methods are less accurate than direct field determination. Broad-scale quantitative site productivity correlation with FHTCS is available through analysis of Wisconsin FIA data (Kotar *et al.* 1999). For more detailed discussion on FHTCS see Ch. 12.

Accurate assessment of site index is another method of determining site productivity. Site index and stand age determinations are important factors in even-aged management of northern hardwood. Northern hardwood present challenges for accurate site index determination because of the difficulty in reading increment cores from diffuse porous species and in determining trees that were not previously suppressed. More precise determination of tree age, height, and site index may be accomplished through felling of representative trees (USDA 2005). Additional discussion on site index considerations and proper measurement can be found in Chapter 11.

3.2.2.1 Range of Habitat Types

The northern hardwood cover type currently is much more common in northern than in southern Wisconsin. About 89% of sugar maple net growing stock volume occurred within the northern habitat type groups. For the other northern hardwood, 94% of yellow birch volume, 74% of basswood volume, 73% of beech volume, and 57% of white/green ash volume occurred within the northern habitat type groups (FIA 2016).

Northern Wisconsin Habitat Types
In northern Wisconsin, the occurrence and relative growth potential of the northern hardwood cover type, and of the individual species comprising the type, vary by habitat type groups and habitat types.

The northern hardwood cover type is currently the predominant cover type occurring on mesic sites in northern Wisconsin. It is of common occurrence on the dry-mesic and the mesic to wet-mesic habitat type groups. It generally does not develop on the very dry to dry, dry to dry-mesic, and wet-mesic to wet groups (Table 40.2 and Table 40.3).

Table 40.2. Northern hardwood tree species – estimated relative occurrence by northern habitat type group.

Northern Habitat Type Groups	Estimated Current Relative Occurrence for NH Species				
	Sugar Maple	Beech[1]	Basswood	White/Green Ash	Yellow Birch
Very Dry to Dry	*	*	*	*	*
Dry to Dry-mesic	*	*	*	*	*
Dry-mesic	***	*	***	**	*
Mesic	****	**	***	**	**
Mesic to Wet-mesic	***	*	***	**	**
Wet-mesic to Wet	*	*	**	**	**

**** Major Dominant, *** Major Associate, ** Minor Associate, * Rarely Occurs (or does not occur)
1 – Beech occurs only in extreme eastern Wisconsin

Table 40.3. Northern hardwood cover type – estimated relative growth potential by northern habitat type group and habitat type.

Northern Habitat Type Groups	Estimated Relative Growth Potential for NH Cover Type				
	None to Very Poor	Poor	Fair	Good	Excellent
Very Dry to Dry	PQE PQG PQGCe PArV PArV-U PArVAo QAp				
Dry to Dry-mesic	PArVHa PArVAm PArVAa PArVAa-Vb PArVAa-Po PArVPo				
Dry-mesic		TFAa AVCl AVVb AVDe AVb-V	ACl AVb AAt ATFPo		
Mesic				AFVb ATM ATFD ATFSt	AAs ATD ATDH AHVb AFAd AFAl ACaCi AOCa AH
Mesic to	PArVRh		ArAbCo	ATAtOn	

Wet-mesic	ArAbVC ArAbVCo ArVRp ArAbSn		TMC ASnMi AAtRp	ASaI ACaI AHI	
Wet-mesic to Wet	All Sites (no habitat types)				

Southern Wisconsin Habitat Types

In southern Wisconsin, the occurrence and relative growth potential of the northern hardwood cover type, and of the individual species comprising the type, vary by habitat type groups and habitat types.

The northern hardwood cover type currently is common (along with central hardwood and oak cover types) only on mesic sites in southern Wisconsin. It is a relatively uncommon cover type, but potentially can develop and become more common, within the dry-mesic, dry-mesic to mesic, dry-mesic to mesic (phase), mesic (phase), and mesic to wet-mesic habitat type groups. It generally does not develop on the dry and wet-mesic to wet groups (Table 40.4 and Table 40.5).

Table 40.4. Northern hardwood tree species – estimated current relative occurrence by southern habitat type group.

Southern Habitat Type Groups	**Estimated Current Relative Occurrence for NH Species**				
	Sugar Maple	Beech[1]	Basswood	White/Green Ash	Yellow Birch
Dry	*	*	*	*	*
Dry-mesic	**	*	**	**	*
Dry-mesic to Mesic	***	*	***	***	*
Dry-mesic to Mesic (phase)	**	*	**	**	*
Mesic (phase)	**	*	**	**	*
Mesic	****	**	****	***	**
Mesic to Wet-mesic[2]	*	*	***	***	**
Wet-mesic to Wet[2]	*	*	**	***	*

**** Common Codominant, *** Major Associate, ** Minor Associate, * Rarely Occurs (or does not occur)

1 – Beech occurs only in extreme eastern Wisconsin

2 – All sites – Habitat types not defined

Table 40.5. Northern hardwood cover type – estimated relative growth potential by southern habitat type group and habitat type.

Southern Habitat Type Groups	Estimated Relative Growth Potential for NH Cover Type			
	None to Poor	Fair	Good	Excellent
Dry	PEu PVGy PVG PVCr PVHa			
Dry-mesic	ArDe-V ArDe	AQVb-Gr ArCi ArCi-Ph AArVb AArL		
Dry-mesic to Mesic			AFrDe AFrDeO ATiFrCi ATiFrVb ATiDe ATiDe-Ha ATiDe-As	
Dry-mesic to Mesic (phase)			AFrDe(Vb) ATiFrVb(Cr) ATiCr(O) ATiCr(As) ATiDe(Pr)	
Mesic (phase)			ATiFrCa(O)	ATiAs(De)
Mesic			ATiSa-De ATiSa	ATTr AFTD AFH ATiFrCa ATiCa-La ATiCa-Al ATiCa ATiH AFAs-O AFAs
Mesic to Wet-mesic	PVRh			

3.2.3 Interfering Vegetation

The presence of native species such as Pennsylvania sedge (*Carex pennsylvanica*), ironwood (*Ostrya virginiana*), and other woody and herbaceous competitors can provide unique challenges when attempting to establish desirable northern hardwood regeneration. Research in the Lakes states has documented these species as a difficult challenge in managing this cover type. The abundance of these competitors is influenced by factors such as herbivory, past land use (grazing), earthworm infestation and other site characteristics. Treatment and management of such stands must begin with a thorough assessment of stand conditions including sedge coverage (%), regeneration, browse severity, and any other factors that may be a cause of inadequate regeneration establishment. The following is a summary of recommendations for treatment of sedge and ironwood based on trials and research conducted in the region.

Sedge Competition and Management: Pennsylvania sedge is considered interfering if it covers more than 30% of a stand's understory (Marquis 1986). It commonly establishes on disturbed sites through rigorous rhizome growth creating a relatively continuous ground cover, inhibiting seedling establishment and development. In spring, Pennsylvania sedge is one of the earliest *Carex* species to flower, making it easier to identify.

Several Wisconsin and Michigan field trials to control Pennsylvania sedge have been documented. Each method has attributes that must be considered in relation to goals and objectives for each stand (Table 40.6). Based on Wisconsin trials, Pennsylvania sedge treatment applied just before or after a regeneration harvest provides the best opportunity for regeneration success, especially when timed with good sugar maple seed crop. Emphasis should be placed on treating only portions of the stand where regeneration is desired. This minimizes treatment cost, reduces overall stand disturbance, and may increase the long-term success of the treatment. Stand wide treatments may be necessary based on other factors such as high deer numbers and the natural regeneration system employed. Stand wide applications in areas with high deer numbers may produce and saturate the area with high quality food, thus allowing some tree regeneration to overcome browsing (Randall 2005). In addition, utilizing lower residual basal areas 50-60ft/acre and "cribbing" by leaving tops may also allow tree regeneration to quickly grow past browse height.

Based on the Wisconsin and Michigan field trials, the most effective methods to control sedge are:

- Foliar herbicide application
- Foliar herbicide application/scarification
- Scarification

Foliar Herbicide Application: The intent of a foliar herbicide application is to set back sedge mats and prepare a seedbed for other native plant species and tree regeneration. Careful evaluation and planning should be done to ensure that the benefits outweigh the costs, economic and ecological.

Foliar herbicide applications should occur after spring ephemerals return to dormancy and other vegetation is fully grown, through the end of the growing season. Applications just after leaf-off have shown to have inconsistent results. When successful, foliar herbicide applications have been shown to adequately control sedge and have very little effect on non-target species. Applications have been successful at providing Pennsylvania sedge control for 3-4 years. Examples of such treatments can be found at the WI DNR silvicultural trials web page (WDNR 2018).

Foliar Herbicide Application & Soil Scarification: Combining soil scarification with an herbicide application is recommended if regeneration is also a management goal. This can be especially beneficial for light seeded species such as yellow birch. Scarification is best conducted using a straight blade, salmon blade or root rake mounted on a dozer to scrap the treated sedge at away exposing mineral soil. An important consideration is to plan the scarification and herbicide application accordingly. Typically, herbicide applications need to occur a week or more prior to scarification. It may also be advantageous to apply a pre-emergent herbicide after scarification if sedge re-establishment is a concern. This application is typically best suited for canopy gaps, group & patch applications.

Soil Scarification: The use of scarification to control sedge should be reserved for sites with sensitive species that require additional protection or properties where herbicide application is restricted. This recommendation is based on past applications that have shown scarification provides adequate canopy gap control approximately 30% of the time and often encourages establishment of noxious weeds (WDNR 2003). Scarification is best conducted using a dozer/blade to scrap the sedge mat away exposing mineral soil. The goal of scarification is to break up the sedge mat to provide exposed mineral soil for 2-3 growing seasons. This method is best suited to canopy gaps, groups, and patches or wherever regeneration is desired.

Table 40.6. Sedge control method comparison.

Treatment	Overall Effectiveness (WDNR 2002)	Summer Application	Fall Application	>2-year control	Stand Application	Group / Patch	Shelterwood	Woody Control Needed
Herbicide Foliar	81%	R	C	R	R	R	R	C
Foliar Herbicide & Scarification	60 %	R	C	C	C	R	R	R
Scarification	30%	R	R	N	N	R	C	R

R = Recommended; C = Conditionally recommended (See sedge & ironwood management for more detail); N= Not Recommended Note, prescribed fire is not recommended for Pennsylvania sedge control due to poor effectiveness (WDNR 2003).

Ironwood Competition and Management: The treatment of ironwood and other similar woody species can be especially difficult due to their ability to regenerate after a disturbance. Ironwood and other (undesirable) woody plants are considered interfering if there are more than eight stems of any size found within a 1/385 ac plot (6' radius) (Marquis 1986). Several methods to control ironwood have been documented in the literature and local trials. Each method has positive and negative attributes that must be considered in relation to the landowner objectives and silvicultural goals for each stand (Table 40.7). It is also necessary to evaluate the size and density of the targeted ironwood as well as the necessity to treat an entire stand or portions such as canopy gaps, groups and patches. This will help ensure that the proper treatment method is applied, and desired control is obtained.

Herbicide Application: The intent of an herbicide application to control ironwood is to either release established regeneration or reduce competition allowing regeneration to establish. Typically, applications are broadcast foliar applications or single stem applications such as cuts stump, basal bark and “hack and squirt.”

Broadcast applications are typically intended to reduce competition and allow regeneration to establish. This treatment is typically a broad-spectrum foliar application and will result in the unwanted take of desirable species. To reduce unwanted take of desirables it may be advantageous to conduct a foliar spot application focusing on individual stems or small groups of stems. Treatments are best suited for stands that have short ironwood (<4.5 tall) depending on application method & equipment limitations. Treatments in harvested stands should not occur until ironwood that was cut or smashed during harvesting has sprouted. This typically occurs after the first summer following the harvest. Foliar applications should take place after full leaf expansion through leaf off. Through observation this treatment is considered to have a 69% effectiveness (Personal communication Schultz)

Single stem applications are typically intended to release established regeneration. Foliar spot applications, cut stump, basal bark, girdling w/ herbicide and hack and squirt treatments are all practical application methods depending on stand conditions and desired results. Because these methods can be very labor intensive and logistically difficult to implement efficiently, they are often not preferred for large scale applications. Foresters who use these treatments find success to be greater than 90% (Personal communication Schultz).

Herbicides labeled specifically for the control of woody species & applicable application type is preferred, always follow label instructions for safety and mixing. Refer to herbicide applications for sedge if control of herbaceous vegetation is also desired along with ironwood.

Mowing: Mowing using a masticating & rotary head will temporarily reduce ironwood competition. However, trials have shown that ironwood sprouted quickly, with multiple stems and shortly outcompeted desirable seedlings that established. Masticating heads are generally preferred over rotary heads because of their ability to shatter the ironwood stems which is thought to provide better results. Use of a masticating mower on rocky sites is very costly due to repairs and is seen as economically unfeasible long term. Foresters who use this method find through observation that they obtain effective control 63% of the time.

Blade Scarification & Pulling: The use of a dozer mounted salmon blade and root rake provides ironwood control and seed bed preparation. The main objective is to destroy ironwood, this is most effectively done by fully uprooting it. Stems that are not fully uprooted often sprout, limiting the long-term effectiveness. During harvest operations harvesters can also effectively uproot ironwood using the felling head to grasp and pull stems.

Additional Methods: These methods are commonly used but have not been evaluated and have varying degrees of success:

- Prescribed Burning (54% effective)
- Manual Felling with high stumps (>2.5’) stump height (59% effective)
- Running over with logging equipment during a timber sale (38 % effective)
- Grazing/Browsing

Table 40.7. Ironwood control method comparison.

Treatment	Overall Effectiveness (WDNR 2002)	Summer Application	Fall Application	>2 year control	Stand Application	Group / Patch	Shelterwood	Herbaceous Control Needed
Herbicide Foliar	69%	R	N	R	R	R	R	R
Single Stem Herbicide	90%	R	PR	R	R	R	R	N
Mowing	63%	PR	R	PR	R	R	R	N
Blade Scarification & pulling	38%	R	R	PR	R	R	R	PR
High Stump (>2.5') Manual Felling	59%	R	R	R	R	R	R	N

R = Recommended; P = Provisionally recommended (See sedge & ironwood management for more detail); N= Not Recommended

3.2.4 Wildlife

Northern hardwood comprises the highest acreage of the northern forest and management decisions affecting stand composition will also affect wildlife use. Maintaining and enhancing the assemblage of wildlife species in the northern forest depends on maintaining a healthy and diverse forest system. The five tree species that define the northern hardwood type provide a variety of benefits to wildlife. Associated tree and shrub species in northern hardwood stands also provide important wildlife benefits. There has been a trend toward greater dominance of sugar maple in the northern hardwood type. This simplification of the type can have negative consequences for wildlife dependent on a diversity of plant species.

Diversity of tree species and structure in the northern hardwood type contribute to the utility of the type for forest wildlife. Vertical structure, the arrangement and quantity of multiple layers in the forest, is of great importance. The forest floor, shrub layer, and sub-canopy along with associated tree species in the canopy contribute as much to wildlife use in the northern hardwood type as do the tree species definitive of the type. The potential for development of cavity trees and coarse woody debris in this type adds to the potential for wildlife use of the type. Harvesting systems appropriate to the northern hardwood type can be conducive to protection of sensitive natural features such as vernal pools, seeps, riparian areas, and microhabitat features such as rock faces.

Ground flora can be affected by silviculture. Studies of changes in ground flora following forest management activities in northern hardwood are few. Some existing results show initial increases in diversity and coverage (see summaries in (Roberts and Gilliam 2003) that are largely due to responses of common species (Crow *et al.* 2002). Some ground flora found in northern hardwood stands are light-sensitive and benefit from the shading provided by a closed canopy. Some of these plants are rare and management actions to protect them should be followed. Even-aged management techniques could be expected to have a greater impact on some sensitive forest interior herbs than uneven-aged techniques. Litter found on the forest floor that can be disturbed by harvesting activities can provide important wildlife benefits.

However, some ground layer plants benefit from moderate disturbance and increased sunlight. Opening the canopy through harvesting techniques that provide a variety of different sized canopy gaps may help encourage a diversity of ground layer plants.

The shrub layer provides foraging and nesting opportunities. It also will increase the use of some mature stands by species more commonly found in early-successional habitats. This component of the vertical structure of a stand can be provided both by shrubs and by tree regeneration. Silvicultural techniques providing light penetration will help in the development of the shrub layer. Conifer species in the understory can be of particular importance to many wildlife species. This is best illustrated in increases in nesting by some neotropical migrant songbirds though many other wildlife species use conifers.

Diversity of tree species in the sub-canopy and canopy will increase wildlife use of a stand. Retention of yellow birch, ash, and associated mid-tolerant tree species in sugar maple stands is desirable. If oak is present, it will contribute greatly to wildlife use of the stand and should be maintained. Conifers, particularly hemlock and white pine, should be retained.

The management objective for optimum quality sawlogs lends itself to producing large trees and many Wisconsin wildlife species take advantage of these large trees. Uneven-aged management can create a diversity of conditions for a variety of niches. Because a wide variety of tree sizes are available in stands managed under uneven-aged regimes, cavities and den trees can accommodate the full range of cavity-using wildlife species

Amphibians are well represented in the northern hardwood type. Coarse woody debris and litter on the forest floor helps maintain amphibian populations. Vernal pools provide productive breeding areas due to the absence of fish. Those pools with thick moss that may harbor four-toed salamander need special management in and around the site. Pools with wood frogs and other salamanders can actually increase productivity if they are opened to sunlight, as long as the surrounding land contains coarse woody debris. These pools also contribute microhabitat diversity and they should be protected to prohibit harvest operations within the basin of these small wetlands. Retention of dead or dying trees is important to promote the recruitment of coarse woody debris in the future. Compaction of the litter and soil in the vicinity of vernal pools should be avoided.

According to Robbins (1991), 66 species of Wisconsin birds use northern hardwood forests for breeding habitat. An additional 11 species use this habitat when a conifer component is found in association with the northern hardwood species. Representatives of most guilds with the exception of grassland and wetland species can be found in some developmental stage of the northern hardwood type. The northern forest of Wisconsin is an important source breeding area for many species of songbirds declining in other portions of the species’ ranges. Because the northern hardwood type is found throughout Wisconsin, some southern species are included in the list of breeding birds. Because these southern species reach the northern extent of their range in Wisconsin, conservation of their breeding habitat might be considered particularly important. Cavity-nesting birds are particularly well represented in the northern hardwood type.

Mammals using the northern hardwood cover type range from shrews and bats to black bears. Though higher populations of game animals can be found in other cover types, the northern hardwood type contributes habitat for deer and elk. Horizontal and vertical structural diversity can be great in the northern hardwood type. Uneven-aged management creates the possibility of developing significant amounts of coarse woody debris utilized by a variety of forest wildlife.

Because of the opportunity for long rotations and the development of large trees, use of northern hardwood stands by cavity-using wildlife is an important feature. Many large-bodied cavity-using wildlife and some colonial roosting species use cavities in trees 18" or greater in diameter. Examples include pileated woodpecker, turkey vulture, fisher, several bat species, and black bear.

Even-aged harvest systems in the northern hardwood type resulted in many of the stands we currently manage. Northern hardwood regeneration following a clearcut or shelterwood can provide many of the habitat requirements of early-successional dependent wildlife. Even-aged management may also help increase the representation of the less tolerant northern hardwood associated tree species in areas where dominance of sugar maple is a concern.

Habitat management for wildlife in the northern hardwood type should capitalize on the diversity possible in the type. The five major tree species definitive of the northern hardwood type as well as the variety of associates found in the type provide many options for wildlife. Tree species diversity should be encouraged within stands when possible. Habitat types and species assemblages dictate the extent to which this is possible but silvicultural techniques to promote diversity should be followed. Structural diversity can be encouraged through a variety of potential management and regeneration techniques.

A variety of canopy gap sizes to allow for the development of vertical structure within the stand should be included in cutting prescriptions if wildlife production is a goal. Retain as much diversity of tree species as possible within northern hardwood. Trees such as yellow birch and hemlock are particularly important. Large trees, cavity trees, and snags all provide important wildlife habitat attributes and should be retained. Microhabitats within the northern hardwood type can contribute disproportionately to wildlife populations and diversity. These features should be identified and protected. Land managers working in the type should be particularly sensitive to wetland features, rock outcrops, and populations of sensitive plants.

Summary of Recommendations

Encourage habitat diversity:

- Tree species diversity especially mid-tolerants and conifers
- Current and future cavity trees
- Current and future snags
- Downed woody debris
- Large trees
- Vertical structure
- Horizontal structure (variety of stand/patch sizes)
- Variety of age-classes (a variety of gap sizes will contribute)

Protect special features:

- Wetland features including vernal pools, seeps, and riparian areas
- Populations of rare plants or animals
- Topographical features such as cliff faces or rock outcrops

<u>Effects of Management on Neotropical Forest Migrants</u>
During the past 20 years, there have been a number of studies that attempt to explain the decline of many neotropical migrant bird species (NTMB's) associated with forested landscapes. One segment of this research investigates the impact of edges and fragmentation generated by forest management.

Landscapes like those of southern Wisconsin were the focus of many NTMB studies conducted during the 1980's (building upon earlier studies going back to the 1950's). These areas have relatively high levels of permanent fragmentation due to agricultural and urban land uses. Most of this fragmentation creates "hard" edges, or abrupt changes between habitat types, such as when woodlands adjoin farm fields. Bird populations within these fragmented woodlots are heavily impacted by nest predation and by high levels of nest parasitism by brown-headed cowbirds. These populations are generally "sink" populations, maintained by recruitment of individuals from "source" populations. ("Source" areas have stable or growing populations that produce emigrants, while "sinks" are dependent upon immigrants to sustain their population size.)

Northern Wisconsin forests have different levels and types of fragmentation as compared with southern Wisconsin. The amount of edge in the northern forest is determined primarily by timber management and its associated infrastructure, and secondarily by permanent fragmentation associated with development.

Forests and associated wetlands of the northern lake states are important habitats - they support some of North America's highest densities and most diverse assemblages of breeding birds (Howe *et al.* 1996). This region is also thought to support source populations of many NTMB's.

Edge and fragmentation studies conducted since the 1990's have devoted more attention to predominantly forested landscapes. Most researchers tested whether hard edges would affect avian productivity as they did in agricultural settings. Predictably, edge effects in forested landscapes are more complex and local than those found in agricultural landscapes. Interspecific competition and predation rates are more significant than nest parasitism. This is partly because cowbird abundance is lower in northern Wisconsin (but can be locally important near agricultural areas). Predators of the northern forests include fishers, skunks, raccoons, foxes, Common Crows, Blue Jays, a variety of other birds, and assorted small mammals. They are the most important demographic factor limiting nest success.

(Flaspohler *et al.* 2001a) studied edge effects generated by clearcuts (6 years or less) adjacent to large stands of older deciduous forests in Wisconsin. Hermit Thrush and Ovenbird, forest interior species that nest on the ground, had lower nest success within 300m of hard edges generated by clearcuts. Forest interior birds that nest in the canopy nested at lower densities within 50 meters of clearcuts, but at higher densities between 50 and 300 meters. American

Robin and Rose-breasted Grosbeak, species known to be less sensitive to edge, had higher nest densities near recent clearcuts. Predation was the leading cause of nest failure for both ground and canopy nesting birds. A related study of Ovenbirds determined that while nest density was similar between edges and interior, predation and mean clutch size were both highest near edges. Therefore, net productivity was similar (Flaspohler *et al.* 2001b). We do not know whether this result applies to other species. More research is needed in this region to better understand local predator populations and how they affect nesting success of NTMB's.

Creation of edge and fragmentation in a landscape often benefits generalist bird species that are adapted to a variety of habitats. Many of these species (e.g. House Wren, Gray Catbird, American Crow, Blue Jay) are egg predators, and crows and jays also prey on nestlings, but their overall effects on local bird populations are not well known. Hamady (2000) found that Black-throated Blue Warblers, a forest gap-dependent species associated with shrub layers, declined in Upper Michigan landscapes with increasing habitat fragmentation because of competition with forest generalist species.

Current research also suggests that vegetation patterns in forest-dominated landscapes can affect the composition of avian communities within individual forest stands. In northeast Wisconsin, forested stands in landscapes with greater amounts of upland open land, as well as higher levels of fragmentation as indicated by measures of landscape pattern, had a lower abundance of edge-sensitive NTMB's (McRae 1995). Amounts of open land were correlated with landscape pattern measures, making it difficult to quantify these effects separately. Pearson and Niemi (2000) sampled mature aspen stands in Minnesota to determine whether both within-stand habitat characteristics and landscape patterns influenced breeding bird abundance in a forested landscape. Habitat specialists (Blackburnian Warbler and Magnolia Warbler) were found in aspen if there was a conifer component retained in the stand and also a large conifer component in the surrounding landscape (up to 1/3-mile radius). Forest generalists (Veery and Ovenbird) were less influenced by conifer components in landscapes. Retaining appropriate landscape-level conditions for certain habitat specialists should prove beneficial to their populations.

The overall effect of habitat fragmentation and edge on NTMB's in northern Wisconsin is not clear. Population estimates suggest that this region is a source population for many NTMB's and other bird species. Generation of excessive amounts of edge and habitat fragmentation within a landscape will be beneficial to some generalist NTMB's but may prove detrimental to source populations of forest interior NTMB's, many of which are of higher conservation concern. Local research results are difficult to extrapolate, appearing to vary by ecosystem type. Additional local research is needed to determine how even-aged management of northern hardwood affects patterns of interspecific competition and nest predation.

<u>Effects of Different Silvicultural Techniques on Neotropical Forest Migrants</u>
Information about effects of uneven-aged management on NTMB's is scarce. A study conducted in northern hardwood in central Ontario suggested that lack of canopy closure in stands with repeated selection harvests could become a limiting factor for some species. Researchers found species-specific differences in breeding season abundance in stands recently harvested (1-5 years), versus stands harvested earlier (15-20 years) and stands in

reserves (harvested more than 30 years ago) (Forests *et al.* 2004). This landscape differed from that of Wisconsin in that rock outcrop occupied a significant part of the area.

A study on the Ottawa National Forest compared 40 acre plots in old growth, managed old growth, uneven-aged selection, and even-aged shelterwood treatments (Andres 1996). Plots were not replicated, but some species richness, composition, and abundance differences were reported among the four plots. The old-growth plot had the highest number of breeding bird territories, and the selection treatment had the second highest.

King and DeGraaf (2000) compared bird species distribution among clearcut, shelterwood, and unmanaged northern hardwood forests in New Hampshire. Again, species-specific differences in bird abundance were apparent. The authors recommended that a variety of management techniques should be used in a landscape to maintain bird species diversity.

3.2.4.1 Deer and Herbivory Effects

In the northern hardwood forest, browsing by white-tailed deer is partly the cause of:

- Reduced regeneration and growth of some tree species, and changes in species composition (possible economic impact in areas of high deer abundance).
- Local extirpation of some understory plant species, and changes in the relative abundance of others. Species most likely to be impacted are those that are less common.
- Reduction of habitat diversity and contribution to forest simplification.
- Indirect effects on other wildlife that depend on understory plants and shrubs (WDNR 1995).

3.2.5 Endangered, Threatened and Special Concern (ETS) Species

Most typical northern hardwood management would not affect Endangered Resources (species listed in the Wisconsin Natural Heritage Inventory [NHI] Working List) (WI DNR 2018). However, in cases where ETS species are found in northern hardwood they may be affected by excessive canopy removal. Many ETS species have habitat requirements that need moist environments protected from the direct sunlight of mid-summer and the desiccating effects of wind. Seventy-two species on the NHI working list occur regularly in northern hardwood stands.

Several species, which are found in a variety of habitats, use northern hardwood primarily for foraging. Several other species use northern hardwood as breeding habitat, but also use many habitats. Several species are found only in northern hardwood.

Wide-ranging species that utilize northern hardwood for foraging:

Timber wolf *Canis lupis,* northern myotis *Myotis septentrionalis,* eastern pipistrelle *Pipistrellus subflavus, w*oodland vole *Microtus pinetorum,* Arctic shrew *Sorex arcticus, p*ygmy shrew *Sorex hoyi, w*ater shrew *Sorex palustris, b*obcat *Lynx rufus, g*reat gray owl *Strix nebulosa,* Cooper's hawk *Accipiter cooperi,* and rhinoceros beetle *Xyloryctes jamaicensis.* The remaining species use northern hardwood as breeding sites and can be more directly influenced by stand management decisions.

Certain rare and uncommon plant species (not all are ETS listed species) are associated with mesic interior hardwood forests. Some of these plant species are poorly adapted to increased light and desiccation and their response to disturbance is unknown; they may grow and mature slowly, produce few propagules, disperse only short distances, or require a specialized pollinator (Meier *et al.* 1995). Several studies conducted elsewhere in the eastern United States indicate that some herbaceous species associated with late-successional hardwood stands may require 72 to more than 150 years to recover to pre-disturbance abundance and distribution after a major canopy-opening disturbance (Flaccus 1959; Maclean and Wein 1977; Duffy and Meier 1992). Matlack (1994) found that proximity to old forest was associated with the presence of shade-tolerant understory herbs in previously farmed successional oak-hickory forests, indicating that recolonization was likely important in maintaining their populations. Even-aged management techniques could be expected to have a greater impact on some sensitive forest interior herbs than uneven-aged techniques; other factors to consider include patch size, distance from potential colonists in older forest, presence of pollinators and dispersal agents, and time for population recovery before the stand is re-entered. Given the nearly complete lack of empirical information on the fate of rare and uncommon herbs in our area, research and monitoring is warranted.

The following is a list of some of the ETS species associated with northern hardwood stands, their general habitat preferences, and known locations in the state where they have been found:

<u>Plants</u>

- Allegheny vine *Adlumia fungosa* (special concern): This plant has a narrow habitat niche growing on ledges imbedded in northern hardwood forests. Most records are from Door County although it could be found throughout the range of northern hardwood. Keeping shade on the ledges would be the primary consideration. Single-tree selection should accommodate the needs of this plant.
- Assiniboine sedge *Carex assiniboinensis* (special concern)
- Pale sedge *Carex pallescens* (special concern)
- Long-spur violet *Viola rostrata* (special concern): These grass-like sedges and the violet can be difficult to identify and may be more common than recorded. They can be found in shaded hardwood across the range of northern hardwood. Selection (single-tree or group) harvesting in the winter is probably compatible with these species.
- Blunt-lobed grape-fern Botrychium oneidense (special concern): These plants of maple/basswood forest are found in moist depressions or along boggy edges. The fern seems to tolerate slight to moderate disturbance, although it still needs shade. Populations have increased in grazed woods or where ground fires have occurred. Selection harvesting including treatment of the shrub layer may enhance populations.
- Braun's holly fern *Polystichium braunii* (state-threatened)
- Green spleenwort *Asplenium viride* (state-endangered)
- Maidenhair spleenwort *Aspenium trichomanes* (special concern)
- Fragrant fern *Dryopteris fragrans* (special concern): All four species grow on wet cliffs or rocky wet talus. All need shade and moisture to thrive. Due to the limited habitat available, most foresters will not encounter these species, however, for those that do,

the management is straight forward. Keep shade on the plants and keep moisture on the roots. Special management should occur within 100 meters of the plant populations. Single-trees could be removed from within the 100-meter area, but the site should be managed for shade on the rare plants rather than applying silviculture to the stand. The surrounding uplands should be managed to avoid soil drying – single-tree selection and group selection would be the most compatible.

- Broad beech fern *Phegopteris hexagonaptera* (special concern): A more southerly plant but can be occasionally found in northern hardwood. This fern prefers sunny, more open spots in moist woods. The populations may be enhanced by selective harvest (single-tree or group), if the landings and skid trails avoid most of the plants.
- Broad-leaved twayblade *Listera convallaroides* (special concern): Another plant that requires very cool soil. It is found almost exclusively on mosses or in springy areas in hardwood or hardwood/conifer areas in counties bordering Lake Superior. Single-tree winter harvesting that leaves most of the canopy intact in the winter is probably compatible.
- Christmas fern *Polystichium acrostichoides* (special concern)
- Glade fern *Diplazium pycnocarpon* (special concern)
- Mingan's moonwort *Botrychium minganense* (special concern)
- Cooper's milkvetch *Astragalus neglectus* (state-endangered): Not much is known about the habitat requirements for these species other than they grow in hardwood and hardwood-conifer forest. If the plant is found in a stand, the forester should contact the BER botanist to develop a management strategy.
- Crinkled hairgrass *Deschampsia flexuosa* (special concern): This grass is found mainly along the coast of the Great Lakes, but occasionally in northern hardwood stand on dry soils. Presumably the more dappled shade found in dry soil hardwood would indicate a tolerance for selection harvest, but the site should be monitored.
- Cucumber-root *Medeola virginiana* (special concern): A plant found on medium nutrient soils on moraines and under beech, sugar maple and/or hemlock. This is another plant potentially affected by deer browse. Cucumber-root is affected in growth and reproductive capability by the light found in large gap edges and compaction but increases in small gaps. The plant favors small gaps and the presence of tip-up mounds. Selection harvesting during frozen conditions with gaps limited to two tree lengths can accommodate cucumber-root.
- Drooping sedge *Carex prasina* (state-threatened): This sedge grows in wet wooded areas and along streams. Sites where the sedge is found remain wet due to springs or seeps. The plant is found primarily in the Baraboo Hills, Blue Hills, Door County and along the St. Croix River. Yellow birch and skunk cabbage are primary associates. Removal of single trees is probably acceptable, but more important is conducting forestry on the surrounding stands that does not affect the water table.
- Foamflower *Tiarella cordifolia* (state-endangered): Of the six known populations, four are on U.S. Forest Service land and two are on private land. This spring bloomer's habitat is stream banks, especially with cobble, and in ravines where cool air drainage and substrate water flow is present. Common tree associates are black ash, yellow birch, sugar maple and conifers. Primary threats are drying of the forest floor, soil compaction, garlic mustard invasion, and beaver. Suggested management on the national forest is to establish a 100-foot buffer around the population and use selection

uneven-aged harvest in the surrounding uplands. The site should be monitored for garlic mustard and beaver activity.

- Great toothwort *Cardamine maxima* (special concern): The only known location is a rich deciduous forest in Ashland County. Searches for the plant should occur in from mid-May to mid-June. Single-tree selection harvesting is probably compatible with this plant.
- Green-leaved rattlesnake plantain *Goodyera oblongifolia* (special concern): This evergreen rosette is mostly found in spruce-fir forest, but it does occur in hardwood/conifer stands. The plant requires very cool soil; thus it is limited to far northern Wisconsin. It is known to die after even-aged harvest. Another concern is collecting by orchid enthusiasts, which almost always dooms the plant. An appropriate strategy would be to use single-tree selection harvesting during periods when snow is on the ground.
- Handsome sedge *Carex formosa* (state-threatened): This sedge grows in moist calcareous soil in deciduous woods. The plant is found only in the Northeast Region. It prefers light dappled shade and should be accommodated by light single-tree selection harvesting.
- Large-leaved sandwort *Moehringia macrophylla* (state-endangered): Only two colonies of ten plants were known from the Penokee and Gogebic Ranges in 1999 down five populations from 1994. The plant lives on cliffs or mossy bluffs. Some botanists speculate that while the plant needs moisture and some shade, they may be influenced by too much shade. The known populations should have specific management plans developed for the sites.
- Little goblin moonwort or Goblin fern *Botrychium mormo* (state-endangered): This minute fern is associated with a thick (greater than 3 inches) organic horizon, also known as the O horizon or litter layer, and dense shade. Forest generally needs to be mid-aged to old, in order for this thick of an O horizon to develop. It is most commonly found in AH, AOCa, ATD, ATFD habitat types without hemlock and especially where pit and mound microtopography is found. The plant is sensitive to soil compaction and is eliminated when the litter layer is significantly reduced. The plant apparently can tolerate individual tree selection, but the effects of equipment need more research. Populations should be marked so vehicles would not travel over the plants. The effect of exotic earthworms in this species needs further research.
- Male fern *Dryopteris filix-mas* (special concern): Habitat for this fern in Wisconsin is the shade of sugar maple, ironwood or choke cherry in a rather open forest growing on 10 to 20% slopes on basalt. In other words, very limited habitat is available in Wisconsin. Management recommendations are unknown, but an adaptive management approach that incorporates light thinning around male fern populations may increase habitat availability.
- Northern lungwort *Mertensia paniculata* (special concern): The habitat is damp woods near the shore of Lake Superior. Little is known regarding species management however, moist soil appears to be most important. Consideration for maintaining water flow in surrounding stand management maybe critical.
- Pinedrops *Pterospora andromedea* (state-endangered): This parasitic plant on pine roots is occasionally found in rich humus under white pines. The plant can be found in predominately hardwood forest with a white pine component. Management recommendations are to maintain a high level of shade (single-tree selection) and avoid

soil compaction. These saprophytic plants depend on humus and roots to attain nutrients and may not flower every year.

- Purple clematis *occidentalis* (special concern): The plant is found on rocky, often calcareous slopes, in hardwood forest. The populations can fluctuate dramatically and are usually found on edges. Group selection next to existing populations may provide additional habitat.
- Ram's-head lady-slipper *Cypripedium arietinum* (state-threatened): This small orchid is most often found in conifer swamps, but it has also been recorded from mixed forests of maple, aspen, white birch, pines and balsam fir. The plant is mostly found in dappled shade with very little competition from understory vegetation. The key element is the presence of marl or lime-rich soils. In hardwood, it seems to prefer a mid-succession forest that has experienced a ground fire or a balsam die-off. As with most orchids, this plant is sensitive to deer browse and soil compaction by equipment. Single-tree selection or group selection harvest should be compatible if soil compaction is kept to a minimum.
- Smith melic grass *Melica smithii* (state-endangered): One known population in the Gogebic range, however conditions elsewhere on this range and the Penokee's are favorable for this species. The grass is found under sugar maples in rather dense shade. Light single-tree selection harvest would presumably be compatible with this grass.
- Snow trillium *Trillium nivale* (state-threatened): This showy flower grows in rich calcareous soils in the presence of beech/maple/basswood. Woodlot grazing is a major problem. Single-tree selection is apparently compatible with this species although harvest should be prohibited from early March through late spring.
- Spreading wood-fern *Dryopteris expansa* (special concern): This fern reaches its southern distribution in Wisconsin and requires cool moist conditions for its persistence. Very limited single-tree selection simulating individual tree gaps should retain this species in the stand.
- White ground cherry *Leucophysalis grandiflora* (special concern): The plant is found in sandier habitat types including northern hardwood. It generally appears many years after a disturbance, especially ground fires, during early to mid-succession, but is seldom found in coppice or clearcut harvest areas. Management of known populations with regenerative fire may be an option for this species.
- White mandarin *Streptosus amplexifolius* (special concern): This plant of the lily family is found with sugar maple, hemlock, and mixed conifer/hardwood in ravines and coves in hilly areas near Lake Superior. The plant is a favorite food of white-tailed deer and appears to have a reproduction bottleneck with small population sizes. The plant is capable of persisting with selection harvesting. The need for relatively large metapopulations indicates management units of 300 to 1000 acres are needed to accommodate this species.

<u>Animals</u>

- American marten *Martes americana* (state-endangered): This species has been reintroduced to the state with populations centered in two locations – the Nicolet National Forest and the Great Divide Ranger District of the Chequamegon National Forest. This species optimal habitat is old conifer forest with numerous windfalls and an abundance of spruce and fir. Marten's will also use old northern hardwood forest if they have numerous hollow trees and a significant conifer component. Stand management should promote snag and conifer retention however, range wide management plans are needed to address the needs of the species more so than stand recommendations.

- Appalachian pillar *Cionella morseana* (special concern)
- Brilliant granule *Guppya sterkii* (special concern)
- Boreal top *Zoogenetes harpa* (special concern)
- Black striate *Striaura ferrea* (special concern)
- Dentate supercoil P*aravitrea multidentata* (special concern): These five terrestrial snails appear to have very restricted habitats, cliffs, rocky talus and seeps. We do not know much about their life history nor their habitat requirements. In general, moisture is key. Where they are found, management should be light with consideration to maintain adequate soil, cliff or rocky talus moisture.
- Bald eagle *Haliaeetus leucocephalas* (special concern)
- Northern goshawk *Accipter gentilis* (special concern)
- Osprey *Pandion haliaetus* (state-threatened)
- Red-shouldered hawk *Buteo lineatus* (state-threatened): All of these raptors should have their active nest sites protected from disturbance during the nesting season. Moreover, to protect these species, they need management considerations that go well beyond silvicultural stand applications and nest site protection. Refer to forest raptor management guidance documents.
- Common goldeneye *Bucephala clangula* (special concern)
- Common merganser *Mergus merganser* (special concern)
- Red-breasted merganser *Mergus serrator* (special concern): All three of these species are very common in winter, but a sparsely found breeding in Wisconsin. All three nest in cavities, especially those found adjacent to large lakes or rivers. One common merganser nest was documented at the bottom of a 25-foot-deep tree cavity. Leave existing cavity trees and future cavity trees when planning a harvest.
- Four-toed salamander *Hemidactylium sculatum* (special concern): This amphibian lays its eggs in April in dense mosses (>1.5 inches in depth, including sphagnum mosses) at either the edges of ephemeral and/or fishless wetlands or in dense mosses growing on large downed woody debris over the water. Upon hatching, the larvae drop into the water and develop until they metamorphose in July or August. Because dense moss is essential to this species, tree cutting should be limited in these wetlands and a 75-foot buffer. This species is also highly dependent on large-diameter (>10") coarse downed woody debris on the forest floor. Forest management in areas surrounding the breeding wetland buffers should plan for the continuous accumulation of large downed woody debris to accommodate this rare forest-dependent species.
- Great blue heron *Ardea herodias* Rookeries (special concern): Avoid harvest in active rookeries. Winter harvest of trees in close proximity to the rookery could occur.
- Northern ring-necked snake *Diadophis punctatus* (special concern): This species is nocturnal living underground, under logs or rocks and is seldom seen. Special management prescriptions are lacking but keeping the forest floor moist with numerous large woody debris and rocks should accommodate this species.
- West Virginia white *Pieris virginiensis* (special concern): This butterfly is found in northern hardwood forests with adults in flight from mid-May to early June. The larvae

feed on toothwort. Management recommendations are lacking, however, identification of patches of toothwort within stands and avoiding equipment compaction could help with enhancing the species populations.

- Wood turtle *Clemmys insculpta* (state-threatened): Prefers hardwood forest or wet meadows associated with moderate to fast-current streams with sandy or gravel substrates. South-facing sand riverbanks are used for nesting. Best Management Practices for Water Quality addresses most of the management issues. Timber sale design should also keep equipment, especially landings away from the sandy nesting sites. Maintain small sandy openings within 200 feet of the river.

Rare Neotropical Migratory Birds

The followed three species have individual stand management silvicultural options that can be employed; however, a stand-by-stand approach may not help these species. All three species probably need to be managed at a large scale. The model for ruffed grouse management areas should be developed to address the needs of these species. Management blocks of 300 to 2,000 acres could be established around known dense populations. The purpose would be to manage the forest to accommodate the needs of the target species.

- Acadian flycatcher *Empidonax virescens* (state-threatened): This small flycatcher of southern interior forest is moving north in Wisconsin. The species prefers large tracts of mature hardwood forest with semi-open understory, with most territories near streams or in ravines. Management of the largest blocks of northern hardwood forest in southern Wisconsin using single-tree selection should accommodate this species.
- Black-throated blue warbler *Dendroica caerulescens* (special concern): This understory warbler nests north of a line from Green Bay to Spooner. Its preferred habitat is dense under story saplings and shrubs primarily in deciduous forest. Populations are most often found in mature to old hardwood forests and reach their highest densities in thickets formed after blowdowns. Stand management should release densely packed but suppressed saplings by single-tree or group selection.
- Cerulean warbler *Dendroica cerulea* (state-threatened): This southern warbler prefers mature to old-growth hardwood of maple, basswood and especially red oak. Cerulean Warbler's are found almost exclusively in the upper canopy. Most of the breeding records are south of a line from Marinette to Spooner, however, they have been recorded in every county of the state. This warbler can tolerate light timber harvest as long as 70% or more of the canopy remains. The most pressing need is for management considerations to cover blocks of potential habitat with a focus on the habitat requirements for this species.

Other rare species may occur in northern hardwood stands considered for harvest. Many of these species will be found in specialized habitats such as rock outcrops, cliffs, ephemeral ponds, and seeps. If an NHI occurrence or species verification is identified, contact the appropriate person according to the Department protocol. Information on species and habitat can be found at the Bureau of Endangered Resources page on the Wisconsin DNR website.

3.2.6 Economic Issues

Forest Products

The primary species that comprise the northern hardwood cover type are utilized for a wide variety of forest products, including pulpwood, biomass, sawlogs, and veneer.

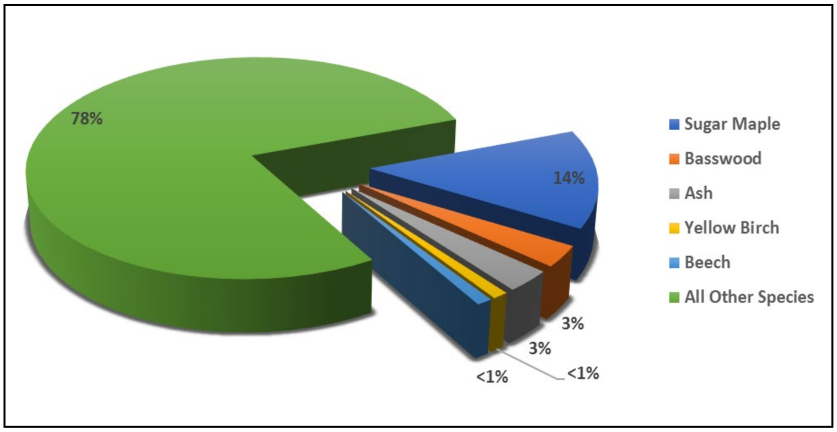


Figure 40.2. Statewide roundwood production percentages from 2009-2012.

Figure 40.2 highlights the proportion of statewide roundwood production generated from primary northern hardwood tree species. Sawlogs and veneer totaled approximately 30% of all northern hardwood production. Northern hardwood outputs from the primary wood-using mills tend to be highest in northeastern Wisconsin, followed by northwestern, central, southwestern, and southeastern Wisconsin. These production rates and each species' commercial value can fluctuate substantially based on resource availability, consumer trends, housing construction, export markets, and other market conditions.

Mill operations and raw material preferences have also experienced notable changes in the past few decades. In general, sawlog preferences have moved to smaller logs due to changes in mill equipment capacity and to target the upper grade material often found in younger, more vigorous trees. Some facilities no longer accept logs 30" and larger. Mixed hardwood pulpwood markets are generally more sensitive to changes in the supply chain, such as increased haul costs, the loss of a consuming mill, or other constraints that impact the flow of roundwood. Regional pulpwood markets vary considerably throughout the state and represent just one of the market forces foresters need to consider when developing silvicultural prescriptions.

Sugar maple has the highest growing stock volume of any species in Wisconsin, with volumes steadily rising since 1956, primarily in sawtimber-size trees. The fine-textured, dense wood of sugar (hard) maple has a high commercial value, particularly in the better-quality grades of lumber, veneer, and in figured grains such as birdseye or curly maple. The light-colored wood of sugar maple is most commonly used for lumber. A large proportion of heartwood discoloration can therefore have a significant impact on its commercial value.

Assessing Tree Value Growth

Forest managers are often interested in assessing the financial value or rate of value growth in trees and stands of trees. This information can be used to inform management decisions, such as when to rotate an even-aged stand to maximize financial performance or at what diameter trees reach financial maturity in an uneven-aged stand (e.g., single-tree selection). These financial analyses have been the subject of much discussion and debate in northern hardwood, due to the high commercial value of quality northern hardwood lumber.

It is important for foresters to have a basic understanding of the relationship between assessing tree size/quality and hardwood tree value. Tree diameter and merchantable height, in large part, determines tree volume, as well as the product class (e.g., pulpwood, sawlog, veneer). Tree diameter and ultimately log diameter will in part differentiate log grades, since defects that reduce quality will have a greater impact on small logs. Foresters should understand these standard size thresholds for product classes and tree/log grades but realize that these “standards” may vary based on markets and systems utilized. For hardwood sawtimber, the quality of the stem is at least as important as its size in determining a tree’s value. Most timber objectives for northern hardwood prioritize the development of stem quality through sound management. Detailed information on assessing stem quality and the risks/impacts of specific defects can be found in the Stem Quality and Forest Health sections of this chapter.

The following tree-level and stand-level financial considerations will highlight some of the general conclusions from a variety of research and financial analysis studies conducted in northern hardwood. The difficulty in presenting detailed financial data is that the parameters used often outdate quickly. For more detailed information on these studies see the reference section of this chapter. These considerations should be used in the context of a silvicultural prescription that incorporates clearly defined landowner goals and site conditions.

Tree-Level Financial Considerations

- Grade increase has the greatest effect on value – keep trees that can increase in grade. Greatest rates of value growth are in the poles and small sawtimber, as these trees are entering potentially higher grades and/or rapidly increasing in merchantable height (Godman and Mendel 1978; Buongiorno and Hseu 1993; Reed and Mroz 1997; Webster *et al.* 2009).
- Consider removing trees that have reached their highest-grade potential, within the context of the silvicultural prescription. Remember to consider size increases into veneer grades, especially on high quality sites (Webster *et al.* 2009).
- Single-tree selection identifies a maximum tree diameter, which may be based on the financial maturity of a tree species – that point at which the rate of value increase falls below the landowner’s desired rate of return. Financial maturity for sugar maple may vary from 15-30” DBH (Godman and Mendel 1978).
- Approximate financial maturity for long-lived northern hardwood ranges from 18-24” DBH on high quality sites, and 16-18” DBH on moderate quality sites (Leak *et al.* 2014).
- Assessing financial maturity or the rate of value growth may be dictated by more than just tree diameter. Foresters need to consider multiple factors, including species, tree age, size, defect impacts, growth rate, ability to jump grade, and site conditions. For

example, keeping more vigorous trees that can substantially increase in diameter and/or merchantable height can improve financial performance (Reed and Mroz 1997; Webster *et al.* 2009).
- Fungal infections and cracks are the quality-degrading defects most associated with losses in tree value in sugar maple and yellow birch (Havreljuk *et al.* 2014).
- Large heart size or dark heart in sugar maple significantly impacts log grade potential. Predicting the extent of heartwood discoloration in standing sugar maple trees is difficult. Current studies attempting to correlate heart size to tree and site characteristics have been inconsistent. In general, most studies have found that the amount of discolored wood increases with increasing tree diameter, but the proportion or ratio of discolored wood to white wood is not consistently related to tree diameter (Erickson *et al.* 1992; Yanai *et al.* 2009; Germain *et al.* 2015; Dey *et al.* 2017).

<u>Stand-Level Financial Considerations</u>
- Uneven-aged selection systems (e.g., single-tree selection) produce greater merchantable heights than even-aged systems (Strong *et al.* 1995).
- Selection systems using medium residual basal areas, ranging from 60-90 ft^2/acre in trees ≥5” DBH, generally produce the best balance between growth and tree grade improvement, along with high net present value (Niese *et al.* 1995; Strong *et al.* 1995; Leak *et al.* 2014).
- Even-aged management of northern hardwood may be a viable choice from a financial perspective, particularly where landowner goals, stand conditions, or site quality do not lend themselves well to uneven-aged management. Currently little published financial data exists on even-aged northern hardwood management.

Uncontrolled and severe diameter-limit cutting can initially produce the highest harvest volumes and undiscounted value, but long-term it produces the poorest grade trees and lowest economic returns (Erickson *et al.* 1990; Niese *et al.* 1995). Controlled diameter-limit cutting with improvement cutting in lower size classes was suggested to limit the negative impacts (Buongiorno *et al.* 2000).

3.2.7 Operational Considerations

The cumulative effects of infrastructure development and soil compaction in forests have been studied in other parts of the country and found to be correlated with changes in hydrologic regimes, surface drainage patterns, and soil moisture. The negative ecological effects of soil compaction and rutting, and of forest roads, are well known at fine scales, but these issues have not been studied in an integrated fashion on larger landscapes in our area. Roads and utility corridors have been implicated in the spread of non-native invasive plants. They also act as barriers to the movement of some species, create fragmentation and edge, and can attract human disturbances.

3.2.8 Vernal Pools

Where northern hardwoods grow on finer textured soils and/or somewhat poorly drained soils, inclusions may be found where seasonal ponding of water occurs. These ponds are called “vernal pools” (Rogers and Premo 1997). Vernal pools are characterized as small, seasonal, ephemeral, pools or ponds that lack predatory fish (Colburn 2004). Due to the lack of predators, these pools are important areas for amphibians and invertebrates to reproduce. The actual size used as definitional criteria of these “small” pools is debatable. Rogers and Premo described size range of vernal pools as “from a puddle to an acre or more.” Vernal pools contain species of aquatic flora and fauna not found throughout the terrestrial matrix of the remaining stand of northern hardwood. The frequency and distribution of vernal pools are of importance to their function in maintaining or enhancing biodiversity. Some vernal pools should be buffered to protect amphibian foraging and breeding habitat. Harvesting should avoid felling trees into or skidding through these vernal pools and avoiding rutting in the nearby vicinity. These areas should be delineated in some manner prior to beginning harvesting. Vernal pools may not be apparent at certain times of the year due to their ephemeral nature and the lack of standing water or during periods of snow cover.

4 STAND MANAGEMENT DECISION SUPPORT

This section offers two tools to help the forester assess and characterize the stand after field reconnaissance data is collected. With this data, the forester can then review landowner objectives and silviculture methods in effort to develop the desired future condition.

4.1 Stand Inventory

In depth and accurate stand assessment will facilitate discussion of management options and objectives in relation to realistic and sustainable management goals. There are several tools available to use in a northern hardwood stand assessment, some of which are included in the appendix of this chapter (e.g., Northern Hardwood Checklist and Northern Hardwood Tally Sheet). Factors to recognize during stand assessment include, but not limited to, the considerations in Table 40.8.

Stand composition and structure assessment can be attained by various inventory procedures. Individual tree species and diameters should be tallied when using either fixed-radius or the more common variable-radius inventory plots. An example variable-radius plot tally sheet to determine species composition and stand structure by size class is provided in Table 40.23. Other similar tally sheets and methods exist. The number of current and potential AGS per acre should also be tallied.

Residual crown cover or crown closure is an important factor when implementing even-aged shelterwood seeding cuts. One method to assess residual crown cover is to utilize fixed area plots and tally crown areas of individual trees. Tree crown areas vary due to a variety of influences and past disturbances such as weather-related events, fire, and root damage. Average tree crown areas by species and DBH for northern hardwood are listed in Table 40.24. Included with Table 40.24 are instructions for a sample shelterwood marking exercise using fixed area plots to determine residual crown areas (USDA 2005). Another tool to visually measure crown cover is a densiometer. Both spherical and flat densiometers use a grid-layout on a mirrored surface. Densiometers are used by counting the number of grid-cells occupied by reflected crowns. Densiometers are most effective when used during leaf on conditions.

Table 40.8. Northern hardwood stand inventory considerations.

Species Composition	
Stand Quality	Acceptable/unacceptable growing stock
Site Potential	Habitat type Soil characteristics Site index
Natural Regeneration	Species; stems/ac; distribution, height Deer browse Health and vigor
Stand Structure	Seedling sapling, pole, small/med/large saw Age-class distribution
Average Stand Diameter	
Total Basal Area	
Overstory Tree Vigor	Crown condition Crown class Growth increment
Competing Vegetation	Pennsylvania sedge Ironwood Invasive species *Rubus spp.*
Past Management History	
Stand Health	Tree diseases Tree pests Animal damage

4.2 Key / Checklist for Evaluating Cover Type Stand Management Options

The Northern Hardwood Stand Management Checklist is a tool designed to help identify management options prior to developing a silvicultural prescription. The checklist along with instructions can be found in the appendices (Table 40.22). The checklist is arranged by stand assessment topic (ex. Landowner Objective, Site Potential / Operability) with 2-6 true or false questions. The forester answers each question by checking (✓) the true or false box to the right of the question. When all questions within a topic have been tallied in each column, the forester then reviews the silviculture management options based on the assessment findings. Due to the complex character of both stands and management, checklist results should be considered collectively, along with other stand data and professional judgment when evaluating management options to best achieve a desired future condition (DFC).

4.3 Cover Type Decision Model

The northern hardwood decision models outline initial considerations in the development of a management plan by integrating silvics, site capabilities (soil, habitat type, competition, regeneration, successional pathways), methods (timing/sequence), site history, and timeline at growth stages under ideal conditions. Sustainable forestry practices must be based on compatible landowner objectives and the capability of each site. Each of these factors should be considered when approaching these models. Detailed considerations of a silviculture method are discussed under the narrative of each method in this chapter and page number is referenced in the model. Within the decision models, both even-aged and uneven-aged management objectives are considered.

Across the spectrum of northern hardwood stands in Wisconsin, there is a range of quality and conditions. Quality can be affected by many things such as stand history, storm damage and site conditions (e.g., soils, hydrology, landform). Using both the northern hardwood checklist (Table 40.22) and northern hardwood decision model (Figure 40.3 and Figure 40.4) offer a wide variety of considerations in making a management decision with the landowner objective in mind.

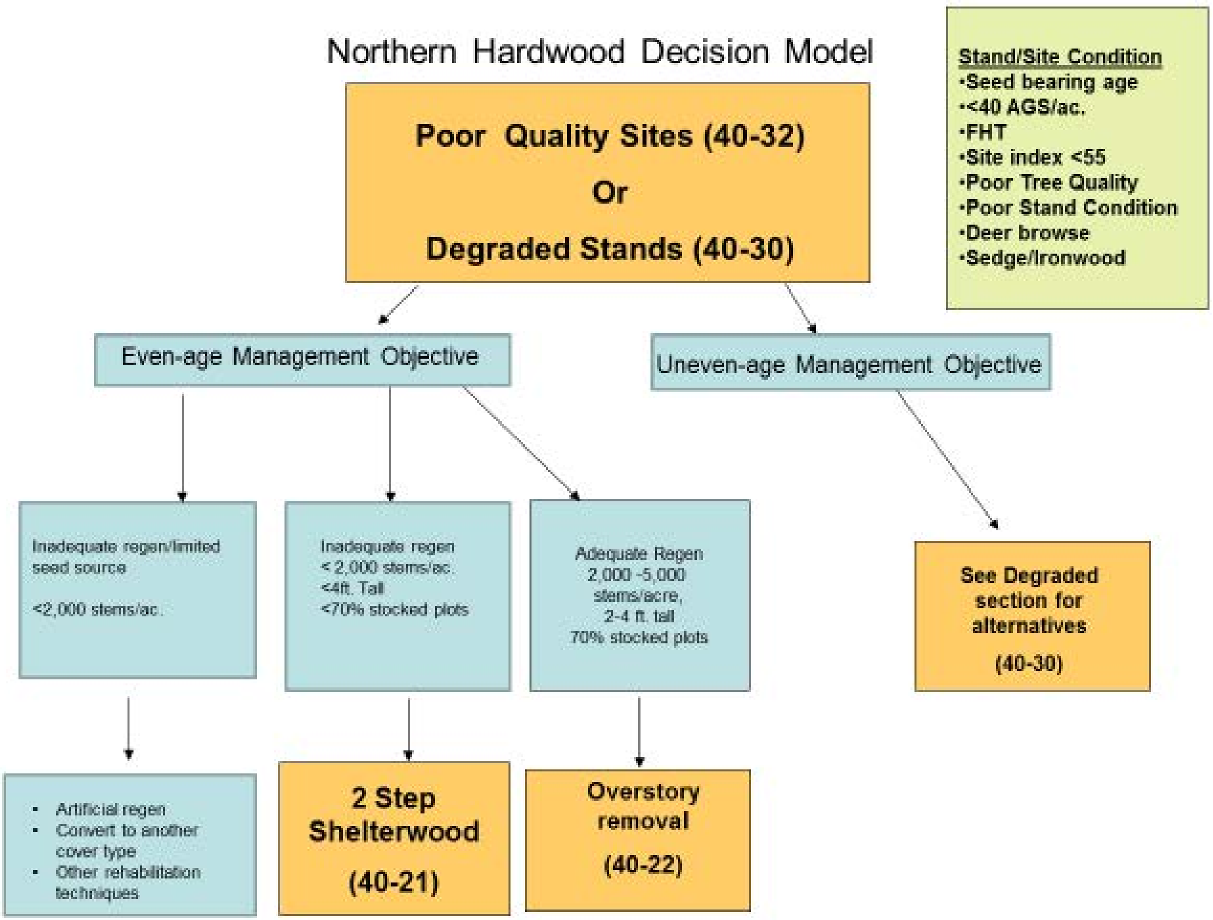


Figure 40.3. Decision model for poor quality or degraded stands.

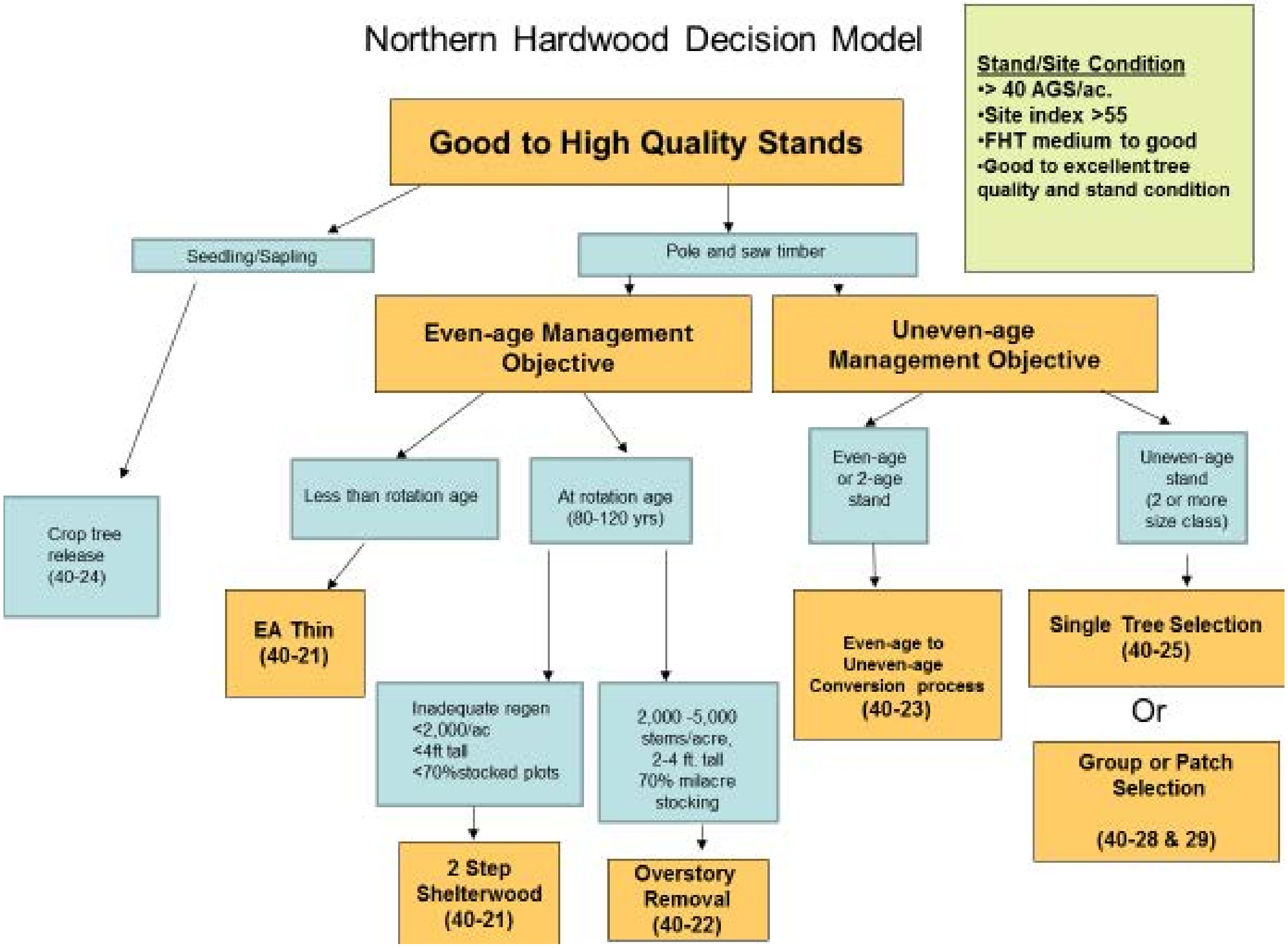


Figure 40.4. Decision model for good to high quality stands.

5 SILVICULTURAL SYSTEMS

Uneven-aged (sometimes called all-aged) silvicultural systems are commonly recommended for the management of northern hardwood. Even-aged silvicultural systems may also be utilized to produce high quality products and to encourage mid-tolerant species that can increase tree species diversity and improve production on poor quality sites. Intermediate treatments are used to promote quality stem development and stand vigor. The generally accepted natural regeneration and management alternatives include (Table 40.10):

- Single-tree selection (uneven-aged)
- Group selection (uneven-aged)
- Patch selection (uneven-aged) – conditionally recommended
- Shelterwood (even-aged)
- Overstory removal (even-aged)

5.1 Seedling / Sapling Stands

Following establishment, seedlings/saplings have potential to exhibit optimal growth and quality. To ensure full stocking while developing stem quality, the stocking of desirable species should be a minimum of 2,000 - 5,000 per acre of well distributed seedlings >3' tall (Erdmannn 1986). Early in sapling development, natural pruning of lower limbs minimizes forking and maximizes quality of potential AGS trees. Cultural practices, such as weeding and other release treatments in sapling stands can improve stand composition and growth. Marquis *et al.* (1992) recommends precommercial thinning only if valuable stems are overtopped by poor quality individuals.

Release treatments may be implemented in young stands of northern hardwood to enhance growth on potential AGS and to eliminate competition from undesirable species. Increased bole lengths can be achieved with natural pruning due to increased stem density. Release of yellow birch can significantly improve growth and survival in young (10-20 year old) even-aged stands (Hutchinson 1992). For best growth and quality, 10-year-old shade tolerant AGS should be cleaned to an 8-foot radius around their boles (5 foot beyond their crown (Erdmannn 1986). Stump sprouts should be thinned early before potential AGS reach 3 inches in diameter. Leave one to two sprouts per clump, as widely spaced as possible. Individual sprout characteristics to favor include low sprouts originating less than six inches above ground, U-shaped stem attachment, well developed crown, large size, good form, and healthy (Hutchinson 1992).

In many situations, existing seedling/sapling stands do not contain sufficient numbers or adequate size of preferred species. One option is to consider altering stand objectives to accept a less desirable species composition. Changing markets (e.g., aspen, red maple) and landscape species dynamics (e.g., emerald ash borer) often alter our understanding of how desirable species are defined. Another option is to interplant the stand with desirable species. Interplanting or "enrichment planting" is often used to establish or increase the number of desirable species in degraded stands. This approach may also be used to introduce genetically superior hardwood (Clatterbuck 2006). Mechanical or chemical competition control will improve the long-term survival and viability of planted trees.

5.2 Intermediate Treatments

5.2.1 Stem Quality

The development of individual stem quality (and ultimately financial value) in northern hardwood stands is paramount for many timber management objectives no matter which silvicultural system is utilized. Managing for quality is a long-term process functioning at both the stand and individual tree level. It is important at all stages of stand and tree development.

Multiple stand and tree-level factors influence stem quality. The quality of a hardwood stem is determined by its size, form, and the imperfections or defects that impact the useable wood. Foresters should attempt to understand these factors and use silvicultural practices to positively influence stem quality development over the entire life of a stand.

<u>Stand-Level Factors</u>
Stand-level factors that influence stem quality can include site quality, species composition, stand history, stand structure, and stand density. Northern hardwood occur over a wide range of sites in Wisconsin and the potential to grow quality stems will vary by site capability and species. What constitutes the ideal tree in one location may not be achievable on a different

site. Species composition can influence stem quality too. Shade tolerant species, like sugar maple, generally have the greatest number of defects, while faster growing mid-tolerant species, like basswood, ash, and northern red oak, have fewer defects and less forking (Godman and Books 1971; Erdmannn 1986). The forest habitat type classification system can help to assess the relative growth potential of individual northern hardwood species across sites. Habitat type is often a more reliable tool to assess site capability than site index, especially in uneven-aged stands where accurate site index determination is not possible. The current stem quality within a stand may not be a good indicator of site capability either. Many stands in Wisconsin have a history of damaging agents such as grazing, insects, disease, ice, wind, and poor harvesting practices that have degraded stem quality.

Stand density and structure are important factors controlling stem quality in northern hardwood due to their influence on main stem forking and epicormic branching. During the seedling and sapling stage, high numbers of stems per acre (e.g., 2000-5000 stems/acre) help limit stem forking and improve long-term quality prospects. Replicated studies for northern hardwood management practices related to density and structure have been conducted on the USDA Forest Service, Argonne and Dukes Experimental Forests. One such study (i.e., Cutting Methods Study) in place for over 60 years has tested alternative residual basal areas under uneven-aged management of 60, 75, and 90 ft^2/acre in trees ≥5” DBH. Marking focused on harvesting in all overstocked size classes based on uneven-aged principles and the order of removal developed by Eyre and Zillgitt (1953) and Arbogast (1957). To date, seven harvests have been implemented and data recorded on each treatment. The 75 ft^2/acre treatment provided the best balance between adequate diameter growth and tree grade improvement (Erdmannn 1986; Strong *et al.* 1995; Kern *et al.* 2014). Repeated cuts to residual basal areas of 60 ft^2/acre or less reduced stem quality and potentially reduced merchantable log heights, while residual basal areas of 90 ft^2/acre or greater reduced diameter growth rates. Other studies have reported similar density recommendations for single-tree selection systems in northern hardwood, generally ranging from 60-90 ft2/acre in trees ≥5” DBH (Arbogast 1957; Kern *et al.* 2014; Leak *et al.* 2014). Stand structure or diameter distribution also influences stem quality. While quality northern hardwood can be grown under both even and uneven-aged systems, uneven-aged management results in greater merchantable log heights for shade tolerant species like sugar maple (Erdmannn 1986).

<u>Tree-Level Factors</u>

Tree-level factors that influence stem quality include both tree vigor and stem defects. Vigor can be defined as healthy, well-balanced growth or the relative capacity of a tree to increase in size (Ontario Ministry of Natural Resources 2004). Trees that exhibit vigorous growth and the ability to rapidly increase in size generally have less forking, greater merchantable heights, and fewer branch related defects (Erdmannn 1986). Foresters should assess the potential vigor of a tree by evaluating characteristics such as crown class, crown silhouette, live crown ratio, foliage condition, and bark characteristics and then use these traits to select crop trees that have the highest potential for future growth and value. Epicormic branching is an example of a defect that is vigor related. Epicormic branch sprouts originate from dormant buds embedded in the bark of many hardwood species. Bud dormancy is controlled by growth regulators (auxins) which are produced by the terminal buds. Trees lacking a healthy, vigorous, and large crown, such as suppressed and intermediate trees in the understory or crowded overstory trees in unmanaged, even-aged stands, do not produce sufficient regulators to prevent epicormic sprouting. Some intermediate and co-dominant trees may develop epicormic sprouts after the stand is first thinned. (Erdmannn 1986; Hutchinson 1992). More information on evaluating tree vigor can be found in Chapter 24 of the Silviculture Handbook.

Stem defects can include deviations from normal stem form (i.e., sweep and crook) and imperfections that impact the slab zone, quality zone, or heart center of a log (e.g., forks, knots, seams, rot, stains, holes, etc.) (Carpenter *et al.* 1989). Common northern hardwood defects include, but are not limited to:

- **Forking** can affect all northern hardwood but is most common in opposite-branched species such as maples and ashes. Forking not only is a stem defect, but it increases the risk of crown or stem breakage. Forking is often caused by an insect called a bud miner which is present in stands from the seedling stage through maturity. Forks are less common in uneven-aged stands than in even-aged stands. Fork correction occurs continually in uneven-aged stands due to taller overstory trees shading out part of the fork. For this reason, uneven-aged stands can generally develop greater merchantable log heights. In even-aged stands fork correction occurs when shade from crowns of adjacent trees causes one side of the fork to lose vigor and the other to acquire dominance. Even-aged stand density should be maintained at or above recommended residual levels to correct forks. Thinning stands heavy to sugar maple prior to 40 years of age or below recommended stocking levels will cause forks to increase in size and increase the time required for correction.
- **Sugar maple borer** is a long-horned wood boring beetle causing defect due to larval galleries and associated wood discoloration and decay. Maple borer damage can be mitigated by maintaining well-stocked stands and removing over mature, low-vigor trees.
- **Seams and cracks** are splitting or separation of the bark extending into the wood and can be open or overgrown with callus tissue. They can be found on all northern hardwood species, but are most common on ash, yellow birch, and sugar maple. Open cracks are more likely to be associated with significant decay and discoloration and have a large negative influence on tree value (Havreljuk *et al.* 2014).
- **Cankers** are localized areas of dead bark and cambium, commonly caused by fungi that infect wounds. Large cankers are often associated with significant decay and discoloration, especially if conks (fruiting bodies) are present.
- **Epicormic branches** are shoots arising from dormant buds on the stem of many northern hardwood species, often following sudden exposure to increased light levels. Trees lacking healthy, vigorous, large crowns are most susceptible. Some species, such as northern red oak and American beech, are also more prone to epicormic branching.
- **Wounds** are any injury to a tree that exposes the cambium or wood beneath the cambium. Wounds can be caused by mechanical damage, fire, animals, birds, or insects. Careless felling in well-stocked stands can result in numerous wounds and be the entry points for further insect and disease damage. The significance to stem quality and value will depend on the tree species, age and size of the wound, causal agent, and other factors.
- **Dark heart** refers to a dark stain or discoloration that forms in the center of sugar maple trees. Large heartwood discoloration is a serious defect because it reduces the amount

of light-colored wood that gives maple its commercial value. The discoloration at the center of sugar maple trees is caused by injury which allows fungi or bacteria to enter (Germain *et al.* 2015). The amount of heartwood discoloration in standing sugar maple trees is difficult to predict and will vary based on the time since injury and the ability of the tree to compartmentalize the injury.

- **Armillaria Root Disease** is caused by a root rot fungus (*Armillaria* spp.) that can infect trees stressed by drought, multiple defoliations, and other factors. Trees declining due to armillaria should generally be harvested before decay and mortality occur.

Multiple resources for defect identification, impacts, and prevention are available in the forest health section of this chapter, as well as in USFS Agricultural Handbook No. 678 – Defects in Hardwood Timber (Carpenter *et al.* 1989).

<u>How to Assess Current and Potential Stem Quality</u>
Foresters must be able to evaluate individual trees and stands of trees for their current and potential stem quality to develop prescription alternatives and make informed marking decisions. Two common types of systems that evaluate standing trees are tree grade and growing stock classification.

The **hardwood tree grades** developed by Hanks (1976) are often utilized as a standard measure for timber product stem quality, although numerous other grading systems exist (Table 40.9). Hank's tree grades evaluate the current <u>standing</u> tree quality in the butt log to help predict lumber grade yields or simply to quantify tree quality in a forest inventory (note- they are not used to appraise value due to variability in timber markets). Tree grading does not help evaluate the quality potential in smaller diameter trees.

Growing stock classification systems are field tools designed to help foresters assess and rate individual trees based on their quality, risk, and vigor characteristics. Information on the growing stock class, in combination with other crop tree selection and silvicultural prescription criteria, can be used to guide both the selection of cut/leave trees, as well as inform stand-level assessments of growing stock quality. Growing stock classification systems do evaluate the potential of smaller diameter trees to increase in volume, form, quality, and value. A Growing Stock Classification for Timber Management field tool is provided in Chapter 24 of the Wisconsin Silviculture Guide. Past versions of the northern hardwood chapter referred to "crop tree" using the definition adapted from The Lake States Manager's Guide for Northern Hardwood (USDA 2005). This new version will use of the term "AGS" in place of crop tree following the Growing stock classification system guidance in Chapter 24.

Table 40.9. Hardwood tree grades for factory lumber (Hanks 1976).

Grade factor	Tree grade 1			Tree grade 2		Tree grade 3
Length of grading zone (ft.)	Butt 16			Butt 16		Butt 16
Length of grading section (ft.)	Best 12			Best 12		Best 12
DBH, minimum (in)	16			13		10
Diameter, minimum inside bark at top of grading section (in)	13	16	20	11	12	8
Clear cuttings (on best 3 faces)						
Length, minimum (ft.)	7	5	3	3	3	2
Number on face (maximum)		2		2	3	Unlimited
Yield in face length (minimum)	5/6			4/6		3/6
Cull deduction, including crook and sweep but excluding shake, maximum within grading section (percent)	9			9		50

5.2.2 Thinning

Thinning is an intermediate treatment applied in northern hardwood stands. Use thinning until rotation aged is reached, in stands which will be managed on an even-aged basis or as part of the even-aged to uneven-aged conversion process. In the appendices, there are two optional even-age stocking charts to reference when determining target residual stocking. (Strong 2005) modified a chart that depicts stocking levels represented by trees per acre and Leak *et al.* (2014) developed a chart that depicts target stocking levels represented by relative density.

When thinning stands, determine which trees to favor (future growth) and which trees to cut by following the recommended sequence of removal (also see Chapters 23 and 24 for discussion). This sequence will often vary depending on landowner goals, stand management objective and the silviculture treatment:

1. Risk – Cut high risk of mortality, failure or loss of quality/value
2. Release acceptable growing stock (AGS) trees
3. Vigor – Cut low vigor trees
4. Adjust residual stand stocking to improve stand growth:
    - Remove poor stem form and quality
    - Remove less desirable tree species
    - Improve spacing

<u>Pole-Sized Stands (Avg. DBH 5-11”) (adapted from Erdmann 1986)</u>

- Don’t thin stands dominated by sugar maple until at least 40 years old to prevent low merchantable log heights.
- Full crown release (approximately 7’) of 40-60 AGS per acre. Leave an adjacent tree crown to shade and correct small forks (<2”) if needed.
- Thin through remaining stand. Use stocking charts and tables (in the appendices) to determine target residual basal area.
- If first thinning and average DBH 5-9 inches, then reduce stocking level to 80% crown cover and wait until crown closure and lower branch mortality on AGS before the next thinning (possibly 20 years).
- If second or later thinning or if average DBH >9”, then reduce stocking level to 90% crown cover and wait 10-15 years until crown closure and lower branch mortality on AGS before the next thinning.

<u>Sawlog-Sized Stands (Avg. DBH >11”) (adapted from Erdmann 1986)</u>

- Partial crown release (1-3 sided) of 40-60 AGS per acre (see Chapters 23 & 24)
- Thin through remaining stand to stocking level at 90% crown cover
- Wait 10-15 years for next thinning.

5.3 Natural Regeneration Methods

Management recommendations include generally accepted methods to convert northern hardwood stands from an even-aged to an uneven-aged (single-tree selection) system. The *conversion process* requires specific stand manipulation techniques that are implemented over a long-term period. In addition, recommendations on managing degraded northern hardwood stands and stands on poor quality sites are addressed later in this chapter. The *conditional recommended method* (patch selection) refers to a method applied to stands that meet a given condition such as having advanced regeneration present. For further consideration, there are alternative management methods mentioned later in the chapter. Comparison of the characteristics of the even-aged and uneven-aged management systems is provided in Table 40.11

Table 40.10. Recommended natural regeneration methods.

Forest Cover Type	Coppice	Clearcut	Seed Tree	Overstory Removal	Shelterwood	Group Selection	Patch Selection	Single-Tree Selection
Northern Hardwood	NR	NR	NR	R	R	R	CR	R

R- Recommended; CR – Conditionally Recommended; NR- Not Recommended

Table 40.11. Comparison of relative characteristics between even-aged and uneven-aged (single-tree selection) silvicultural systems on good to excellent sites (USDA 2005).

Even-aged	Uneven-aged (regulated)
Requires a rotation, with the elimination of the previous stand and establishment of a new stand	Continuous maintenance of a mature and structurally diverse forest
Provides opportunity for less shade tolerant species when combined with seedbed preparation	Favors shade tolerant species, especially sugar maple
Requires a different basal area target for every thinning depending on average tree diameter and species composition	Basal area target remains constant for every entry (thinning, harvesting, and regenerating at each entry)
Removes many small trees in each thinning	Removes fewer trees and larger trees at each entry
Early thinnings are all pulpwood and could be economically marginal	Timber products are mainly sawlogs with a small amount of pulpwood
A half to two-thirds of periodic growth can be sold while stocking is building	Nearly all the volume growth at each entry can be sold once the stand is regulated
Butt rot, resulting from winter sunscald of 1-3-inch diameter saplings on exposed sites, can reduce volume and grade in sugar maple and other species	Sunscald rarely occurs
Merchantable height will usually be less than two 16-foot logs in sugar maple	Merchantable height can be two to three 16-foot logs in sugar maple due to fork correction
Ideal for fiber production. Can produce high yields of high-quality logs of mid-tolerant species	Produces the optimum balance of quantity and high-quality logs in tolerant species such as sugar maple
Provides excellent habitat during the first 10-15 years of stand development for wildlife that prefer dense cover and browse	Provides increased structure favorable for some wildlife

5.3.1 Even-Age Regeneration Methods

5.3.1.1 Shelterwood

The shelterwood regeneration method is used to manipulate the overstory to create conditions favorable for the establishment and survival of desirable tree species. The shelterwood regeneration method is described in Chapter 21- Natural Regeneration. In northern hardwood stands, shelterwood should be considered for regeneration of even-aged stands or degraded stands (regardless of age structure), or to convert to another cover type.

The shelterwood method is comprised of multiple steps:

- preparatory cut (optional)
- seed or seeding cut
- overstory removal.

The preparatory cut is applied to increase tree vigor, crown area, and seed production. The preparatory cut is optional and it may not be needed if seed sources are well developed and spaced appropriately.

The seeding cut alters crown cover and spacing, ideally leaving a high, uniform crown cover (50-70%) in the residual overstory. A uniform residual stand is often difficult to achieve in the field as the desired and acceptable seed sources may be irregularly located. When marking the seeding cut, the crown area of target leave trees should be considered. Crown area can vary substantially between diameters and species. A useful tool to help determine and achieve target crown cover is the shelterwood calculator located on the WDNR internet site. Once the target crown cover is determined, it is recommended that leave trees are marked to target crown cover. Desirable leave tree characteristics include dominant/codominant crown position, mature seed producer, desirable species, good form, vigor and quality. Greater residual crown cover may be necessary if severe competition from interfering vegetation is anticipated. Lesser crown cover is recommended when mid-tolerant species are included in desired regeneration.

Additional considerations while using this method include site prep, timing and undesirable vegetation (scarification, mowing, or herbicides). Site preparation can be useful in a variety of situations such as lower quality hardwood; stands with an oak component; or when interfering vegetation is a problem. Also consider timing the seed cut and site preparation to production of good seed crops. Once regeneration objectives are achieved, overstory removal method is the next step in this process described in the following section.

5.3.1.2 Overstory Removal

Overstory removal is an even-aged regeneration method where the canopy is removed, placing advance regeneration in a “free to grow” position. Overstory removal is typically applied when a stand is degraded or mature and adequate desirable regeneration is present.

Sufficient established regeneration is required prior for overstory removal. For northern hardwood stands, regeneration is considered “established” when seedlings reach a height of 2’-4’ tall. On some sites there may be exceptions due to deer browse or site quality. If deer browse is a problem, consider removing the overstory when regeneration is taller than 4’ tall. Poor quality sites might require regeneration up to 15’ tall, however, consider the potential of damage to the tall regeneration from harvesting.

Sufficient well distributed, established regeneration of 2,000 to 5,000 stems per acre or more is optimal prior to overstory removal. See Chapter 21 – Natural Regeneration for further information regarding adequacy of regeneration. Post-harvest, no more than 10% residual overstory crown cover is recommended to avoid a reduction in regeneration growth. Sufficient regeneration is not always achievable, especially in degraded stand situations or on poor quality sites. In these instances, the forester may consider other treatments such as supplemental planting or forgoing treatment.

Many factors can affect overstory removal success. To minimize damage to established regeneration, harvesting during the dormant or late growing season with frozen or dry soil conditions is optimal. Regeneration which is hardened off is more apt to respond positively if damaged. Regeneration may be further protected with snow cover. The lack of leaves in the overstory also helps prevent the “fly-swatter effect” damaging seedlings and saplings as trees are felled.

Equipment operators play a pivotal role in the success of overstory removal. A conscientious operator can limit understory damage to main operational corridors and areas where multiple trees can be processed. Regardless, some damage and loss of existing regeneration will occur. A forester needs to monitor and evaluate the above considerations to be certain that overstory harvest will be successful.

5.3.2 Uneven-Age Regeneration Methods

5.3.2.1 Single-Tree Selection

Single-tree selection has been widely prescribed for the northern hardwood cover type in Wisconsin since at least the 1950’s (Eyre and Zillgitt 1953; Arbogast 1957). Commonly prescribed across Federal, State, County, and private lands, single-tree selection offers several advantages when considering options for northern hardwood management:

- Steady, periodic harvests of timber
- High quality sawtimber production
- Mitigation of aesthetic and ecological concerns associated with timber harvests, maintenance of continuous canopy cover.

For single-tree selection to be effective it must first be appropriate. Single-tree selection is broadly applicable for uneven-aged northern hardwood stand management assuming the following conditions are met:

- The site is dry-mesic or mesic, capable of quality sawtimber production
- Two or more age/size classes are present
    - Note: foresters should not assume that smaller diameter size classes are necessarily different age classes. At first glance many stand diameter distributions have a reverse J-shape and appear to support the use of single-tree

selection. This can be deceptive. Two examples, stands with reverse J diameter distributions that are not uneven-aged, are:
    - even aged stands with a component of fast-growing shade intolerant trees overtopping northern hardwood
    - stratified northern hardwood stands where size classes stratify and linger as intermediate and suppressed trees

  - A quick way to differentiate between stratified and uneven-aged stands is to examine the following questions:
    - Does the live crown ratio average 45%-60% in all size classes? If "no" then the stand is likely even-aged, and conversion may be more appropriate (Nyland 2017).
    - Does the stand present a "green wall" of regeneration, not a "naked" understory? If "no" then the stand is likely even-aged, and conversion may be more appropriate (Nyland 2018).

- Are current age/size classes of sufficient quality to assume they will maintain or improve in quality? This is especially important for smaller age/size classes as a lack of smaller age/size class quality will lead to a lack of larger age/size class quality over multiple entries.
- Can regeneration be successfully established or released with each stand entry?

With single-tree selection, diameter distributions are commonly used to describe current stand structure. In North America, some of the earliest work regarding single-tree selection and diameter distributions was conducted in Lake States uneven-aged northern hardwood stands (Eyre and Zillgitt 1953; Arbogast 1957). This effort led to northern hardwood stand structure recommendations for sustained yield of high-quality products known popularly as the "Arbogast Curve". Unique among single-tree selection structural recommendations, this work has been tested and verified through long term, replicated, research studies at The Dukes and Argonne Experimental Forests (Eyre and Zillgitt 1953; Arbogast 1957; Crow *et al.* 1981; Strong *et al.* 1995). A recommended residual stand structure is presented in the tables found in the appendices. Here they provide alternatives for scenarios where different maximum diameters or cutting entry intervals may be appropriate. This is not an exhaustive or complete list. Based on differing stand conditions and landowner objectives, other maximum diameters, residual basal areas and diameter distributions may be appropriate as well.

For northern hardwood stands managed with the single-tree selection method; regeneration, tending, and harvesting occur at each stand entry. Using current stand information, management involves moving the current stand closer to a predetermined set of target stand conditions. These conditions are summarized as BDq:
- Residual basal area (B): Commonly ranges between 60-90 ft^2 / acre
- Maximum tree diameter (D): Regularly ranges between 18" – 24"
- Target diameter distribution (q): Both the Arbogast Curve and q factors 1.3 – 1.5 are frequently used.

Stands are moved closer to their target condition by harvesting trees singly or in small clusters, maintaining or improving the residual stand while creating regeneration openings (canopy gaps). The key is in balancing productivity and quality. To aid foresters with implementation of single-tree selection, the following guide is adapted from Arbogast 1957 and T. Strong (USDA 2005):

- With current stand information in hand, identify a target residual basal area, diameter distribution, and maximum stand diameter per the BDq method. Utilize at least three size classes. Table 40-10 outlines recommended BDq targets with broad application in Wisconsin. Alternative BDq targets based on differing stand conditions and landowner objectives may be appropriate as well.
- Calculate the difference between target and actual stand conditions. This identifies both where (i.e., size classes) harvest priorities occur as well as how much (i.e., trees per acre, basal area, volume) to remove. Table 40.12 illustrates one method to quantify the difference.
    - In overstocked size classes, remove the lowest quality trees to achieve the recommended target density. Tree selection should be based on recommended removal or retention criteria.
    - In understocked size classes, remove only high-risk trees. To compensate for understocked size classes, additional basal area may need to be left in other size classes to the target stand condition.
        - Failure to recognize the importance of harvesting based on size class or basal area targets can lead to unintended consequences. If too few trees are retained, future yield and quality may be diminished due to low stocking. If too many trees are retained, regeneration can be compromised through insufficient disturbance.

- Repeat cutting on 10-20 year intervals (depending upon stand growth and volume requirements for operability).

Previous View

Table 40.12. Example NH single-tree selection worksheet with targets of 85 ft^2, The Arbogast Curve, and a 24" maximum diameter.

			Current Stand		Residual Target					
	DBH	BA/tree	Total trees	Total BA	Target Trees	Target BA	Tree Difference	BA Difference	Harvest Ratio	Harvest BA
Poles	6	0.2			36.00	5.8				
	8	0.3			21.00	6.3				
	10	0.5			15.00	7.3				
		Class Total			72.00	19.4			**1 out of X tree(s)**	**XX BA**
Sm. Saw	12	0.8			11.00	7.9				
	14	1.0			10.00	9.9				
		Class Total			21.00	17.8			**1 out of X tree(s)**	**XX BA**
Lg. Saw	16	1.3			8.00	10.5				
	18	1.7			6.00	10				
	20	2.1			5.00	10.3				
	22	2.3			4.00	10.1				
	24	3.0			2.00	6				
		Class Total			25.00	46.9			**1 out of X tree(s)**	**XX BA**
Larger than maximum DBH	26	3.6			0.00	0				
	28	4.1			0.00	0				
	30	4.7			0.00	0				
	>30	5.0			0.00	0				
		Class Total			0.00	0			**1 out of X tree(s)**	**XX BA**
		Total			118.00	84.1				

Target residual basal area, maximum tree diameter, and diameter distribution are all flexible in application. The goal is to move closer to the target residual criteria. Using BDq targets provides a set of guidelines, rather than a strict regime for sustained yield regulation and is not intended to be rigid.

When choosing stand structure targets, foresters should keep the following points in mind:

1. The target residual structure and density should reflect a landowner's management goals and objectives.
2. The residual density and maximum diameter should be consistent with the intended cutting cycle length, with less residual stocking and smaller maximum diameters for longer cutting cycles.
3. The residual structure should provide an excess of trees to cut from across the diameter distribution at the end of each cutting cycle to insure consistent yields at regular intervals over multiple entries.
4. The choice of an appropriate set of targets must provide an attractive cut of salable material and ensure a good return on the investment of management if the enterprise has commercial objectives (Nyland 1986).

Recruitment of regeneration with single-tree selection occurs when openings or "canopy gaps" are created. Canopy gaps for regeneration (25-75' diameter) are created when large-crowned trees are harvested. Gaps serve to either release established regeneration or recruit a new cohort of seedlings. In stands where trees have not yet reached the maximum diameter, clusters of trees can be removed to mimic maximum diameter tree removal. Variation in canopy gap size (Table 40.13) can also promote a greater diversity of mid-tolerant species

(Strong 1998; Webster and Lorimer 2005). Since many stands contain a suppressed sapling component, cleaning gaps by cutting all poor-quality stems greater than 1" DBH may be appropriate.

5.3.2.2 Group Selection

Group selection is a feasible natural regeneration method over a wide range of sites, from dry-mesic to wet-mesic and nutrient medium to rich. This method tends to promote increased species diversity in northern hardwood stands as compared to single-tree selection. It is particularly useful for promoting species less tolerant of shade including yellow birch, northern red oak, basswood, red maple, white pine, and black cherry.

With group selection, clusters of trees are selectively or systematically removed to create regeneration openings (groups). Groups range in size from 0.1– 0.5 acre. (see Chapter 21, Natural Regeneration Methods). Factors affecting placement and size of a group include stand management objectives, current stand structure, stand quality, vigor, slope/aspect, competing vegetation and the silvics of desired species. The larger the group, the greater the potential representation of mid-tolerant and intolerant regeneration. In application, group openings are cleaned of UGS stems down to one inch in diameter. The number of groups and individual group "rotation length" are dependent upon landowner objectives, current stand age, stand condition, and stand area. Groups can be installed where tree quality is poor, trees are mature, or where adequate established regeneration is present. Groups often require site preparation or the release of preferred species regeneration. Thinning or tending may occur throughout the remainder of the stand. On steep topography, group selection is commonly employed without thinning or tending in the remainder of the stand, due to harvesting limitations.

Group selection generally achieves regulation utilizing area control, whereby a designated percentage of the stand is harvested in groups during each cutting cycle. When considering regulation of the stand assess the current stand age, desired rotation length, and the percentage of stand area to harvest at each entry.

5.3.2.3 Patch Selection

An alternative to group selection is patch selection. With patch selection, trees are periodically removed to create regeneration openings .5 – 2 acres in size. Unlike group selection, patch selection is only advisable when releasing established regeneration, not initiating regeneration. The spatial distribution of regeneration openings may be regular, or irregular as dictated by variations in stand condition, such as the age, size, vigor, quality, composition, and health of patches of trees. Patch selection is a conditionally recommended method, in that, advanced regeneration should be present before the method is applied.

There are some considerations, however, to patch selection. The size of the opening produces variable effects. The larger the group, e.g., 2/3 acre or larger, the more shade intolerant species can establish post-harvest such as aspen, pin cherry, paper birch, raspberry (Kern *et al.* 2017) and elderberry. Some of these species could be undesirable competitors. Foresters should also consider factors such as desiccation or stand drying once the overstory is removed. This can inadvertently result in the loss of advance regeneration.

5.3.2.4 Irregular Shelterwood

Stand age structure and cohorts are distinguishing characteristics in defining even-aged vs uneven-age stands. The main contrast is that even-age stands have trees of the same age class and uneven-age stand containing at least three age classes (Erdmannn 1986; Smith *et al.* 1997; Nyland 2003). However, intermediate structures with variable stand features have been widely acknowledged. The question arises on how to emulate that structure using a silviculture method.

Irregular stand structure usually develops from episodic or partial disturbance leaving behind a residual stand with variable sizes; several or grouped cohorts; diversity of species composition and spatial heterogeneity (Raymond *et al.* 2009). This variability has been recognized having ecological significance by providing diversity for a wide variety of species and known for encouraging growth on the most valuable trees.

One silviculture method to emulate this type of variability is irregular shelterwood. Although descriptions of this method vary, the common objective is to establish a new cohort that may be composed of mid-tolerant and tolerant species in the northern hardwood cover type. In addition, another characteristic of this method is having a longer or indefinite regeneration period than the regular (two step) shelterwood method described above. Earlier in this chapter we explained the (Femelschlag) expanding gap, irregular shelterwood method but other variants include *continuous cover* or *extended irregular shelterwood*. The intent is to create and release larger groups of multiple cohorts and have variable densities across the stand instead of the uniform spacing of residual seed trees in regular shelterwood method. In addition, longer retention period of residual trees is encouraged to prevent undesirable species and encourage a longer period of growth on the most valuable trees.

<u>Variations on the Method</u>
An uneven-aged variant to shelterwood is the expanding gap system, often described as at type of irregular shelterwood or “femelschlag.” Irregular refers to the potentially unbalanced distribution of age classes, arrangement of trees and the variable production of forest products. Like group and patch selection, the expanding gap system utilizes an uneven-aged, area control approach. Initial stand entries create openings to establish or release established regeneration. With this and subsequent entries, the margin of the opening may be modified (thinning, midstory removal, etc.) to release or establish desirable regeneration. Since the margin is modified by the presence of the opening itself, margin modification may not be necessary in all situations. At subsequent entries, established regeneration in the margin is released via overstory removal and a new margin is assessed for potential modification. With this method, the opening is gradually enlarged in concentric rings until the stand is completely harvested. Reserves may be utilized to further enhance structural diversity but are not required.

5.3.2.5 Even-aged to Uneven-Aged Conversion Process

Many northern hardwood stands in Wisconsin are even-aged and not regulated. They often lack several size classes, especially the seedling/sapling size class, due to a number of factors including closed canopy conditions, past stand management (thinning from below) and other regeneration limiting factors. Stands that are even-aged or two-aged may be converted to uneven-aged management by combining AGS release, even-aged thinning and canopy gap installation. Application of the conversion process will create stand conditions which initiate or release regeneration, improve stand quality, and develop a diverse diameter distribution. Modified to incorporate large gaps, it can encourage tree species diversity.

Key components of the even-aged to uneven-aged conversion process include installation of canopy gaps, crown release of acceptable growing stock (AGS) and thinning throughout the remainder of the stand. The recommended procedure to convert or adapt even-aged stands to single-tree selection is adapted from Argonne Experimental Forest studies, (USDA 2005; Erdmann 1986):

First Entry into Even-Aged Stand
Create canopy gaps and apply even-aged thinning with crop tree release:

Canopy Gaps: Create canopy gaps for regeneration on approximately 5-15% of the area at each entry. Gaps may be created by cutting large mature, defective and diseased trees or by removing groups of poor-quality poles. Canopy gaps may also be used to release desirable advance regeneration or be placed near a desirable seed tree. Undesirable regeneration and competing vegetation should be removed from the canopy gaps so that vigorous regeneration can develop from new seedlings or advance seedling or sapling reproduction.

Canopy gap creation may encourage species diversity. Smaller regeneration gaps generally favor shade tolerant species (sugar maple, beech, hemlock). Larger gaps may favor mid-tolerant species (e.g., yellow birch, white ash, oak) especially if placed near a potential seed tree. Site preparation may also be needed to reduce undesirable competing vegetation and prepare a suitable seed bed.

Canopy gaps >25’ in diameter are created when single large-crowned trees or clusters of trees are cut. Smaller gaps usually close quickly through crown expansion of dominant and codominant border trees and may reduce the recruitment of regeneration into the canopy (Goodbum 2004; Webster and Lorimer 2005). Smaller gaps tend to close within 10-12 years (WDNR 2003; Kern *et al.* 2017). Kern *et al.* (2017) suggest that regeneration may be enhanced if a variety of gap sizes and shapes are installed and by retaining biological legacies (snags, cavity trees, long lived conifers, coarse woody debris, etc.) within the gaps to enhance diversity.

Canopy gaps can be installed in a variety of ways (“on the fly,” grid system, random placement, other methods). Regardless of installation method it is important to ensure an adequate number of gaps, sufficient gap sizes to achieve objectives, and proper location by cutting large mature, defective and diseased trees, removing groups of poor-quality poles, or releasing desirable advance regeneration. Marking gaps in a different paint color may help identify gap location, where trees need to be harvested and where gap cleaning is necessary.

Table 40.13 references a wide range of canopy gap research (Erdmannn 1986; Leak 2004; USDA 2005; Webster and Lorimer 2005; Kern 2016) in North America. In addition to the size of gap, the table also summarizes the considerations of each size, referenced from the literature.

Table 40.13. Circular canopy gap sizes for regeneration in northern hardwood.

Diameter	Area (acres)	Considerations
25	0.011	Favors the most shade tolerant species; canopy closes quickly
30 - 40	0.016 – 0.029	Typical crown area of 18-26” DBH sugar maple trees (see Table 40.18).
50 - 60	0.045 – 0.065	For canopy recruitment of mid-tolerant species (Kern; Lorimer)
66	0.079	Preferred size for establishing regen and release of advanced regeneration
75	0.101	Small group selection. Potential for increased shrub competition. Consider site preparation and release needs.
118	0.251	Group selection (consider site preparation and release)
167	0.503	Upper range for group selection

Thinning: Apply even-aged thinning guidelines with crop tree release to the remainder of the stand. Select individual trees to retain considering their current and future bole quality. A critical consideration in marking the first entry is retaining and releasing trees that will increase in grade and merchantable height.

Some small pole-sized understory sugar maple trees in even-aged stands are the same age as the overstory trees but are slower growing. These intermediate and suppressed understory trees will reduce the future quality and value of the stand if retained for structure. Quality in the pole-size class can be improved by cutting heavily from below (closer to the B-line) when even-aged stands are first entered.

<u>Second Entry into Two-Aged Stand</u>

To facilitate the development of timber quality, the second cut should not be implemented until after crown closure and lower branch mortality occurs, possibly 15 to 20 years. The second cut should concentrate on improving basal area stocking in the uneven-aged target condition using the single-tree selection guidelines and developing quality small sawtimber. Create canopy gaps.

<u>Third and Fourth Entries into Uneven-Aged Structure Stands</u>

Depending on the stand conditions (determined by the stand assessment), it will probably require at least 3-4 cutting operations to develop a relatively well regulated and fully stocked (by size class) uneven-aged stand. Future entries may occur at 10 to 15-year intervals and should concentrate on improving basal area stocking in the uneven-aged target condition using the single-tree selection guidelines. Create canopy gaps.

The decision to switch over to the single-tree selection method after implementing the EA to UA Conversion Process may be based on several site/stand conditions. For instance, the stand could lack regeneration where further gap installation could be an option in future entries. Also, stand structure in various size classes could still be lacking and need further development in various size classes. In any case, a thorough stand assessment is recommended before deciding on a silviculture method.

5.5 Rotation Lengths and Cutting Cycles

Rotation Definition
In even-aged silvicultural systems a rotation is defined as the period between regeneration establishment and final cutting. The length of rotation may be based on many criteria, including culmination of mean annual increment (CMAI), target size, attainment of a physical or value growth rate, and biological condition.

Choosing an Appropriate Rotation Age
Selecting when to rotate a stand is based on multiple considerations, including landowner goals, stand condition, and expected future growth. The rotation ages provided are guidelines based on literature, empirical data, and professional experience. In application, foresters will need to regularly review stands in the field and exercise professional judgment concerning quality, vigor, mortality, merchantability, stand growth and productivity. Different rotation lengths can result in increased production of some benefits and reduced production of others, and landowner goals will help inform the evaluation of the benefits and costs (ecological, economic, social) associated with different forest management strategies.

5.5.1 Even-Aged Management

Northern hardwood are usually managed to produce sawtimber on sites where relative potential productivity is good to excellent (sugar maple SI>60). The recommended even-aged rotation to balance high quality development, high growth rates (vigor), and economic risk is 80-120 years. Rotations up to 150 years can be considered (on excellent sites), but volume growth rates may decline, and economic risk will increase. On poorer sites (sugar maple SI<55) and unmanaged stands, recommended biological rotation ages (CMAI) may be somewhat shorter (80-100 years), however expect reduced quality, reduced growth rates, and increased mortality. Conversely, economic rotation ages (maximum net present value) may be reached earlier on good quality sites as growth rates are higher and upper grades are achieved sooner. Individual trees and stands may maintain vigor longer or decline earlier than these rotation length guidelines indicate.

5.5.2 Uneven-Aged Management

Uneven-aged management rotates individual trees or groups of trees rather than entire stands. For northern hardwood stands managed with the single-tree selection method; regeneration, tending, and harvesting occur at each stand entry. Stand management involves moving the current stand closer to a predetermined stand structure, summarized by the BDq target (see Single-Tree Selection section). The target structure identifies a maximum tree diameter (D) where mature trees are rotated from the stand based on financial, ecological, or other objectives.

The selection of an appropriate stand structure and associated maximum tree diameter for single-tree selection is flexible depending on stand conditions and landowner objectives. Table 40.15 provides a recommended stand structure using the “Arbogast Curve,” which is the most tested and prescribed structure in the Lake States. Table 40.17 provides alternatives for scenarios where a larger or smaller maximum diameter may be appropriate based on stand conditions (e.g., poor quality sites) and landowner objectives (e.g., desired products, market considerations, extended rotation). See the Single-Tree Selection and Economic Considerations sections of this chapter for more detailed discussion on stand structure options.

In stands managed with uneven-aged management, the cutting cycle re-entry interval generally ranges from 8 to 20 years based on landowner objectives, site quality, stand growth, and operability. Shorter cutting cycles can maintain higher tree growth rates but operability due to lower available volume per acre must be considered. Shorter, more frequent re-entries may increase the potential for degrading stand quality through stem damage and soil compaction. Conversely, shorter cutting cycles will allow for capture of more high risk and low vigor trees succumbing to mortality. Longer cutting cycles can maximize tree quality and reduce negative impacts, such as damage to residual trees, soil compaction, aesthetic impacts (e.g., reduced slash), and ecological impacts (e.g., habitat disruption).

5.5.3 Extended Rotation

Extended rotation involves growing stands beyond typical biological rotation ages yet younger than average tree life expectancy, with the objective of managing for both commodity production and the development of some ecological and social benefits associated with older forests. Ecological benefits of extended rotations can include an abundance of large trees, more diverse vertical structure, and greater levels of standing snags and coarse woody debris that support organisms associated with these structures. In northern hardwood, extended rotations are most compatible with uneven-aged management.

Appropriate stand structures can utilize a 24-plus to 30-plus inch maximum diameter. Longer cutting cycles generally would be appropriate. Additional ecological management techniques may be applied, such as the retention of reserve trees, management of coarse woody debris (large snags and downed rotting logs), and the encouragement of coniferous associates (especially hemlock and white pine).

5.6 Other Silvicultural Considerations

5.6.1 Managing “Degraded” Stands

Degraded stands can broadly be characterized as having a structure and quality that is poorer than what is generally expected on similar sites. Degraded stands differ from poor quality stands on poor quality sites in that their degraded condition resulted from a past event(s), not site deficiencies. These stands often have trees that are crooked, rotten, and/or diseased.

They also may have undesirable species composition, variable stocking, physical damage from previous logging or poor growth rate, and may lack desirable regeneration. Degraded stands are found growing on all sites; the level of their degradation is a function of both site quality and intensity of the degrading event. Degraded stands do not contain large volumes or numbers of desirable growing stock (Clatterbuck 2006).

Many stands throughout Wisconsin have been “degraded” or reduced in stand quality due to a multitude of factors (events) including poor harvesting techniques such as high-grading and diameter limit cutting, grazing, fire, and other biotic and abiotic agents (disease, insects, wind, ice). Many of these stands have either an abundance of poor-quality stems or some poor-quality larger diameter stems overtopping a younger stand (seedlings, saplings, or poles).

Degraded stands are a financial liability and landowners face a heavy cost in lost production opportunities due to poor stocking, reduced quality and vigor of residual trees and reduced future revenues due to prior cutting of the most desirable trees (Nyland 2014). Alternatives for improving stand conditions through commercial logging are limited by low stocking, low value, and an abundance of undesirable or nonmerchantable species. Inadequate stocking compromises growth potential and could make continued management financially unattractive (Kenefic and Nyland 2005). Thinning is usually not economically feasible in degraded stands because of the lack of acceptable growing stock (AGS) (Clatterbuck 2006). This is especially true in southern Wisconsin with a lack of small diameter wood markets. Kenefic *et al.* (2014) found that precommercial treatments such as crop tree release, timber stand improvement and supplemental planting were unlikely to increase stand values enough to compensate for the high cost of implementing the practices. However, left unmanaged, degraded stands are unlikely to improve much (McGee 1982).

A thorough stand assessment is required to determine the cause of the degraded condition as well as the site quality, species composition, stand age, stand structure, advance regeneration, and amount of AGS (using the growing stock classification system in Chapter 24). Below in the Key to Recommendations section, are the NH assessment checklist and Decision model tools to help the forester with the decision process. Technical research on stand degradation has been presented in a few ways. Bédard *et al.* (2014) did not consider a stand degraded if at least 40% of stocking was acceptable. Clatterbuck (2006) and McGee (1982) stated that stands were not considered seriously degraded if they contain at least 50 sq.ft. of basal area of acceptable growing stock per acre.

At some point in the degraded stand history, a decision must be made to either regenerate or rehabilitate these stands. If a stand’s degraded condition is due largely to site deficiencies, then little will be accomplished attempting to rehabilitate this stand. (Clatterbuck 2006). Stands considered for rehabilitation should contain 30-50 sq. ft. of basal area of AGS per acre or about 40 to 50 small saw-log per acre (Clatterbuck 2006; Erdmann 1986) (Table 41.14). The acceptable growing stock range referenced here (e.g., 40-50 AGS/acre) was based on work conducted by Clatterbuck, Erdmann, and past WDNR silviculture guides. Stands with less than 30 sq. ft. of basal area of AGS per acre should be regenerated (Clatterbuck 2006, McGee 1982). Although useful, Clatterbuck’s research and recommendations were developed for southern hardwood stands and not in the Lakes States.

Table 40.14. Acceptable Growing Stock (AGS) guidelines for defining degraded stands.

Basal Area (sq.ft./ac) AGS		AGS Trees per acre	Condition	Recommendation
> 50 sq.ft. AGS		>50 AGS	Not degraded	Apply generally accepted silviculture methods
30-50 sq.ft./ac AGS	OR	40-50 AGS	Degraded	Rehabilitate or regenerate
< 30 sq.ft./ac AGS		< 40 AGS	Severely Degraded	Regenerate

<u>Even-Aged Management Objective – Severely Degraded (<30 sq. ft./ac. AGS or <40 AGS/acre)</u>

If a sufficient number of AGS trees are not present in the stand or landowner objectives are better met by even aged management, then the stand should be regenerated as soon as possible to improve future stand quality. The stand may be regenerated as soon as it reaches seed bearing age. Even-aged management systems using either shelterwood or overstory removal are the preferred management options:

- If good quality, established, advance regeneration is lacking (< 2000 stems/acre, 2-4 feet tall, 70% stocked plots), then follow the process to regenerate the stand utilizing the shelterwood system.
- If adequate good quality, established, advance regeneration is present (2000-5000 stems/acre, 2-4 feet tall, 70% stocked plots), then follow the guidelines for overstory removal.

Depending on species composition and the landowner's objectives, the stand could be considered for other treatment options:

1. Artificial regeneration following generally accepted practices (Chapters 21 & 22).
2. Conversion to another cover type.
3. Other rehabilitation techniques: Various irregular shelterwood techniques may be used to better meet landowner objectives with given stand conditions - shelterwood with reserves, Femelschlag, low density shelterwood (Leak *et al.* 2014; Lussier and Meek 2014; Bédard *et al.* 2014). See chapter 21 for more even-age options.

<u>Uneven-Aged Management Objective - Degraded (30-50 sq.ft /ac. AGS or 40-50 AGS per acre)</u>

Stand rehabilitation involves improving the existing stand by harvesting less desirable trees and retaining desirable growing stock and securing & protecting desirable regeneration. (Clatterbuck 2006). In degraded stands, group selection harvest is an acceptable alternative. To initiate group selection, create canopy gaps up to 0.50 acres in size located in areas of poorest quality trees. This will maximize removal of undesirable trees while creating conditions that promote regeneration. Thin between groups to a minimum desired residual basal area concentrating on releasing trees to improve residual stand quality.

Depending on present species composition and the landowner's objectives, the stand could be considered for other treatment options:

- Artificial regeneration following generally accepted practices (Chapters 21 & 22); conversion to another cover type or other rehabilitation techniques such as conversion EA to UA; or patch/group selection.

5.6.2 Managing Stands on Poor Quality Sites

Poor quality sites may not be suitable for producing quality northern hardwood sawtimber. These sites might have thin or sandy soils and droughty conditions or may be too wet. Poor quality sites will typically have a site index less than 50-55 and are often found in the dry-mesic and wet-mesic, nutrient medium habitat type groups.

Many of the recommendations and research on northern hardwood management are based on studies conducted on good to very good quality sites such as the Argonne and Dukes Experimental Forests. The recommendation developed from these research sites may not apply as well on poorer quality sites.

Poor quality sites are not expected to grow high quality hardwood trees. Suitable management for hardwood on these sites includes pulpwood, limited sawtimber, fuel wood and chipping (McGee 1982). If continued northern hardwood management is the goal, consider even-aged management to encourage increased representation of mid-tolerant associates. These species generally offer greater potential growth and timber quality on these sites.

Group selection methods with larger patch sizes (up to 0.50 acres) may also promote mid-tolerant species. Group selection on these sites may require site preparation and release to achieve adequate regeneration of mid-tolerant species.

Depending on present species composition and the landowner’s objectives, the stand could be considered for other treatment options:

- Artificial regeneration following generally accepted practices (Chapters 21 & 22).
- Conversion to another cover type.
- Manage stand for other uses such as wildlife, aesthetics, watershed protection.

6 PRESCRIPTIONS

6.1 Development of a Prescription and Marking Guide

A silvicultural prescription is a site and stand-specific operational plan that describes the forest management objectives and activities for an area. It prescribes a series of silvicultural treatments to establish or maintain a free growing stand in a manner that accommodates the landowner objectives such as economics, wildlife and biodiversity, aesthetic and other.

Prescriptions are developed through a series of steps before implementation of treatments in the field. The first step of development is the stand assessment as referred to the Northern Hardwood Checklist (Table 40.22) in the appendix. This information is then analyzed along with landowner goals. This series of diagnostic steps is to develop a desired future condition for the target stand being managed. Development of a silviculture prescription considers evaluating all the alternatives to achieve the desired future condition. The northern hardwood checklist and decision model can help in that process.

Once the silviculture prescription is completed, an appropriate marking guide for the stand should be developed before the implementation stage of the process. Achieving the objectives of a silvicultural prescription ultimately relies on decisions tree markers make in the stand. Often stand conditions when marking (e.g., stocking levels, species composition, forest structure) can be quite variable. Minor adjustments and flexibility often occur. Before heading for the field, it is recommended that the marker(s) have a guide or format in hand. The marking guide is a form that can be used for many reasons: in the field to guide a marking crew for quality assurance and consistency, during field audits, and justification as a companion guide to the silviculture prescription.

A marking guide can be as brief or thorough as one develops. The guide can outline current site conditions, short and long-term landowner objectives. Marking instructions are highlighted such as silviculture method, residual density, species priority and AGS characteristics, installation of gaps (size and number), tree retention and other considerations during the marking implementation. For future consideration in development of a northern hardwood marking guide, see the marking examples in the appendix of this chapter (Table 40.25, Table 40.26, and Table 40.27). These examples are not intended to cover all site and stand conditions but offer considerations in development of a marking guide for a stand prescription.

7 APPENDICES

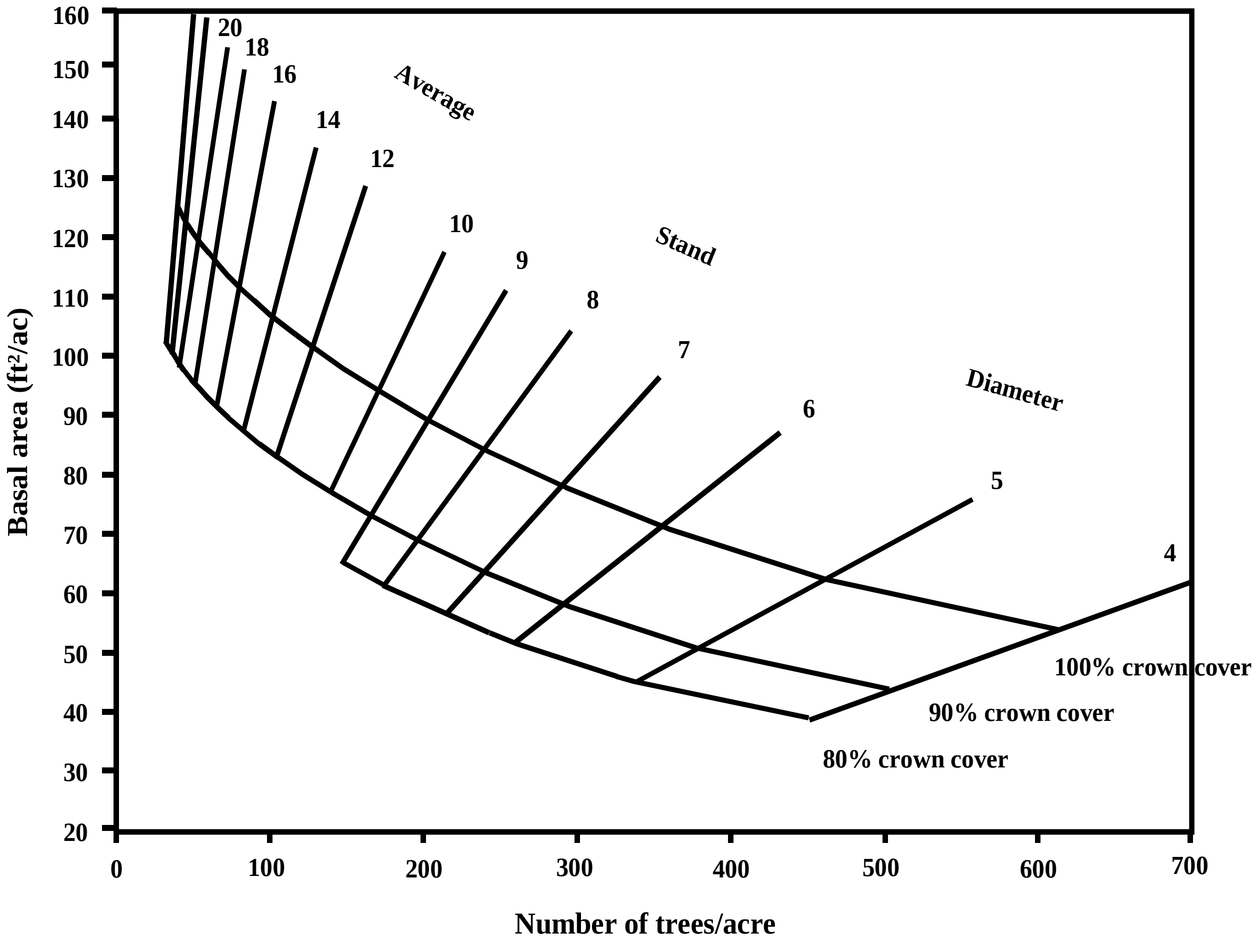


Figure 40.5. Stocking level chart for northern hardwood in even-aged stands (USDA 2005).

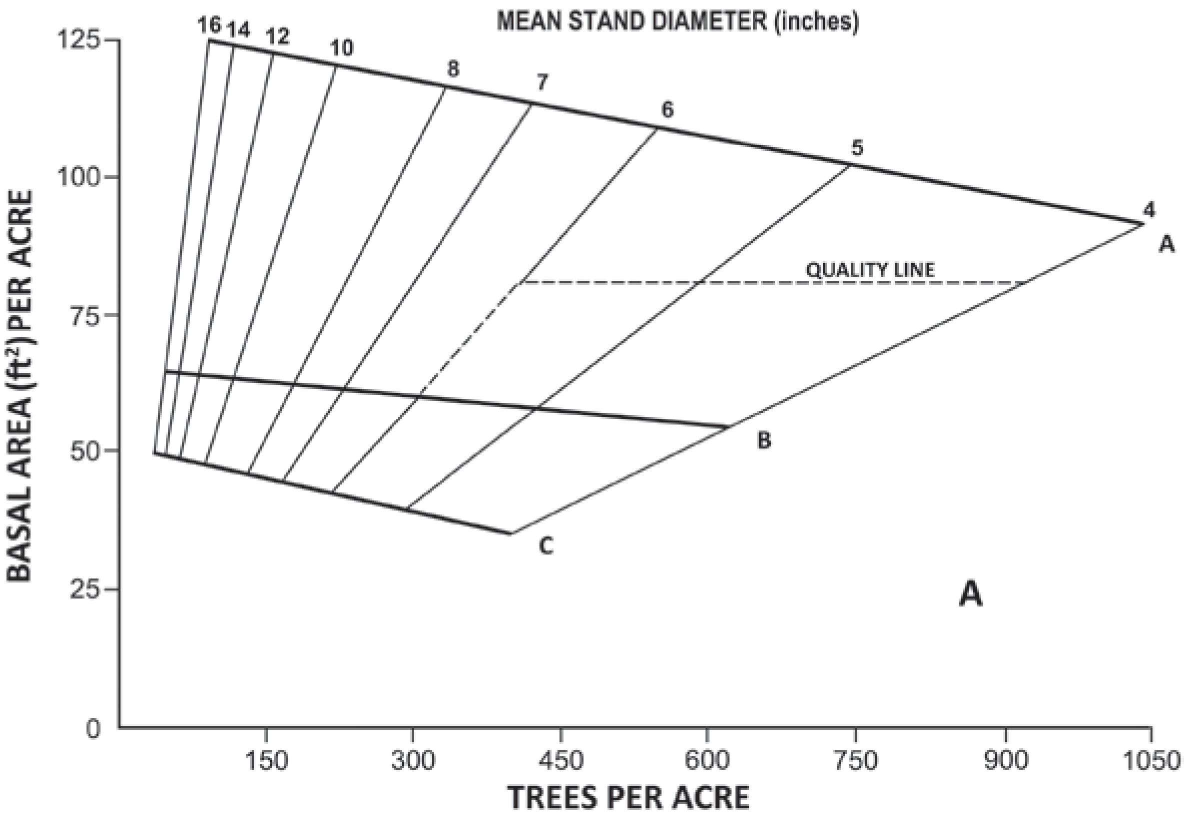
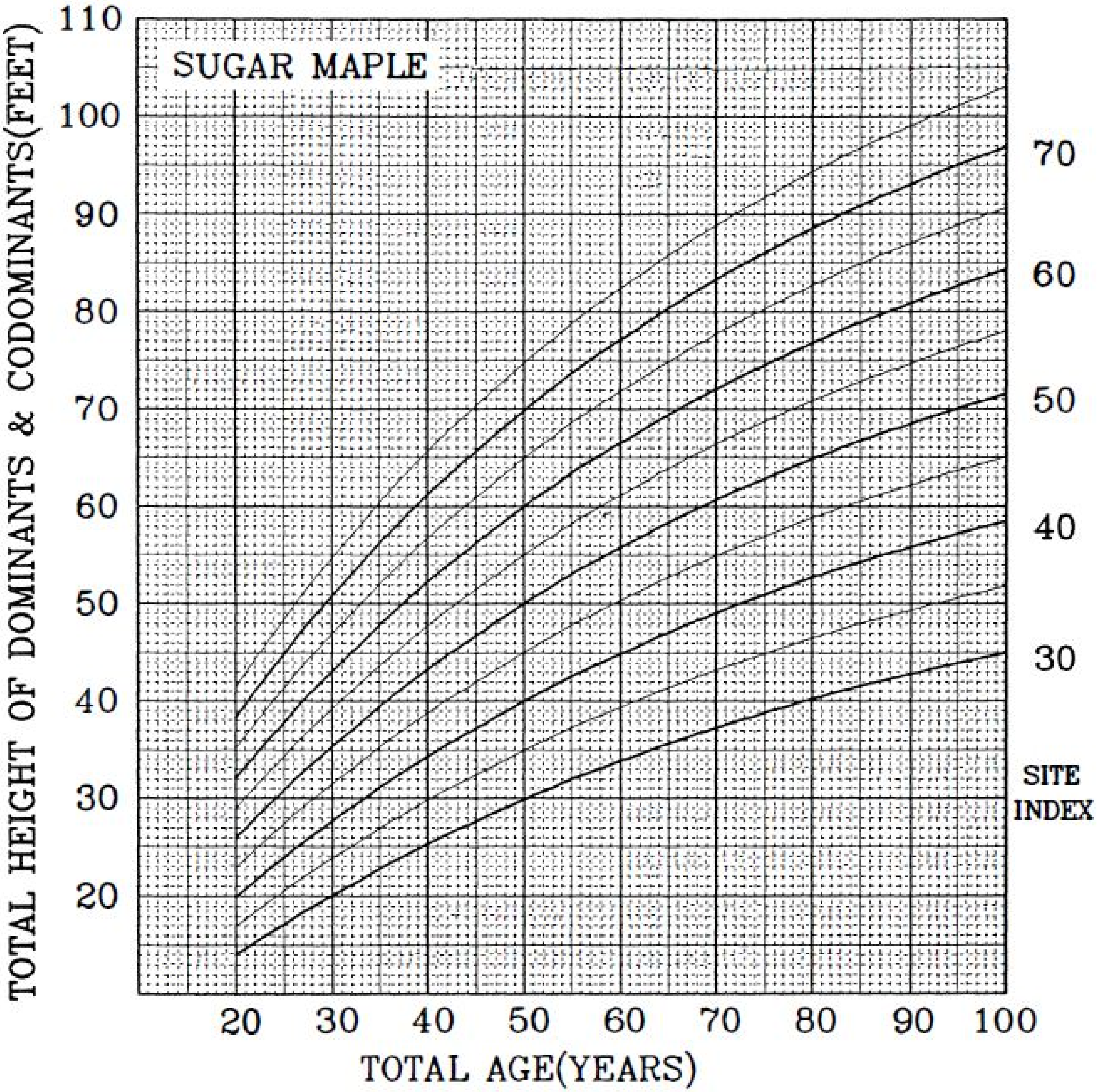


Figure 40.6. Optional stocking level chart for northern hardwood in even-aged stands (Leak *et al.* 2014).

Table 40.15. Recommended residual stocking per acre (trees≥5" DBH) for fully regulated uneven-aged stands (Arbogast 1957).

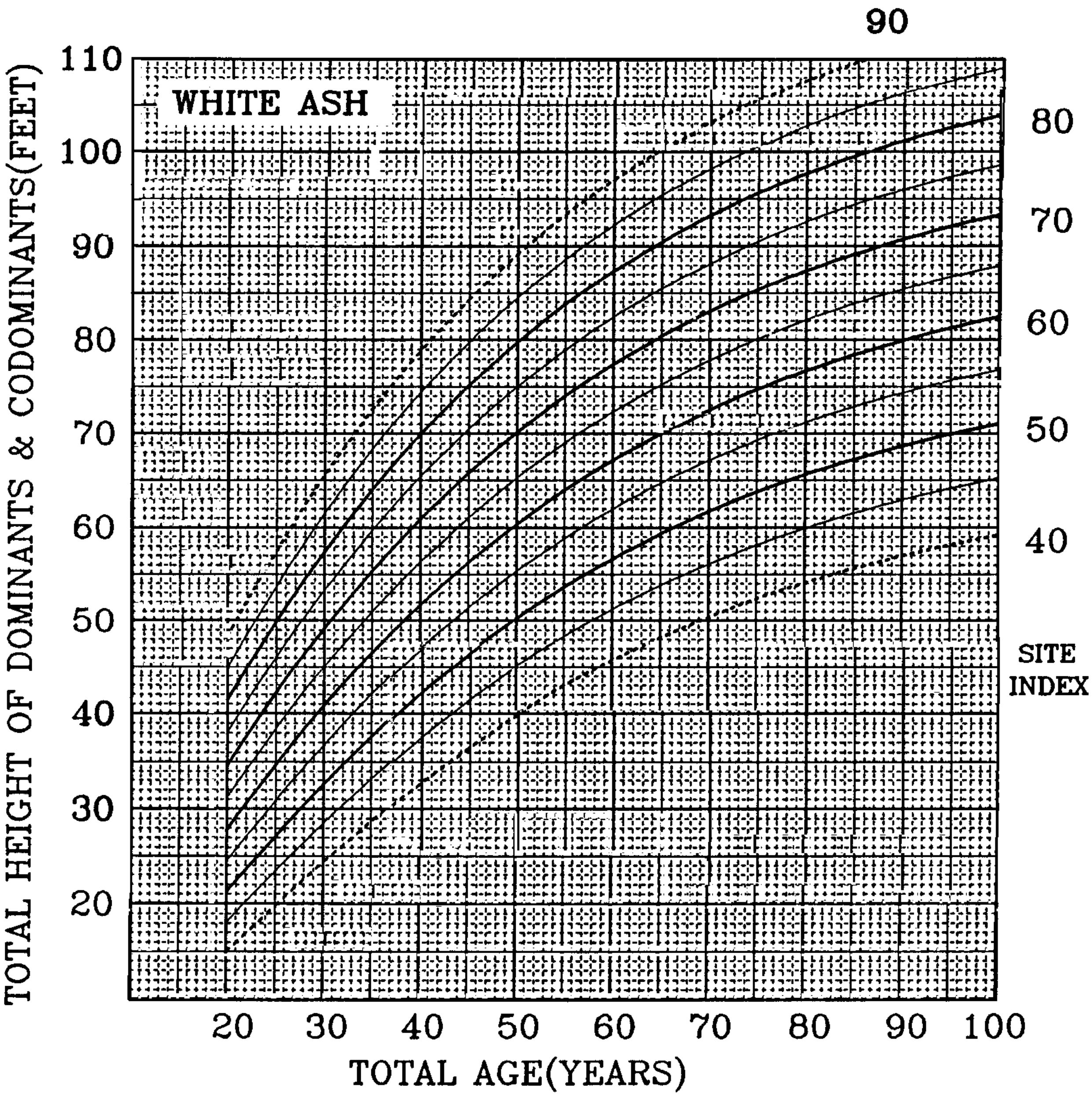
DBH (inches)	No. of Trees	No. of Trees by size class	Basal Area (square feet)	Basal Area by size class
5	21	65	2.9	16
6	15		2.9	
7	12		3.2	
8	9		3.1	
9	8		3.5	
10	7	28	3.8	22
11	6		4.0	
12	5		3.9	
13	5		4.6	
14	5		5.3	
15	4	17	4.9	26
16	4		5.6	
17	3		4.7	
18	3		5.3	
19	3		5.9	
20	2	8	4.4	20
21	2		4.8	
22	2		5.3	
23	1		2.9	
24	1		3.1	
Total (per acre)	118	118	84	84



Sugar maple (Curtis and Post 1962, Solomon 1968)
Vermont Green Mountains
67 plots having 136 dominant and codominant trees
Stem analysis, logarithm equation, anamorphic, original curves redrafted from d.b.h. age to total age and from SI age 75 to SI age of 50
Add 4 years to d.b.h. age to obtain total age (BH = 0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	3.3721	0.8407	-0.0150	2.6208	-0.2661	0.99	0.88	0.3
SI	0.1771	1.2075	-0.0066	-1.7003	-0.2189	0.99	0.98	1.9

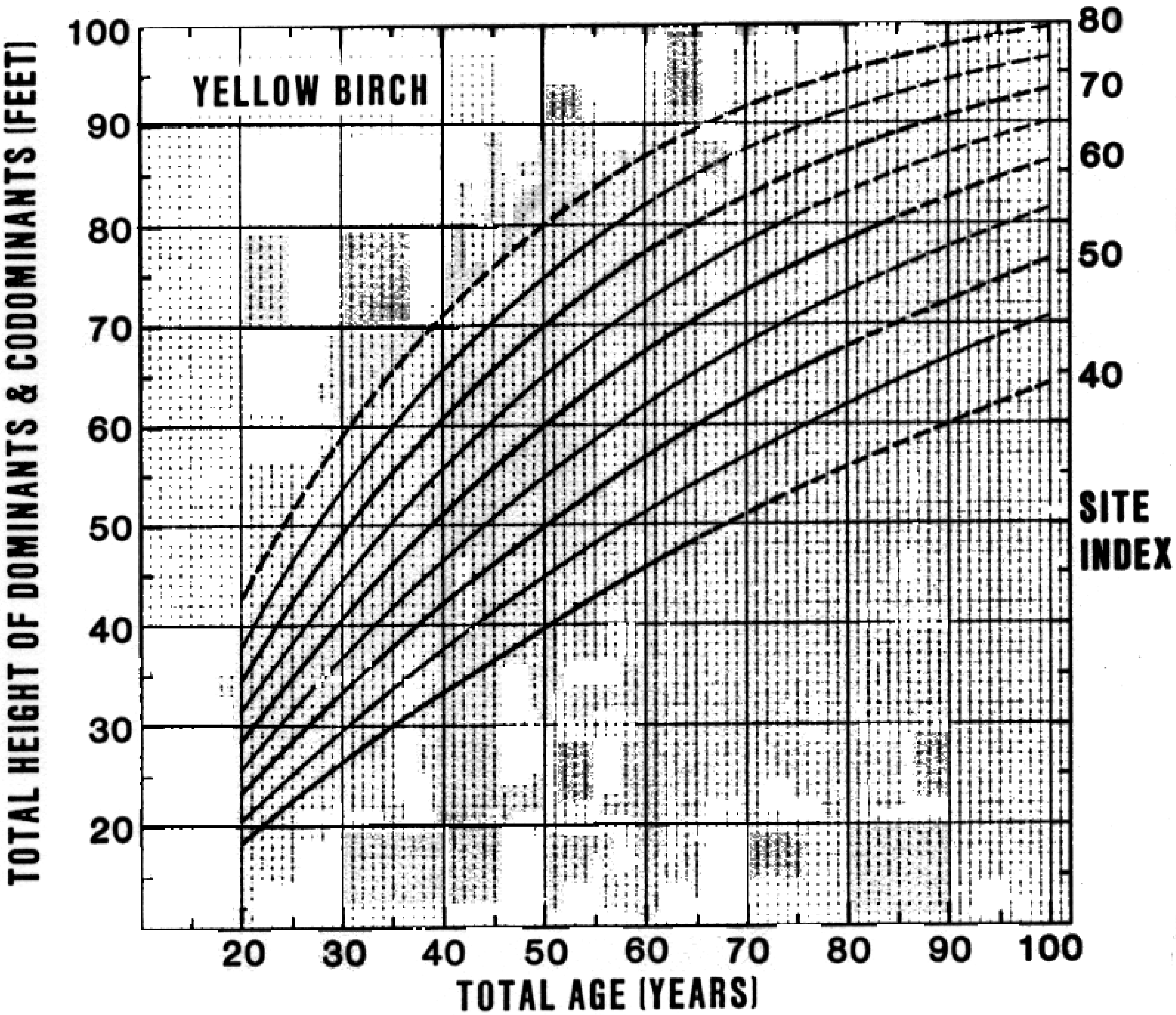
Figure 40.7. Site index curves for sugar maple in northern Wisconsin and upper Michigan (Carmean *et al.* 1989).



White ash (Carmean 1978)
Northern Wisconsin and Upper Michigan
73 plots having 275 dominant and codominant trees
Stem analysis, nonlinear regression, polymorphic
Add 4 years to d.b.h. age to obtain total age (BH = 0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	4.1492	0.7531	-0.0269	14.5384	-0.5811	0.99	1.37	5.1
SI	0.1728	1.2560	-0.0110	-3.3605	-0.3452	0.99	1.99	9.5

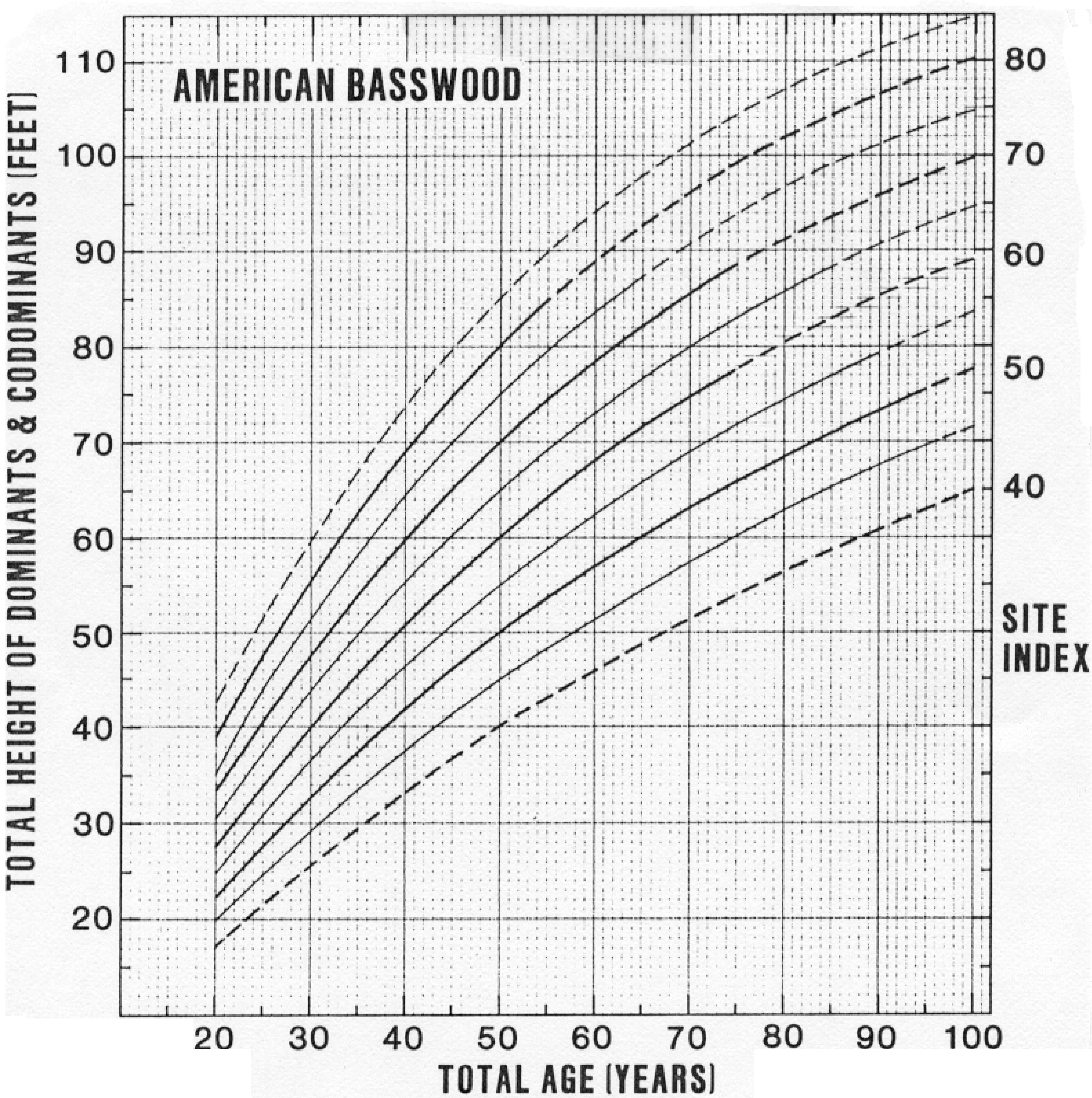
Figure 40.8. Site index for white ash in northern Wisconsin and upper Michigan (Carmean *et al.*, 1989)



Yellow birch (Carmean 1978)
Northern Wisconsin and Upper Michigan
119 plots having 459 dominant and codominant trees
Stem analysis, nonlinear regression, polymorphic
Add 4 years to d.b.h. age to obtain total age (BH = 0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	6.0522	0.6768	-0.0217	15.4232	-0.6354	0.99	1.29	5.0
SI	0.1817	1.2430	-0.0110	-3.0184	-0.3180	0.98	2.05	7.7

Figure 40.9. Site index curves for yellow birch in northern Wisconsin and upper Michigan (Carmean *et al*., 1989).



American basswood (Carmean 1978)
Northern Wisconsin and Upper Michigan
122 plots having 483 dominant and codominant trees
Stem analysis, nonlinear regression, polymorphic
Add 4 years to d.b.h. age to obtain total age (BH = 0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	4.7633	0.7576	-0.0194	6.5110	-0.4156	0.99	0.70	2.7
SI	0.1921	1.2010	-0.0100	-2.3009	-0.2331	0.99	1.24	4.5

Figure 40.10. Site index curves for basswood in northern Wisconsin and upper Michigan (Carmean *et al*., 1989).

Table 40.16. Alternative residual basal area targets for regulated stands with differing cutting cycles (Nyland 2017).

	Cutting Cycle		
	15 yrs.	20 yrs.	25 yrs.
Diameter Class (in.)	Basal Area (ft^2 / acre)		
2"-5"	10	10	10
6"-11"	25	20	30
12"-16"	35	30	25
18+"	15	10	0
Total	**85**	**70**	**65**

Table 40.17. Alternative residual stocking levels for single-tree selection with different maximum tree size classes (prepared by T. Strong 2005).

	Maximum Tree Size Class					
DBH (inches)	**18"**		**24"**		**30"**	
	No. of Trees	Basal Area	No. of Trees	Basal Area	No. of Trees	Basal Area
2	118	2.6	118	2.6	118	2.6
3	53	2.6	53	2.6	53	2.6
4	31	2.7	31	2.7	31	2.6
Sub-Total	**202**	**8**	**202**	**8**	**202**	**8**
5	22	3.0	21	2.9	12	1.6
6	19	3.7	15	2.9	11	2.2
7	17	4.5	12	3.2	9	2.4
8	15	5.2	9	3.1	8	2.8
9	13	5.7	8	3.5	7	3.1
Sub-Total	**86**	**22**	**65**	**16**	**47**	**12**
10	11	6.0	7	3.8	6	3.3
11	10	6.6	6	4.0	5	3.3
12	9	7.0	5	3.9	5	3.9
13	8	7.3	5	4.6	4	3.7
14	7	7.4	5	5.3	4	4.3
Sub-Total	**45**	**34**	**28**	**22**	**24**	**19**
15	6	7.3	4	4.9	3	3.7
16	5	7.0	4	5.6	3	4.2
17	4	6.3	3	4.7	3	4.7
18	4	7.0	3	5.3	2	3.5
19			3	5.9	2	4.0
Sub-Total	**19**	**28**	**17**	**26**	**13**	**20**
20			2	4.4	2	4.4
21			2	4.8	1	2.4
22			2	5.3	1	2.6
23			1	2.9	1	2.9
24			1	3.1	1	3.1
Sub-Total			**8**	**20**	**6**	**15**
25					1	3.4
26					1	3.7
27					1	4.0
28					0.5	2.1
29					0.5	2.3
30					0.5	2.4
Sub-Total					**4.5**	**18**
Total ≥5"DBH	**150**	**84**	**118**	**84**	**94.5**	**84**

Table 40.18. Even-age stocking levels for northern hardwood by mean stand diameter, basal area, and number of trees per acre for specified crown covers after thinning (USDA 2005).

Mean Stand Diameter (in)	Crown area/tree (ft2)	Basal area/tree (ft2)	Crown cover (percent of 43560 ft2/acre)			
			80 percent		90 percent	
			Trees/ac (No.)	BA/ac (ft2)	Trees/ac (No.)	BA/ac (ft2)
4	78	0.0873	447	39	503	44
5	104	0.1364	335	46	377	51
6	133	0.1963	262	51	295	58
7	164	0.2673	212	57	239	64
8	199	0.3491	175	61	197	69
9	238	0.4418	146	65	165	73
10	279	0.5454			141	77
11	325	0.66			121	80
12	373	0.7854			105	83
13	422	0.9218			93	86
14	480	1.069			82	87
15	536	1.2272			73	90
16	598	1.3963			66	92
17	662	1.5762			59	93
18	728	1.7671			54	95
19	803	1.9689			49	96
20	881	2.1817			44	97
21	952	2.4053			41	99
22	1035	2.6398			38	100
23	1120	2.8852			35	101
24	1207	3.1416			32	102

Table 40.19. Even-age stocking levels (residual basal area (ft²/ac) for northern hardwood with various amounts of basswood by mean stand diameter (inches) for specified crown covers after thinning (USDA 2005).

Percent of basswood (*Tilia americana*)								
	20		**40**		**60**		**80**	
Crown cover (percent of 43,560 ft²/ac)								
DBH	**80**	**90**	**80**	**90**	**80**	**90**	**80**	**90**
5	57	64	62	70	70	78	79	89
6	61	69	67	76	75	84	84	95
7	65	73	71	80	79	89	89	100
8	69	77	75	85	84	94	94	106
9	72	81	79	89	87	98	98	110
10		84		93		103		115
11		88		96		106		119
12		91		100		110		123
13		94		103		113		127
14		97		106		117		130
15		99		109		120		134
16		102		112		123		137
17		105		114		126		140
18		107		117		129		143
19		109		119		131		146
20		112		122		134		149
21		114		124		137		152
22		116		127		139		154
23		118		129		141		157
24		120		131		144		159

Table 40.20. Even-age stocking levels (residual basal area (ft^2/ac) for northern hardwood with various amounts of red oak and /or red maple by mean stand diameter (inches) for specified crown covers after thinning (USDA 2005).

Percent of red oak (*Quercus rubra*) and/or red maple (*Acer rubrum*)								
	20		**40**		**60**		**80**	
Crown cover (percent of 43,560 ft^2/ac)								
DBH	**80**	**90**	**80**	**90**	**80**	**90**	**80**	**90**
5	55	62	59	66	63	71	68	76
6	59	66	62	70	66	74	70	79
7	62	70	65	73	68	77	72	81
8	65	73	68	76	71	80	74	83
9	68	77	70	79	73	82	76	85
10		80		82		84		87
11		82		84		86		88
12		85		87		88		90
13		87		89		90		91
14		90		91		91		92
15		92		92		93		93
16		94		94		94		94
17		96		96		96		95
18		98		98		97		96
19		100		99		98		97
20		102		101		99		98
21		104		102		101		99
22		105		103		102		100
23		107		105		103		101
24		109		106		104		101

Previous View

Table 40.21. Even-age stocking levels (residual basal area (ft²/ac) for northern hardwood with various amounts of hemlock by mean stand diameter (inches) for specified crown covers after thinning (USDA 2005).

Percent of eastern hemlock (*Tsuga canadensis*)								
	20		**40**		**60**		**80**	
Crown cover (percent of 43,560 ft2/ac)								
DBH	**80**	**90**	**80**	**90**	**80**	**90**	**80**	**90**
5	48	53	44	49	41	46	38	43
6	52	59	49	56	47	52	44	50
7	57	64	54	61	52	59	50	56
8	61	69	59	67	57	65	56	63
9	65	73	64	72	62	70	61	69
10		77		76		76		75
11		81		81		81		81
12		84		85		86		87
13		88		89		91		92
14		91		93		96		98
15		94		97		100		103
16		97		101		105		109
17		100		105		109		114
18		103		108		113		119
19		106		111		117		124
20		109		115		122		129
21		111		118		126		134
22		114		121		129		139
23		116		124		133		144
24		119		127		137		149

Table 40.22. Checklist for evaluating northern hardwood stand management options.

This decision tool is designed to help identify management options prior to developing a silvicultural prescription. Due to the complex character of both stands and management, checklist results should be considered collectively, along with other stand data and professional judgment, when evaluating management options to best achieve a desired future condition (DFC).

Instructions: Within each stand assessment topic (ex. Landowner Objective, Site Potential / Operability) there are 2-6 true or false questions. Answer each question by checking (✓) the true or false box to the right of the question. If you do not have sufficient information to make an informed decision, leave the question blank. When all questions within a topic have been reviewed, tally true and false answers and circle the assessment answer at the bottom of the column with the most checked boxes. When ties occur, use your professional judgement to decide between assessment answers. If curious, you might also assess multiple option sets using both assessment answers for a topic.

When all assessment topics have been reviewed, transfer assessment answers to page 2. Circle the assessment answers below each assessment topic which correlate to page 1 answers. Use the table to locate the Options Set which matches your answers. X's indicate options worthy of consideration. In some cases, X[1], X[2], and X[3] indicate a unique condition which is briefly described below the table. Note, the assessment topics: Deer Browse, Interfering Vegetation, and Enrichment are located on a separate table, below the main table.

	TRUE	FALSE
Objectives		
Landowners favor maintenance of a structurally diverse stand. For aesthetics or other reasons, they wish to avoid large scale overstory removal.		
Wildlife habitat focus is not dense cover (ex. ruffed grouse) or browse production (ex. deer).		
Timber income from stand should be regular, every 10-15 yrs., avoiding periods longer than 20 years without timber revenue.		
Harvest options are limited due to a lack of small diameter timber markets. Harvests are mainly sawtimber with limited amounts of other products.		
	Uneven-**A**ged	**E**ven-**A**ged
Site Potential / Operability		
Soils are sands (dry) or clay, poorly drained soils (wet)		
N WI - If known, the stand's forest habitat type classification is **Very Dry to Dry-Mesic**: PQE, PQG, PQGCe, PArV, PArV-U, PArVAo, Qap, PArVAm, PArVHa, PArVAa, PArVAa-Vb, PArVAa-Po, PArVPo, AVVb, AVCl, TFAa, AVDe, AVb-V, ACl, AVb, AAt, or ATFPo		
N WI - If known, the stand's forest habitat type classification is **Mesic to Wet-mesic** : PArVRh, ArAbVC, ArAbVCo, ArVRp, ArAbSn, ArAbCo, TMC, AAtRp, ASnMi, or ATAtOn		
S WI - If known, the stand's forest habitat type classification is **dry to dry-mesic**: ArDe-V, ArDe, AQVb-Gr, ArCi, ArCi-Ph, AArVb, AArL, PEu, PVGy, PVHa, PVCr, or PVG		
Site Index is < 55		
Slopes limit the use of CTL / mechanized processors		
	Poor-**F**air	**G**ood-Excellent
Stand History		
Indications of past high grading evident (ex. poor quality residual trees, patchy distribution of overstory trees)		
Indications of past cattle grazing (ex. barbed wire fence on stand boundary, prevalence of thorny understory)		
Storm damage present (ex. many damaged trees in the stand, crown breakage, lots of trees on ground)		
Insect and/or disease problems are a threat to the stand.		
Stand level evidence of crown dieback or loss of tree / stand vigor		
	Limiting	**N**ot **L**imiting
Stand Stocking & Quality		
Relative density is above the B-line (greater than 60%) or above 80% canopy cover		
≥40 acceptable growing stock (AGS) trees per acre		
35% or more of the stand's relative density is comprised of acceptable growing stock (AGS) trees		
	Sufficient	**N**ot **S**ufficient

	TRUE	FALSE
Stand Age / Structure		
Stand is dominated by stems less than 5" DBH (overstory)		
Stand does not have 2 or more WDNR size classes with sufficient quality (i.e., AGS) for continued management		
Individual tree live crown ratio tends to decrease across crown classes, highest with dominant and lowest with overtopped trees. The understory looks "naked" and lacks advance regeneration.		
Stand consists of a single size class or multiple size classes but only one has potential for improvement		
	Single **C**lass	**M**ulti-**C**lass
Regeneration		
≥2000 seedlings, at least 4' tall, per acre		
Seedlings and saplings are well distributed in the stand (≥70% of regeneration plots are stocked)		
Regeneration is vigorous, few saplings have lost a dominant leader		
Saplings are predominantly less than 15' tall		
Seedling / sapling species composition meets stand management goals		
	Stocked	**N**ot **S**tocked
Deer Browse		
More than 50% of palatable tree and shrub regeneration is browsed (≥BSI 4)		
The understory is dominated by ironwood, buckthorn, Eurasian honeysuckle, or other non-native trees and shrubs.		
Stump sprouts and seedlings are hedged, a distinct browse line has developed in the stand.		
	Browse	**N**o **B**rowse
Interfering Vegetation		
Interfering plants, including Penn. Sedge, etc., are infrequent (<30% cover) or do not pose a problem for initiating or advancing seedlings and/or saplings		
Ironwood, buckthorn, Eurasian honeysuckle, raspberries, blackberries or other problematic trees and shrubs are largely absent from the stand.		
	Not **I**nterfering	**I**nterfering
Enrichment		
Seed sources for shade-tolerant and mid-tolerant tree species other than sugar maple, red maple, and balsam fir (i.e., basswood, yellow birch, red oak, hemlock, etc.) are largely absent, not well distributed		
Seedling/sapling composition not projected to fare well with climate change (see https://forestadaptation.org/Northwoods_treehandouts)		
	Uniform	**V**aried

	Stand Assessment Answers										Silvicultural Systems						
	Site Potential		Stand History		Stand Stocking and Quality		Age / Structure		Regeneration		Landowner Objective: Uneven-Aged Management				Landowner Objective: Even-Aged Management		
Option Set	Poor-Fair	Good-Excellent	Limiting	Not Limiting	Not Sufficient	Sufficient	Multi-Class	Single Class	Stocked	Not Stocked	Single Tree Selection (40-X)	Single Tree Selection Conversion (40-X)	Group Selection / Conversion (40-X)	Patch Selection / Conversion (40-X)	Tending / Intermediate Thinning (40-X)	Shelterwood (40-X)	Overstory Removal (40-X)

Option Set	Site Potential	Stand History	Stand Stocking and Quality	Age / Structure	Regeneration	Single Tree Selection (40-X)	Single Tree Selection Conversion (40-X)	Group Selection / Conversion (40-X)	Patch Selection / Conversion (40-X)	Tending / Intermediate Thinning (40-X)	Shelterwood (40-X)	Overstory Removal (40-X)
1	Poor-Fair	Limiting	Sufficient	Multi-Class	Stocked			X	X	X		X
2	Poor-Fair	Limiting	Sufficient	Multi-Class	Not Stocked			X		X	X	
3	Poor-Fair	Limiting	Sufficient	Single Class	Stocked			X	X	X		X
4	Poor-Fair	Limiting	Sufficient	Single Class	Not Stocked			X		X	X	
5	Poor-Fair	Limiting	Not Sufficient	Multi-Class	Stocked			X	X			X
6	Poor-Fair	Limiting	Not Sufficient	Multi-Class	Not Stocked			X			X	
7	Poor-Fair	Limiting	Not Sufficient	Single Class	Stocked			X	X			X
8	Poor-Fair	Limiting	Not Sufficient	Single Class	Not Stocked						X	
9	Poor-Fair	Not Limiting	Sufficient	Multi-Class	Stocked			X	X	X		X
10	Poor-Fair	Not Limiting	Sufficient	Multi-Class	Not Stocked			X		X	X	
11	Poor-Fair	Not Limiting	Sufficient	Single Class	Stocked			X	X	X		X
12	Poor-Fair	Not Limiting	Sufficient	Single Class	Not Stocked			X		X	X	
13	Poor-Fair	Not Limiting	Not Sufficient	Multi-Class	Stocked			X	X			X
14	Poor-Fair	Not Limiting	Not Sufficient	Multi-Class	Not Stocked						X	
15	Poor-Fair	Not Limiting	Not Sufficient	Single Class	Stocked			X	X			X
16	Poor-Fair	Not Limiting	Not Sufficient	Single Class	Not Stocked						X	
17	Good-Excellent	Limiting	Sufficient	Multi-Class	Stocked	X		X		X		X
18	Good-Excellent	Limiting	Sufficient	Multi-Class	Not Stocked	X		X^1		X	X	
19	Good-Excellent	Limiting	Sufficient	Single Class	Stocked		X	X		X		X
20	Good-Excellent	Limiting	Sufficient	Single Class	Not Stocked		X	X^1		X	X	
21	Good-Excellent	Limiting	Not Sufficient	Multi-Class	Stocked		X^3	X	X			X
22	Good-Excellent	Limiting	Not Sufficient	Multi-Class	Not Stocked			X^2			X	
23	Good-Excellent	Limiting	Not Sufficient	Single Class	Stocked		X^3	X	X			X
24	Good-Excellent	Limiting	Not Sufficient	Single Class	Not Stocked		X^3	X^2			X	
25	Good-Excellent	Not Limiting	Sufficient	Multi-Class	Stocked	X		X	X	X		X
26	Good-Excellent	Not Limiting	Sufficient	Multi-Class	Not Stocked	X		X^1		X	X	
27	Good-Excellent	Not Limiting	Sufficient	Single Class	Stocked		X	X	X	X		X
28	Good-Excellent	Not Limiting	Sufficient	Single Class	Not Stocked		X	X^2		X	X	
29	Good-Excellent	Not Limiting	Not Sufficient	Multi-Class	Stocked			X	X			X
30	Good-Excellent	Not Limiting	Not Sufficient	Multi-Class	Not Stocked			X^2			X	
31	Good-Excellent	Not Limiting	Not Sufficient	Single Class	Stocked		X^3	X	X			X
32	Good-Excellent	Not Limiting	Not Sufficient	Single Class	Not Stocked		X^3	X			X	

X^1 Condition: Group selection may require seed bed site: preparation.
X^2 Condition: Possibly degraded, may require planting in addition to site preparation.
X^3 Condition: Thin where appropriate, focus gaps on existing regeneration or poorly stocked areas. Planting may be required.

NOTES:

Previous View

Table 40.23. Northern hardwood stand exam tally sheet.

Property of Forest	Comp. No.	~~Stand No.~~	Date	Estimator

Section	T.	R.	Description	Acres	Primary	Secondary	Understory

Plot	Species Code						Total Cord	Trees/Acre				Basal Area				
								C	A	U	Regen 0-5	Pole 5-9	SS 10-14	MS 15-19	LS 20+	Total
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
Cord Total Acre																

	P	SS	LS	P	SS	LS	P	SS	LS	P	SS	LS	P	S	L	P	S	L
Basal Area Total Acre																		
BA/Ac																		

Tree Diameters

Habitat Type

No. of 16 – foot logs BAF 10

Small Sawtimber 10-14	Sp	1/2	1	1 ½	2	2 ½	3	BD/FT
		3 7 10 13 16	~~6 12~~ 18 24 30 36 42 48 54 60 66 72 78 94	~~9 17~~ 26 35 43 52 61 70 78 96 104 113	10 21 32 42 52 63 73 84 95 105 115	13 26 39 52 65 78	15 30 45 60 75 90	
		3 7 10 13 16	~~6 12~~ 18 24 30 36 42 48 54 60 66 72 78 94	~~9 17~~ 26 35 43 52 61 70 78 96 104 113	10 21 32 42 52 63 73 84 95 105 115	13 26 39 52 65 78	15 30 45 60 75 90	
		3 7 10 13 16	~~6 12~~ 18 24 30 36 42 48 54 60 66 72 78 94	~~9 17~~ 26 35 43 52 61 70 78 96 104 113	10 21 32 42 52 63 73 84 95 105 115	13 26 39 52 65 78	15 30 45 60 75 90	
		3 7 10 13 16	~~6 12~~ 18 24 30 36 42 48 54 60 66 72 78 94	~~9 17~~ 26 35 43 52 61 70 78 96 104 113	10 21 32 42 52 63 73 84 95 105 115	13 26 39 52 65 78	15 30 45 60 75 90	
		3 7 10 13 16	~~6 12~~ 18 24 30 36 42 48 54 60 66 72 78 94	~~9 17~~ 26 35 43 52 61 70 78 96 104 113	10 21 32 42 52 63 73 84 95 105 115	13 26 39 52 65 78	15 30 45 60 75 90	
		3 7 10 13 16	~~6 12~~ 18 24 30 36 42 48 54 60 66 72 78 94	~~9 17~~ 26 35 43 52 61 70 78 96 104 113	10 21 32 42 52 63 73 84 95 105 115	13 26 39 52 65 78	15 30 45 60 75 90	

Med. Sawtimber 15-19	Sp	1/2	1	1 ½	2	2 ½	3	BD/FT
		4 8 12 ~~16 20~~	7 14 21 28 35 41 48 55 62 69 76 82 89 96 102	10 19 28 38 48 57 67 76 85 95 105 114 123 133	12 23 35 47 58 70 82 94 105 117 129 140	14 28 42 56 70 84 98	17 33 49 66 83 99	
		4 8 12 ~~16 20~~	7 14 21 28 35 41 48 55 62 69 76 82 89 96 102	10 19 28 38 48 57 67 76 85 95 105 114 123 133	12 23 35 47 58 70 82 94 105 117 129 140	14 28 42 56 70 84 98	17 33 49 66 83 99	
		4 8 12 ~~16 20~~	7 14 21 28 35 41 48 55 62 69 76 82 89 96 102	10 19 28 38 48 57 67 76 85 95 105 114 123 133	12 23 35 47 58 70 82 94 105 117 129 140	14 28 42 56 70 84 98	17 33 49 66 83 99	
		4 8 12 ~~16 20~~	7 14 21 28 35 41 48 55 62 69 76 82 89 96 102	10 19 28 38 48 57 67 76 85 95 105 114 123 133	12 23 35 47 58 70 82 94 105 117 129 140	14 28 42 56 70 84 98	17 33 49 66 83 99	
		4 8 12 ~~16 20~~	7 14 21 28 35 41 48 55 62 69 76 82 89 96 102	10 19 28 38 48 57 67 76 85 95 105 114 123 133	12 23 35 47 58 70 82 94 105 117 129 140	14 28 42 56 70 84 98	17 33 49 66 83 99	

Lg. Sawtimber 20+	Sp	1/2	1	1 ½	2	2 ½	3	BD/FT
		4 8 12 16 20	7 15 22 29 36 43 51	10 20 30 40 49 59	12 25 37 50 62 75 87	15 30 ~~44 59~~	17 34 51 68	
		4 8 12 16 20	7 15 22 29 36 43 51	10 20 30 40 49 59	12 25 37 50 62 75 87	15 30 ~~44 59~~	17 34 51 68	
		4 8 12 16 20	7 15 22 29 36 43 51	10 20 30 40 49 59	12 25 37 50 62 75 87	15 30 ~~44 59~~	17 34 51 68	
		4 8 12 16 20	7 15 22 29 36 43 51	10 20 30 40 49 59	12 25 37 50 62 75 87	15 30 ~~44 59~~	17 34 51 68	
Remarks:							Total	
							Average/Acre	

Invasive Spp.

Soils & Hydrology

Remarks:
Crown vigor/Dieback –
Age Class Dist. – EA/2A/UA
Seedling Bank -
Penn. Sedge -
Ironwood -
Past mgt. -
% Deer browse – 0, 25, 50, 75, +75
Basal Area/acre/year growth rate

TJP/PRA Rev. 06/27/16
Hardwood

Table 40.24. Tree crown area (ft²) by species and DBH (USDA 2005).

DBH (in)	Hardwood[1]	Red oak - red maple	Basswood	Hemlock
5	92	65	52	133
6	122	92	71	163
7	156	122	91	193
8	193	157	114	224
9	232	196	138	256
10	274	239	164	287
11	319	286	192	319
12	366	337	221	352
13	415	392	252	385
14	467	451	285	418
15	521	513	319	451
16	577	580	354	484
17	635	650	392	518
18	695	723	430	552
19	757	801	470	586
20	821	882	511	621
21	886	967	554	655
22	954	1055	598	690
23	1024	1147	643	725
24	1095	1243	690	760
25	1168	1342	738	795
26[2]	1242	1445	787	831
27[2]	1319	1551	837	866
28[2]	1397	1661	889	902
29[2]	1476	1775	941	938
30[2]	1558	1891	995	974

[1]Hardwood includes sugar maple, yellow birch, white and black ash.
[2]Crown areas of these diameters are extrapolated.
[3]Data derived from even-aged, forest grown, dominant and co-dominant trees in northern WI and MI. Unpublished data from T. Strong and G. Erdmann, USFS, NCFRS, Rhinelander, WI.

Instructions for a sample shelterwood marking exercise:
Lay out a 0.4-acre square plot (132 feet on a side) in the stand you are marking. To reach 60 percent crown cover in the practice plot you will need an accumulated crown area of 10,454 ft² (43,560 ft²/acre for 100 percent crown cover X 0.4-acre X 60 percent). Mark residual trees and tally the diameter, species, and crown area. Make sure the residual trees are well-spaced, low risk, and the desired species. Accumulate the crown area until reaching 10,454 ft². Visualize what the remaining crown cover would look like with all unmarked trees cut and proceed to mark through remaining stand.

Note: The following 3 marking guides are a few examples for a forester to consider as a template. These are not intended to address every site or stand but rather to offer ideas in developing a marking guide.

Table 40.25. Marking guide example #1 – Single-tree selection.

TIMBER SALE MARKING GUIDE

WDNR Draft 05_01_2017

District	Property	Code				County
ND	Chequamegon-Nicolet NF					Florence

Sale Name	Sale Number	Tract Number
Dolphin	GNA 2120-12	

Site Considerations

EXISTING STAND CONDITION - BA & TREES / ACRE BY SPECIES AND DBH (WDNR NED-3 data, measured 05/18/16)

	5" – 11"		12" – 15"		16" – 22"		>22"		**Total**	
	BA	Trees	BA	Trees	BA	Trees	BA	Trees	**BA**	**Trees**
Sugar Maple - ACSA	32.0	75.5	22.0	25.0	22.0	13.4	2.0	0.7	78.0	114.5
Red Maple- ACRU	4.0	8.4	8.0	9.5	5.0	3.0	0.0	0.0	17.0	20.9
Basswood - TIAM	1.0	1.8	1.0	0.9	7.0	4.6	1.0	0.3	10.0	7.7
Red Oak - QURU	0.0	0.0	0.0	0.0	3.0	1.5	4.0	1.1	7.0	2.6
Yellow Birch - BEAL	0.0	0.0	2.0	2.6	2.0	1.2	0.0	0.0	4.0	3.7
Paper Birch - BEPA	0.0	0.0	2.0	2.2	1.0	0.6	0.0	0.0	3.0	2.8
Aspen - POGR4	1.0	1.8	0.0	0.0	0.0	0.0	1.0	0.3	2.0	2.1
Balsam Fir - ABBA	2.0	10.2	0.0	0.0	0.0	0.0	0.0	0.0	2.0	10.2
White Pine - PIST	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.4	1.0	0.4
Total	40.0	97.7	35.0	40.2	40.0	24.2	9.0	2.8	**124.0**	**164.8**

Stand 12 is a mixed northern hardwood stand located north of Indian Road, northeast of the Beaver Creek. The stand is likely an even-aged or two aged stand. While all size classes are represented, age class diversity is largely absent. The overstory is dominated by sugar and red maple. The maple is of poor quality, with most stems exhibiting forks, seams, bumps or cankers. Mid-tolerant species like basswood and yellow birch are also present. Scattered red oak can also be found. The oak is of exceptional quality. Large, super-canopy white pines are in the eastern portion of the stand, along the intermittent stream and banks. Although the growing stock quality is poor, the stand does have a good diameter distribution and proportion of sawtimber. The stated management objective is for uneven-aged management through single tree selection.

The soils in the stand consist of Wabeno/Goodman silt loam throughout the majority of the interior, with some Padus sandy loam around the edges. Mudlake silt loam is found in the stream valley. There are some slopes that may approach 30% along the intermittent stream (see prescription map). Despite the rich soil and AOCa/ATD habitat types, the overall quality of the growing stock is poor and the relative growth potential is average (SI 60 ACSA3). Perhaps some of the growing stock quality is a result of distant management practices. Management records state that the stand was cut in 1977 and 1997, but there was a conspicuous lack of stumps observed in the field. Stand density averages 124 ft^2 / acre of basal area with an average stand diameter of 11.7". Basal areas throughout the stand are consistent, ranging from a low of 90ft^2 to a high of 160ft^2. The current inventory did not have any snags fall within the sample plots, but some snags were noted in the stand. The understory is open in the south and north ends of the stand, while the remainder contains a dense understory of balsam fir 10 to 20 feet tall. Some sugar maple saplings, 10 to 30 feet tall, can be found, especially in the more open areas.

An intermittent stream, not displayed on available maps, was discovered in the north and east portion of the stand during the field inspection. The stream channel was GPS'd and is displayed on the prescription map. A field inspection for cultural resources was also conducted, with the results discussed below.

Short Term Silvicultural Objectives
• Utilize uneven-aged conversion harvests (gap establishment and thinning) to reduce stocking, initiate new age classes, and improve growth, quality, and health while moving the stand toward desired diameter distribution over future entries. • Create gaps to recruit and release established regeneration and to create additional age (size) classes, and to promote the establishment and development of mid-tolerant tree species. • Provide timber products to local operators

Desired Future Condition
• To encourage and maintain an uneven-aged northern hardwood stand with high structural class diversity. A long-lived conifer component of white pine is to be protected and maintained within the stand. • To have trees in the stand growing at an optimum rate and which are resilient to insect and disease attacks.

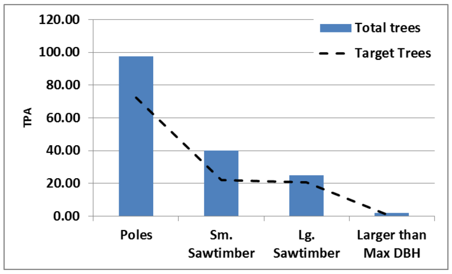
Marking Instructions		
Treatment Method: Single-Tree Selection	**Target Residual Density:** 80 ft^2/acre	**Estimated Treatment Acres:** 39

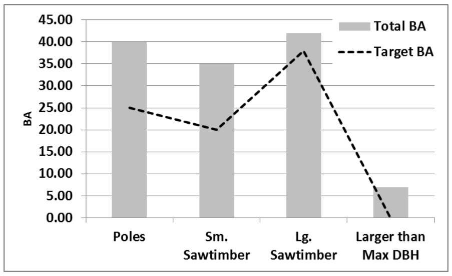
Marking Instructions		
Treatment Method: Single-Tree Selection	**Target Residual Density:** 80 ft^2/acre	**Estimated Treatment Acres:** 39

Species / Marking Priority

- Designate all merchantable ironwood, white birch, balsam fir and aspen for harvest.
- Harvest to an average 80 ft² residual BA in trees greater than 5" DBH, Recognizing 4 size classes (*G59*)
  - o Remove 15 ft² in the 5"-11" (approx. 1 of every 4 trees)
  - o Remove 15 ft² in the 12"–15" class (approx. 1 of every 2 trees)
  - o Remove 5 ft² in the 16"–22" size class (approx. 1 of 5 trees)
  - o Remove any high-risk trees in the 22+" size class

Size Class	Desired TPA	Existing TPA	Excess TPA	Trees to Mark
5"-11"	73	98	25	1 of 4
12"-15"	22	40	18	1 of 2
16"-22"	21	25	4	1 of 5
22" +	0	2	2	H. Risk





Leave tree Priority

- To foster diversity and resiliency, favor yellow birch, northern red oak, and basswood over sugar maple for retention.
- Reserve all white pine.
- Reserve all snags and live den trees, up to 10 per acre unless they present a safety concern

Canopy Gaps

- Through marking the stand to size class targets, create no more than four 25 to 40-foot canopy gaps per acre. Removal of 1-2 large trees or groups of smaller trees will accomplish this target.
- Establish 1 canopy gap approximately 60-feet in diameter every 2 acres (*G57*).
- Locate gaps in areas where regeneration is abundant, stem quality is poor, or where potential mid-tolerant seed trees occur (i.e., red oak).
- In all gaps, cut poor quality stems larger than 1" DBH (*G58*).

Tree Marking and Boundary Designation Methods:

- **Orange Paint:** Harvest boundaries, excepting boundaries bordering public roadways, will be marked *with orange paint*, including boundaries protecting reserved areas or other areas from harvesting.
- **Blue Paint:** Individual trees will be marked for removal *using blue paint.*
- **Yellow or Purple Paint:** If 60' gaps are designated prior to harvest, mark boundary or trees within the gap *with yellow or purple paint*.
- **Red Paint:** Mark the private boundary along the northern edge of the stand *with red paint*.

Timber Sale Design Features and Remarks

Operating Requirements:

- Harvesting may occur only during the winter or under frozen ground conditions. At the WDNR National Forest Liaison's discretion, this may be waived during dry summer or fall conditions. In any event, harvesting may not occur between March 15 and July 15 to protect nesting songbirds (*M3*).

Soil/Watershed

- The intermittent stream located in the stand flows from the northwest to the southeast. There is a very distinct flow channel upstream, but this dissipates downstream until the flow becomes dispersed and moves completely underground. Establish a 35-foot RMZ along this stream and keep it out of the sale. Locate the boundary line further back from the RMZ as necessary to avoid steep slopes. Do not dispose of or pile slash in the RMZ. Operate wheeled or tracked equipment in the RMZ only when the ground is frozen or dry. The stream can only be crossed during frozen ground conditions.

Scenery

- Establish a 10-foot slash removal zone adjacent to the private land on the north end of the stand (*G302*).

- Up to 100’ from the edge of the road(s), within the area visible from the road, keep the slash height less than or equal to 24 inches (*G308*).

Endangered, Threatened, and Sensitive Species

- No endangered, threatened or sensitive species were identified within the sale area or through Forest Service records.

Non-Native Invasive Plants or Animals

- There are no known non-native invasive plants or animals in the stand.

Cultural Resources

- Screening was completed and historic sites 09060200337 and 09060200389 were shown as being near the stand (*G262*). A field inspection was conducted, and it was discovered that the GIS locations of these sites are inaccurate. Site 337 is located where site 389 is shown, and 389 is located further south than that. Both sites are removed from the sale area and should not be impacted by sale activities, but sale access will be prohibited from FS Roads 603284 and 603283 to protect these sites (*M7*).

Miscellaneous

- Stand access is off Indian Road (FS Road 2178) via old logging roads, some of which are undocumented.
- The stand boundary has been modified slightly to reflect a more accurate private land border.
- A snowmobile trail traverses a portion of the logging road that will be used to access the stand. Warning signage will need to be posted during the snowmobile season.

Prepared by: Paul Schultz	**Title:** Forester	**Date:** 08/01/2016

Timber Sale Map

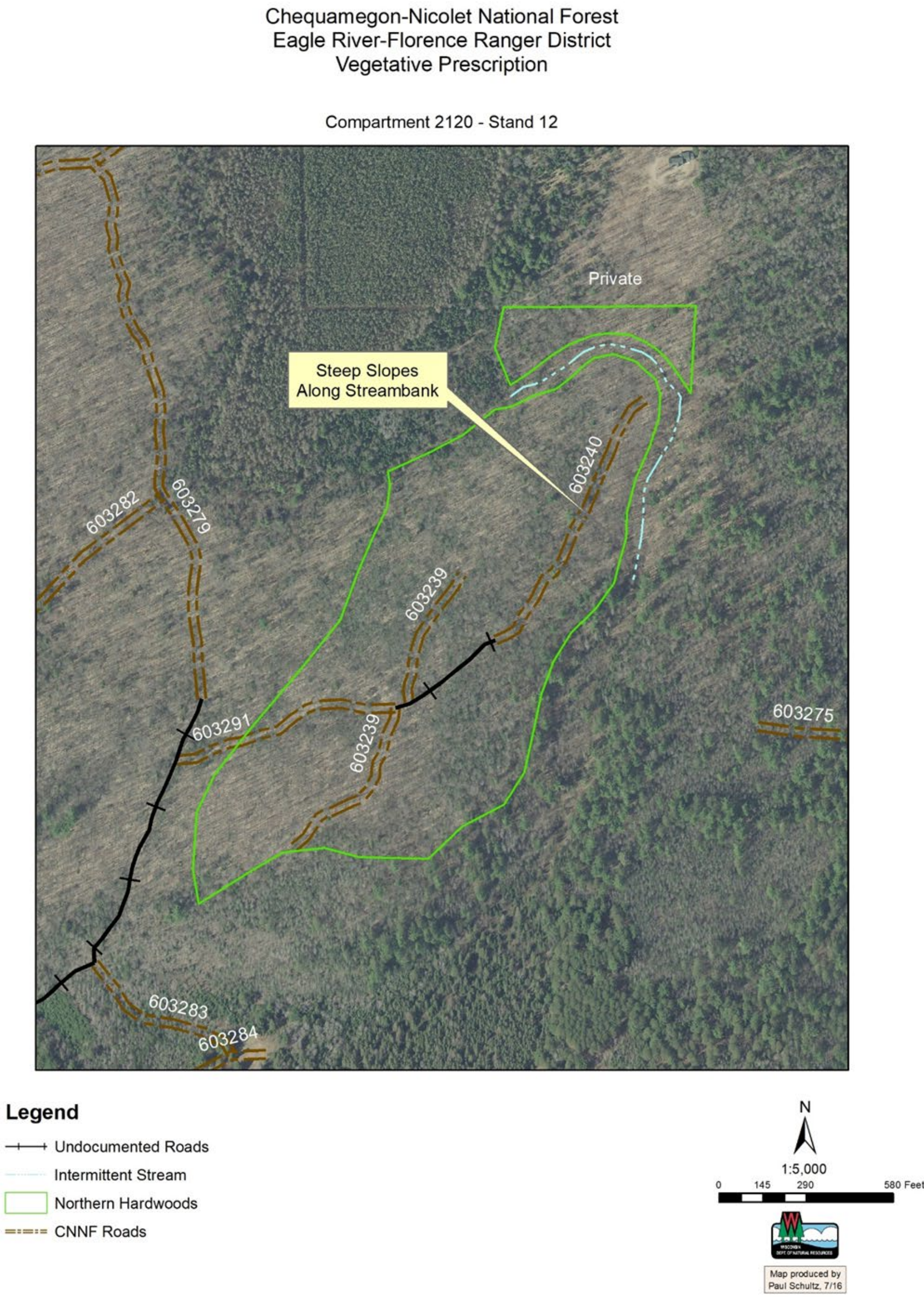


Table 40.26. Marking guide example #2 – Even-aged to uneven-aged conversion process.

Property: Lincoln Sale name: Underdown Lake	Comp #: 127	Stand #: 6	Acres: 91

Prescription: Stand is even aged, primarily NH pole timber with a small saw timber component. The goal is to improve the overall quality of the stand and develop uneven aged structure by releasing advance regeneration where possible and creating canopy gaps to maintain some species diversity.

Treatment: Even age to uneven age conversion/single-tree selection (thinning (comm, pre-comm), single-tree selection (with gaps, groups, patch), even to uneven age conversion, shelterwood, seed tree)

Goal density: 70-90 basal area (basal area/crown cover/trees per acre, etc.)

Retain:

AGS/Crop trees/seed trees: Crown release of AGS trees, two side of saw and at least two of pole timber trees (crown release, number per acre, characteristics of trees)

Wildlife trees: Goal of 3 per acre, cavity trees and poor-quality oversize oaks (number per acre of cavity/den, mast producer)

Desirable species: Poor quality oversize oaks for wildlife trees (oak, BY)

Understocked size classes: Large saw timber (less strict on quality?)

Special considerations: Large white pine legacy trees (Historic sites, snags, nest trees, RMZ, ephemerals, legacy trees, etc.)

Remove:

Risk trees: High risk trees unless there is high wildlife potential, financially mature trees DBH = 20"+ (mortality risk, financially mature)

UGS: Low quality trees to release AGS trees (remove low quality to release AGS, improve spacing)

Undesirable species: Saw timber size white ash and declining white birch (discriminate against ash)

Overstocked size classes: Pole timber (stricter on quality?)

Designated species to cut: All ironwood, merchantable aspen and balsam fir (Cut all A, fir, BW etc.)

Gap, group, patch: Approximately 10% of area in 30-60' canopy gaps, several UGS or large trees (Size and number per acre)

Other:

Paint Color Code: Red = sale boundary, Green = prescription change, Blue = property/sale boundary

Table 40.27. Marking guide example #3 - Example northern hardwood multi-treatment marking guide for a complex stand with financial objectives (Mike Demchik, University of Wisconsin – Stevens Point).

Marking Guidelines Template (Example)

Property:	**Sample NH stand**	**Comp #:**	**Stand #:**	**Acres:**
John Doe Property		1	3	45

Stand and Site Information:

This is a 90-year-old northern hardwood stand that has variable density throughout the stand. Regeneration is variable ranging from 0-3,000 stems per acre greater than 4’ in height.

Habitat type: ATM
Soil type: Padus Sandy Loam
Stand Density: Basal area is variable throughout stand ranging from 50-135 ft^2/acre.

Avg. Diameter distribution:

Poles:	10 ft^2/acre
Small saw:	20 ft^2/acre
Medium saw:	60 ft^2/acre
Large saw:	30 ft^2/acre

Small and medium sawtimber size classes are predominantly AGS

Stand Objectives (short and long-term):

- Encourage and maintain uneven-aged NH stand
- Harvest saw logs at financial maturity
- Develop future AGS saw logs by releasing crowns
- Recruit and release regeneration

Treatment Method(s) Description:

Using a combination of even and uneven-aged silvicultural methods (variable stand), use the treatment guide below to adapt marking to match stand conditions. Marking will focus on releasing saplings and poles with good growth potential. Maintain at least 60 ft^2/acre. Look for opportunities to release or develop areas with well-established advance regeneration, 2’-4’ in height.

Treatment Method Guide: The intent of this guide is to provide a set of treatment methods for northern hardwood sites that have a high degree of variability in condition across a single stand. The guide provides timber marking crews with basic guidance when considering heterogenous nature of some northern hardwood sites.

Structure			System	Marking Instructions
Overstory	Midstory	Advance Regeneration		
mature (any quality)	good quality	any	EA to UA Conversion (Consider **STS** where stand structure exists)	Install new gaps, up to 20% of the stand area in gaps Cut mature and high risk Release desirable mid-story trees Maintain at least 60 ft^2 basal area Note: objectives may consider marking towards a prescribed structure
mature (any quality)	poor quality or minimal	good	Shelterwood	Maintain desirable seeding trees to prescribed canopy cover; remove midstory
			Group Selection	Install groups 60 feet diameter or larger
			Overstory Removal	Remove overstory and midstory
immature (good quality)	good quality	any	Thin from above & below	Focus harvest on release of AGS
	poor quality or minimal	any	Thin from below	Focus harvest on release of AGS
immature (poor quality)	any	any	Do nothing	Wait until commercial
			Overstory Removal	Remove overstory and plant artificial if necessary

Notes to use this guide:

- Financial maturity: sugar maple is 18-24” DBH on the best high-quality sites with quality stems, but can be substantially smaller on poor quality sites; generally trees that have reached their highest grade and product class in the lower half of the bole.
- Good quality: one or more 8-foot (plus trim) pieces are grade 1 sawlogs or better.
- Poor quality: only capable of grade 2 or less sawlogs
- Immature: one or more pieces in the lower half of the bole will increase in product class.
- Maintain diversity by leaving species such as yellow birch, hemlock, white pine and other species.

Marking Priority Guide: To use the marking priority guide, a basic knowledge of log grading specifications is needed (both general and relevant to the local markets). As a general rule, for single-tree selection to be an economically stable system, trees with good quality potential need to be released at each stand entry. The guide below can promote long-term timber quality improvement under many stand conditions. This marking guide is for stands where uneven-aged management is viable; in many stand conditions, even-aged silviculture may be a more feasible alternative.

<table>
<tr><th colspan="2"></th><th colspan="2">Should Keep</th><th>Subject to Goals</th><th colspan="2">Should Take</th></tr>
<tr><td rowspan="3">QUALITY</td><td>Tree quality</td><td>Exceptional</td><td>Good</td><td>BA tree</td><td>Moderate-Poor</td><td>Very Poor</td></tr>
<tr><td>Number of 8’4” or longer sections in the lower half of the tree capable of increasing in product class with increase tree growth (i.e., increase from pulp to bolt/sawlog etc.).</td><td>2+</td><td>1</td><td colspan="3">0</td></tr>
<tr><td>Is the merchantable portion of the tree likely to decline in grade by next stand entry?</td><td colspan="3">No</td><td colspan="2">Yes</td></tr>
<tr><td rowspan="3">RISK</td><td>Likelihood of stem failure</td><td colspan="3">Low</td><td colspan="2">Moderate-High</td></tr>
<tr><td>Overall health</td><td colspan="3">Healthy</td><td colspan="2">Moderate or declining</td></tr>
<tr><td>Stem rot/decay (location)</td><td colspan="2">None</td><td>Minor or high in tree</td><td colspan="2">Significant or low in tree</td></tr>
<tr><td rowspan="3">VIGOR</td><td>Crown radius</td><td colspan="2">At least 0.75 feet of crown radius for every inch of DBH</td><td colspan="3">Less than 0.75 feet of crown radius for every inch of DBH</td></tr>
<tr><td>Foliage condition</td><td colspan="2">Healthy</td><td colspan="3">Poor</td></tr>
<tr><td>Bark character</td><td colspan="2">Indicates fast growth</td><td colspan="3">Indicates slow growth</td></tr>
</table>

Simplified (easy and quick) grade rules: Grading specifications for logs vary between mills. Hanks (1976) provided the basis for tree grading and Great Lakes Timber Professionals Association (2016) Official Grading Rules for Northern Hardwood and Softwood Logs and Tie Cuts followed similar guidance with minor variation in specifications.

- 4 side clear (with qualifiers) = potential veneer
- 5-7 ft clear cuts = potential grade 1
- 3 ft clear cuts = potential grade 2
- anything poorer should be targeted subject to landowner goals

7.1 Forest Health Guidelines - Forest Health Protection (FHP)

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
DEFOLIATING INSECTS			
Basswood leafroller – *Sparganothis pettitana* Heavy infestation of this insect, often together with other spring defoliators occasionally causes severe defoliation.	Basswood	Maintain healthy forests through proper forest management	
Birch Leafminer – *Fenusa pusilla* Browning of leaves. Repeated heavy leafmining weakens trees to become susceptible to bronze birch borer.	Birch	No direct control practical Monitor heavily defoliated stands for birch dieback.	Birch Leaf Miner. P. Pellitteri. 1997. Univ. of Wisc. Ext. A2117
Bruce Spanworm – *Operophtera bruceata* Occasional outbreaks of repeated heavy defoliation in early spring may cause twig/branch dieback and mortality	Sugar Maple, Beech	Maintain healthy forests through proper forest management Monitor defoliated stands for possible salvage	Pest alert: Bruce Spanworm. USDA FS NA-FB/P-26
Forest Tent Caterpillar – *Malacosoma disstria* Widespread heavy defoliation occurs periodically at intervals of 5-15 years. An outbreak usually lasts 2-5 years.	Northern Hardwood	Maintain healthy forests through proper forest management During an outbreak, insecticide applications can be an option to minimize the damage on highly valuable stands with high proportion of susceptible species.	Forest Tent Caterpillar in the Upper Midwest. 2001. USDA FS NA-PR-02-01
Spongy Moth – *Lymantria dispar* Widespread heavy defoliation occurs periodically at intervals of 5-15 years.	Northern Hardwood except ash (Spongy moth does not feed on ash)	Maintain healthy forests through proper forest management During an outbreak, insecticide applications can be an option to minimize the damage on highly valuable stands with high proportion of susceptible species.	https://dnr.wisconsin.gov/topic/foresthealth/spongymoth
Introduced Basswood Thrip – *Thrips calcaratus* Occasional outbreaks of early spring defoliation may cause growth loss, branch dieback, and mortality	Basswood	Maintain healthy forests through proper forest management Conduct salvage or presalvage harvest of declining trees to minimize economic losses.	How to Identify Introduced Basswood Thrips. 1992. USDA FS NA-FR-01-92
Linden looper – *Erannis tiliaria* Although this spring defoliator is commonly found on a northern hardwood stand, outbreaks are infrequent.	Northern hardwood	Maintain healthy forests through proper forest management	Sugarbush Management: A Guide to Maintaining Tree Health. 1990. D. Houston, et. al. USDA FS General Technical Report NE-129
Maple Leafrollers – *Sparganothis acerivoran; Acleris chalybeana* Occasional outbreaks of spring defoliation may cause twig dieback. A combination of this pest and multiple defoliators together with some pathogens and adverse weather factors may cause maple blight (see maple blight under decline).	Sugar Maple	Maintain healthy forests through proper forest management	Studies of Maple Blight. 1964. Univ. Wis. Agr. Exp. St. Res. Bull. 250
Maple Webworm – *Tetralopha asperatella* Occasional outbreaks of summer defoliation may cause twig dieback. A combination of this pest and multiple defoliators together with some pathogens and adverse weather factors may cause maple blight (see maple blight under decline).	Sugar Maple	Maintain healthy forests through proper forest management	Studies of Maple Blight. 1964. Univ. Wis. Agr. Exp. St. Res. Bull. 250
Saddled Prominent – *Heterocampa guttivitta* Occasional outbreaks of repeated heavy defoliation in mid-summer may cause twig/branch dieback. A combination of this pest and multiple defoliators together with some pathogens and adverse weather factors may cause maple blight (see maple blight under decline).	American Beech, Sugar Maple, Yellow Birch	Maintain healthy forests through proper forest management During an outbreak, insecticide applications can be an option to minimize the damage on highly valuable stands with high proportion of susceptible species.	Saddled Prominent. 1987. P. Rush and D. Allen. USDA FS Forest Insect & Disease Leaflet 167.
LATE SEASON DEFOLIATORS			
American daggermoth – *Acronicta americana* **Orange-humped mapleworm** – *Symmerista leucitys* **Green-striped mapleworm** – *Dryocampa rubicunda* **Maple trumpet skeletonize**r – *Epinotia aceriella* **Variable oakleaf caterpillar** – *Heterocampa manteo* Defoliation by multiple defoliators occasionally causes severe defoliation. Late season defoliator complex may result in growth loss but mortality is rare.	Basswood, Beech, Maple	Maintain healthy forests through proper forest management No chemical control is necessary	Sugarbush Management: A Guide to Maintaining Tree Health. 1990. D. Houston, et. al. USDA FS General Technical Report NE-129

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
SCALE INSECTS			
Lecanium Scale – *Parthenolecanium* spp. This insect sucks plant juice, causing twig and branch dieback, and growth loss.	Northern Hardwood	Chemical control is impractical, and usually unnecessary.	Scale Insects of Trees and Shrubs. R. Wawrzynski and M. Ascerno. 1999. Univ. Minn. Ext. FO-01019.
Beech Scale (Beech bark disease) - *Cryptococcus fagisuga and Neonectria spp.*	American Beech	Remove low vigor and/or rough bark beech. Retain vigorous trees with smooth bark Maintain healthy forests through proper forest management A small percentage of beech are resistant to beech bark disease so don't remove all beech.	Biology and Management of Beech Bark Disease. D. McCullough, R. Heyd, J. O'Brien. 2005. Michigan State Univ. Ext. E-2746.
WOOD BORERS			
Sugar Maple Borer – *Glycobius speciosus* Value loss through wood decay and discoloration, initiated by larval feeding. Stem breakage at point of attack.	Sugar Maple	Maintain healthy forests through proper forest management. Maintain well-stocked stands. Remove overmature, low-vigor trees. Monitor sugar maple on stand edges and along roads, especially trees that are recently exposed to full sunlight. See FHP Table 2 for specific recommendations related to impact.	How to Identify and Control the Sugar Maple Borer. W. Hoffard. 1978. USDA FS. NSEFES.
Bronze birch borer – *Agrilus anxius* Branch dieback. Mortality. Infestations are more successful and widespread during years of drought.	Birch (Yellow birch is less susceptible compared to white birch)	Maintain healthy forests through proper forest management. Thinning should be done with care to minimize stand disturbance.	Bronze Birch Borer. S. Katovich et. al. Forest Insect & Disease Leaflet 111. USDA FS.
Emerald Ash Borer – *Agrilus planipennis*	White, Green, and Black Ashes	Evaluate stand characteristics to determine management alternatives, utilizing recommendations in the Emerald Ash Borer Silviculture Guidelines document. Conduct salvage or pre-salvage harvest of declining trees to minimize economic losses. Retaining a small ash component will be beneficial for ecological purposes, species diversity, wildlife habitat, and seed production.	https://dnr.wisconsin.gov/topic/foresthealth/emeraldashborer

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
FOLIAGE DISEASES			
Anthracnose – multiple Anthracnose causing fungi (see reference) Irregular dead blotches on foliage. Growth loss.	Northern Hardwood	Direct control is impractical and usually unnecessary. Silvicultural measures to encourage air circulation may reduce infection.	Anthracnose Diseases of Eastern Hardwood. F. Berry. 1985. Forest Insect & Disease Leaflet 133
Tar Spot – *Rhytisma* spp. One to multiple black, shiny, tar-like spots on foliage. Growth loss.	Maple	Direct control is impractical and usually unnecessary.	Sugarbush Management: A Guide to Maintaining Tree Health. 1990. D. Houston, et. al. USDA FS General Technical Report NE-129
CANKERS/CANKER ROT[1]			
Nectria Canker – *Nectria cinnabarina* Trunk deformity and growth loss (all ages). Although it rarely causes mortality, a tree may break off at the point of canker.	Northern Hardwood	Silvicultural control measures are based on percent of infected trees in stand (see reference). Most infections occur when trees are 12-20 years old. Conduct improvement cut after age 20.	How to Identify and Control Nectria Canker of Hardwood. R. Anderson. 1978. USDA FS
Eutypella Canker – *Eutypella parasitica* Trunk deformity and growth loss (all ages). Although it rarely causes mortality, a tree may break off at the point of canker.	Sugar Maple	Avoid wounding. Spores can be produced and infections can occur from spring through fall. Spore dispersal can be minimized by placing cankers face down on the forest floor.	How to Identify and Minimize Damage Caused by Eutypella Canker of Maple. K. Robbins. 1979. USDA FS. NA-FR-10 Eutypella canker of maple: Ascospore discharge and dissemination. Phytopathology 69:130-135
Canker Rots *Inonotus obliquus* (birch) *Cerrena unicolor* (maple & oak) *Inonotus glomeratus* (maple) *Phellinus everhartii* (oak) *Inonotus hispidus* (oak) Wood decay. Entry through wounds. These fungi are not compartmentalized and continue to attack newly formed wood.	Sugar Maple, Beech, Birch	Minimize wounding. Remove canker-rot infected trees during thinning. Trees infected with canker rots may also provide excellent den trees. Consider leaving an occasional canker-rotted tree as a cavity tree for wildlife.	A Photo Guide to the Patterns of Discoloration and Decay in Living Northern Hardwood Trees. A. Shigo and E. Larson. 1969. USDA FS Research Paper NE-127
WILT DISEASES			
Ash Yellows – Phytoplasma Tufted foliage. Crown thinning. Slow growth. Branch dieback. Mortality. White ash that become infected when young do not grow to merchantable size. Most merchantable sized diseased trees live for at least 5-10 years. More common in urban settings or in small woodlots that adjoin agricultural fields.	Ash	No known way to prevent or cure this disease. Harvest trees with more than 50% crown dieback within 5 years. Remove other infected trees during harvests.	How to Identify and Manage Ash Yellows in Forest Stands and Home Landscapes. 1994. USDA FS. NA-FR-03-94.
Sap Streak Disease – *Ceratocystis coerulescens* Early fall color and progressive dieback. Tree mortality and wood discoloration. Fungus is soil-borne; infection occurs through root and basal wounds.	Sugar Maple	Minimize basal and root wounds Remove infected trees Harvest for pulp or firewood	How to Control Sapstreak Disease of Sugar Maple. K. Kessler. 1978. USDA FS
ROOT DISEASE			
Armillaria Root Disease (Shoestring root rot) – Armillaria spp. Stringy white rot. Dieback and mortality, especially during drought years or following 2 or more years of defoliation (all ages).	Northern Hardwood	Maintain stand in healthy condition. Harvest declining trees before mortality and decay take place.	R. Williams, *et al*. 1986 USDA Forest Service, Forest Insect and Disease Leaflet 78

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
ANIMAL DAMAGE			
Sapsuckers (*Sphyrapicus varius*) Value loss through wood decay and discoloration. Occasional tree mortality.	Northern Hardwood	Leave attacked tree in place. It will concentrate most of the attacks on one tree.	How to Identify Sapsucker Injury to Trees. M. Ostry. 1976. USDA FS. NSEFES.
Voles/Mice (*Microtus* spp.) Mortality of reproduction through stem girdling in grassy plantations.	Northern Hardwood	Control grass first five years	Animal Damage to Hardwood Regeneration and Its Prevention in Southern Ontario. F.W. Von Althen. 1983. Information Report 0-X-351.
Rabbits/Hares (*Sylvilagus* spp./*Lepus americanus*) Mortality of reproduction through stem girdling.	Northern Hardwood	Control usually unnecessary	Animal Damage to Hardwood Regeneration and Its Prevention in Southern Ontario. F.W. Von Althen. 1983. Information Report 0-X-351.
Squirrels (*Sciurus* spp., *Tamiasciurus hudsonicus*, *Glaucomys* spp.) Gnawing on bark of maple saplings occasionally causes tree mortality. Squirrels also tend to feed on the edges of fungal cankers. Entire branches may be debarked and can die.	Northern Hardwood	Control usually unnecessary Population management by hunting	Animal Damage to Hardwood Regeneration and Its Prevention in Southern Ontario. F.W. Von Althen. 1983. Information Report 0-X-351.
White-tailed Deer (*Odocoileus virginianus*) Browsing can cause mortality, deformity, or reduced growth rates of seedlings. Preferential browsing can alter forest composition. Antler polishing can shred bark and can cause deformity or mortality of small trees.	Forests, including Northern Hardwood	Population management by hunting Fencing (exclusion) Tree shelters, bud caps, and repellents	Controlling Deer Damage in Wisconsin. S. Craven *et al*. 2001. UW Extension G3083. Animal Damage Management Handbook. 1994. USDA FS. PNW-GTR-332.
Livestock Potential impacts include: soil compaction, root and stem wounding, reduced tree vigor and sap production, mortality and deformity of seedlings, and altered forest composition. Damage can be severe when soil is saturated or grazing is heavy (large populations or extended time periods).	Forests, including Northern Hardwood	Eliminate or limit livestock from forests.	Sugarbush Management: A Guide to Maintaining Tree Health. 1990. D. Houston *et al*. USDA FS GTR-NE-129. Wisconsin Forest Management Guidelines. 2003. WDNR PUB-FR-226.
European Earthworms (*Lumbricus, Dendrobaena, Octolasion, and Aporreclodea* species) Declines in native understory plant species and tree seedlings follow the invasion of non-native earthworms. They rapidly decompose the leaf litter that makes up the duff layer, leaving a bare soil surface inhospitable to tree seedlings and other plants that germinate in the duff or require it for protection. Partial recovery occurs after the invading front has passed and the earthworms become naturalized.	Forests, including Northern Hardwood	Prevent new earthworm introductions. Don't transplant plants and trees into areas where earthworms are not present. Dispose of extra fishing bait in the trash. Experts recommend limiting deer populations in areas with new invasions to avoid stacking stresses on flora.	

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
ABIOTIC and MECHANICAL DAMAGE			
Storm damage Limb and trunk breakage. Decay and discoloration through wounds.	Northern Hardwood	See FHP Table 2 for specific recommendations related to impact.	Caring for ice-damaged woodlots and plantations. 1999. Ontario Extension Notes
Cold injury Cold injury occurs when the winter temperature falls to approximately -35° F or colder. Species' sensitivity varies. Injury is typically manifested by patches of dead (brown and black) cambium. In spring, affected trees will have reduced bud break and may have epicormic sprouts.	Northern Hardwood	Monitor for dieback in upper and outer crown. If more than 50% of the crown dies, expect decline to continue to mortality.	
Late Spring Frost Damage This phenomenon is unpredictable and occurs when temperatures dip below freezing during bud expansion, break and when foliage is just emerging. Foliage turns black and wilts. Twig dieback can occur. New lateral buds can break within 4 weeks after damage.	Northern Hardwood	In frost pockets, expect injury to new expanding growth during years with late spring frost. Monitor for dieback in upper and outer crown. If more than 50% of crown dies, expect decline to continue to mortality.	
Drought Symptoms of drought include premature defoliation, thin crowns, subnormal leaf size and in severe cases, wilting foliage. If drought persists for more than one year, dieback of the upper and outer crown may occur.	Northern Hardwood	Monitor for dieback in upper and outer crown. If more than 50% of crown dies, expect decline to continue to mortality. Hardwood take longer to recover from drought than conifers. Improvement in crown may not be noticeable for a year after normal precipitation returns.	
Logging damage Wounds. Limb and trunk breakage. Decay and discoloration through wounds.	Northern Hardwood	Careful felling and skidding, directional felling techniques, careful harvest plan layout. Limit harvest activities to times when soil is frozen or dry enough as to minimize soil compaction. See FHP Table 2 for specific recommendations related to impact.	
DECLINE			
Maple blight Maple blight was first reported in Florence County in 1957. Affected trees suffer branch dieback, foliage chlorosis and wilt, epicormic sprouting and tree mortality. It is caused by a combination of stand conditions, weather, insects and diseases. Maple blight causes up to 30% mortality of pole and sawlog sized trees and up to 50% mortality of saplings.	Sugar Maple	Maintain healthy forests through proper forest management. In known problem areas where defoliation has caused tree mortality, reduce maple in overstory to less than 35% of the trees. Monitor stands for possible salvage.	Studies of Maple Blight. 1964. Univ. Wis. Agr. Exp. St. Res. Bull. 250

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
INVASIVE PLANT SPECIES			
Amur Maple *Acer ginnala* A tall shrub or small tree that can outcompete and displace other flora. Foliage turns bright red in fall.	Northern Hardwood and other upland forests. Tolerates shade. Prolific stump sprout reproduction and viable seeds.	Mechanical removal of small infestations Cut stump and treat with glyphosate or basal bark spray stem with triclopyr.	https://dnr.wisconsin.gov/topic/Invasives/fact/AmurMaple
Amur Cork Tree *(Phellodendron amurense)* A tree species that can outcompete native tree seedlings and displace shrub and herbaceous layers. Allelopathic and produce chemicals that can affect surrounding vegetation.	Forests, including Northern Hardwood, and open lands.	Prioritize control of female (fruiting) trees first Herbicides applied by hack-and-squirt, basal bark spray, or cut stump treatment are effective Trees can be controlled by girdling.	https://dnr.wisconsin.gov/topic/Invasives/fact/AmurCorkTree
Bishop's Goutweed, Snow-on-the-Mountain, Bishop's Weed *Aegopodium podagraria* Aggressively invades forests and forest edges. Outcompetes native herbaceous layer, reduces tree seedling germination and inhibits tree seedling establishment. Spreads through rhizomes.	Forests, including Northern Hardwood.	Hand pull removing as much of the rhizome as possible and disposing of plant material. Plant pieces will readily resprout. Foliar application of glyphosate	https://dnr.wisconsin.gov/topic/Invasives/fact/BishopsGoutweed
Buckthorn. Common Buckthorn and Smooth (Glossy) Buckthorn (*Rhamnus cathartica* and *R. frangula*) Tall shrubs form dense thickets that outcompete and displace other flora. There is some evidence that they are also allelopathic. Seeds are spread by birds, and in mud on equipment.	Forests, including Northern Hardwood, and open lands. Smooth buckthorn is more restricted to wet and wet-mesic areas.	Monitor to ensure early detection. Clean equipment before entering the forest. Small plants can be eradicated by hand pulling. Large shrubs can be mechanically removed, cut and stump-treated, or controlled with a basal bark application. Foliar sprays should be restricted to fall months when buckthorn is still actively growing but other species are dormant, to avoid impacts to non-target vegetation. Trichlopyr may be more selective than glyphosate. In areas with high water tables, use herbicides labeled for use over water. Continued monitoring and follow-up are needed after treatment.	https://dnr.wisconsin.gov/topic/Invasives/fact/CommonBuckthorn https://dnr.wisconsin.gov/topic/Invasives/fact/GlossyBuckthorn
Burning Bush, Winged Euonymus, Spindle Bush *Euonymus alatus* Prolific seeder, can invade forests and forest edges. Not palatable by deer. Straight species and the cultivar "Nordine" are considered invasive, while other cultivars are not. Leaves turn bright red in fall.	Forests, including Northern Hardwood. Can dominate the shrub layer in hardwood forests.	Hand pull seedlings, using a weed wrench for larger plants Foliar spray using glyphosate in early summer Cut stump herbicide treatments	https://dnr.wisconsin.gov/topic/Invasives/fact/Euonymus
Bristly Locust *Robinia hispida* Shrub or small tree. Forms dense thickets with extensive small thorns/bristles all over the plant. Seeds remain viable in the soil for up to 10 years.	Forests, including Northern Hardwood, invades forest edges.	Pull small plants, use weed wrench on larger shrubs to remove all roots. Monitor for resprouting. Cut stump or basal bark herbicide techniques in fall with glyphosate or triclopyr.	https://dnr.wisconsin.gov/topic/Invasives/fact/BristlyLocust
Bush Honeysuckles *Lonicera* species Forms dense shrub thickets that outcompete and displace other flora. Seeds are spread by birds, and in mud on equipment.	Forests, including Northern Hardwood, and open lands.	Monitor to ensure early detection. Clean equipment before entering the forest. Small plants can be eradicated by hand pulling. Large shrubs can be mechanically removed, or cut and stem-treated. Foliar spray using glyphosate in spring, prior to emergence of native plants. In areas with high water tables, use herbicides labeled for use over water.	https://dnr.wisconsin.gov/topic/Invasives/fact/TatarianHoneysuckle
Garlic Mustard *Alliaria petiolata* A major invasive plant that outcompetes herbaceous flora and tree seedlings. There is some evidence of allelopathy to beneficial mycorrhizae. Small seeds spread easily on equipment and clothing.	Forests, including Northern Hardwood. One of the few invasive understory plants to thrive in full shade.	Use preventative measures; clean equipment and clothing before entering the forest. Monitor to ensure early detection. Small infestations can be eradicated by hand pulling, or by repeatedly cutting the flower stalk close to the soil surface before flowering begins. Spray with glyphosate in spring or fall to kill basal rosette; avoid non-target species.	https://dnr.wisconsin.gov/topic/Invasives/fact/GarlicMustard
Hedgeparsley, Japanese Hedgeparsley *Torilis japonica* Herbaceous perennial in the carrot family, invades forests.	Forests, including Northern Hardwood.	Pull or mow prior to flowering Glyphosate or triclopyr herbicides can be effective in early spring.	https://dnr.wisconsin.gov/topic/Invasives/fact/JapaneseHedgeparsley

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
INVASIVE PLANT SPECIES			
Japanese Barberry *Berberis thunbergii* Has potential to limit forest regeneration as it becomes more abundant. With a concerted effort, potential remains to suppress this species. It can outcompete and displace other flora. Its thorns make it difficult to work or recreate in an infested area.	Forests and semi-open areas, including Northern Hardwood. Tolerates full shade.	Mechanical removal in early spring is recommended for small infestations. Wear thick gloves. Glyphosate or triclopyr herbicides can be effective. Avoid impacts to non-target vegetation.	https://dnr.wisconsin.gov/topic/Invasives/fact/JapaneseBarberry
Japanese Knotweed *Polygonum cuspidatum* Outcompetes and displaces other flora. Early emergence, height, and density allow it to shade out other vegetation and limit tree regeneration. Not yet widespread in Wisconsin. Difficult to eradicate once established.	Northern Hardwood forests, riparian forests, open lands with mesic or wet-mesic conditions.	Repeated cutting (3x per growing season) provides control but may not eradicate a stand. The herbicide glyphosate can be effective, especially applied in fall. Continued monitoring and follow-up are needed after treatment.	https://dnr.wisconsin.gov/topic/Invasives/fact/JapaneseKnotweed
Hemp Nettle *Galeopsis tetrahit* Annual plant. Invades from forest edges into disturbed areas of forests. Spreads rapidly along skid trails, scrapes and new roads.	Forest edges, Mesic forests, skid trails, forest roads.	Dig or hand pull when in flower bud stage. Dispose of plants in landfill. Seeds can still mature after the plant has been pulled.	https://dnr.wisconsin.gov/topic/Invasives/fact/HempNettle
Norway Maple *Acer platanoides* A tree species that can outcompete and displace other flora, including sugar maple seedlings. The sap is not suitable for maple syrup. Identification is difficult, as morphology is ambiguous with sugar maple. Flattened seed cavity is distinctive. Norway maples may or may not have milky sap.	Northern Hardwood and other upland forests. Tolerates shade. Prolific stump sprout reproduction and viable seeds.	Pull seedlings. Cut stump and treat with glyphosate or basal bark spray stem with triclopyr.	https://www.dnr.state.mn.us/invasives/terrestrialplants/woody/norwaymaple.html
Oriental Bittersweet *Celastrus orbiculatus, Celastrus loeseneri* Vine can girdle trees, can shade out a tree, and can add weight to the crown of the tree causing branches to break. Sprouts vigorously from root crowns and root fragments.	Forests, including Northern Hardwood. Can grow under dense forest canopy.	Dig out or hand pull seedlings. Cut the base of the vines strangling trees, allowing upper foliage to die back, use cut stem treatment with glyphosate or triclopyr Cut or mow starting in the spring and every 2 weeks throughout the year to exhaust root reserves. Basal bark treatment with glyphosate or triclopyr Cut stem treatment with triclopyr Foliar spray with glyphosate or triclopyr	https://dnr.wisconsin.gov/topic/Invasives/fact/OrientalBittersweet
Pennsylvania Sedge *Carex pennsylvanica* This native sedge can impact northern hardwood regeneration by forming impenetrable mats on the forest floor. Physical impedance is the mechanism by which damage occurs. Past management may have contributed to development of existing sedge mats; increases in size and density after opening the forest canopy have been observed.	Mesic forests, including Northern Hardwood.	There is limited information on control. Fire, herbicide, scarification, or tilling (particularly on roadbeds or landings) may be effective in some situations.	https://www.fs.usda.gov/database/feis/plants/graminoid/carpes/all.html

Table 40.28. Northern hardwood trees: common defects, signs of defect, and evaluation of potential impacts on risk, vigor and value.

DEFECT	High Probability of Mortality or Failure (high risk)	High Probability[1] of Degrade due to Defect
Canker Localized area of dead bark and cambium; wood behind canker may or may not be decayed. Commonly caused by fungi. Fungal cankers are a source of spores that may infect healthy trees.	Canker affects >50% of the stem's circumference or >40% of the stem's cross section. Horizontal crack on a canker face. >20% of combined circumference of the stem and root collar are affected by butternut canker. White pine blister rust canker on main stem but located below crown where stem failure would leave a minimal crown.	Decay associated with large canker (affects >50% of stem's circumference). Fruit body visible in the canker's face. Extent of decay and discoloration will vary depending on organisms involved. Basswood infected with Nectria canker, if multiple infections on the main stem are common.
Wounds Any injury to tree that exposes the cambium or wood beneath cambium.		Maple, white and yellow birch: 1 or more wounds ≥50 in^2 or ≥30% of tree's circumference. >1 sugar maple borer wound (discoloration associated with borer typically limited to 24" above and 12" below). >2 large (>5") branches broken close to the stem. Codominant ripped from stem.
Decay Wood that is missing or structurally compromised. Canker rot fungi are not compartmentalized and will cause significant decay.	Decay in main stem results in <1" of sound wood for every 6" in diameter; must have 2" of sound wood for every 6" DBH if there is also a cavity present. Decay or cavity affects >40% of the stem's cross-section. Tree infected with a canker-rot fungus (see next column).	Tree infected with a canker-rot fungus including but not limited to: *Inonotus obliquus (birch),* Cerrena unicolor (maple & oak), Innonotus glomeratus (maple), Phellinus everhartii (oak) *Inonotus hispidus (oak).*
Cracks (open, can see into the tree at least an inch) A split through the bark, extending into the wood. Wood fibers are not fused. Cracked stems or branches cause the affected area to act as 2 or more separate beams, weakening mechanical support. Open cracks are more likely to be associated with decay and discoloration.	Crack goes completely through a stem or is open for >4-6' (length). Two open cracks occur on the same stem segment. The stem has an open crack in contact with another defect such as decay, a canker, or weak union.	>1 face with open crack or seam or any spiral crack.

[1] There is a high probability that the defect will cause a significant reduction in value over a 15-year period; rate of decay/stain development varies by species. Defect may be limited to localized area.

DEFECT	High Probability of Mortality or Failure (high risk)	High Probability[1] of Degrade due to Defect
Weak Union Union with ingrown bark between stems; wood fibers are not fused. Weak unions are characterized by an acute angle between stems.	Stump sprouts joined above ground in V-shaped union and associated with a crack, showing failure has already begun.	Large (>8" diameter stems) tight union that is either cracked or decayed or associated with another defect. Could result in failure; stain and decay will vary.
Structural Compromise Unusual form typically initiated by storm damage.	Leaning tree with recent root lifting. Leaning tree with a horizontal crack, long vertical crack, or buckling wood on the underside of the tree. New leader formed in response to a dead or broken top. Risk increases as top gets larger and stem decays at break point.	
Root Defects Loss of structural support due to root rot, wounding, severing or any other factors that cause root mortality.	More than 33% of roots severed, decayed or otherwise compromised. Stump sprouts with a tight union where root structure is not sufficient to support stems.	>3 root wounds within 4' of the main stem; each wound encompasses >30% of root diameter.
Crown Density/Dieback/Leaf Condition Crown symptoms are often showing a response to poor root health, stress such as defoliation or drought or infestation by cambium-mining beetles. Large dead branches/tops/codominants keep wound "open"; decay will advance more rapidly with an open wound. Failure of dead wood is unpredictable. Could cause damage upon failure.	50% of the crown dead, unless loss of crown is due to stem breakage. 75% of leaves subnormal in size or abnormal in color. (excluding iron chlorosis.) Signs of cambium miners such as the two-lined chestnut borer or bronze birch borer.	Multiple large (>5" diameter) dead branches, dead top or codominant (>10" diameter).

[1] There is a high probability that the defect will cause a significant reduction in value over a 15-year period; rate of decay/stain development varies by species. Defect may be limited to localized area.

Summary of Principles Related to Discoloration and Decay Development

Jane Cummings Carlson

1. Wounding: the death of large branches, sprouts or codominants; and any activity that exposes the cambium to air and moisture initiate discoloration in trees with naturally white wood throughout.
2. After wounding, discoloration may be caused by bacteria, oxidation of phenolic compounds and degradation of the cells by fungi.
3. Discoloration and decay typically do not move throughout a tree as it ages but are compartmentalized and limited to tissue present at the time of wounding. Known exceptions to this include trees that are infected with canker-rot fungi.
4. Discoloration tends to form in vertical columns, tapered at the ends.
5. The further the wound or breakage is from the main stem, the lower the chance discoloration and decay will occur to the main stem.
6. Discoloration resulting from a broken top or split stem will progress downward and be limited to the diameter of the tree at the time of wounding. Rate of spread is variable; approximately 4 inches per year has been noted in sugar maple if wound is significant (> 40% of circumference).
7. Wounds initiated in the spring will form callus more quickly than wounds initiated in the fall but if the wounds are the same size, the discoloration resulting from both wounds will likely be similar after 3 years.
8. The presence of prior defects appears to influence the rate of formation (hasten) of additional discoloration from newer wounds.
9. Trees with lower starch content (i.e., defoliated) tend to be more negatively impacted by wounds, as there is a reduced rate of callus formation. Vigorous trees may slow or halt the discoloration/decay process more readily than trees of poor vigor.
10. Decay and discoloration are more likely and more extensive in wounds that remain open; decay and discoloration move more slowly after wounds are closed.
11. Volume of discoloration and decay increases with increasing wound width; wound area is a good indicator of value loss.
12. Wounds are initiation points for cracks.
13. Factors such as site, genetic controls, wound type, frequency of wounding, host species and microorganisms present all potentially influence wound closure and in turn the rate and severity of discoloration and decay development.

Table 40.29. Summary of guidelines related to stain and decay development.

Species	Issue	Rule of Thumb
Maple, No. Hdwds.	Oxyporus populinus Ganoderma applanatum Canker rots	Decay 2-4' above and below Decay 4-6' above and below Decay 5-7' above and below
Sugar Maple	Rate of vertical development of discoloration.	Wound 20% of circumference: 1"/yr. 30% of circumference: 2"/yr. 40% of circumference: 4"/yr. These numbers are for upward movement from a basal wound, downward movement may be slower.
	Decay/discoloration severity	Age, severity and proximity to other wounds all influence volume of discoloration and decay.
	Sugar Maple Borer Wounds	Discoloration more likely when both a horizontal and vertical trail is present. Discoloration/decay columns typically limited to 24" above and 12" below the scar.
	Discoloration common in larger/older trees.	Large Dead branches appear to result in physiologically induced discoloration in the main stem. This is also influenced by the presence of certain microorganisms.
Yellow Birch	Rate of development of column of decay	5 years: column length equal to wound length 15 years: column length 2 X wound length 20 years: column length 3-5 X wound length

Slower decay → **Faster decay**

Hickory, Sugar Maple White, Red Oak Cherry	**Ash**	**Red Maple Black Oak**	**White Birch Basswood**	**Yellow Birch Beech, Aspen**

Less discoloration (with same wound size/severity) → **More discoloration**

Hickory, Ash Oak Cherry	**Basswood**	**White Birch**	**Sugar Maple**	**Red Maple Yellow Birch**

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Chapter 41

Oak Cover Type

Last Full Revision: 11/12/2012
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand composition
Oak comprises 50% or more of the basal area in poletimber and sawtimber stands, or 50% or more of the stems in seedling and sapling stands. The five common upland oak species are: northern red oak (*Quercus rubra*), white oak (*Q. alba*), bur oak (*Q. macrocarpa*), black oak (*Q. velutina*), and northern pin oak (*Q. ellipsoidalis*). For information on swamp white oak (Q. *bicolor)*, see Bottomland Hardwood Cover Type Chapter 47.

Associated species
Overstory and understory composition of oak dominated communities varies significantly between southern and northern Wisconsin. Within each region, composition also varies across the range of sites where oak forests occur, from dry to mesic to wet. For each of the following site types, typical oak forests are described in terms of dominant trees and principal associates. These descriptions of characteristic overstory associations are derived primarily from analysis of Forest Inventory and Analysis (FIA) data (Schmidt 1997, Kotar et al. 1999) and the Forest Habitat Type Classification System (FHTCS – see Section B).

1.2 Silvical Characteristics

The primary source for the following descriptions and tabular summary is from *Silvics of North America* (Burns and Honkala 1990). Other sources: *The Ecology and Silviculture of Oaks* (Johnson et al. 2002), *Trees and Shrubs of the Upper Midwest* (Rosendahl 1955), and *North American Trees* (Preston 1976).

1.2.1 Black Oak

Flowers and fruiting
Black oak catkins emerge before or at the same time as the leaves in April or May. Black oak can hybridize with northern pin and red oak. Acorns occur singly or in clusters of 2-5, are about one-third enclosed in a scaly cup and mature in two years. Black oak acorns are brown when mature and ripen from late August to late October, depending on geographic location. It is a consistent seed producer with good crops of acorns every 2 to 3 years.

Germination
Black oak acorns germinate in the spring following seed fall. The most favorable conditions for germination occur when the acorns are in contact with or buried in mineral soil and covered with a light layer of litter. Acorns on top of the litter generally dry excessively during early spring and lose viability before temperatures are favorable for germination.

Seedling development
After harvesting, black oak seedlings will be present in approximately the same numbers as in advance reproduction prior to harvesting. New seedlings established at or just after harvest typically grow too slowly to compete with sprouts of other tree species and other vegetation.

Light intensity is critical to the survival and growth of black oak seedlings. Light intensity under undisturbed forest stands is often very low at the height of the new seedlings (about 6” high). Even-aged silvicultural systems satisfy the reproduction and growth requirements of black oak better than uneven-aged selection systems. Under the selection system, black oak is unable to reproduce because of inadequate light.

Black oak seedlings seldom remain true seedlings for more than a few years because drought, low light intensity, fire, animals, or mechanical agents kill the tops. Then dormant buds near the root collar produce new sprouts. The dieback and re-sprouting process can occur several times; thus the roots of black oak saplings may be 10 to 20 years older than the tops. If environmental conditions are favorable, these root systems can support rapid shoot re-growth when the shoots are broken off. Growth of black oak sprouts, like that of seedlings, is slow under forest canopies.

Vegetative reproduction

Small stumps of young trees on good sites (dry-mesic to mesic) sprout most frequently and large stumps of old trees on poor sites (dry) sprout least frequently. The probability a stump with a living 1-year old sprout will have at least one dominant or codominant sprout at 5 years is predictable based on stump diameter. It ranges from near 100% for 3” stumps to about 15% for 30” stumps (41.10).

Growth and development

Black oak is intermediate in shade tolerance. Seedlings usually die within a few years of establishment under closed canopies. Most black oak sprouts in mature stands develop crooked stems and flat-topped or misshapen crowns. After the overstory is removed, only the large stems are capable of competing successfully. Seedlings are soon overtopped. The few that survive usually remain in the intermediate crown class.

Fire

Wildfires damage black oak trees by killing the cambial tissue, creating an entry point for decay with the result of volume loss due to heart rot. Trees up to pole size are easily killed by fire, and severe fires may kill sawtimber. Many of the killed trees sprout and form a new stand, giving black oak a competitive edge over other tree species that do not readily sprout after a fire (Sander: Burns and Honkala, 1990).

Longevity

Black oak grow to heights of 60-80 feet, up to 24” to 36” dbh, become physiologically mature (the stage prior to the beginning of senescence) at about 100 years of age, with some living to 200 years.

1.2.2 Bur Oak

Flowers and fruiting

Bur oak flowers shortly after the leaves appear in mid-late May in Wisconsin. Pollen from one tree appears to germinate better on the stigmas of another, favoring cross pollination. Acorns ripen within the year and drop from the tree as early as August or as late as November.

Germination usually occurs soon after seed fall, but acorns of northern trees may remain dormant through winter and germinate the following spring.

Bur oaks up to age 400 years bear seed, older than reported for any other American oak. Good seed crops occur every 2 to 3 years, with no crops or light crops in intervening years.

Germination
Germination of acorns and early development of bur oak are often best where litter has been removed. When covered by litter, acorns are more susceptible to pilferage by rodents and the newly developed seedlings are more likely to be attacked by fungi and insects.

Seedling development
Root growth of juvenile bur oaks is rapid, and the taproot penetrates deeply into the soil before the leaves unfold. At the end of the first growing season, bur oak roots have been found at depths of 4.5 ft., with a total lateral spread of 30 inches. This strong early root development, along with high water-use efficiency, may explain why bur oak can pioneer on droughty sites and can successfully establish itself in competition with prairie shrubs and grasses.

Vegetative reproduction
Vigorous sprout growth follows the burning or cutting of pole-size or smaller bur oaks. Except for seedling sprouts, the quality and form of sprout stems are poor. In northwestern Wisconsin, bur oak often breaks bud before the last spring frosts, resulting in development of a shrubby form of the tree.

Growth and development
Bur oak is intermediate in shade tolerance. Bur oak is slow growing. In 12- to 16-year-old plantations on Iowa upland sites, average annual height growth ranged from 0.3 to 1.7 ft. and diameter growth from less than 0.1-0.25”.

Flood tolerance
Bur oak is relatively tolerant of flooding, compared to the other oaks (except swamp white oak). In open bottom lands, reproduction of bur oak may be prolific, but first-year mortality may be 40-50% when seedling submersion continues for two weeks or longer during the growing season. Although bur oak seedlings can endure flooding for up to 30 consecutive days during the growing season, root growth is greatly reduced, thus reducing drought tolerance after flood waters have receded.

Longevity
Bur oaks generally grow to heights of 80-100 feet, can range from 36-48” dbh, and live for 200 to 300 years. Maximum individual tree longevity can be 500 years.

1.2.3 Northern Pin Oak

Flowers and fruiting
Northern pin oak flowers open when leaves are half developed. Acorns ripen the second season and are either solitary or in pairs. Acorns are ellipsoidal, light brown, and usually

striped with darker lines. The cup covers 33-50% of the acorn, with the cup scales closely appressed.

Growth and development
Northern pin oak is the most shade intolerant of all the oaks and cannot reproduce in shade. Northern pin oak can hybridize with black and red oak. Growth form can be almost shrub-like where stems are frequently damaged from fire, frost, or browsing. Sprouts from smaller diameter stumps are prolific. Northern pin oak is distributed throughout the state and is frequently associated with jack pine in the north. It is common, and, in places, abundant on acid, sandy soils.

Northern pin oak reaches seed bearing age at about 20 years with optimum seed bearing at 40- 50 years, producing good seed crops every 2-4 years. It reproduces vegetatively by sprouting prolifically from stumps of cut trees or root collars of top killed trees.

Vegetative reproduction
Sprouts are an important component of the regeneration of northern pin oak. This species will produce a vigorous sprout nearly 100% of the time on small diameter stumps (< 4”) and very large diameter stumps (>18”) will produce sprouts up to 70% of the time. On average, 85% of all northern pin oak stumps will sprout (Mujuri and Demchik 2009).

Fire
The thick bark of older trees (>10 dbh) minimizes fire damage. Smaller trees are easily damaged by surface fires but commonly sprout vigorously from the root collar after top-kill.

Longevity
The largest northern pin oak known in Wisconsin is 92’ tall with a dbh of 52”. The average longevity of northern pin oak is 80-100 years.

1.2.4 Northern Red Oak

Flowers and fruiting
Red oak flowers emerge before or at the same time as the leaves in April or May. The acorn occurs singly or in clusters of 2-5, is partially enclosed by a scaly cup, and matures in 2 years. Northern red oak acorns are brown when mature and ripen from September to late October, depending on geographic location.

Good to excellent seed crops are produced at irregular intervals, usually every 2-5 years. Acorn production is highly variable among trees even in good seed years. Some trees are always poor producers (<8 acorns/branch tip) while others are always good producers (>17 acorns/branch tip) (Grisez 1975). Crown size seems to be the most important tree characteristic affecting acorn production. Dominant or codominant trees with large, uncrowded crowns produce more acorns than trees with small, restricted crowns.

Germination
Even in good years only about 1% of the acorns become available for regenerating northern red oak due to predation by insects and animals. To produce one 1-year old seedling in unmanaged situations, 500 or more acorns may be required.

Best germination occurs when the acorns are in contact with or buried in mineral soil and covered by a thin layer of leaf litter. Acorns on top of the leaf litter or mixed with litter become excessively dry during early spring and lose viability before temperatures are favorable for germination. Management practices, such as scarification, that protect acorns and improve the germination environment can increase the percentage of acorns available to produce seedlings.

Seedling development
Germination is followed by vigorous and rapid taproot development, and if the taproot is able to penetrate the soil, seedlings survive considerable moisture stress later in the growing season. Northern red oak seedlings are the least drought tolerant of the oak species.

Growth and development
Northern red oak is intermediate in shade tolerance. “Light intensity appears to be the most critical factor affecting not only first year survival, but also survival and growth in subsequent years” (Sander: Burns and Honkala 1990). Northern red oak reaches maximum photosynthesis at about 30% of full sunlight. Light intensity under undisturbed forest stands, at new seedlings height, is often much lower and results in poor growth.

Where red oak receives adequate sunlight, it is among the fastest growing upland oaks, with average radial growth rates of 1-1.5”/decade (Johnson et al., 2002). Growth and development are best on mesic habitat types, where trees in excess of 150 years of age have been observed with radial growth rates in excess of 1”/decade**.** Red oak can hybridize with pin and black oak.

Conditions such as fire, poor light, poor moisture conditions, or herbivory can kill the tops, but the roots often survive. Dormant buds near the root collar can produce new sprouts. This dieback and resprouting may occur several times; the result can be a crooked, flat-topped, or forked stem. Such stems have root systems that may be 10 or more years older than the tops. When the tops are broken off (such as may occur during logging) during favorable environmental conditions for oak, the older, larger root system can support rapid shoot re-growth. Stem form can often be improved when this occurs.

Growth of northern red oak seedlings and sprouts is slow and generally restricted to one growth flush under undisturbed or lightly disturbed forest canopies.

Vegetative reproduction
Northern red oak stumps sprout more frequently than black oak or white oak stumps. Sprouting frequency is related to parent tree size with more small stumps sprouting than large ones. More than 60% of stumps from 11” dbh or smaller trees will sprout, while 30% of 17+” dbh trees will sprout (Sander 1977). Sprouting ability is also influenced by tree age. In studies

of northern red oak, 93% of trees 50-60 years old had live sprouts, while live sprouts occurred on less than 60% of 80-110 years old trees (Johnson 1975, Wendel 1975). Sprouts of low origin are much less likely to develop decay than sprouts that originate high on the stump, but they may develop severe crook or sweep at the base.

Fire
"Wildfires seriously damage northern red oak by killing the cambial tissue at the base of trees, thus creating an entry point for decay-causing fungi. Wildfires can be severe enough to top kill even pole- and sawtimber-size trees. Many of the top-killed trees sprout and thus create new even-aged stands, but the economic loss of the old stand may be great. Small northern red oak seedlings may be killed by prescribed fires, but larger stems will sprout and survive, even if their tops are killed." (Sander: Burns and Honkala, 1990)

Longevity
Typical size at maturity on good sites is 65-100' tall and 24-36" dbh. Maximum tree size recorded in Wisconsin is 112' tall and 85" at dbh. Maximum individual tree longevity is 400 years.

1.2.5 White Oak

Flowers and fruiting
White oak flowers in the spring at about the same time leaves appear. The time may vary from late March to late May depending on latitude. Physiological maturity of acorns, as indicated by normal germination, is reached when acorns change color from green to light brown.

White oak can produce seeds prolifically, but frequency of good acorn crops is inconsistent and occurs only every 4 to 10 years. Several studies have shown that only a small portion of the total mature acorn crop (sometimes only 18%) is sound and fully developed; the remainder is damaged or destroyed by animals and insects so seedlings may be established only during heavy crop years.

Germination
Seeds germinate in the fall soon after dropping in September or October, requiring no pretreatment for germination. For germination to occur, the moisture content of acorns must not fall below 30-50%. Germination is favored at soil temperatures between 50° and 60° F. When acorns germinate, their roots begin to grow but the shoot remains dormant. This trait serves to protect it from damage by freezing. After germination, root growth continues until interrupted by cold weather. Broken radicles are replaced on freshly sprouted seeds. Root and shoot growth resumes in the spring, and after the first growing season, seedlings 3-4" high normally develop a large taproot 0.25 - 0.50" in diameter and more than 12" long.

Seedling development
Under ideal growing conditions it is common for individual seedlings to grow 2' or more per year. However, white oak seedlings germinated in the year of overstory removal normally grow slowly and are frequently outcompeted by other species, so they are of little value in stand reproduction.

Vegetative reproduction

Small white oak trees sprout prolifically and vigorously when cut, or damaged by fire. The ability to sprout depends on the dbh of the parent trees. Trees less than 5” dbh will sprout 80% of the time, 50% of the trees 6-11” dbh will sprout, and 15% or less of trees larger than 12” dbh will sprout.

Growth and development

White oak is intermediate in shade tolerance and the most tolerant of the oaks. It is most tolerant during youth and becomes less tolerant as the tree grows larger. It is common to find white oak seedlings accumulating to high densities in an understory over time. White oak seedlings, saplings, and even pole-size trees are able to persist under a forest canopy for more than 90 years periodically dying back and resprouting from the root system (Burns and Honkala 1990).

White oak is deep rooted, a trait that persists from youth to maturity. White oak seedlings produce a conspicuous, well-developed taproot which gradually disappears with age and is replaced by a fibrous root system with well-developed, tapered laterals. Fine roots are typically concentrated in dense mats in the upper soil horizons usually close to tree trunks but occasionally lying beneath the base of neighboring trees. Root grafts between white oak trees can occur, especially among trees within 50’of each other, although root grafting among the white oak group is less common than among the red oak group.

Longevity

Typical size at maturity on good sites is 80-100’ tall and 36-48” dbh. Maximum tree size recorded in Wisconsin is 98’ tall and 64” at dbh. Oaks in general and white oak specifically, are long-lived trees. Under ideal conditions, white oaks can live to 600 years of age (Rogers: Burns and Honkala, 1990).

Table 41.1. Summary of selected silvical characteristics.

Species	**Black oak**	**Bur oak**	**Northern pin oak**	**Northern red oak**	**White oak**
Flowers (All monoecious)	April-May	April-May	April-May	April-May	April-May
Seed Ripens	2nd year, Sept.-Oct.	1st year, Aug.- Nov.	2nd year, Sept.-Oct.	2nd year, Sept.-Oct.	1st year, Sept.-Oct.
No. seeds/lb.	245	75	245	105	215
Seed dispersal	Fall. Rodents and gravity. Blue jays at larger distances.	Fall. Rodents and gravity.	Fall. Rodents and gravity.	Fall. Rodents and gravity. Blue jays at larger distances.	Fall. Rodents and gravity.
Minimum Seed-Bearing Age	20 years	35 years	15 years	25 years	30 years

Species	**Black oak**	**Bur oak**	**Northern pin oak**	**Northern red oak**	**White oak**
Optimum seed-bearing age	40-75 years	75-150 years	40-50 years	50+ years	50-200 years
Good Seed Years	Every 2-3 years	Every 2-3 years	Every 2-4 years	Every 2-5 years	Every 4-10 years
Average Seed viability	47%	45%	95%	58%	50-99%
Cold Stratification	30-60 days @ 20-30°F	In Wisconsin: 30-60 days @ 33-40°F	60-90 days @ 34-41°F	30-45 days @ 32-41°F	None
Germination Temp.	65-80°F	60-80°F	30-60°F	>34°F	50-60ºF
Seedbed Requirements	Mineral soil with cover of light leaf litter	Mineral soil contact	Mineral soil contact	Mineral soil with cover of light leaf litter	Light to moderate leaf litter
Seed Germinates	Spring after seed fall	In Wisconsin, remain dormant until spring.	Spring after seed fall	Spring after seed fall	Immediately after seed fall
Seedling development	Rapid root growth. Slow shoot growth compared to competition. Growth under forested condition is slow.	Rapid root growth compared to shoot growth. Slow shoot growth	Rapid root growth. Slow shoot growth compared to competition. Growth under forested condition is slow.	Rapid root growth. Slow shoot growth compared to competition. Needs >30% of full sunlight.	Rapid root growth, shoot remains dormant until next spring. > 35% full sunlight for best growth.
Vegetative reproduction	Poletimber and smaller sized trees sprout readily. Sawtimber-sized trees sprout less frequently	Poletimber and smaller sized trees sprout readily. Sawtimber-sized trees sprout less frequently	Sprouts prolifically.	Poletimber and smaller sized trees sprout readily. Sawtimber-sized trees sprout less frequently	Poletimber and smaller sized trees sprout readily. Sawtimber-sized trees sprout less frequently
Shade Tolerance	Intermediate. Less tolerant than white oak	Intermediate	Intolerant	Intermediate. Less tolerant than white oak	Intermediate. Most tolerant as seedling.
Maximum individual tree longevity	200 years	500 years	Unknown	400 years	600 years

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

Management objectives should be identified in accordance with landowner goals within a sustainable forest management framework, which gives consideration to a variety of goals and objectives within the local and regional landscape. The silvicultural systems described herein are designed to promote the optimum quality and quantity of oak timber products. High quality sawlog and veneer production is the objective for most sites of fair (dry-mesic) to excellent quality (mesic), while sites of poor quality (very-dry to dry) will be managed for optimum health and vigor. Modifying these silvicultural systems to satisfy other management objectives could potentially result in reduced vigor, growth and stem quality. The habitat type is the preferred indicator of site potential. Other indicators of site potential include site index, aspect, position on the slope, and soil characteristics. In addition to clearly identifying landowner goals and objectives, in-depth and accurate stand assessment will facilitate discussion of management options and objectives in relation to realistic and sustainable management goals. Oak stand assessment should include quantifying variables such as present species composition, stand structure, stand quality (present and potential crop trees), stand age, ground layer competition, site quality, and herbivory potential.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.1 Landscape Considerations

Oak forests provide significant ecological, economic and social benefits. Although these forests are still very common, an increase in oak acreage on dry sites has offset recent decreases on more productive, mesic sites. There are concerns that select red and white oaks are declining as components of Wisconsin's forests. Forest and Inventory Analysis (FIA) data show a decline in acreage of oaks in the youngest and oldest age and size classes. Landscape-scale considerations for the oak cover type include concerns for the decrease in oak species' dominance on dry-mesic and mesic sites, a lack of regeneration, and a decline in representation of older oak (>100 years old). Possible reasons include land and forest management goals/objectives/practices, altered disturbance regimes, and herbivory. Forest fragmentation is another concern because of impacts on ecosystem function.

3.1.1 Historical Context

When the General Land Office Public Lands Surveys (PLS) were conducted in Wisconsin (1832-1866), oak-dominated cover types occurred on about 10.8 million acres, including 5.0 million acres of oak forest primarily composed of black, white and bur oaks, as well as 2.4 million acres of scrub oak/jack pine forest and barrens, and 3.4 million acres of oak openings (Finley 1976). In addition, red, white, and black oaks were a significant component, particularly in southern and central Wisconsin, of northern hardwood forests dominated by beech or sugar maple. The historic predominance of oaks was likely due to several factors, including natural disturbances (e.g., fire, wind), and Native American land use practices, particularly burning (Abrams and Nowacki 1992).

In northern and central Wisconsin, oaks were commonly found in scrub oak/jack pine forests and barrens on sandy soils with a frequent and severe fire disturbance regime. Oak species also occurred as a component of northern hardwood and northern pine forest communities. In the northern hardwoods, the oak component is believed to have been maintained by localized fire disturbances. Fires were significantly less frequent on loamy moraines, where northern hardwoods typically dominate, than in sandy outwash areas (Radeloff et al. 2000). The oak component would have developed where fire regimes were of low to moderate intensity, such as in transitional areas between outwash and moraines, or where till materials are intermingled with outwash sands. Severe fires that originated in outwash sands would occasionally run for some distance into loamy moraines if driven by strong winds, particularly during periods of drought. Some fire occurrences within northern hardwoods were associated with blowdowns which ignited after fuels had dried. Fire disturbance exposed mineral soils for seed germination, and reduced competition for oak seedlings.

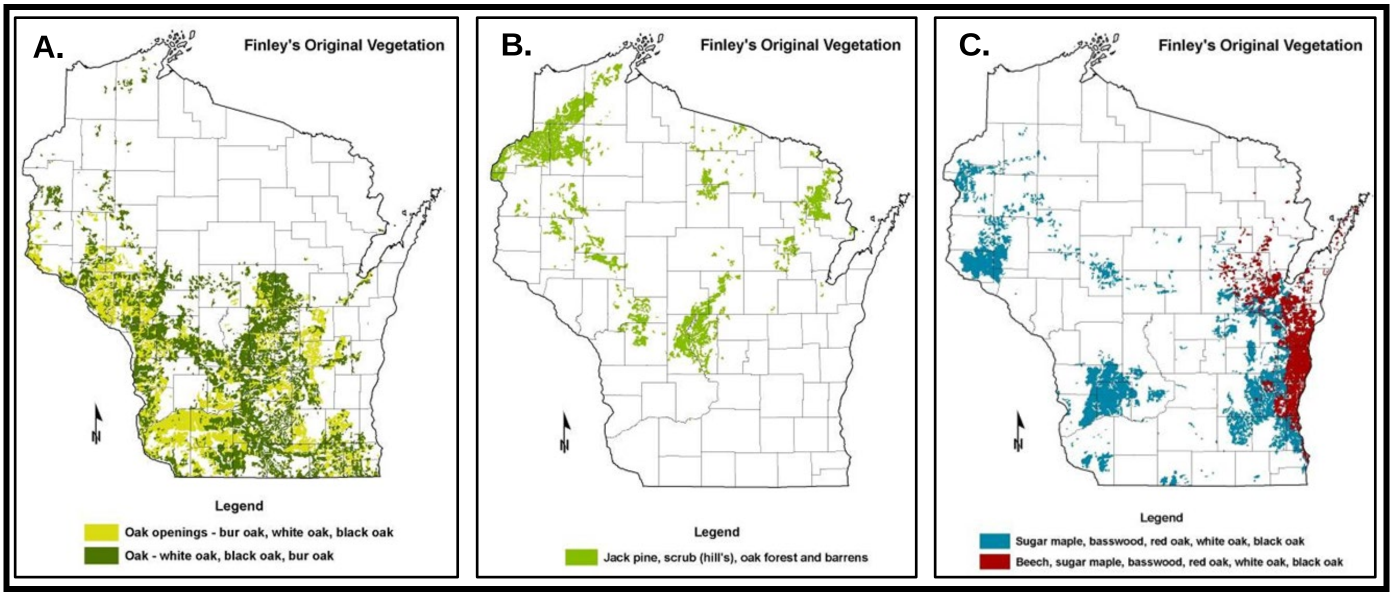

Figure 41.1. Finley's original vegetation maps for oak woodlands from 1832-1866. (A.) Pure oak stands and openings (white, black and bur oak), (B.) mixed stands in barrens conditions, (C.) mixed stands with northern hardwoods species

The oaks of southern Wisconsin were commonly described by early explorers, missionaries, and settlers as open, "park-like" forests dominated by widely spaced oaks with a paucity of shrubs or saplings. Oak forests were more common in the Driftless Area, but savannas dominated the landscape of southeast Wisconsin. The oak forests and savannas were interspersed with prairies, wetlands, and maple-dominated forests. Oak woodland is sometimes defined as an intermediate structural stage between closed forests and savannas, with more canopy closure and an open understory. This structure would have been created by ground fires of relatively low intensity and shorter intervals.

The close association of fire and oak forests has led to some research on type, intensity, timing, frequency, and pattern (Brose et al. 2005). Evidence indicates that periodic fire disturbance played an important functional role in development and maintenance of pre-Euro-American settlement oak ecosystems (Abrams 2005). The frequency and severity of fire disturbance affects stand structure, composition, and ecosystem processes such as nutrient cycling. High frequency fires at less than 50-year intervals have been credited with creating and maintaining savannas and woodlands prior to European settlement (Reich et al. 1990; Anderson et al.1999).

Historically, most oak forests would have had a low intensity and less frequent interval of fire (>50 years). Variations in southern Wisconsin's fire disturbance regime, both spatially and temporally, led to the range of structural conditions of oak cover types. Low intensity fires with intervals of 5-15 years are defined as those with flames less than two feet long, which consume the leaf litter and small woody debris. Low intensity fires usually enhance oak regeneration. Historically, oak forests would have experienced these fires at less frequent intervals (>50 years) while fires in oak savanna were of low to moderate intensity with intervals estimated at 16 years (Peterson et al. 2001).

High intensity fires are defined as those with flame length greater than two feet or that kill significant numbers of overstory trees. Generally, these fires enhanced the competitive status of oak regeneration by increasing the amount of light reaching the forest floor. The scrub oak/ jack pine barrens likely experienced surface fires annually (Dorney 1981).

When Euro-American settlement began in southern Wisconsin in the early 1800s, land clearing for agriculture led to the loss of many oak forests and savannas. Oaks were used for fences, building materials, and fuels, and many were cut and burned to clear the land. As marginal agricultural areas reverted to forest, the combined effects of burning and pasturing led to suitable conditions for the establishment of oak.

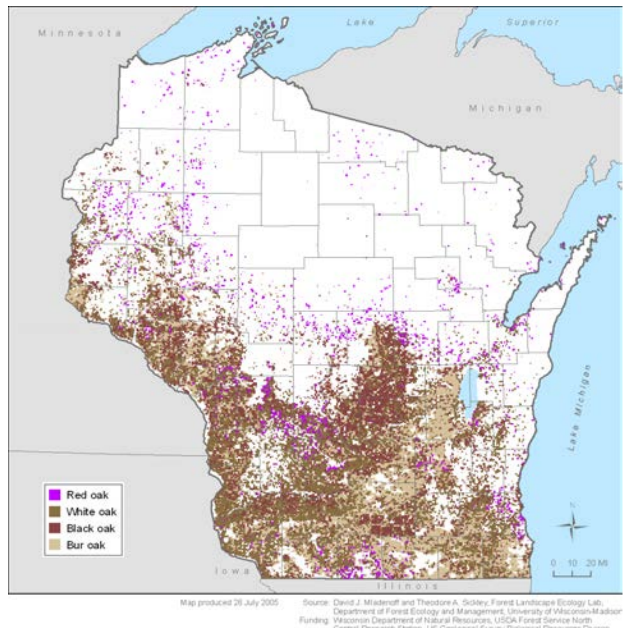

Figure 41.2. Distribution map of four species in Wisconsin

3.1.2 Current Context

According to Forest Inventory and Analysis (FIA) data summarized in 2004, the oak-hickory forest type is still widespread in Wisconsin, occupying about 3.4 million acres (Schmidt 1997). The oak-hickory forest is the 3rd most abundant cover type in Wisconsin and represents about 21% of forestland. A distribution map of four oak species is shown in Figure 41.2. Today, oak forests are a result of post-Cutover era land management practices including clearing, short-term intense fires, farming, and pasturing, which favored oaks over more shade-tolerant species. In many areas, the canopy composition of the forest is now steadily shifting from oak dominance to more shade tolerant mesic hardwoods, primarily due to the absence of widespread fire disturbances and the selective removal of commercially valuable oaks. Today, competition from native and non-native species in the absence of fire is contributing to the succession of oak forests to central and northern hardwood species, including red and sugar maple, basswood, elms, green and white ash, black cherry, and ironwood.

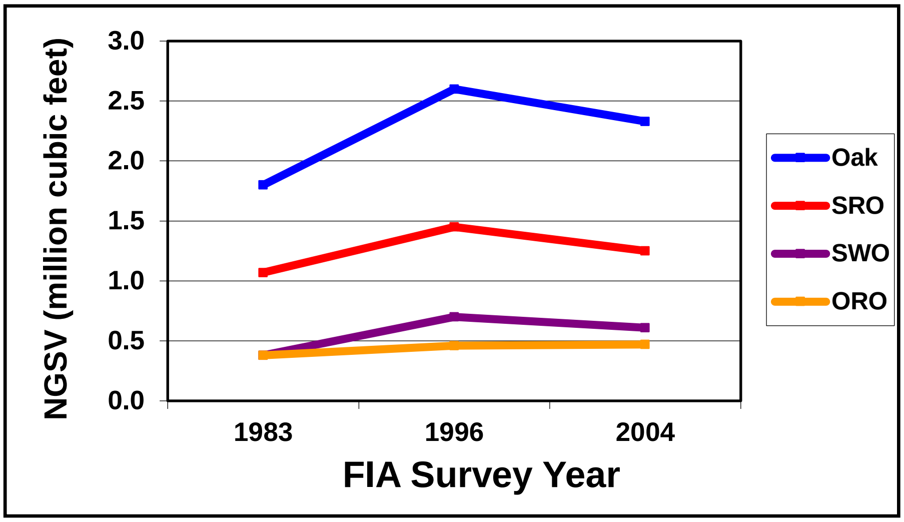

Figure 41.3. Change in net growing stock volume (NGSV) of select oaks: SRO (northern red oak), SWO (white, swamp white and bur oaks), and ORO (northern pin and black oaks) (site index > 60 sq. ft.) on timberland.

FIA data reveal a downward trend in net growing stock of oak in stands with site index >60 (Figure 41.3) between 1996 and 2004. Implications for the decline in this category suggest the removal of high value trees can leave a degraded forest and possibly an imbalance in size or ages class within the stand.

Figure 41.4 shows a decline in acreage of young oak-hickory stands and stands older than 100 years between the 1996 and 2005 inventories, leading to concerns that representation of oak forests will continue to decline in the future. A decline in the young age class may reflect the difficulty in regenerating oak. This may contribute to a gradual succession of oak forests to other forest types (mixed central hardwood, red maple, northern hardwood). A decline in the older age class may affect habitat available for certain plant and animal species and overall biodiversity in older oak forests.

The future representation of oak forests on dry-mesic and mesic sites is uncertain. Oak regeneration is uncommon and succession of oak forests to other community types is widespread. Primary factors that may be contributing to the decline of oak in some age classes on the landscape are forest management goals/objectives/practices, altered disturbance (particularly fire) regimes, and herbivory.

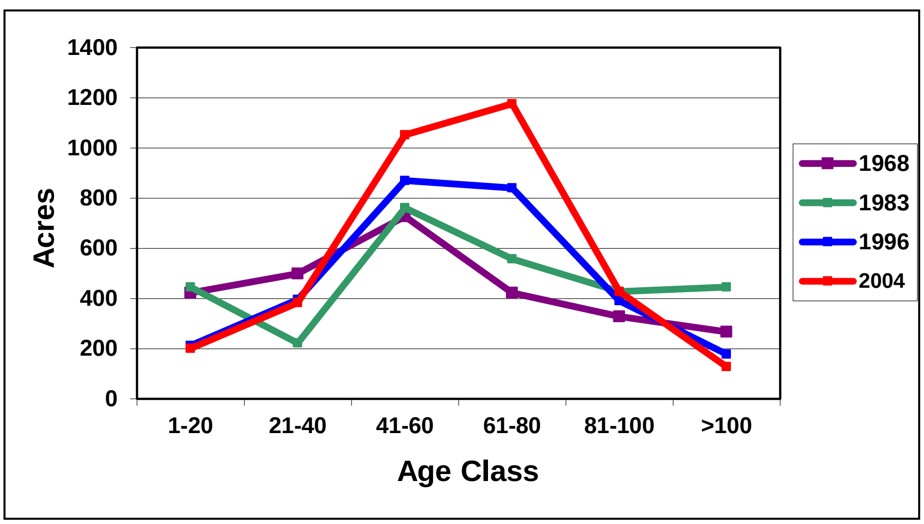

Figure 41.4. Forest age-class distribution for the oak-hickory forest type group in Wisconsin, from FIA measurements taken in 1968, 1983, 1996 and 2005.

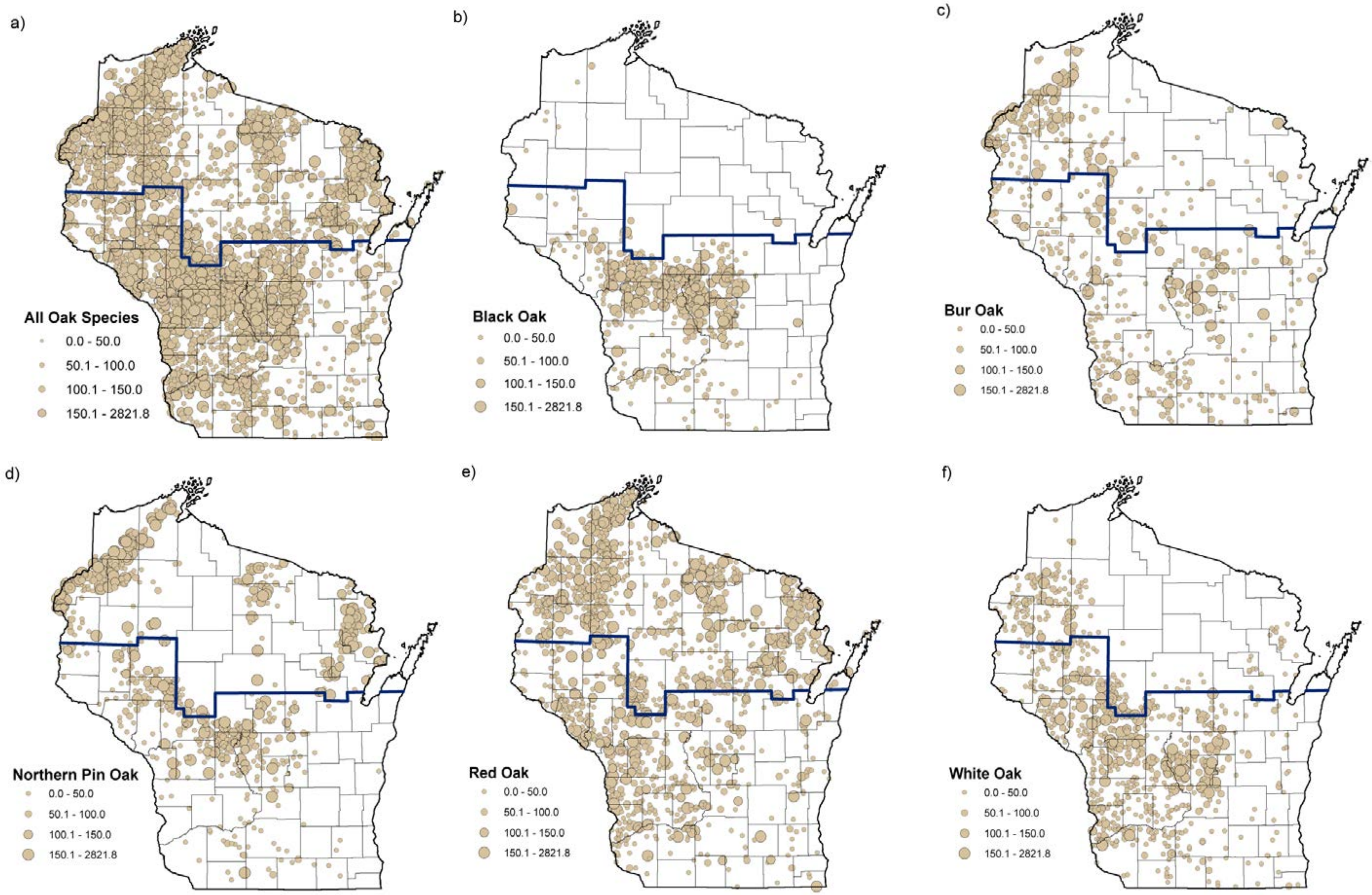

Figure 41.5. Volume of oak from Wisconsin FIA plots (USDA-FS 2009). Figures are for a) all oaks b) black oak c) bur oak d) northern pin oak e) red oak and f) white oak. The blue line on each map separates the northern and southern habitat type regions.

3.1.4 Fragmentation

Fragmentation is a term used to describe certain kinds of landscape structure and is often characterized as permanent versus habitat fragmentation. “Permanent” fragmentation refers to a long-term conversion of forest to urban, residential or agricultural uses. “Habitat” fragmentation refers to a shorter-term disruption of habitat continuity caused by creation of a mosaic of successional stages within a forest tract. Habitat fragmentation represents a short-term loss of habitat for some species and a gain for others. Some animals and plants can be negatively affected by fragmentation, particularly those that are area-sensitive, or subject to impacts associated with forest edges. Dispersal can be affected if species or their propagules cannot cross or get around the open land. In Wisconsin and elsewhere, the loss of forest habitat has a larger impact on species than shorter-term habitat fragmentation.

Considerable forest fragmentation has occurred during the past 150 years, especially in the oak-hickory forests of southern Wisconsin. Due to increasing human population and associated development pressure, there are few large tracts of southern forest remaining. The remaining southern forests are located in areas where development has been limited by public ownership, low commercial value, or relative inaccessibility (e.g., rough topography, susceptibility to flooding).

Edge effects can benefit some species while negatively impacting others, and effects vary depending on the type of edge. “Hard” edges occur at abrupt habitat boundaries, such as when agricultural fields or residential developments adjoin forests. “Soft” edges occur where forests are adjacent to shrubby riparian zones or patches of younger forest. Hard edges are a common condition in southern Wisconsin, where most of the mesic oak forests occur. As fragmentation progresses and forest patch sizes become smaller, more of the area is edge-affected. Small patch sizes and hard edges are associated with cowbird parasitism and nest predation, which are limiting factors for many bird populations in southern oak forest fragments. However, species such as ruffed grouse and small mammals benefit from edge habitat.

Forest fragmentation and edge effects have been associated with declines in populations of neotropical migratory songbirds (NTMB’s). Edge effects on other wildlife species are not as well documented. NTMB’s are considered “indicators of ecosystem health” in part because of the insect pests they consume (Robinson et al. 1995). During the 1980’s, research studies identified increases in predation and nest parasitism along forest edges (Brittingham and Temple 1983, Wilcove 1985). These effects are more harmful to songbirds in areas where agricultural and urban land uses predominate (Small and Hunter 1988). Nest parasitism from cowbirds has been shown to be less of a problem in areas where the forested matrix is dominant, as in northern Wisconsin, although parasitism can be “locally common in forest areas that are fragmented by agricultural or urban environments, especially if livestock or horses are present” (Howe et al. 1995). With the mixed ownership pattern that exists in southern Wisconsin, cowbird parasitism is of large concern for NTMB’s. Predation from small mammals, crows, jays, raccoons, skunks, domestic pets, and feral cats and dogs is also associated with fragmentation and edges.

Some species are "area-sensitive", requiring large patches of relatively contiguous forest cover. Mossman and Hoffman (1989) summarized a number of breeding bird surveys, noting that isolated forest patches of 40-80 acres in size were dominated by generalist species, while interior forest specialists such as Cerulean Warbler and Acadian Flycatcher occurred in patches of 100 acres or larger. Among the interior forest species, the Worm-eating Warbler, Kentucky Warbler, and Hooded Warbler only bred consistently in forest patches larger than 500 acres. As larger forest patches become increasingly scarce in southeast and south-central Wisconsin, smaller patches of mature oak or mixed oak-central hardwoods may be important if they are located near large forested tracts, especially if there is potential for restoring connectivity or increasing patch size in the future. These smaller tracts may also be important as migratory stopovers, and as habitat for amphibians.

3.1.5 Invasive Species

The ecology of the oak-hickory forests is also being affected by non-native species. Unlike the northern forests, the southern oak forests have been widely colonized by troublesome invasive plants, including non-native buckthorns (*Rhamnus* spp.), honeysuckles (*Lonicera* spp.), multiflora rose (*Rosa multiflora*), and garlic mustard (*Alliaria petiolata*). Other problematic forest invasive species include Japanese barberry (*Berberis thunbergii*) and Oriental bittersweet (*Celastrus orbiculatus*). When abundant, invasive plants alter forest composition and structure, and can ultimately affect successional patterns and future forest conditions (WDNR 1997). Plants like buckthorn suppress regeneration, while vines like Oriental bittersweet climb and girdle trees. Honeysuckles and garlic mustard are implicated in impacting forest growth rates.

Woody shrub species may be the most widespread and problematic invasive plants currently affecting our forests, and they are expensive to control. Two buckthorn species and four bush honeysuckle species have already invaded large acreages of forest understory. Other invasives such as autumn olive and multiflora rose are common in areas where agriculture has been practiced, and Japanese barberry is gaining a hold throughout the state. Few herbaceous species can compete in the shade of a forest understory, but garlic mustard is an exception and is rapidly spreading across the state. The WDNR Best management Practices for Invasive Species have additional guidance on management planning and mitigation of invasive species before timber harvesting is conducted (WDNR 2009).

3.1.6 Summary of Landscape Considerations

When deciding whether to actively manage for oak-hickory stand assuming the habitat type is suitable, consider the following factors:

- What are the characteristics of the broad-scale ecological unit (Landtype Association (LTA) or Subsection) around the stand?
- Is the prospective management area already fragmented by either habitat or permanent fragmentation?
- In even-aged management, are there opportunities to aggregate individual cuts to reduce the overall amount of edge?
- Is there an abundance of invasive plants in the stand being managed? Is there an opportunity to control them before harvesting?

- Is the forest patch large enough to support bird species uncommon at the landscape or regional scale, and how is the proposed management likely to affect them?
- Large forest patches with older age-class structure are scarce and managing for interior NTMB's such as cerulean warbler or Acadian flycatcher may be an important consideration.
- Can the management activity be designed to limit fragmentation that may be caused by development of infrastructure (e.g., roads and landings)?
- Is there an opportunity for extended rotation, to increase or partially maintain the extent of older oak forest?
- Are there problems with herbivory in the vicinity (e.g., lack of oak regeneration, excessive browsing of herbaceous vegetation)? If so, consider methods of limiting post-harvest damage to regeneration.
- Is there an opportunity to incorporate prescribe fire into the management plan to retard competition and enhance oak regeneration?
- Is there an opportunity to develop structure through canopy gaps?

3.2 Site and Stand Considerations

3.2.1 Soils

Characteristic soil textures are also identified in the FIA data (Schmidt 1997, Kotar et al. 1999) and the FHTCS. Northern and southern regions and site types are derived from the FHTCS. Exceptions to these typical conditions should be expected.

Oak stands grow on a variety of soils, but individual oak species are associated with soils of a particular moisture and nutrient status.

Northern red oak, and to some extent, white oak and bur oak, occur on loamy soils, as evidenced by their association with dry-mesic Northern and dry-mesic to mesic Southern Habitat Type Groups (Table 41.2 and Table 41.4). Vehicle traffic on loamy soils can cause detrimental soil compaction. A number of studies of conifer species have found that soil disturbances including compaction, rutting, and surface displacement decreased tree growth (NCASI 2004, Table 3.1). Growth decreases have also been documented in experimentally compacted aspen stands on clay and loam soils in the Lake States, but growth increased on compacted sand soils (Stone 2001). It is likely that compaction and associated soil disturbances have detrimental impacts to oaks growing on loamy soils. These disturbances cannot be avoided entirely during a harvest but can and should be minimized. A system of pre-planned skidding routes and landing areas can be designed to meet the needs of the harvest while impacting as little of the stand area as possible. As a general rule, less than 15% of a harvest area should be devoted to haul roads, skid trails, and landings (WDNR 2011b). Soils are most susceptible to compaction and rutting when they are saturated, so harvesting when the soil is frozen or dry can reduce the potential for compaction. Increasing the interval for re-entry into stands may partially mitigate and reduce the amount of compaction and rutting, although soil compaction is not readily ameliorated and effects can persist for several decades (NCASI 2004).

Many northern red oak, white oak, and bur oak stands, and mixed stands, are located in southwest Wisconsin's "Driftless Area", which is characterized by steep, easily eroded hillsides, and shallow bedrock. In these areas, soil compaction, displacement, and erosion are a particular concern. Shallow soils can be squeezed between equipment and bedrock, increasing the likelihood of compaction and rutting, and damaging soil structure so that rainfall can transport and erode the soil more readily. Roads should be designed with a consideration for slopes, and operations during periods of rainfall should be carefully monitored to ensure that compaction, rutting, and erosion do not exceed guidelines. See "Wisconsin Forest Management Guidelines" (WDNR 2011b). An additional concern on shallow soils is the decreased volume of soil available to supply nutrients. In a deep soil, 95% of tree roots occur in the upper 40", and this is the depth generally considered to supply most of the nutrition for tree growth (Gale and Grigal 1987). A site on shallow soils has a lower amount of nutrients and could become nutrient-depleted by harvest removals in fewer rotations than a site with deep soils. Shallow soils over sandstone bedrock, or hard bedrock of volcanic origin, tend to have less nutrient capital than soils that overlie limestone or dolomite.

Oak species that typically grow on sandy sites include northern pin oak and black oak. Table 41.2 and Table 41.4 indicate these species are most associated with very dry to dry Northern, and dry Southern Habitat Type Groups. On these sandy sites, displacement of the surface mat of vegetation is a concern. If the surface is removed or worn away on roads and skid trails, bare mineral soil is exposed and new vegetation is often slow to establish. Erosion by wind and water can keep these areas open, and bank slumping can prevent road cuts from stabilizing. Cumulatively, these impacts make parts of the stand non-productive.

Another concern regarding oaks on sandy sites is the potential for nutrient depletion over repeated rotations. Sites accrue nutrients through mineral weathering and atmospheric deposition. Nutrients can be lost from a site through leaching, volatilization (in the case of nitrogen), and removals in harvested wood. If losses are greater than inputs over the course of a rotation, nutrient depletion occurs. If losses are relatively small and the site is "rich", or has a large amount of nutrient capital, then concerns are minimal. However, if the site is sandy and has little nutrient capital, losses may be significant. There is uncertainty in predicting the exact amount of potential nutrient losses, and more research is needed in this area, particularly as there are not published data for nutrient concentrations of northern pin oak. Nutrient concentrations for mixed oak stands in three studies were compiled and averaged (Tritton et al.1987, for stands with 40-50% of basal area in northern red, chestnut, white and black oaks; Johnson et al. 1982, for stands with 70% of above-ground biomass in chestnut, white, northern red, and black oaks; Rolfe et al. 1978, for stands with 85% of total biomass in white and northern red oak). Average calcium concentrations were applied to biomass data for northern pin oak stands (Reiners 1972), and nutrient balance calculations using these estimates suggested a potential for net losses of around 150-200 lbs. calcium/acre for an 80-year rotation with whole-tree harvesting.

3.2.2 Site Quality

3.2.2.1 *Range of Habitat Types*

See Chapter 12 – Forest Habitat Type Classification System for information summarizing the system and the habitat type groups. Habitat type regions 1-5 (northern Wisconsin) contain the northern habitat type groups; these represent 67% of the total forest land acres and 70% of the total net growing stock volume statewide. Habitat type regions 6-11 (southern Wisconsin) contain the southern habitat type groups; these represent 33% of the total acres and 30% of the total net growing stock volume on forest land statewide. However, the southern habitat type groups contain 74% of the oak cover type acres and 61% of the oak volume statewide (1996 FIA). The oak cover type currently is much more common in southern than in northern Wisconsin.

Another useful resource is *Vegetation of Wisconsin* (Curtis 1959) which divides Wisconsin into two floristic provinces based on climatic conditions and plant species distribution. Within each province, five to six forested community types are defined based on overstory associations. These forest types are further characterized, including understory associations and site characteristics. Most oak forests are classified into one of four groups: dry and dry-mesic southern hardwoods, and dry and dry-mesic northern hardwoods.

The different oak species are distributed differently across the state (Figure 41.5). Northern red oak demonstrates the most even geographic distribution with about 56% of its total statewide net growing stock volume occurring within the northern habitat type groups (and 44% in the south). In contrast, about 81% of northern pin oak and black oak combined volume occurs within the southern habitat type groups. However, whereas black oak occurs almost exclusively within the southern groups, northern pin oak occurs in both southern and northern Wisconsin. White oaks (white, bur, swamp white) are much more common in southern Wisconsin, where about 78% of their statewide volume occurs (1996 FIA).

<u>Northern Wisconsin habitat types</u>
In northern Wisconsin, the occurrence and relative growth potential of the oak cover type, and of the individual species comprising the type, vary by habitat type groups and habitat types.

Oak is currently the predominant cover type occurring on very dry to dry sites in northern Wisconsin; oak occurs on about 28% of the total area occupied by these dry sites. Oak is a common cover type on dry to dry-mesic (15% of the area) and dry-mesic (21% of the area) sites but is less abundant than the aspen and maple-basswood cover types. It is a minor cover type on the mesic (4%) and mesic to wet-mesic (2%) habitat type groups. The oak cover type rarely occurs on wet-mesic to wet sites (<1%) in northern Wisconsin.

The distribution of oak volumes by site type contrasts with the distribution of oak cover type acres. The greatest volume (both net volume and average volume per acre) of oak occurs within the dry-mesic habitat type group. Mesic sites also contain a large net volume of oak; mesic acres are extensive and high-quality oak occurs as a common associate within the maple-basswood cover type. In northern Wisconsin, about 75% of the total oak volume is northern red oak, 15% white oaks (mostly white and bur), and 10% northern pin oak (with a little black oak).

Northern dry (very dry to dry and dry to dry-mesic habitat type groups): Oak is a common cover type. Characteristic dominants in oak forests are northern pin oak and red oak, although white and bur oaks can be locally important. Common associates include aspen, white pine, red pine, jack pine, red maple, and white birch. Typical surface soil textures are sand and loamy sand.

Northern dry-mesic (dry-mesic habitat type group): Oak is a common cover type. The characteristic dominant in oak forests is northern red oak, although white oak can be locally important. Common associates include aspen, red maple, sugar maple, white birch, white pine, and basswood. Typical surface soil textures are loamy sand and sandy loam.

Northern mesic (mesic habitat type group): Oak is a minor cover type. The characteristic dominant in oak forests is northern red oak, although white oak can be locally important. Common associates include sugar maple, basswood, red maple, aspen, white birch, and ashes. Typical surface soil textures are sandy loam and silt loam.

Northern wet-mesic and wet (mesic to wet-mesic and wet-mesic to wet habitat type groups)[1]: Oak is a minor to rare cover type on these sites. Soils exhibit impeded drainage (any texture).

Table 41.2 shows the relative representation of oaks within northern habitat type groups (based on volume) and trends across groups. Table 41.3 and Figure 41.6 are useful to evaluate potential growth and productivity for oaks.

Southern Wisconsin Habitat Types

In southern Wisconsin, the occurrence and relative growth potential of the oak cover type, and of the individual species comprising the type, vary by habitat type groups and habitat types.

In southern Wisconsin, oak is currently the predominant cover type occurring on dry, dry-mesic, dry-mesic to mesic, dry-mesic to mesic phase, and mesic phase habitat type groups (site types). It occupies 50-60% of total acres within each of these groups, except for dry sites where it occupies about 43% of total acres. On mesic sites, oak is the second most common cover type (32% of total acres) following maple-basswood. On mesic to wet-mesic and wet-mesic to wet sites, the oak cover type commonly occurs (about 11% of the area of each) but is much less abundant than maple-basswood and elm-ash-soft maple.

The greatest net volumes of oak occur on dry-mesic and dry sites (many acres and many oak trees). However, the most productive sites with abundant oak and high average standing volumes per acre are dry-mesic, dry-mesic to mesic, dry-mesic to mesic phase, and mesic phase. In southern Wisconsin, about 39% of the total oak volume is northern red oak, 34% white oaks (white, bur, swamp white), and 27% other red oaks (black and northern pin).

Southern dry (dry habitat type group): Oak is a predominant cover type. Characteristic dominants in oak forests are black oak and northern pin oak, although white, bur, and red oaks sometimes exert dominance. Common associates include aspen (*Populus* spp.), white pine (*Pinus strobus*), red pine (*Pinus resinosa*), jack pine (*Pinus banksiana*), and red maple (*Acer rubrum*). Typical surface soil textures are sand and loamy sand.

Table 41.2. Oak species – abundance within each northern habitat type group. Values are % of the total volume for all species (net volume and average volume per acre) represented by each oak species group within each habitat type group (1996 FIA).

Northern Habitat Type Groups	% Volume of Oak Species within Habitat Type Groups			
	N. Red Oak	N. Pin Oak[1]	White Oak & Bur Oak[2]	Total – All Oaks
Very Dry to Dry	11	10	<1	22
Dry to Dry-mesic	11	3	2	16
Dry-mesic	24	<1	5	29
Mesic	7	<1	1	8
Mesic to Wet-mesic	3	<1	1	5
Wet-mesic to Wet	<1	<1	<1	1

1 – Includes a small amount of black oak
2 – Includes a small amount of swamp white oak

Southern dry-mesic (dry-mesic habitat type group): Oak is a predominant cover type. Characteristic dominants in oak forests are red oak, white oak, bur oak, and black oak. Common associates include aspen, red maple, white birch (*Betula papyrifera*), and white pine. Typical surface soil textures are loamy sand and coarse or shallow loams.

Southern mesic (dry-mesic to mesic and mesic habitat type groups): These sites can be subdivided based on historic disturbance regimes and the current representation of mesic hardwoods in current communities. Typical surface soil textures are loams.

1. Phases – occur in extreme southern and southwestern Wisconsin
    a. Oak is a predominant cover type. Characteristic dominants in oak forests are white oak and red oak. Common associates include: bur oak, black oak, hickories (*Carya* spp.), elms (*Ulmus* spp.), black cherry (*Prunus serotina*), black walnut (*Juglans nigra*), and aspen.

2. Typical sites – mesic hardwoods usually represented
    a. Oak is a common cover type. Characteristic dominants in oak forests are red oak and white oak. Common associates include sugar maple (*Acer saccharum*), basswood (*Tilia americana*), ashes (*Fraxinus* spp.), aspen, red maple, elms, hickories, bur oak, and black oak.

Table 41.3. Oak cover type – estimated relative growth potential by northern habitat type group and type.

Northern Habitat Type Groups	Estimated Relative Growth Potential for Oak Cover Type[1]				
	Very Poor	Poor	Fair	Good	Excellent
Very Dry to Dry	PQE PQG	PQGCe PArV PArV-U PArVAo QAp			
Dry to Dry-mesic			PArVHa PArVAm PArVAa PArVAa-Vb PArVAa-Po PArVPo		
Dry-mesic				TFAa AVCl AVVb AVDe AVb-V ACl AVb	AAt ATFPo
Mesic					AFVb ATM ATFD ATFSt AAs ATD ATDH AHVb AFAd AFAl ACaCi AOCa AH
Mesic to Wet-mesic[2]		PArVRh ArAbVC ArAbVCo ArVRp ArAbSn	ArAbCo TMC ASnMi AAtRp	ATAtOn ASal ACal AHl	

1 – Estimation of relative growth potential for oak cover type based on: oak cover type average volume/acre, oak site index, potential tree vigor and form, and oak species typically present.
2 – See Table 41.2; oak occurs infrequently on most habitat types within this group.

Southern wet-mesic and wet (mesic to wet-mesic and wet-mesic to wet habitat type groups): Oak is a common cover type. The characteristic dominant in oak forests is swamp white oak, although bur oak, white oak and black oak can occur. Common associates include red maple, silver maple (*Acer saccharinum*), ashes, elms and basswood. Soils exhibit impeded drainage.

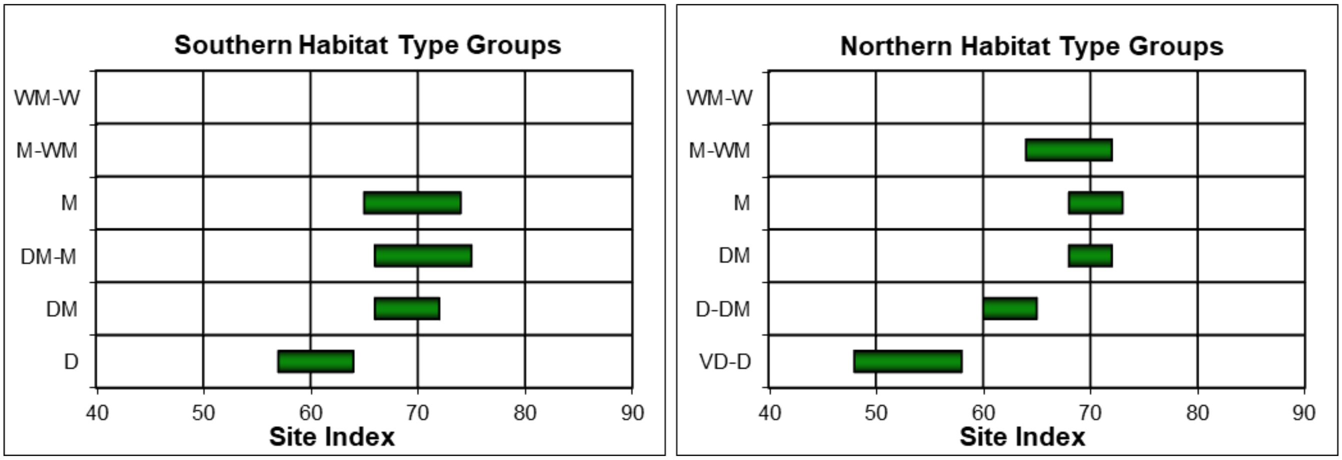

Figure 41.6. Site index for northern red oak across northern and southern habitat type groups (1996 FIA). Bars indicate 95% confidence limits for the mean.

Table 41.4 shows the relative representation of oaks within southern habitat type groups (based on volume) and trends across groups. Table 41.5 and Figure 41.6 are useful to evaluate potential growth and productivity for oaks.

Table 41.4. Oak species – abundance within each southern habitat type group. Values are percent of the total volume for all species (net volume and average volume per acre) represented by each oak species group within each habitat type group, (1996 FIA data).

Southern Habitat Type Groups	% Volume of Oak Species within Habitat Type Groups			
	N. Red Oak	Black Oak and N. Pin Oak	White Oaks[1]	Total – All Oaks
Dry	8	25	7	41
Dry-mesic	21	13	17	51
Dry-mesic to Mesic	21	4	21	45
Dry-mesic to Mesic (phase)	16	7	24	47
Mesic (phase)	16	7	20	43
Mesic	17	1	10	29
Mesic to Wet-mesic[2]	2	7	9	17
Wet-mesic to Wet[2]	<1	2	7	9

1 – White, bur, and swamp white oaks
2 – All sites – Habitat types not defined

Table 41.5. Oak cover type – estimated relative growth potential by southern habitat type group and habitat type.

Southern Habitat Type Groups	Estimated Relative Growth Potential for Oak Cover Type[1]				
	Poor	Fair	Fair to Good	Good	Excellent
Dry	PEu PVGy PVCr	PVG PVHa			
Dry-mesic			ArDe-V ArDe	AArVb ArCi ArCi-Ph AQVb-Gr AArL	
Dry-mesic to Mesic					AFrDe AFrDeO ATiFrCi ATiFrVb ATiDe ATiDe-Ha ATiDe-As
Dry-mesic to Mesic (phase)					AFrDe(Vb) ATiFrVb(Cr) ATiCr(O) ATiCr(As) ATiDe(Pr)
Mesic (phase)					ATiFrCa(O) ATiAs(De)
Mesic					ATiSa-De ATiSa ATTr AFTD AFH ATiFrCa ATiCa-La ATiCa-Al ATiCa ATiH AFAs-O AFAs
Mesic to Wet-mesic	PVRh	No habitat types defined			

1 – Estimation of relative growth potential for oak cover type based on: oak cover type average volume/acre, oak site index, potential tree vigor and form, and oak species typically present.

3.2.3 Forest Health

The numerous pests of oak are summarized in Forest Health Protection Guidelines (Appendix). There are three oak pests with significant impact to the oak in Wisconsin and warrant an expanded discussion.

<u>Oak Wilt</u>

Oak Wilt is a vascular disease caused by the fungus *Ceratocystis fagacearum*. There is no cure, but there are several preventive measures. Site-specific guidelines on oak harvesting in the forest setting were developed and implemented in 2007. These guidelines were designed to provide information on the relationship between the risk of introduction of oak wilt and the timing of any activities that may wound oaks or leave oak stumps, based on site factors in a stand. The guidelines incorporate information such as the proximity of a stand to a county where oak wilt is confirmed, preharvest BA of oak, terrain, and soil texture and give a site-specific risk level of introduction and spread in a particular stand when a stand is harvested in the spring, summer, or fall-winter. The guide should be used to help make decisions about when harvesting may occur. For the oak cutting guidelines in the forest setting, refer to the Forest Health Protection Guidelines (Appendix). The guidelines can be viewed and downloaded at https://dnr.wisconsin.gov/topic/foresthealth/oakwilt/ An interactive user-friendly version is also available at the website.

Spongy Moth

Spongy moth is an invasive pest that periodically increases to very high numbers, causing significant defoliation similar to the native forest tent caterpillar. Oak is a favored host of spongy moth larvae and typically sustains greater damage from this pest than less favored species such as maples or conifers. Where spongy moth is established, outbreaks can occur about every 10 years in mesic forests or as frequently as every 5 years in dry, oak dominated forests. Some deciduous forests of the state have yet to be impacted by spongy moth despite its presence in them for nearly 20 years. For a current map of counties where spongy moth is established, go to http://spongymoth.wi.gov/, click learn more under State and Fed. Quarantines and view the quarantine map. Counties are quarantined when this pest becomes established, though populations may be low.

Population outbreaks can typically last 1-3 years before collapsing. A rule of thumb is that following heavy defoliation, the amount of mortality that would have occurred in a stand over the following 10 years will be compressed into 3 years as suppressed and stressed trees die. Individual tree mortality can occur for up to 3 years following heavy defoliation. Tree mortality is usually highest following the first outbreak in an area and is greatest among overmature, weakened or suppressed trees of preferred species. Mortality rates of 5-25% can be expected in stands dominated by preferred species. Avoid multiple simultaneous stress agents. Heavy or catastrophic mortality is likely to occur if defoliation coincides or occurs within a year of another significant stress such as recent prior defoliation, drought or thinning. In Wisconsin, 50-95% mortality has occurred following heavy defoliation of stressed, overmature northern pin oak, in northern pin oak stands thinned the year prior to defoliation, and in stressed white oak defoliated during a drought. Do not conduct thinning in susceptible stands 1 growing season before or after heavy defoliation occurs or is predicted. On dry sites leave 2 growing seasons to allow trees to recover vigor.

There are several options for reducing or preventing losses from spongy moth. Increasing species diversity and reducing the proportion of preferred species can reduce the frequency and intensity of outbreaks. A preferred species composition of 50% or less is suggested where practical. Improving stand vigor by thinning more than 2 years before defoliation can improve survival of the remaining trees. Harvest susceptible trees before overmature unless left for green tree retention. Aerial spraying can prevent heavy defoliation and associated tree stress and may be appropriate if a stand is already under stress and harvest is not desirable. Autumn egg mass surveys are used to predict the size of the pest population and the level of potential damage the following spring, allowing ample time to plan for a spray of the stand if appropriate. For directions on how to conduct a predictive survey, silvicultural guidance, and how to arrange for an aerial spray of a woodlot, go to https://spongymoth.wi.gov

Herbivory by Deer
High deer densities are significantly altering forest composition through herbivory, impacting the herbaceous layer, and reducing regeneration success of some tree species (WDNR 1995). Rooney Waller (2003) showed that deer limit oak regeneration in Wisconsin forests. Both young oak branches and acorns are browsed, leading to poor seedling establishment, slow growth, and high mortality.

High density deer populations in oak-dominated forests cause significant regeneration failure, reduced plant species richness and biomass, and loss of structural diversity through shifts in species composition (McShea and Healy 2002). Although oak has a long re-initiation phase and can compete with other species over long periods of time, oak regeneration will eventually succumb to continuous browsing, especially in combination with competition from shade tolerant species. Methods of protecting regenerating areas include fencing, tube shelters, bud caps and repellents. These techniques are costly and labor intensive but offer some relief from browse impacts.

In general, Wisconsin experience suggests deer populations at or below 50% of maximum “natural” carrying capacity for the deer management unit will not prevent oak regeneration. Natural carrying capacity is average deer carrying capacity that is not artificially inflated by baiting, feeding, or agricultural practices designed to increase deer populations. Researchers in Pennsylvania (DeCalesta and Stout 1997) have advanced a conceptual framework for relating deer population levels to a variety of potential management goals. Under this framework, management of deer in a forested system managed for timber in Pennsylvania would hold the population near 30% of maximum carrying capacity and hold deer populations below 20% of maximum carrying capacity to make deer impacts negligible. Wisconsin experience suggests that successful silviculture can usually be practiced where herds are maintained at 50-65% of natural carrying capacity.

Regardless of goals and population levels on a deer management unit basis, herbivory is a local and seasonal phenomenon. Foresters must assess site-specific indicators of deer density when planning silvicultural treatments. Recent browse damage to trees and shrubs within reach of deer is the most indicative sign of potential deer problems. The extent of recent browse damage and growth form, e.g., “brooming”, of woody browse present in the stand should be assessed as part of the stand examination when prescribing a regeneration treatment. This assessment is best done in late winter or early spring before leaf break.

Preferred species of woody browse commonly associated with oak include red maple, white pine, oak, aspen, alternate-leaved dogwood, and juneberry. Severe browsing (>2/3 of available twigs browsed) on these species indicates a potential problem. Some browsing pressure should be expected on these preferred food species. If these species are present in the stand understory, less than 1/3 of the available twigs are browsed, and some individuals are 4’ tall or greater, oak regeneration techniques that result in sufficient seedling establishment should be successful.

Intermediate browse pressure is indicated when >1/3 and < 2/3 of the available twigs are browsed. This indicates a potential problem. Regeneration may be possible under these conditions, but it will require an excellent seedling establishment and possibly a treatment area greater than 10 acres.

Beech, red pine, ironwood, and walnut are generally avoided by deer. Any noticeable level of browsing by deer on these species indicates a potential problem. Oak regeneration may not be possible until local deer numbers are reduced or other measures are used to prevent browsing.

Hunting can be effective in reducing overabundant deer populations to achieve forestry goals. Individual landowners may not control enough land to affect local deer populations but should be encouraged to allow harvest of deer if herbivory is a problem. Females display more philopatry than males and shooting does is more likely to reduce local populations than shooting bucks. Local deer populations must be held at sustainable levels relative to forestry objectives for an extended period of time to allow forest regeneration to occur.

In areas where high deer numbers are likely to contribute to a regeneration failure, several techniques have been used to protect seedlings and saplings. Fencing, shelters, and repellents are available in a variety of types. Area fencing can be used to protect regeneration by excluding deer from a site. A woven wire or polypropylene fence at least 8' tall is the best barrier to deer entry into a regenerated stand. These fences are costly to install and require inspection and maintenance. Multiple strand electric fences are less costly to install but require more maintenance. Individual tree shelters are generally used in artificial regeneration applications but could be placed on select advance regeneration in a natural regeneration treatment. A variety of shelters are commercially available and additional types can be constructed. Installation and maintenance requirements vary by shelter type. Repellents function by inducing fear in deer or by reducing the palatability of plants to which they are applied. Products vary in effectiveness and may require frequent repeat applications. Any of these options are rather costly means to achieve regeneration compared to herd reduction. A review of available techniques is available on the WDNR Forestry website.
https://dnr.wisconsin.gov/sites/default/files/topic/TreePlanting/managingDeerBrowseTreePlantings.pdf

Experience shows food plots and feeding will not buffer plant communities from deer herbivory but will exacerbate the problem by concentrating deer activity in proximity to the “artificial” food source (Brown and Cooper 2006; Donier et al. 1997). Deer herd reproductive response to supplemental food also leads to higher deer densities. Foresters should be aware small areas of regeneration in a landscape with limited deer preferred food sources may concentrate deer activity. Similarly, increasing timber management on a landscape scale has been proposed as a means of providing additional browse availability to mitigate deer impacts on desired regeneration. This is a solution that works only if the deer population is not allowed to respond (increase) to the improved habitat. Absolute numbers of deer must remain constant as habitat improves for this strategy to succeed.

3.2.4 Interfering Vegetation

Site factors influence oak regeneration potential and vary by habitat type (group). The potential for and success of oak regeneration is strongly influenced by the density, size, and type of competing vegetation. This level of competition is influenced by habitat type and disturbance history. On most sites, significant oak regeneration is unlikely unless competing vegetation is limited through natural disturbance (e.g., fire) or controlled by human cultural activities (e.g., release). In general, the necessary intensity and frequency of control of competing vegetation is greatest on the more mesic sites, because of the presence and vigorous growth of shade tolerant advance regeneration. Often, on drier sites competition is less intense which can facilitate the success of targeted oak regeneration practices. Identification and interpretation of habitat types can provide an indication of how vegetation will respond to silvicultural treatments (Table 41.6).

Table 41.6. Oak regeneration – typical level of competition and primary competitors.

Northern Habitat Type Groups	Typical Level of Competition	Most Common Competitors
Very Dry to Dry	Low – Medium	White pine, Red maple, Shrubs
Dry to Dry-mesic	Low – Medium	Red maple, White pine, Shrubs
Dry-mesic	Medium	Red maple, Mesic hardwoods
Mesic	High	Mesic hardwoods[1]
Southern Habitat Type Groups		
Dry	Low – Medium	Red maple, White pine, Shrubs
Dry-mesic	Medium	Mixed hardwoods2, Mesic hardwoods, Shrubs
Dry-mesic to Mesic	High	Mesic hardwoods, Shrubs
Dry-mesic to Mesic (phase)	High	Mixed hardwoods, Shrubs (mesic hardwoods)
Mesic (phase)	High	Mixed hardwoods, Shrubs (mesic hardwoods)
Mesic	High	Mesic hardwoods

1 – Mesic hardwoods include: sugar maple, beech, basswood, white ash, yellow birch, and ironwood.
2 – Mixed hardwoods include: red maple, elms, hickories, and black cherry.

Stand disturbance history (type, severity, and timing) can significantly alter expected levels of competition. For example, dense shrub layers (e.g., hazel) can develop following successive thinnings and exclude oak regeneration on dry sites. Shrubs and invasive exotic plants can become abundant and provide intense competition across a wide range of habitat types; this problem is particularly prevalent on sites that were previously non-forested (e.g., agricultural lands or historic savannas). Aggressive shrub and herb layers can out-compete oak seedlings; intensive management techniques may be required to control competition and establish regeneration. Within each stand being managed, established competition and potential control measures should be evaluated.

3.2.5 Wildlife

Oak forests are found on a wide variety of habitat types throughout the state. Several species of oak with different silvical characteristics and habitat requirements produce a diversity of oak habitat for wildlife. However, all oak species share some characteristics that make them attractive to wildlife. Consumption of acorns may be the most noticeable wildlife use of oak stands but the growth characteristics and associated tree, shrub, and ground layer species found in the oak type also contribute to the value.

The sapling stage of an oak stand resulting from a regeneration cut provides food and cover to many early-successional specialists. Regenerated stands in the sapling stage have a high population of birds, peaking 5-6 years after stand initiation on good sites. Ground layer specialists such as flickers colonize the site. As the regeneration grows, shrub-nesting specialists dominate the site. Opportunities to manage for ruffed grouse nesting and brood rearing habitat become important in some portions of the state during this phase of stand development. A series of different species and foraging guilds are present as the stand matures. The original assemblage of bird species stabilizes at around 40-50 years of age and is maintained as stand structural development continues. Extended rotation in this type benefits bark gleaners and cavity nesters.

Breeding bird populations in oak as well as other forest types are enhanced by treatments that increase structural complexity of stands, increase the variety of stands, or increase the rotation age. Oak forests have from 28 species of breeding birds present in dry, nutrient-poor northern stands to 41 species of breeding birds present in more mesic southern stands. Structural development and complexity of all levels of the stand is more important in determining the bird assemblage than is the geographic area of the state. In other words, the habitat type on which oak is found determines its use by wildlife in general and breeding birds in particular. Regardless of this, persistence of oak snags and den trees extends the usefulness of this important wildlife feature.

Shelterwoods and thinnings may increase use of the type by flycatchers and orioles. These birds forage by using the high canopy trees to set out in search of prey. Foraging by midlayer or ground specialists may be available if a midlayer of shrubs or small residual remains in the stand.

Acorns are high in fats and metabolizable energy but low in sodium and calcium and relatively low in protein. The nutritive value of acorns is affected by phenols which interfere with digestion. The red oak group has higher concentration of phenols than the white oak group. Other differences such as acorn size and shell thickness from different oak species affect wildlife use of this food source. As an example, ruffed grouse tend not to eat acorns with the caps on. Animals on an acorn diet usually need to supplement with other foods although the fats present in acorns and the potential for weight gain can outweigh the nutritional deficiencies of acorns. It is a popular belief that white oaks are more beneficial to wildlife than red oaks. While the palatability of white oak acorns and the nutritive value of the nuts may be higher, white oaks do not provide as dependable a source of acorns as do red oaks. Additionally, the timing of acorn drop and germination affects availability of the acorns for foraging wildlife.

Management should be directed toward providing representatives from both oak groups wherever possible if wildlife habitat is a concern.

Small mammal populations can be sensitive to the nutritional benefits provided by acorns. Overwinter survival and breeding rate of squirrels depend mainly on fall mast crop. The age at which gray squirrels become sexually mature and the breeding rate in gray squirrels is directly affected by the mast crop. Small mammals also benefit from cavities in oaks for protection.

As with small mammals, large mammals such as black bear and deer take advantage of the nutritional benefits of acorns when available. Survival of bear cubs and breeding success are impacted heavily by the nutritional status of female bears. Oak stands represent an important food source remembered and monitored yearly by bears. Knowledge of the location of oaks may be transmitted from female bears to their offspring. While browse is the primary source of food for deer, they take advantage of acorn crops and benefit greatly from them. A good mast crop can also positively affect winter survival of deer and subsequent fawn production and survival. However, high deer populations can affect regeneration of oak (refer to Herbivory by Deer section of Appendix C: Forest Health Management Guidelines).

Wild turkey populations fluctuate with food production, and adverse food conditions affect winter survival and reproduction. Mast production of any kind is important but not reliable and turkeys rely on other sources of food. When available, acorns are a major food source in every season. If managing for turkeys, an interspersion of oak and other hardwoods with openings provides good habitat.

Acorns are the mainstay of the diet for wood ducks in fall and winter. Wood ducks will leave the water to forage on upland sites, but these sites must be relatively free of undergrowth. Wood ducks forage on all types of acorns but prefer smaller nuts with thin shells. Tannin concentration within the nuts does not seem to affect wood ducks as much as it does other animals.

Cavity promotion and protection may be as important to wood ducks as the mast production. Natural cavities used by wood ducks are almost always in live trees. Most wood duck nests are located within 200 yards of water. The trees or the portion of the trunk containing the cavity should have a diameter of 12" to provide for an inside diameter of the nest cavity of 7” or greater. Cavities with a roof are better than cavities without and an entrance of 3.5-4” is preferred. Small cavity entrances provide better protection from predators. High cavities are more readily found and provide some protection from predation. In general, cavities higher than 30’ are preferentially used over cavities located closer to the ground. As with entrance size, predator exclusion may be the major factor determining suitability. Cavities in which the wood duck hen is successful in nesting are more likely to be used in subsequent years. Other cavity users will have different requirements. Cavity development and retention in oak trees is an extremely important wildlife consideration because of the potential for large cavities and the persistence of this attribute. Many large-bodied cavity users in Wisconsin need cavities of 18” or larger. Examples of large-bodied cavity users include vultures, barred owls, and bears.

Maintaining oak wherever possible will benefit a wide array of wildlife. The benefits of the type extend from thermal protection to nesting habitat to a food resource. Many Wisconsin wildlife species will spend at least a portion of their annual cycle in oak. If oak is not a major component of the forest in the area, any stand may be particularly important to local wildlife populations. When regenerating a stand in this situation, consider adjusting the rotation to take some portions of the stand early or late, so that 25-40% of the stand can be maintained in acorn production at all times. If possible, a diversity of oak species in a stand or closely associated in a landscape will benefit wildlife particularly if representatives of both the white oak and red oak groups can be maintained.

Summary of oak recommendations to benefit wildlife:

- Maintain and encourage oak
- Promote a diversity of oak species
- Maintain cavity trees
- Maintain acorn production
- Consider oak stand contribution in landscape

3.2.5.1 *Deer and Herbivory Effects*

Deer can have a significant impact on the success or failure of regenerating oak. A survey conducted of DNR foresters in 2006 identified deer browsing as the most common reason for lack of natural oak regeneration. Success of oak regeneration will vary across the state depending on local deer densities and carrying capacity. It is projected that regeneration of oak will be successful where deer densities are at or below 50% of carrying capacity. Oak regeneration where deer densities are above 50% carrying capacity will most likely require protection from deer to be successful. Fencing or individual tree protection has been shown to be the most successful. (Dey et al. 2008). Brose et al. (2008) recommend that up to 8 times the number of smaller established seedlings (less than 3’ tall) may be needed in areas of high deer numbers. See the discussion on deer herbivory in the Forest Health section.

3.2.6 Endangered, Threatened and Special Concern (ETS) Species

Oaks can be dominant in at least 10 different natural community types, including some globally rare types, and these are associated with many rare species. Maintaining oak on the landscape will be important for many species, and there are often opportunities to maintain habitats for rare species while managing for high quality timber and other objectives.

From a biodiversity perspective, a challenge with oak-dominated ecosystems is determining where to attempt regeneration versus where to try to keep existing oak on the landscape for as long as possible. Even for sites where biodiversity is the primary management objective, there are decisions regarding where to manage for closed canopy forest versus maintaining rare, fire-dependent community types such as Oak Openings or Oak Barrens communities that support many rare plant and animal species.

Stand conversion, in general, is an important issue. For example, a site classified as oak based on basal area could have a heavy component of young jack pine and be located next to a known population of the federally listed Kirtland’s warbler (*Dendroica kirtlandii*), a species that uses scrubby jack pine for its breeding habitat. Another oak stand could contain the largest block of mature oak forest in the county and be extremely important for an entirely different group of species. Issues such as these are best addressed using a broad, landscape-scale examination that includes the species present, as well as the site's context, viability, and the feasibility of maintaining the site at the desired stage, among other considerations. See the Landscape Considerations section, as well as the Ecological Landscapes of Wisconsin Handbook (WDNR 2011a) for more information.

Some of the rare species associated with oak can be found in closed-canopy forests such as Cerulean warbler (*Dendroica cerulea*) or autumn coral root (*Corallorhiza odontorhiza*), while others require much more open conditions such as red-headed woodpecker (*Melanerpes erythrocephalus*), slender glass lizard (*Ophisaurus attenuatus*) or kitten tails (*Besseya bullii*). As oak has a major role in so many different habitats with an extremely wide range of structure, composition, moisture, nutrients, and geography, it would be impossible to cover all the important rare species considerations in this brief section. Instead, the major themes are highlighted here, and the reader is encouraged to use the Bureau of Endangered Resources Web pages (*dnr.wi.gov/org/land/er/*), as well as other sources for more information.

There are several general considerations related to rare species and oak management. These include special microsites, developmental stages, the size of forested blocks and their context, special natural communities and habitats, and important structural features within stands. Although direct harm or "take" of rare species can often be avoided through simple prescription modifications such as changes to the timing of harvests, there are often opportunities to provide long-term sustainable habitat for species through more comprehensive planning and management.

Rare species are under threat from shrinking habitat, the direct/indirect effects of invasive species, and other factors. Using ecosystem management principles (WDNR 2011a), habitat can be maintained for rare species and produce a sustainable timber supply within a given planning unit/group of planning units. The best management plans will include considerations for a broad suite of plant and animal species, with information regarding how a given stand fits into the ecological context of the larger landscape.

<u>Identify special habitats</u>
Special microsites for rare species can be important during oak management, as many rare species are limited to these small areas within larger blocks of forested habitat. For example, cliffs, ephemeral ponds (vernal pools), seeps or springs, or rock outcrops, as well as prairie, savanna, or barrens remnants may harbor rare species. Most areas have not been thoroughly surveyed for rare species, so it is important to maintain these habitats, proactively, so undocumented species can continue to persist and/or additional species can begin to colonize these areas in the future.

Cliffs and bedrock glades: These features may require one of two different approaches, depending on their physical characteristics and the species present. For moist cliffs, which sometimes exhibit seepage, modify harvests near the feature to retain shade and provide moisture for species requiring those characteristics. For dry cliffs or bedrock glades with species requiring more open conditions, the removal of shade, especially by removing trees from the base of the cliff, may greatly improve conditions.

Ephemeral ponds (vernal pools): Small seasonally flooded areas that add significant biological diversity to forest stands. Although usually found on mesic sites, these features can sometimes be found in dry-mesic forests. They are especially important breeding sites for amphibians which are, in turn, an important food source for other wildlife. Shade should be retained on these ponds whenever possible, and harvesting should avoid felling trees into or skidding through them. Some species can also benefit from maintaining additional coarse woody debris in the stands surrounding the ponds. Conversely, in dry habitats, such as places in the Northwest Sands, oak forests or savannas may be located on former prairie or barrens sites that had been regularly affected by fire in the past. These ponds are not well-understood in the Lake States, but there may be benefits to greatly reducing the shade around them, as they can contain species adapted to more open conditions.

Native prairie and savanna remnants: Native prairies cover less than 8,000 acres statewide, and over half of these acres are protected and managed to expand and enhance the prairie community. Most of the remaining prairies are very small and continue to decrease in size every year through woody species encroachment. Virtually all of the known remnants are adjacent to, or near, an oak forest. These fire-dependent communities, once identified, are often maintained at the size at which they were found. However, these prairies have often been greatly reduced in size over the past several decades, and there are opportunities to expand these areas.

Oak openings: Oak savannas are now globally rare and often contain many of the same herbaceous species found in prairies, along with others adapted to partial shade conditions. These areas require active restoration, and there can be benefits to managing them as part of a prairie/savanna/oak forest continuum. Enlarging the prairie and softening the edges enhances habitat and improves viability for rare species populations. Depending on landowner objectives, a shift in management direction toward non-forest community management could be needed to maintain larger areas of savanna habitat, although limited timber production could be a viable part of the management plan. At a minimum it would be best to manage the oaks and hickory at savanna densities (i.e., 1 to 17 trees per acre) next to the prairie whenever possible.

Sand blows and barrens remnants: These communities are primarily found in sandy nutrient-poor to very nutrient-poor habitat types. Characteristic features are bowl-shaped areas of open sand, scrubby oaks with multiple short stems, and a sparse ground layer with an abundance of foliose lichens. These areas can harbor numerous rare species such as tiger beetles, skippers, reptiles, and plants. Most often basal area would need to be kept near or at the minimum stocking level to maintain habitat for these sand-loving species. Reduction of tree density by thinning or treating oaks, use of prescribed fire, and avoidance of open sand areas as landing sites or logging roads can increase both economic and ecological benefits. These areas might best be managed from a non-commercial perspective to continue to support light-demanding species. Often times, however, these areas will be small patches that could be managed compatibly with the larger surrounding forest through simple modifications. Where these patches exist, it is important to use care during site preparation activities by avoiding spraying herbicides on understory plants (other than exotics) and being careful with mechanical site preparation.

Riparian habitats: Wisconsin's Best Management Practices for Water Quality have greatly improved our protection of riparian areas in an effort to maintain water quality. However, additional considerations may be needed to sustain rare species habitats. For example, wood turtles spend portions of the year foraging in the forest well away from the rivers, so harvest timing considerations would be needed, at a minimum. Acadian Flycatchers (*Empidonax virescens*) sometimes prefer deep, shady ravines along streams, so a broader landscape approach might be best for determining how to best accommodate that species. The best approach to maintain rare species habitats is to look at the habitat needs of the species in question, the topography and hydrology of the area, and the relationship of the riparian area to the surrounding landscape.

Biological "hotspots": In addition to the special habitats already mentioned, bird rookeries, bat hibernacula, herptile hibernacula, migratory bird concentration areas, and cave/sinkhole systems can harbor many rare species. These hotspots can be permanent such as caves, or temporary like bird rookeries. Different strategies may apply, depending on the characteristics of the site and the species in question. Consultation and advice from wildlife or endangered resources specialists should be sought when these hotspots are encountered.

<u>Retain and enhance structure to managed forests</u>
Structural retention is modeled on the biological legacies that remained after natural disturbances, and these legacies are largely missing from much of our actively managed forests. After windstorms, tornadoes, or even the most intense forest fires, many tree individuals and clumps could be expected to survive. Old retained trees can provide numerous ecological benefits, such as current and future cavities, distinctive architecture with large branches that are used as movement corridors or the foundation for large nests, and diverse habitats for insects and spiders. Retaining large vigorous trees, decadent trees, snags, and downed logs enhances structural complexity and provides specialized habitats for numerous species. This also contributes to the food web of the forest ecosystem and helps to maintain diverse fine root and fungi systems in the soil.

Recent literature has also highlighted the importance of cavities, as well as large trees with loose bark for several forest-dwelling bat species (Lacki et al. 2007), and many other species have long been known to use these features like northern flying squirrels, lizards, and several bird species. Consider retaining these features whenever possible. For example, include scattered large trees and snags in clearcut/coppice harvests, or remove only a portion of the oak in the second stage of a shelterwood operation.

Little data exists on how much structure should be retained to benefit rare species in the Lake States. Chapter 24, Marking Guidelines, provides the general retention guidelines recommended by the department. These guidelines could be exceeded for stands where management goals include maintaining or enhancing biodiversity such as High Conservation Value Forests (HCVFs).

Remnant patches of late developmental forest: Maintenance of long-rotation forest with high canopy closure can greatly benefit certain rare species. For example, cerulean warbler prefers old mixed hardwood forest, especially with oaks, that occurs in large patches (>250 acres) with at least 70% crown closure. Planning for this species requires examining its life history to develop a management strategy. By using a landscape approach, a forest management plan could consider forest size, age, and crown closure within the various units of the property or group of properties for which plans are being developed. See the Old Growth Handbook (WDNR 2006a) for a discussion of managed old-growth and extended rotation forestry techniques.

Utilizing alternative approaches

Prescribed burning: Fire is now routinely used for restoring savanna, prairie, and barrens habitats, and there is potential to increase its use as a silvicultural tool in Wisconsin (see Prescribed Fire, Management Alternatives Section). Regular fire was applied to Wisconsin's landscape for at least a few thousand years. This long period of fire followed by fire suppression and decades of grazing provided the unique conditions that led to much our present-day oak forest. Several rare species were well-adapted to the filtered sunlight and low shrub competition that resulted from these conditions, and these species could now benefit from the use of fire along with understory removal in many cases.

Artificial habitats: In some instances, a critical habitat requirement for a species is largely missing from the landscape, and there is often a high degree of competition for the few remaining habitats. For example, the cavity-dwelling Eastern Bluebird (*Sialia sialis*), known historically from savanna habitats, and the Prothonotary Warbler, known from bottomland hardwoods along water, both may lose competition battles with other more aggressive birds. Erecting and monitoring suitable nest boxes in favorable locations can greatly increase the chances for these birds' survival. Nest boxes may also be useful for augmenting populations of northern flying squirrel (*Glaucomys sabrinus*), a Species of Greatest Conservation Need, at sites where there are not ample opportunities to provide large cavity trees, snags, and woody debris (WDNR 2006b). Although this work may not always be practical from an operational standpoint, landowners could be encouraged to erect and monitor these structures with good chances for success.

Adaptive management and monitoring: Many aspects of endangered and threatened species management are not well-understood, yet management activities are being carried out by hundreds of foresters across the state. Managers often have to rely on scarce information for species life history or ecological disturbance patterns, and information on species' responses to silvicultural techniques is often notably lacking. It is very important, therefore, to learn from foresters' shared experiences by monitoring the results of the various management trials and techniques currently in use. As we learn more about rare species and how they respond to our activities, the practice of sustainable forestry can continue to evolve along with our knowledge base.

Table 41.7. Select rare vertebrates that can be associated with oak stands, general habitat preferences, and sample beneficial management considerations. Scores are from the Wildlife Action Plan (WDNR 2006b) and indicate the species' affinity with a particular natural community type on a scale from 1-3, with 3 being the highest. There is potential for species to occur in natural community types not indicated in the Wildlife Action Plan; good examples of this are indicated with an "X," rather than a numerical score. The considerations column is provided for broad planning purposes, and these are not avoidance measures. Please consult additional sources for life history information. The species list is not exhaustive, as other rare species may be found in oak-dominated ecosystems.

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
Rare Birds														
Acadian flycatcher (*Empidonax virescens*) – THR						X	1	3	2			3	Mature hardwood forest, with semi-open understory and a preference for deep, shaded ravines.	Extended rotation and landscape planning. Maintain large blocks of forest where possible.
Black-throated blue warbler (*Dendroica caerulescens*) - SC/M			2							3			Mature hardwood forest with areas of dense understory in	Maintain large blocks of mesic forest where possible. Group selection patches and blowdown

Species / State Status *	Central Sands Pine–Oak Forest	Northern Dry Forest	Northern Dry-Mesic Forest †	Oak Barrens	Oak Opening	Oak Woodland	Southern Dry Forest	Southern Dry-Mesic Forest	Floodplain Forest	Northern Mesic Forest	Pine Barrens	Southern Mesic Forest	Habitat	Considerations
	oak often dominant								oak can be common					
													northern Wisconsin.	patches could be beneficial.
Cerulean warbler (*Dendroica cerulea*) - THR						2	1	3	3	1		2	Full-canopied mature to old oak, central hardwoods, and floodplains.	Extended rotation and landscape planning. Maintain large blocks of forest where possible.
Great egret (*Ardea alba*) - THR									2				Floodplain Forests and other riparian forests.	Maintain large blocks of floodplain and riparian forest where possible. Consult with department biologists/ecologists regarding active colonies.
Hooded warbler (*Wilsonia citrina*) - THR								3				3	Brushy gaps in large blocks of oak and other hardwood forests.	Group selection management and landscape planning.

Previous View

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
Kentucky warbler (*Oporornis formosus*) – THR								2	3			3	Large blocks of mature hardwood forest usually near streams or in ravines w/ a dense understory.	Extended rotation and landscape planning.
Lark sparrow (*Chondestes grammacus*) - SC/M				3							2		Oak Barrens, sand Prairies, and some shrub, old field, and open grassland areas w/ bare soils or sand blows.	Barrens management and landscape planning.
Louisiana waterthrush (*Seiurus motacilla*) - SC/M								3	X	X		3	Large blocks of mature hardwood forest usually near streams or in ravines.	Riparian BMPs on small streams and extended rotation. Maintain large blocks of forest where possible.

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
Northern goshawk (*Accipiter gentilis*) - SC/M		1	2							3			Mature deciduous, coniferous, or mixed forest types, mostly in the northern 2/3 of the state.	Maintain large forested blocks through landscape planning. Follow department guidance around nest trees.
Prothonotary warbler (*Protonotaria citrea*) - SC/M									3				Bottomland hardwoods in the southern 2/3 of the state, typically in truncated snags among flooded timber.	Retain trees with nest cavities and/or retain snags and stumps in floodplain forests. Can benefit from nest boxes.
Red-shouldered hawk (*Buteo lineatus*) - THR		1	2					2	3	2		2	Floodplain forest and mature to old-growth hardwoods are preferred.	Riparian BMPs and extended rotation.
Worm-eating warbler (*Helmitheros vermivorus*) – END							2	3				2	Prefers wooded slopes within mature	Extended rotation and landscape planning.

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
													to old blocks of hardwoods.	
Yellow-billed cuckoo (*Coccyzus americanus*) - SC/M						1	1	2	3	1		2	Prefers floodplains and mature hardwoods.	Riparian BMPs and extended rotations
Yellow-crowned night-heron (*Nyctanassa violacea*) – THR									3				Bottomland hardwoods in southern Wisconsin.	Maintain large blocks of Floodplain and riparian forest where possible. Avoid disturbance during breeding season.
Yellow-throated warbler (*Dendroica dominica*) – END								2	3				Bottomland hardwoods in extreme southern Wisconsin (usually associated with sycamores).	Maintain large blocks of Floodplain Forest. Conserve and restore large sycamore trees.
Rare Reptiles and Amphibians														

Species / State Status *	Central Sands Pine–Oak Forest	Northern Dry Forest	Northern Dry-Mesic Forest †	Oak Barrens	Oak Opening	Oak Woodland	Southern Dry Forest	Southern Dry-Mesic Forest	Floodplain Forest	Northern Mesic Forest	Pine Barrens	Southern Mesic Forest	Habitat	Considerations
	oak often dominant								**oak can be common**					
Blanding's turtle (*Emydoidea blandingii*) – THR				3	3	2		2	2		3	2	Variety of aquatic marsh habitats, but they occupy terrestrial habitats for nesting or commuting to nest sites.	Protect nest sites which are usually in open, sunny areas on well-drained soils and probably reused annually.
Eastern massasauga (*Sistrurus catenatus catenatus*) – END ‡				3					3		3		Strongly associated with floodplain habitats along medium to large rivers in very few locations.	Consult department biologists / ecologists. Protect wetland hydrology.
Four-toed salamander (*Hemidactylium scutatum*) - SC/H									3	3		3	Hardwood forests and to a lesser degree, conifer swamps. Require dense mosses near	Maintain forest cover around isolated wetlands. Provide buffers around known wetland habitats, and maintain large

Previous View

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
													fishless water for breeding.	forest blocks wherever possible. Avoid negatively impacting moss habitats.
Gophersnake (*Pituophis catenifer*) - SC/P	2			3	3	3	2	2			3	2	Open upland habitats with dry, sandy soils such as prairies, oak savannas, barrens pastures, and meadows.	Barrens/savanna/prairie management. Reduce cover on dry bluff habitats.
Gray ratsnake (*Pantherophis spiloides*) - SC/P					2	3	3	3	2			3	Oak forest and savanna habitats in southwest counties.	Maintain forest and savanna habitats. Reduce cover near known overwintering habitat.
North American racer (*Coluber constrictor*) - SC/P				2	X		2	2			2		Prairie and savanna habitats.	Manage to minimum stocking levels or convert to

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
														barrens/savanna/prairie native community management.
Ornate box turtle (*Terrapene ornata*) – END	3			X	3	3	3	3				2	Sand prairies, sand barrens, and sandy, open oak woods.	Manage to minimum stocking levels or convert to barrens native community management.
Pickerel frog (*Lithobates palustris*) - SC/H									2	2		2	Riparian habitats along streams and rivers especially springs and spring runs.	Protect riparian areas, including habitats surrounding ephemeral ponds.
Prairie ring-necked snake (*Diadophis punctatus arnyi*) - SC/H	2			2	3	2	2	2					Variety of open or partially open habitats such as prairies or savannas.	Manage to minimum stocking levels or convert to barrens/savanna/prairie native community management.

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
Prairie skink (*Plestiodon septentrionalis*) - SC/H		2	2	3	3	2	2	2			3		Barrens, savanna, and grassland habitats w/ sandy soils.	Manage to minimum stocking levels or convert to barrens/savanna/prairie native community management.
Six-lined racerunner (*Aspidoscelis sexlineata*) - SC/H				3	3								Savanna and dry prairie habitats w/ sandy soils.	Manage to minimum stocking levels or convert to barrens/savanna/prairie native community management.
Slender glass lizard (*Ophisaurus attenuatus*) – END				3	2						3		Sandy oak woods, oak barrens, and sand barrens.	Manage to minimum stocking levels or convert to barrens native community management.
Timber rattlesnake (*Crotalus horridus*) - SC/P					3	3	3	3	2			3	Steep, rocky prairies and adjacent oak woodlands.	Manage near minimum stocking levels and use of prescribed fire.

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
														Protect known hibernacula.
Upland sandpiper (*Bartramia longicauda*) - SC/M				X	2	1	2				X		Tallgrass prairies, sedge meadows, unmowed fields, barrens, and scattered woodlands.	Grassland / barrens management, if possible. Highly area-sensitive, manage at landscape level.
Western ribbonsnake (*Thamnophis proximus*) – END				2	1								Along rivers and adjacent to marshes.	Consult department biologists / ecologists.
Western wormsnake (*Carphophis vermis*) - SC/H							2	2					Bluff prairies, adjacent savannas and open woodlands. Known only from Grant County.	Extremely fossorial snake, maintain CWD. Consult department biologists / ecologists. Protect known sites.

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
Wood turtle (*Glyptemys insculpta*) – THR				3	2	2			3	3	3	2	Clean rivers and streams with moderate to fast flows and adjacent riparian wetlands and upland deciduous forests.	Protect riparian areas, adjacent upland forest, and avoid locating landings on sandy openings near rivers where nest sites are located.
Rare Mammals														
Franklin's ground squirrel (*Spermophilus franklinii*) - SC/N				3	3	2					3		Brushy and partly wooded barrens areas, dense grassy, shrubby marshland, and prairie edges	Barrens/savanna/prairie management. Protect known sites.
Northern flying squirrel (*Glaucomys sabrinus*) - SC/P	1	2	3				1	1	2	3	1	1	Northern forests, often, but not always, with conifers.	Retain current or future large cavity trees, snags, and coarse woody debris.

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
Northern long-eared bat (*Myotis septentrionalis*) – THR	2	2	2	2	1	2	2	2	2	2		2	Colonies in tree cavities and crevices, under exfoliating bark, in live trees, and bridges (expansion joints). Most prefer trees over man-made structures. Most often feeds within the forest and can forage in more cluttered vegetation than other bats.	Maintain forest cover. Retain large cavity trees, and large diameter living trees whenever possible. Consider extended rotation or managed old-growth.
Prairie vole (*Microtus ochrogaster*) - SC/N				2	2						1		Dry open areas; seldom in sparsely wooded areas	Manage to minimum stocking levels or convert to barrens / savanna /

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
														prairie management.
Water shrew (*Sorex palustris*) - SC/N									2	2		2	Marshes, bogs, swamps, and cold, small streams with cover along the banks.	Protect riparian areas.
Woodland jumping mouse (*Napaeozapus insignis*) - SC/N		1	1						2	3	1	2	Forested or brushy areas near water, wet bogs, stream borders.	Protect riparian areas.
Woodland vole (*Microtus pinetorum*) - SC/N	2			1	3	3	3	3	1			1	A variety of habitats, but most often found in hardwood forests.	Maintain a component of dead and down woody material.

* State status definitions: THR = Wisconsin Threatened, END = Wisconsin Endangered, SC = Wisconsin Special Concern with following modifiers SC/P = fully protected; SC/N = no laws regulating use, possession, or harvesting; SC/H = take regulated by establishment of open closed seasons; SC/M = fully protected by federal and state laws under the Migratory Bird Act

† Typically dominated by red and white pine, but oak may be dominant where pines have been removed.

‡ Also a candidate for federal listing

Table 41.8. Select rare invertebrates that can be associated with oak stands, general habitat preferences, and sample beneficial management considerations. These are meant as broad considerations for planning purposes, rather than avoidance measures; please consult additional sources for life history information. The species list is not exhaustive, as other rare species may be found in oak-dominated ecosystems.

Species / State Status *	**Habitat**	**Considerations**
A looper moth (*Euchlaena milnei*) – SC/N	Dry prairie and oak savanna	Prairie management, expansion and feathered savanna edge
A tiger beetle (*Cicindela patruela patruela*) - SC/N	Sand Blows and sand barrens	Sand blow and sand barrens
Frosted elfin (*Callophrys irus*) - THR	Oak barrens - host larval plant is lupine	Manage to minimum stocking levels or convert to sand barrens native community management
Henry's elfin (*Callophrys henrici*) - SC/N	Oak forest edges and sandy oak woods	Manage to minimum stocking levels or convert to sand barrens native community management
Hickory hairstreak (*Satyrium caryaevorum*) - SC/N	Host plant is hickory	Retention of hickory
Phlox moth (*Schinia indiana*) - THR	Sand prairies, sand barrens and sandy open oak woods	Manage to minimum stocking levels or convert to sand barrens native community management
Pink sallow (*Psectraglaea carnosa*) - SC/N	Sandy oak barrens	Manage to minimum stocking levels or convert to sand barrens native community management
a tiger beetle (*Cicindela patruela huberi*) - SC/N	Sand blows and sand barrens	Sand blow and sand barrens
Whitney's underwing (*Catocala whitneyi*) - SC/N	Dry prairie and oak savanna	Prairie management, expansion and feathered savanna edge

* State status definitions: THR = Wisconsin Threatened, END = Wisconsin Endangered, SC = Wisconsin Special Concern with following modifiers SC/P = fully protected; SC/N = no laws regulating use, possession, or harvesting; SC/H = take regulated by establishment of open closed seasons; SC/M = fully protected by federal and state laws under the Migratory Bird Act

Table 41.9. Select rare plants that can be associated with oak stands, general habitat preferences, and sample beneficial management considerations. These are meant as broad considerations for planning purposes, rather than avoidance measures; please consult additional sources for life history information. The species list is not exhaustive, as other rare species may be found in oak-dominated ecosystems.

Species / State Status	Habitat	Considerations
Brittle prickly pear (*Opuntia fragilis*) - THR	Grows in sand barrens and on open rock outcrops.	Open bedrock management, sand barrens – no landings
Clustered sedge (*Carex cumulata*) - SC	A species of grass found mostly on sandy soils and rocks	Open bedrock management or sand barrens conversion.
Fragrant sumac (*Rhus aromatica*) - SC	Prairie edges, oak openings and woodlands.	Manage near minimum stocking levels or convert to oak savanna native community management and prescribed fire.
Hairy-jointed meadow parsnip (*Thaspium barbinode*) - END	Oak woodlands near loess capped crests or in ravines.	Manage near minimum stocking levels or convert to oak savanna native community management and prescribed fire.
Hoary tick-trefoil (*Desmodium canescens*) - SC	Rich oak woodlands	Manage near minimum stocking levels or convert to oak savanna native community management and prescribed fire
Kittentails (*Besseya bullii*) - THR	Oak savanna	Manage to minimum stocking levels or convert to oak savanna native community management and prescribed fire
Mullein foxglove (*Dasistoma macrophylla*) - SC	Found in rich oak and hardwood forest mostly southwest.	Extended rotation or old-growth management, especially near shaded rocks.
October ladies-tresses (*Spiranthes ovalis*) - SC	Found in oak and central hardwood forests.	Extended rotation or old-growth management.
Oval-leaved milkweed (*Ascelpias ovalifolia*) - THR	Sand prairie, sand barrens open sand oak forests	Manage to minimum stocking levels or convert to sand barrens native community management
Prairie fame-flower (*Talinum rugospermum*) - SC	A rare species in Wisconsin growing on bedrock or in sand prairies and sand barrens.	Open bedrock management, sand blows, sand barrens

Species / State Status	Habitat	Considerations
Prairie trillium (*Trillium recurvatum*) - SC	Rich oak and central hardwoods in the southern two tiers of counties	Extended rotation or old-growth management.
Purple milkweed (*Asclepias purpurescens*) - THR	Rich oak woodlands and wet-mesic prairie	Manage to minimum stocking levels or convert to oak savanna native community management and prescribed fire
Rocky Mountain sedge (*Carex backii*) - SC	A species of grass found mostly on sandy soils and rocks.	Open bedrock management or sand barrens conversion.
Sand violet (*Viola fimbrulata*) - END	Sand Barrens and sand prairies	Convert to sand barrens management
Slender bush clover (*Lespedeza virginica*) - THR	Rocky oak woodland glades.	Partially shaded bedrock with oak canopy and prescribed fire.
Three birds orchid (*Triphora trianthophora*) - SC	Rich oak and central hardwood forests.	Extended rotation or old-growth management
Upland boneset (*Eupatorium sessilifolium*) - SC	Rich oak woodlands	Manage near minimum stocking levels or convert to oak savanna native community management and prescribed fire
Wafer-ash (*Ptelea trifoliate*) - SC	Habitat is oak central hardwood forest edges and gaps	Prescribed fire.

* State status definitions: THR = Wisconsin Threatened, END = Wisconsin Endangered, SC = Wisconsin Special Concern

Other rare species may occur in oak-dominated stands. Many of these species will be found in specialized habitats such as rock outcrops, cliffs, ephemeral ponds, prairie/savanna openings, and seeps. If a rare species is known to be present in an area, including Element Occurrences from the NHI Database, refer to the department screening guidance for avoidance and contact the appropriate staff, as needed. Information for NHI Working List species and their habitats can be found through the Bureau of Endangered Resources Web pages (*dnr.wi.gov/org/land/er/*).

Figure 41.8. Ephemeral Pond (vernal pool) in an unusual location: a dry-mesic forest. Sauk County, Photo by Drew Feldkirchner, WDNR.

Figure 41.9. Slender glass lizard a species associated with Wisconsin oak savannas. Adams County, Photo © Nick Walton.

Figure 41.7. Dwarf milkweed (Asclepias ovalifolia), a species associated with barrens that can be found in patches of dry oak-dominated forests. Monroe County, Photo by Eric Epstein, WDNR.

4 STAND MANAGEMENT DECISION SUPPORT

4.2 Key/Checklist for Evaluation Cover Type Stand Management Options

Note: The following recommendations assume the management objective is to maximize quality and quantity of oak sawtimber.

1. Seedling and saplings	2
1. Pole and/or sawtimber	4
2. Adequate stocking (see appendix to evaluate stocking)	3
2. Inadequate stocking (see appendix to evaluate stocking	Plant to bring up to adequate stocking.
3. Poor site (typically < 50 site index) (Table 41.3 and Table 41.5) (includes most northern pin oak)	Grow to rotation
3. Fair to excellent sites (typically > 50 Site Index) (Table 41.3 and Table 41.5)	Evaluate need for release
4. Poor site (typically < 50 site index) (Table 41.3 and Table 41.5) (includes most northern pin oak)	5
4. Fair to excellent sites (typically > 50 site index) (Table 41.3 and Table 41.5)	7
5. Stocking slightly below, at or above B-line	6
5. Stocking significantly below B-line (≤ 40 to 50 ft^2 basal area)	Conduct a regeneration harvest (overstory removal, coppice, clearcut, or combination thereof
6. Not at rotation age	Let grow
6. At rotation age	Conduct a regeneration harvest (overstory removal, coppice, clearcut, or combination thereof
7. Stand not degraded: Stand quality and stocking levels sufficient for continued management: >40 crop trees per acre	8
7. Stand degraded: stand quality and stocking levels insufficient for continued management: <40 crop trees per acre	11
8. Age less than 75% of rotation	9
8. Age greater than 75% of rotation	10

9. Stocking below B-line	Let grow
9. Stocking above B-line and operable	Intermediate thinning to no lower than B-line
10. Not at rotation age	Let grow
10. At rotation age	11
11. Adequate advanced regeneration not present	Apply shelterwood
11. Adequate advanced regeneration present	Overstory removal

5 SILVICULTURAL SYSTEMS

A silvicultural system is a planned program of vegetation treatment during the entire life of a stand. Silvicultural systems typically include three basic components: intermediate treatments (tending), harvesting, and regeneration. With the oak type, silvicultural systems are frequently adapted to meet site-specific and species-specific conditions. As generally accepted in Wisconsin, oak regeneration is accomplished using even-aged methods.

The even-aged regeneration methods generally accepted and supported by literature are:

- Coppice
- Overstory removal
- Shelterwood

5.1 Seedling / Sapling Stands

The first 10-20 years of stand development is called the stand initiation stage and occurs immediately after the disturbance. During this stage, there are typically thousands of trees and shrubs per acre. Competition between trees and shrubs is intense during this period of rapid change. As few as 100 shade-tolerant stems per acre may be a concern at this time (e.g., ironwood, red maple, hazel, prickly ash, etc.). If allowed, these stems could out-compete oak and may eventually dominate the main canopy. Initiation of oak is slow compared to other hardwood trees and shrubs.

If existing seedling/sapling stands do not contain sufficient numbers and/or adequate size of preferred species, one option is to interplant the stand with desirable species. Mechanical or chemical competition control will improve the long-term survival and viability of planted trees.

As a forest progresses through the stand initiation stage to the stem exclusion stage (Frelich 2002, Oliver and Larson 1996), oaks have a higher chance of becoming dominant on low to average quality sites than on higher quality sites (Johnson et al. 2002). On high quality sites, without management intervention, intermediate and codominant oaks have a low probability of becoming more dominant as the stand advances toward maturity. Stocking of dominant, competitive oak can be increased on high quality sites by cleaning (thinning) to release potential crop trees (Dey et al. 2008).

In young stands, release is an important consideration and is often critical to put oak in a competitive position. The best time to apply release treatments is between when the canopy begins to close to within 10-15 years after canopy closure. Canopy closure will vary by site quality and generally occur between 8-15 years of age. Opportunities to improve long term composition of quality oak in the overstory is greatest in young stands that are less than 25-30 years old (Dey et al. 2008).

The number of oak stems required to provide a fully stocked stand for the final harvest is determined by following the evaluation method in Appendix B. Dominant and co-dominant oak stems should be encouraged and released from direct crown competition. Delaying more than 4-5 years could result in reduced growth and possible loss of reproduction. Where oak is not overtopped, defer thinning until crop trees are at least 25' tall (Lamson and Smith 1978).

Locally high populations of whitetail deer are a serious threat to forest regeneration throughout Wisconsin. It is important for foresters prescribing treatments in oak stands to anticipate and plan for this additional problem when establishing seedlings and saplings. In areas of extremely high deer populations, regeneration should be protected against browsing (Marquis et al. 1992).

5.2 Intermediate Treatments

5.2.1 Stem Quality

Factors affecting stem quality include stand history (such as over cutting, high grading, long periods of overstocked conditions), site capability, stand age, genetic variability and damage due to factors such as grazing, insects, disease, ice, wind, and poor harvesting practices and techniques. Hybridization among species within the red oak group has also been observed and can have an impact on quality. Stem characteristics such as forks, epicormic branches, seams, cankers, rot, and logging damage all contribute to lower log grades (See Forest Health Protection Guidelines, Appendix). Damage during harvest should be avoided at all times of the year. Root damage is more common when soils are not dry or frozen. Short cutting cycles combined with frequent entries for thinnings can increase the potential for damage during logging operations, and may also stress the stand due to repeated disturbances.

<u>Site selection</u>
Development of stand quality is the primary focus on sites that are classified as fair to excellent (Table 41.3 and Table 41.5). The focus on quality should occur from establishment of seedlings and saplings through harvest and regeneration treatments. Developing stand quality is not a primary concern on poor sites. Generally, these sites are limited in their capability to produce stands of high-quality oak sawtimber but are managed to maximize vigor.

<u>Density</u>
Stand density should be maintained at or above recommended residual levels to maintain bole quality. Stem form problems, such as epicormic branching, are directly related to stand density and crown development. Epicormic branch sprouts originate from dormant buds embedded in the bark. Bud dormancy is controlled by growth regulators (auxins) which are produced by the terminal buds. Trees lacking a healthy, vigorous, large crown, such as suppressed and intermediate trees in the understory or crowded overstory trees in unmanaged stands, do not

produce sufficient regulators to prevent epicormic sprouting. White oak produces more epicormic branches than red oak within the same crown class (Miller 1996). Dominant trees are less likely to produce epicormic branches than trees in lower crown classes.

Heavy thinnings that subject trees to sudden exposure to high light intensities increase the risk of epicormic branching and can reduce quality. “Trees around the perimeter of openings created by harvesting may also develop many epicormic branches, because the boles of northern red oak in fully stocked stands contain numerous dormant buds.” (Johnson et al. 2002) However, most epicormic branches on dominant and codominant trees develop in the upper stem just below the crown, which is of less concern as this area of the stem typically produces lower quality products.

Branches that result in forking are a stem defect increasing the risk of crown or stem breakage and can subject the stand to greater risk of oak wilt infection if breakage occurs during the growing season.

Crop Trees

Thinning regimes focus on the recognition, selection, and development of high-quality future crop trees. Evaluation of risk, vigor, and attention to future crop trees should be incorporated into the use of recognized marking guidelines. Crop trees are released by following the standard order of removal. Development of stand quality may be a long-term process involving three or more entries, on a cycle of 10-15 years.

The following criteria are generally used to select crop trees (see specifications in Chapter 24):

- Low risk – Tree has little (<10%) or no signs of defect and is likely to live through the cutting cycle to the next entry
- Good crown vigor – Tree is dominant or co-dominant with a good silhouette, healthy foliage, and a full concentric crown.
- Good timber quality – Tree has usable lengths commensurate with site, dbh/length ratio is good, there are no defects that reduce usable length, and any slight crook or sweep can be cut out. Tree has potential for at least one 16’ butt log of tree grade 2 or better.
- Desirable species – Tree is of a species well adapted to the site and of good commercial value with consideration given to landowner objectives.

The process of crop tree selection and management is described in greater detail in Chapter 24, Tree Marking and Retention Guidelines. Also described is the selection and management of residual trees for non-timber benefits.

5.2.2 Non-Commercial Intermediate Treatments

On fair to excellent sites, it is often necessary to enhance stand development with non-commercial intermediate treatments or timber stand improvement practices (TSI). These sites are capable of producing a greater yield and have a greater potential to develop stand quality. On poor sites, after the overstory removal has been completed, it is not necessary to conduct intermediate cuttings.

Where enhancement of stand development and quality are warranted, several methods are available to treat competing vegetation. Stand conditions must be evaluated when deciding which method to use.

5.2.2.1 *Methods to Control Competing Vegetation*

Herbicides
Herbicides can be effectively used against vegetation that competes with oak. The specific herbicide is dependent upon several factors such as the target species and preferred application technique. Stand conditions must also be considered when selecting between application techniques. These techniques include broadcast spraying; cutting the oak and broadcast spraying target species; stem injection; basal application; and cut stump treatments. All techniques require adherence to herbicide labels, appropriate safety clothing and equipment, and following applicator laws, licensing, and applicable forest certification standards.

Mechanical Treatments
Mechanical treatments include cutting, lopping, girdling, ripping, and other use of mechanized equipment. This method usually doesn’t kill the competitor species; however, it can put oak in a more advantageous position to grow through the competitor species. Sometimes this method can be included in a timber sale contract and completed as part of the conditions of the timber sale.

Prescribed Burning
Prescribed burning is an effective means of controlling oak competitors. Oak is more resistant to burning because of its thicker bark and larger root systems as compared to competing species (e.g., maple). Timing the burn to late spring or summer will increase efficacy of the burn, because root reserves are at their lowest and the burn is more lethal. Burning should be conducted when advance regeneration has developed, generally about 3-5 years after a shelterwood cut. More than one burn may be needed, depending on the burn intensity. All burns should be evaluated afterward to determine the need for follow-up treatments. Avoid burning when an acorn crop has just occurred or when oak seedlings are small, of low vigor, or recently established. Care must be taken to avoid basal damage to the seed trees. These trees are of the highest quality and contain the greatest value in the stand. Consideration must be given to the effect the burn may have in future marketing of the seed trees. See Prescribed Fire in Management Alternatives section.

5.2.2.2 *Practice of Release*

Weeding
Weeding eliminates or suppresses undesirable vegetation (trees, shrubs, vines, herbaceous vegetation, and invasive species) regardless of crown position within a stand. Most often these undesirables are fast-growing tree, aggressive shrub, or herbaceous species that retard advance regeneration or prevent the establishment of desirable regeneration. Intensive management techniques may be required to control competition and establish regeneration.

Cleaning
Cleaning releases desirable seedlings and saplings from undesirable tree species in the same age class that overtop them or are likely to do so. It is used to control a stand's species composition and to improve growth and quality of crop trees. Studies show that cubic foot yields of oak stands are more than 50% greater when cleaning (thinning) is begun at age 10 than when thinning is begun at age 60 (Gingrich 1971).

Liberation
Liberation frees favored trees from competition with older, overtopping trees. It is applied when a young crop of desirable seedlings and/or saplings are overtopped by less desirable, older competitors. Overtopping can reduce growth, cause stem deformations, and increase mortality due to excessive shade. In instances where cutting competitors would excessively damage the understory oak, girdling or applying herbicides to overtopping standing trees will accomplish the objective of the release while providing other benefits by creating snags. To achieve multiple benefits and ecological objectives, consider leaving reserve trees.

5.2.3 Thinning

5.2.3.1 *Non-Commercial Thinning and Improvement*

Crown release thinnings in young non-commercial pole stands will favor crop trees by removing adjacent crown competitors. This allows crop trees to develop full, vigorous crowns necessary for improving growth and quality. It is sometimes referred to as "crop tree release". If small diameter wood markets exist, non-commercial thinning and improvement may be deferred until a timber sale is viable, but there is a risk of losing potential oak crop trees due to competition. However, if a delay is feasible, a commercial intermediate thinning may allow residual trees to maintain or increase their growth and quality without the expense of a non-commercial practice.

Management should focus on improving stand composition and growth (Smith and Lamson 1983). Even when desired species are present in sufficient numbers, growth is often slow and mortality high due to intense competition from herbaceous vegetation and less preferred species. Early, intensive release can be used to improve stand species composition and growth by reducing competition (Della-Bianca 1969). Individual release of selected stems can facilitate adequate stocking of preferred species as the stand matures. Select 50-100 trees/acre, approximately 20-30' apart, and remove all trees whose crown touches the crown of the selected tree. At this stage, be conservative, creating spaces no more than five feet wide on 3 or 4 sides of selected crop trees (Sampson et al. 1983). This should occur when a stand is 10-20 years old or when tree height averages 25'. Delaying cutting until trees are 25' high may allow for better access into the stand and there will be fewer trees to cut. Stump sprouts of undesirable trees will not be a problem as they will be in the understory of these young dense stands. However, apply the release cut before selected crop trees fall below the codominant size class.

Thinning clump (stump) sprouts that originate from a single stump is a consideration in young stands. This practice can maximize residual stem growth and quality when thinned to one stem before reaching 3" dbh (age 12-15) (Johnson and Rogers 1984). Thin stump sprouts only on fair to excellent sites. Simulations indicate that thinning clumps to 1 stem at 5 years of age in stands of site index 70 can produce boles 11.6" dbh at age 25 when coupled with periodic thinnings around crop trees to a spacing that approximates B-level stocking. See Chapter 23, Intermediate Treatments for more detailed information on clump thinning.

General clump (stump) thinning guidelines (Lamson et al. 1988):

1. Thin clumps when 10-20 years old and only on good sites
2. Select crop stems that are dominant or codominant, straight, and free of forks and other defects and originate not more than 6" above the ground line.
3. Retain the best 1-2 crop trees/clump. If two crop stems are retained, the stems should be far enough apart so the stems do not fuse together at a common base (Roth 1956, Stroempl 1983)
4. Remove all intermediate or codominant trees if the crowns touch the crop stem crown, or if the crowns are above the crop stem crown.
5. Thin around thinned clumps in about 10 years to sustain maximum diameter growth.

5.2.3.2 *Commercial Thinning and Improvement*

Intermediate thinning is used in oak stands on fair to excellent sites (Table 41.3 and Table 41.5) to control stand density and structure. Regeneration is not an objective of thinning. The primary objectives of intermediate thinnings in oak stands are:

- To capture losses that would occur as a result of competition and suppression
- To improve overall stand quality by concentrating growth on the most desirable trees
- To improve stand vigor, growth and health
- To improve species composition
- To generate income during the stand rotation

Stocking charts have been developed for many timber types to determine how much basal area to remove with an intermediate thinning. These charts identify a stand's relative density when stand basal area and the number of trees per acre are known (see Chapter 23 – Intermediate Treatments).

Relative density is a measure of tree crowding that accounts for both the size of the tree and the amount of space typically occupied by a tree of that size and species, so it is an especially useful measure in mixed species stands (Stout and Nyland 1986). A relative density of 100% implies the growing space is fully occupied; growth will slow and some trees will be crowded out and die. On most stocking charts, 100% relative density is represented as the A-line. If relative density is at least 60% and below 100%, trees can fully occupy the growing site. The optimum relative density to retain after a thinning is a compromise between an individual tree's rate of growth, quality, and the number of trees needed to fully utilize available growing space (Gingrich 1967). The lower limit of stocking necessary to reach 60% (B-line) stocking in ten years on average sites is represented as the C-line and corresponds roughly to 40-50% relative density. Typically, thinnings are implemented at 80-100% stocking (usually economically operable), and density is reduced to 60-70% stocking to optimize sawtimber growth and quality.

Intermediate thinnings control stand density to maximize both stand growth and quality. Yields of high-quality crop trees are increased dramatically if stands are thinned early and regularly, particularly on good sites. Pole-size trees respond well to thinning. Diameter growth of released trees for a 20-year period can be expected to be about double that of non-released trees. Oak stands grown for quality timber should be kept fairly dense until the lower 20-25' of the boles are relatively free of branches. This will generally be when the trees are 40-50' tall (30-45 years old). Crop trees released at age 45 can average a 40% increase in diameter growth over unreleased trees in the 10 years immediately following release.

When thinning oak stands, determine which trees to cut by following the order of removal (also see chapters 23 and 24):

1. Risk – Cut high risk trees likely to die between cuttings (unless retained as a wildlife tree)
2. Release crop trees – Cut poorer quality competitors to provide crown growing space around crop trees to promote growth and quality development
3. Vigor – Cut low vigor trees, based on crown size and condition, crown class, and potential stem decay
4. Stem form and quality, based on usable log length and potential decay
5. Less desirable species (determined by landowner objectives)
6. Improve spacing

Free thinnings are generally recommended in oak. Removing trees of the lower crown class facilitates the utilization of trees likely to die due to suppression and captures income that would otherwise be lost. Thinning should be heavy enough not only to remove suppressed and intermediate stems but also the poorer, codominant trees as well. Follow crop tree selection and order of removal guidelines. Even though crown thinning is most applicable in stands of shade tolerant hardwoods, some degree of crown thinning is conducted in practice to provide release of codominant and dominant crown class. Ideally, crop trees should be 20-25' apart, however if they are unevenly distributed, leaving two crop trees close together and treating them as one tree is recommended. Note: spacing is last on the order of removal. Improving stand quality is a primary objective.

Thinning young stands offers the best opportunity to influence stand species composition and increases the growth rate of residual trees. If thinning is applied in a timely fashion to a young stand, the first thinning should be heavy, reducing stocking to approximately 50% (see stocking charts fig. 41.11a and b). Thinned stands should be allowed to grow to an operable stocking level before thinning again, generally 8-15 years. To maximize diameter-growth rates of crop trees, it is recommended that all subsequent thinnings should target a residual of 60 to 70% stocking.

First thinnings applied late (in overstocked stands) should take a more conservative approach, reducing the residual stocking to 60% for poletimber and 70% for sawtimber but removing no more than one-third of the stocking (see stocking chart, fig. 41.11a and b). Thinning lightly and more frequently will more safely develop tree vigor and strength until target residual densities can be achieved.

As a general guideline, if site preparation techniques are used to control understory development, thinning may continue until the time of regeneration. Refraining from thinning during the last 20% of the rotation may reduce development of a brushy understory that could interfere with desirable regeneration at stand rotation. This may reduce the need for site preparation (competition control) to ensure adequate regeneration of oak.

The thinning systems described above are not suitable for high graded stands with an abundance of undesirable growing stock. Assuming adequate good growing stock still exists; several improvement cuts may be applied in order to rehabilitate these stands (see degraded stands).

Cutting cycle intervals

The cutting cycle re-entry interval generally ranges from 8-15 years based on landowner objectives. Shorter cutting cycles can maintain higher tree growth rates, but operability (costs and benefits) must be considered. Shorter, more frequent re-entries may increase the potential for degrading stand quality through stem damage, root damage, and soil compaction. Conversely, shorter cutting cycles will allow for capture of more high risk and low vigor trees that would otherwise succumb to mortality. Longer cutting cycles can maximize tree quality and reduce negative impacts, such as damage to residual trees, soil compaction, aesthetic impacts (reduced slash), and ecological impacts (habitat disruption).

5.3 Natural Regeneration Methods

Two important rules of oak regeneration apply to most methods of oak regeneration for successful representation of oak in a future stand: 1) there must be competitive sources of oak regeneration in advance of the final overstory harvest, and 2) the advance oak regeneration must be adequately and timely released (Loftis 2004) especially on fair to excellent sites. Regenerating oak stands, especially on better quality sites, should be thought of as a process rather than an event. Several years to decades may be required to properly implement multiple practice prescriptions (preharvest site preparation to release of saplings). A commitment to long term management will be required to successfully regenerate and establish new oaks. On dryer habitat types, where competition is less intense, adequate natural advanced regeneration is sufficient, and tree diameter is smaller, regeneration can be accomplished with one harvest operation relying on a combination of systems (i.e., overstory removal, coppice, and clearcut).

Regeneration systems recommended to regenerate oak vary by habitat type due to variation of oak species, maximum tree size, and competition across ranges of habitat conditions. Table 41.11 and Table 41.12 indicate regeneration systems by habitat type groups that can be successfully applied in Wisconsin.

Table 41.10. Northern habitat type groups – generally accepted regeneration methods.

Habitat Type Groups	Coppice	Overstory Removal	Shelterwood
Very Dry to Dry	GAP	GAP	X
Dry to Dry–Mesic	GAP	GAP	GAP
Dry-Mesic	X	GAP	GAP
Mesic		GAP	GAP
Mesic to Wet–Mesic		GAP	GAP

GAP – Generally Accepted Practice
X – Method may have potential for application (See discussion under specific regeneration method)

Table 41.11. Southern habitat type groups – generally accepted regeneration methods.

Habitat Type Groups	Coppice	Overstory Removal	Shelterwood
Dry	GAP	GAP	X
Dry–Mesic	XX	GAP	GAP
Dry-Mesic to Mesic, and Mesic inc. phases	XX	GAP	GAP
Mesic to Wet–Mesic		GAP	GAP

GAP – Generally Accepted Practice
X – Method may have potential for application. (See discussion under specific regeneration method)
XX - On steep slopes in the Driftless area with small diameter trees where shelterwood is not practical.

5.3.1 Even-Age Regeneration Methods

<u>Advanced reproduction, stump sprouts and regeneration potential</u>
The key to successful regeneration of oak is to have sufficient numbers of large advance reproduction and/or potential oak stump sprouts to provide adequate oak stocking at the end of the regeneration period. Oak stands will depend on regeneration from new seedlings, seedling sprouts and/or sprouts from the stumps of overstory trees cut during harvesting (Johnson 1993). Seed origin trees are preferred for producing high-quality sawtimber.

Advanced reproduction exists either as true seedlings (recent germinants) or seedling sprouts. The root systems of seedling sprouts are usually considerably older than the stems and are capable of supporting much greater stem growth than those of true seedlings.

The size of advance regeneration is important, with taller stems having a greater chance of surviving and competing to be part of a future stand of oak. Jacobs and Wray (1992) developed a system for determining the regeneration potential of oak stands (Appendix B).

Jacobs and Wray defined competitive oak seedlings taller than 4’ as those with the greatest potential to contribute to the future stand. Quantity can make up for seedling size but requires greater number of smaller seedlings to contribute to the future stand. Guidelines indicate that twice as many seedlings 2.1- 4.0’ tall are needed, or, six times the seedlings 1.1- 2.0’ tall, or, thirty times the seedlings <1.0’ tall. Based on this system, a minimum of 515 seedlings (>4’ tall) per acre are needed to produce a fully stocked stand of oak by the time the stand reaches an average diameter of 9”.

In many of the drier oak forests of Wisconsin, advanced oak reproduction naturally accumulates to sufficient numbers over time prior to reaching rotation age. In dry-mesic or better site oak forest, accumulation of sufficient advance oak reproduction may take up to a decade or more to amass after initiating a disturbance or series of disturbances (shelterwood system).

Sprouting of overstory oaks after harvesting is an important source of regeneration and should be considered if there is a need to compensate for seedling oak regeneration deficiencies. The sprouting probability of oak species varies considerably, but generally decreases as tree size and age increase. Figure 41.10 shows the estimated sprouting probability for oak stumps in relation to site index and parent tree diameter. Table 41.16 lists the potential (percentage) of oak sprouts expected by species, site index, and age class. Deer have shown a preference for stump sprouts over seedlings.

Prior to the final overstory removal for any of the recommended oak regeneration systems, the adequacy of oak advance regeneration and/or potential of oak stump sprouting to compensate for oak advance regeneration deficiencies needs to be evaluated. See Appendix B for a procedure to evaluate the adequacy of advance oak regeneration and stump sprout potential.

The publication, “Prescribed Regeneration Treatments for Mixed–Oak Forests in the Mid-Atlantic Region” (Brose et al. 2008) provides an alternative method of evaluating the adequacy of oak seedlings that may have some application in Wisconsin based on height and/or root collar diameter. This publication defines “competitive” oak seedlings as being at least 3’ tall with a root collar diameter greater than 0.75”, which are highly likely to be dominant or codominant at crown closure of the new stand following harvest.

“Established” oak seedlings (0.5-3.0’ tall with a root collar diameter of 0.25-0.75”) are too small to compete on their own but with silvicultural treatments designed to give them a competitive edge they may develop.

“New” oak seedlings (< 0.5’ tall with a root collar < 0.25”) are considered too small to be determined established and should not be counted on for advance regeneration while implementing regeneration practices. Although this method of evaluating oak seedlings may have application in Wisconsin, further testing and development will be needed to adapt it to Wisconsin’s oak forest.

5.3.1.1 *Coppice*

Coppice regeneration relies on a mixture of seedling sprouts and stump sprouts for oak regeneration. It is most applicable on dry sites. On dry-mesic northern sites, coppice has potential to augment regeneration with advance seedling established at the time of overstory removal. Typically, regeneration will also be supplemented with advance regeneration, and potentially with acorn germination at the time of the harvest.

Frequency of sprouting is related to species, tree diameter, age, and site index (Johnson 1977, Weigel and Johnson 1998). In general, sprouting decreases with increasing diameter and age (Figure 41.10 and Table 41.16).

Follow-up thinning treatments of stump sprouts may be a consideration on dry-mesic and better sites to improve quality of stems (see Non-Commercial Thinning and Improvement section and Chapter 23).

Newly regenerated oak stands should be evaluated for competition after five years. If overtopping competition is present and becomes detrimental to the oak seedlings, mechanical control, herbicide, or a prescribed burn may be required to release seedlings (see Non-Commercial Intermediate Treatment and Prescribed Fire sections).

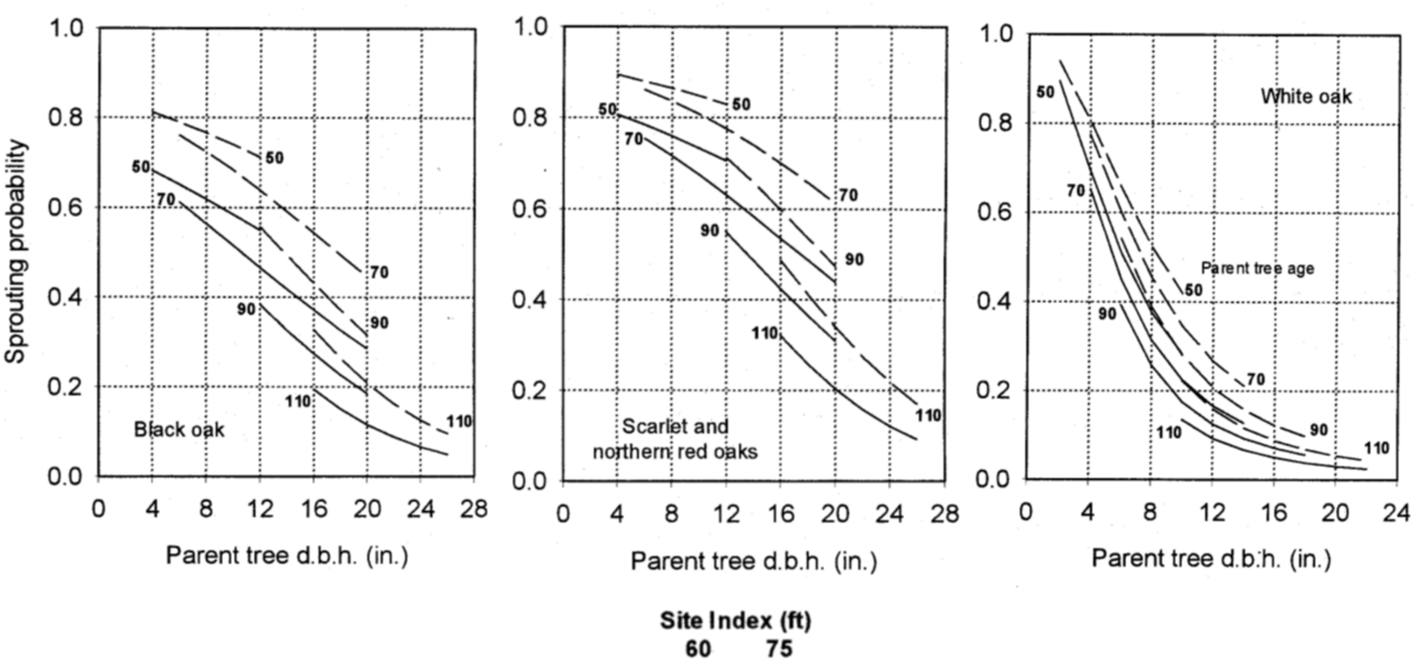

Figure 41.10. The estimated probability that an oak stump will have at least one living sprout one year after the parent tree is cut, by species, and parent tree age and dbh (Weigel and Johnson 1998).

5.3.1.2 *Overstory Removal*

This even-aged regeneration method removes all the overstory trees to release existing advanced oak regeneration beneath it. Success depends on adequate advance oak regeneration as described in Appendix B: Advance Reproduction and Regeneration Potential. Acceptable regeneration can generally be defined as a minimum of 515 seedlings/saplings per acre that are greater than 4' tall, to as many as 3100 seedlings/acre that are 1-2' tall. Damage to regeneration should be minimized by limiting the extent of skid trails and/or conducting operations during winter or fall. Overstory removal is used more frequently as the sole regeneration method on drier oak sites where adequate advance regeneration is established and is used in combination with shelterwood harvests on better sites. In practice, regeneration may also be supplemented with seedling and stump sprout development, as well as acorn germination at the time of harvest.

Newly regenerated oak stands should be evaluated for competition after five years. If overtopping competition is present and becomes detrimental to the oak seedlings, then mechanical control, herbicides, or a prescribed burn may be required to release seedlings (see Non-Commercial Intermediate Treatment and Prescribed Fire sections).

5.3.1.3 *Shelterwood*

This even-aged regeneration system involves 2-3 cutting treatments extended over a 5-30 year period and may include a preparatory cut or burn, or scarification to encourage the development of advanced reproduction, a seeding cut with site preparation, and an overstory removal cut. Table 41.10 and Table 41.11 identify site types where the shelterwood method is commonly applied. Although the shelterwood method may have potential on dry sites, generally it is not needed due to the presence of advance regeneration, the potential for stump sprouting, and because competition is less of a factor. Establishing oak on better quality sites (mesic) will entail greater effort and costs.

Three key aspects of applying a shelterwood system are controlling the amount of light, controlling competition, and incorporating acorns into mineral soil. The primary purpose for retaining a partial overstory after the first seeding cut is not to modify the understory but rather to provide a seed source to help establish advance regeneration. Results of present studies suggest it is the shade cast by the development of shade-tolerant midstory and ground layers, rather than the main canopy (shelterwood canopy) itself, that hinders the survival and growth of oak seedlings (Lorimer et al. 1994). Thus, controlling understory and midstory vegetation prior to and following a shelterwood cut is as important as the shelterwood cut itself. Thorough evaluation of potential competing vegetation (e.g., ferns, shrubs, small tress) is essential and may be accomplished by methods described in Appendix B for evaluating oak regeneration potential. If greater than 30% of the plots have competing vegetation, treat with herbicides, prescribed fire, or mechanical removal.

An optional preparatory cut may be needed in oak stands not previously thinned. A preparatory cut may be applied 10-15 years prior to rotation designed to remove non-oak and poor-quality trees and facilitate crown expansion of residual good phenotype oak trees to increase seed production.

Recommended crown closures for the first of a two stage shelterwood cut is approximately 40-60%. Retained trees should:

- have a dominant, large, vigorous crown
- have a high-quality bole
- be evenly spaced

An important component of the shelterwood system is evaluation of the acorn crop (see Appendix A) (Grisez 1975). Mature acorn crops are best evaluated in August or for one-year acorns in the red oak group, any time after the first growing season. Time site preparation treatments with a good or bumper acorn crop (August to November). If there is a thick duff layer, scarification may be necessary at the time of acorn drop, or shortly after, to incorporate the acorns into mineral soil. Scarify at least 50% of the stand area.

Successful shelterwood cuts have been accomplished with either of two separate methods.

1. The first method involves establishment of the shelterwood harvest and either:
    a. Timing the harvest (August to November) with a good or bumper acorn crop or
    b. Scarifying the harvest area (August to November) at the time of a good or bumper acorn crop, and then harvesting that winter or the following winter. Experience has shown a salmon blade works well for preharvest scarification. Scarification should emphasize mixing of the top 6” of soil, incorporating the acorns and uprooting undesirable competition.
2. The second method involves completing the seed cut of the shelterwood without regard for timing or size of the acorn crop. After the seeding cut is completed, the site will require monitoring as above for a good or bumper acorn crop. All site preparation treatments are timed to the occurrence of a good acorn crop. Chemical application and prescribed burning to control competing vegetation should occur prior to acorn drop (generally in August to September). Scarification is done during or shortly after the acorn drop. Silviculture field trials in Wisconsin have shown that use of an anchor chain works well for post-harvest scarification.

Under shelterwood methods, once adequate advance oak regeneration is present (within 3-5 years after germination) (see Appendix B on Evaluating Adequacy of Oak Regeneration), remove the residual overstory while maintaining reserves. If there is not adequate oak regeneration, consider planting oak to supplement natural regeneration or repeating site preparation for natural oak regeneration. Protection from deer may be necessary.

Newly regenerated oak stands should be evaluated for competition after 5 years. If overtopping competition is present and becomes detrimental to the oak seedlings, mechanical control, herbicide, or a prescribed burn may be required to release seedlings (see Non-Commercial Intermediate Treatment and Prescribed Fire sections).

5.3.1.3.1 Shelterwood and Plant

Shelterwood and plant is an alternative used on good to excellent sites (dry mesic or better) when scarification and other site preparation techniques are impractical due to site limitations (e.g., steep slopes, rocky, etc.). A 19-year study of various oak regeneration treatments concluded that underplanting on mesic sites is necessary to achieve established dominant oaks (Povak et al. 2008). Planting under the shade of a shelterwood can give the seedlings time to overcome planting stress before overstory removal. The residual overstory trees also provide some natural seeding and oak establishment to supplement planting. Cut from below to leave approximately 40-60% stocking in dominant and codominant trees. Control of mid-story competition and stump sprouts of undesirable species is essential. Plant large seedlings (at least 3/8" stem diameter) from a known source with fibrous root system (at least six permanent, first order laterals). Plant twice as many seedlings as needed to supplement natural regeneration. If oak stock is smaller than recommended, plant 3x as many seedlings as needed to supplement natural regeneration. Planting the "extra" seedlings assures the establishment of the desired number of trees. Remove the overstory during the dormant season in 3-6 years when planted seedlings are at least 2' tall (Jacobs and Wray 1992). See Appendix B: Evaluating the Adequacy of Oak Regeneration.

Newly regenerated oak stands should be evaluated for competition after 5 years. If overtopping competition is present and becomes detrimental to the oak seedlings, mechanical control, herbicide, or a prescribed burn may be required to release seedlings (see Non-Commercial Intermediate Treatment and Prescribed Fire sections).

5.3.1.4 *Clearcutting*[1]

Clearcutting is the process of removing most or all of the woody material creating an open area leading to the establishment of an even-aged stand. Regeneration is natural seeding from the trees cut in the harvest operation. If attempted, timing of cut is critical and must occur after August coinciding with an abundant, mature acorn crop (See Appendix A, Evaluation of Acorn Crop), control of competing tree saplings, and scarification. This method is silviculturally risky because there is only a single opportunity to naturally regenerate the stand.

Planting large oak seedlings in combination with clearcutting can help improve regeneration success. It is essential to control undesirable hardwood trees, preferably with spot treatment with herbicides to prevent hardwood sprouting. Plant large seedlings (at least 3/8" stem diameter) from a known source with fibrous root system (at least 6 permanent, first order laterals). Plant 3x as many trees as desired to supplement natural regeneration in the established stand. Planting the "extra" seedlings assures the establishment of the desired number of supplemental oak trees. Evaluate the stand for competition to planted oak after 5 years. If overtopping competition is present and becomes detrimental to the oak seedlings, mechanical control, herbicide, or a prescribed burn may be required to release seedlings (see Non-Commercial Intermediate Treatment and Prescribed Fire sections, and Artificial Regeneration guidance in Chapter 22). Refer to the Chapter 21 for more details on artificial regeneration.

[1] Management practice that may have potential for application in managing oak but has not been widely utilized and tested.

5.3.2 Uneven-Age Regeneration Methods

5.3.2.1 *Patch Selection*[2]

Trees are periodically removed in patches greater than 0.5 acres to typically less than 2 acres in size to create conditions favorable for the regeneration and establishment. The smallest canopy openings are larger than 0.5 acre, which is equivalent to a 167' diameter circular opening (approximately 2x tree height). This system generally favors regeneration and maintenance of shade mid-tolerant species; however, relatively intolerant or tolerant species can be encouraged. Shading effects will vary across the canopy opening, ranging from completely open at the center to shaded at the edge. The distribution of canopy openings may be regular, or irregular depending on variations in stand condition, such as the age, size, vigor, quality, composition, and health of patches of trees.

Acreage regulation determines the number of canopy openings. Patches of trees are harvested at rotation age creating new canopy openings. In addition, site preparation and follow-up release may be needed to establish desired regeneration, and regeneration recruited by past cutting may require release, while the remainder of the stand is thinned (see tending section). Many cohorts of trees must be tracked to evaluate rotation, site preparation and regeneration, release, and thinning of different aged patches. Patch selection is a system to manage uneven-aged stands essentially composed of many small even-aged patches. Both even-aged and uneven-aged silvicultural techniques are employed. Note: patch selection differs from group selection. Under group selection, openings are smaller, ranging from 0.2-0.5 acres in size. Group selection applications to date have proven unsuccessful in regenerating oaks.

5.5 Rotation Lengths and Cutting Cycles

<u>Rotation Definition</u>
In even-aged silvicultural systems a rotation is defined as the period between regeneration establishment and final cutting. The length of rotation may be based on many criteria, including culmination of mean annual increment (CMAI), target size, attainment of a physical or value growth rate, and biological condition.

<u>Choosing an appropriate rotation age</u>
Selecting when to rotate a stand is based on multiple considerations, including landowner goals, stand condition, and expected future growth. The rotation ages provided are guidelines based on literature, empirical data, and professional experience. In application, foresters will need to regularly review stands in the field and exercise professional judgment concerning tree vigor and mortality and stand growth and productivity. Different rotation lengths can result in increased production of some benefits and reduced production of others. Landowner goals and objectives, along with accurate stand assessment, will help evaluate the benefits and costs (ecological, economic, social) associated with different forest management strategies.

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[2] Management practice that may have potential for application in managing oak but has not been widely utilized and tested.

Below are rotation age guidelines based on three different management emphases to accommodate a variety of landowner goals.

Table 41.12. Biological and extended rotation age (years) recommendations for oak by Habitat Type groups and species groups (1st and 2nd numbers represent the biological rotation age range, and the 2nd and 3rd numbers represent the extended rotation age range).

Habitat Type	**Black/N. Pin Oaks**	**Red Oak**	**White Oak**
Dry	70-90-110	70-100-120	80-110-150
Dry-mesic	80-110-140	80-120-150	80-140-250
Mesic	90-120-150	100-140-200	100-160-300

5.5.1 Economic Rotation (Maximum Net Present Value)

The economic rotation age maximizes the net present value of the stand. It may only include financial aspects but could also include non-timber benefits. The inclusion of non-timber benefits may shorten or lengthen the optimal rotation depending on the non-timber benefits included. Landowners who choose economic rotation ages generally want to maximize the financial performance of the stand. Economic rotations will vary depending on the target discount rate and factors such as estimated costs and revenues. In practice, there can be significant overlap between economic and biological rotations, but economic rotations are often shorter. For more details on the factors that affect economic rotation age, please refer to the Economics Chapter (Chapter 62).

Oak is an important timber species in Wisconsin, however the products and associated financial returns vary widely by species and site quality. On very dry/nutrient-poor sites (Tables 41.2 and 41.4) with fair to poor potential productivity (SI<50), oak is managed primarily for pulpwood, firewood, and low grade sawtimber. On dry-mesic/medium sites (Tables 41.2 and 41.4) with good productivity (SI ~ 50-60), oak is managed primarily to produce sawtimber with occasional trees reaching veneer quality. On mesic/medium-rich sites (Tables 41.2 and 41.4) oak is managed to produce sawtimber and veneer where relative potential productivity is very good to excellent (SI>60). A recent study found that the best economic returns were found by thinning oak stands before age 50, however later thinning of previously unthinned stands between 60-78 years still increased volume growth rates and provided economic benefits (Demchik et. al. 2016).

Economic rotation data for oak in Wisconsin are very limited (Buongiorno and Hseu 1993, Demchik et. al. 2018). A few studies in the eastern United States calculated the maximum NPV for red oak rotations ranging from 80-125 years, depending on factors such as discount rate, stand quality, thinning regime, and logging system (Hibbs and Bentley 1983, Michie and McCandless 1986, LeDoux 2007). Alternatively, economic rotations can be based on a target rotation size. An economic rotation based on an optimal stem size attempts to capture the greatest stand-level value once the overall dominant/codominant cohort has achieved the highest value product class. The rotation sizes given are based on the average stand diameter of the primary size class, which can be determined from basic cruise data. Rotations based on a size target still must consider appropriate silviculture and regeneration methods for managing oak stands. On medium-rich sites managed for grade 1 and veneer logs, the economic rotation size can typically range from 18”-22” DBH. On poor-medium sites managed for logs grade 2 and below, the economic rotation size can range from 16”-20” DBH (Trimble and Mendel 1969, Hibbs and Bentley 1983, Demchik et. al. 2018). Financial returns on the very dry/nutrient-poor sites are minimal, so rotations are most often based on stand health/vigor and other landowner goals.

5.5.2 Biological Rotation (Culmination of Mean Annual Increment)

The biological rotation seeks to maximize long-term sustained yield, or volume production, and is defined by the age at which maximization or culmination of mean annual increment (CMAI) growth occurs. Biological rotation should therefore not be confused with the term “biological maturity” which is based on a species’ life expectancy. Refer to Table 41.13 for recommended biological rotation ages by Habitat Type groups and species groups. In this guideline, the range in rotation ages is defined at the lower end by CMAI and at the upper end by the average stand life expectancy. The recommended rotations provided are our best estimates of these endpoints based on the literature, Forest Inventory and Analysis (FIA), and other empirical data. On the very dry/nutrient poor sites, the shorter rotation ages are due to expected reduced quality, reduced growth rates, and increased mortality. On medium to rich sites, well-managed stands are often capable of growing longer and maintaining productivity.

5.5.3 Extended Rotation

Extended rotation involves growing stands beyond typical biological rotation ages yet younger than average tree life expectancy, with the objective of managing for both commodity production and the development of some ecological and social benefits associated with older forests. Refer to Table 41.13 for recommended extended rotation ages by Habitat Type groups and species groups. Ecological benefits of extended rotations can include an abundance of large trees, more diverse vertical structure, and greater levels of standing snags and coarse woody debris that support organisms associated with these structures.

5.6 Other Silvicultural Considerations

5.6.1 Prescribed Fire

Fire has played a major role in the regeneration and development of oak-dominated forests. Until recently, prescribed fire has been used infrequently in maintaining open oak-hickory forests and in facilitating regeneration of these species (Lorimer 1993). In the absence of such a disturbance, competition by other species can lead to loss of oak and conversion to a more mesic forest. Past research on prescribed fire in oak has produced mixed results. More recent studies, however, have documented effective ways of applying prescribed burning along with silvicultural methods.

Prescribed fire, especially in dry mesic and mesic oak forests, is used for several reasons, including reducing competition (release burn), preparing seedbed (site preparation burn), and controlling invasive species (Brose et al. 1999). Oak-dominated stands on better quality sites often have considerable competition from more shade-tolerant hardwood species, and if left untreated, establishment of oak seedlings is difficult. If site preparation and release techniques are not used, then further recruitment of oak typically will be minimal. Prescribed fire is a tool that can be applied to enhance the recruitment and establishment of oak regeneration.

Oaks have many fire-resistant adaptations. Mature white oaks tend to be more resistant than mature red oaks due to differences in bark characteristics and ability to compartmentalize (Lorimer 1985). The adaptations are as follows (Savanna Oak Foundation 2010):

- Mature oaks have thicker bark than most other hardwood species and can tolerate moderately intense ground fires.
- Oak regeneration can increase its root to shoot ratio following disturbance and can resprout after top kill.
- Acorns have hypogeal germination, which means that cotyledons are often located well below the soil surface and can survive fire.

Planning the timing and intensity of prescribed fires is important in achieving the desired results. Fire intensity (low and high), number of burns, seasonal timing and stand conditions are factors monitored in recent studies (Brose, 2006). Most research suggests spring understory fire effectively reduces competition and enhances regeneration and establishment of the more fire-resistant oaks. Timing the fire to late spring or summer will increase efficacy of the fire, because root reserves are at their lowest and the fire will be more lethal. High intensity fires (flames greater than 2’) decrease dense understory competition more quickly than low intensity fires. When conducting prescribed fires, care must be taken to protect residual oak trees from basal fire damage. Slash and other fuels must be removed from the base of residual oaks to prevent fire damage (Van Lear and Watt 1993).

Two types of prescribed fires recommended for oak are release burns and site preparation burns (Brose et al. 2006):

1. **Release burns** are used to treat competing, undesirable vegetation. Burning can be done after the first removal harvest of the shelterwood or after the final removal cut in mid to late spring during bud-swell and before leaf expansion of canopy trees. Fire intensity should be moderate to high intensity to ensure complete top kill of the undesirable vegetation.
2. **Site preparation burn** is a method to prepare an oak stand for seedling establishment. Timing with a good acorn crop is recommended. The objective is to reduce dense competition and litter so an acorn crop can successfully germinate. Burning can be done in late spring or fall, preferably in spring with a moderate to high intensity fire to top kill competition. Multiple fires at 2-5-year intervals may be needed to reduce competition and enhance the accumulation of oak seedlings over time. It is best to avoid burning if an acorn crop has just fallen or new oak seedlings have just established (Van Lear and Watt 1993).

In Wisconsin, there are examples of using fire in combination with shelterwood harvest. The objectives of the fire are to reduce competition and prepare the seed bed. The technique is attractive because of the relatively low cost of prescribed burning (Becky Marty, MN DNR, personal communication).

The shelterwood-burn method is a 3-step process (Brose et al. 1999):

1. First, the shelterwood seed cut, removes about half of the overstory basal area, retaining the best quality dominant and codominant oaks for further acorn production. This partial harvest is followed by a period of up to 5 years during which the stand is allowed to recover after harvest. During this period the shelterwood stand continues to produce litter, and fine fuel from the harvest dries out in preparation for the effective burn. Also, residual overstory trees continue to develop vigorous crowns and produce a good seed crop.
2. Second, a spring (growing) season burn is applied to set back competition and enhance the seedbed for more oak recruitment. The burn must be considered with regard to impacts on marketability of harvested seed trees, avoiding basal damage to the valuable seed trees. Oak regeneration is then evaluated over a period of 2-4 years.
3. Third, the overstory removal harvest is conducted when oak regeneration is established and of adequate density. Remaining trees can be harvested, leaving up to 15% residual crown closure for green tree retention.

Monitoring and documenting prescribed burn trials is recommended during pre- and post-burn application. The intent is to assess and document fire effects on competition, seed bed enhancement, regeneration stocking, and fire conditions. Recommendations for monitoring include:

- Document pre-burn and post-burn forest conditions – density, size and vigor of regeneration, competition, and crown cover
- Measure fire conditions – fuel load, fire intensity/severity, flame length, rate of spread
- Document the cost – equipment time and labor
- Examine the site the first year and then 3-5 years after the burn - document density, size and vigor of regeneration, competition, and crown cover

5.6.2 Managing “Degraded” Stands

Many stands throughout Wisconsin have been “degraded” or reduced in stand quality due to a multitude of factors including grazing, poor harvesting techniques, high-grading, fire, and other biotic and abiotic agents (e.g., disease, insects, wind, ice). Many of these oak stands have either an abundance of poor-quality stems or some poor-quality larger diameter stems overtopping a younger stand (poles, saplings or seedlings) containing potential crop trees. Some historically oak stands have converted to other hardwood types. If oak is no longer the management objective, refer to the handbook chapter of the new timber type for management guidelines.

Thorough stand assessment is required to determine the site quality, species composition, stand age, number of potential crop trees, and management potential. If a minimum of 40 well-distributed, potential crop trees/acre exist on sites with “fair” or better growth potential (Table 41.3 and Table 41.5) the stand can be managed to rotation length using systems described in this chapter. If remaining crop trees are of poor quality and/or low vigor, consider managing at the lower end of the rotation length for the site. If less than 40 potential crop trees/acre exist and natural regeneration is lacking, the stand could be allowed to reach seed bearing age and then follow the process to conduct a two-step shelterwood to regenerate a new stand. If adequate established regeneration is present, then follow the guidelines for Overstory Removal. Depending on present species composition and the landowner's objectives, the stand could be considered for artificial regeneration following generally accepted practices (Chapters 21 and 22).

Stands growing on sites with "very poor" to "poor" growth potential (Table 41.3 and Table 41.5) are not capable of producing quality crop trees. Stands at or near b-line on stocking chart should be grown to rotation. Stands younger than rotation and significantly below b-line (basal area of 40-50'^{2}), should be regenerated following guidelines in this chapter.

8 APPENDICES

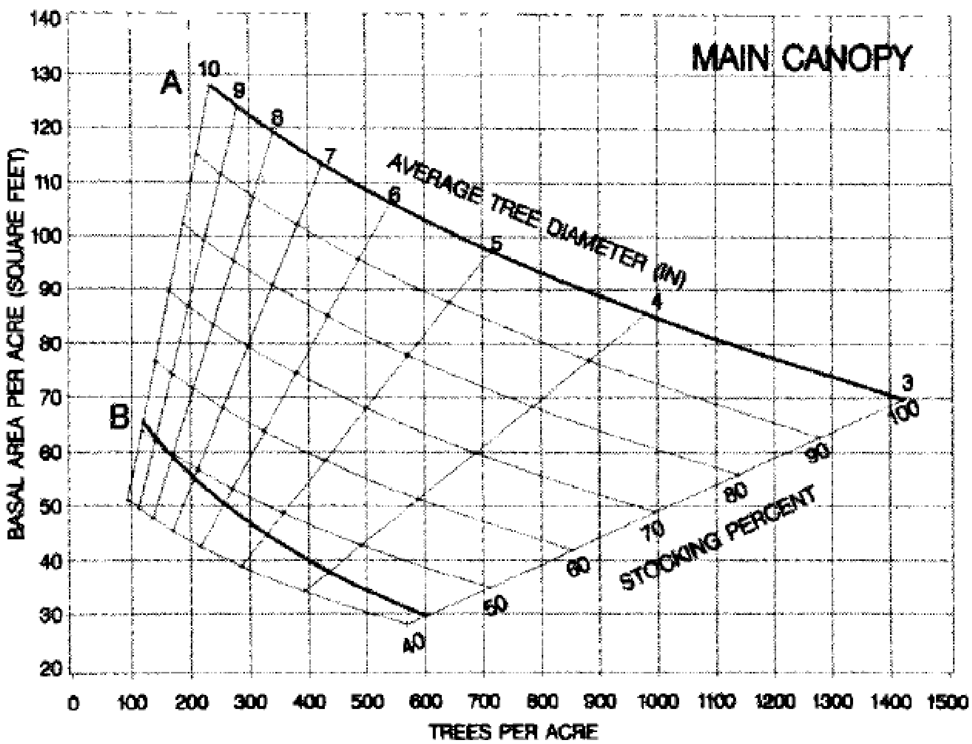


Figure 41.11. Stocking guide for northern red oak stands (average dbh 3-10") in Wisconsin (McGill et al.1999).

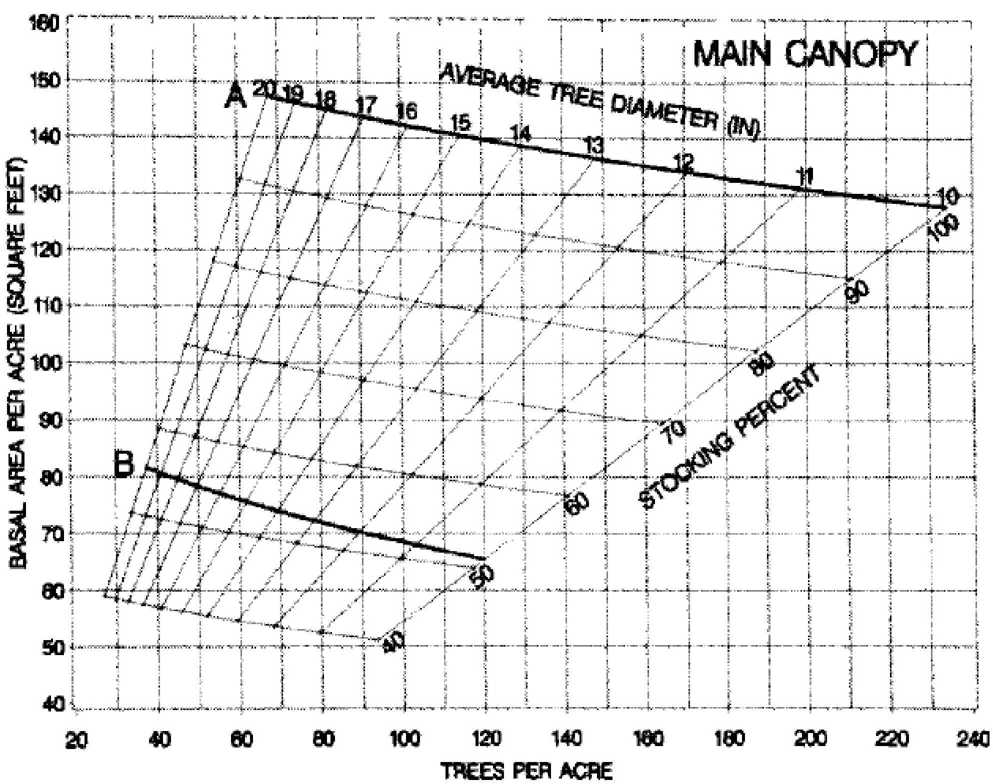


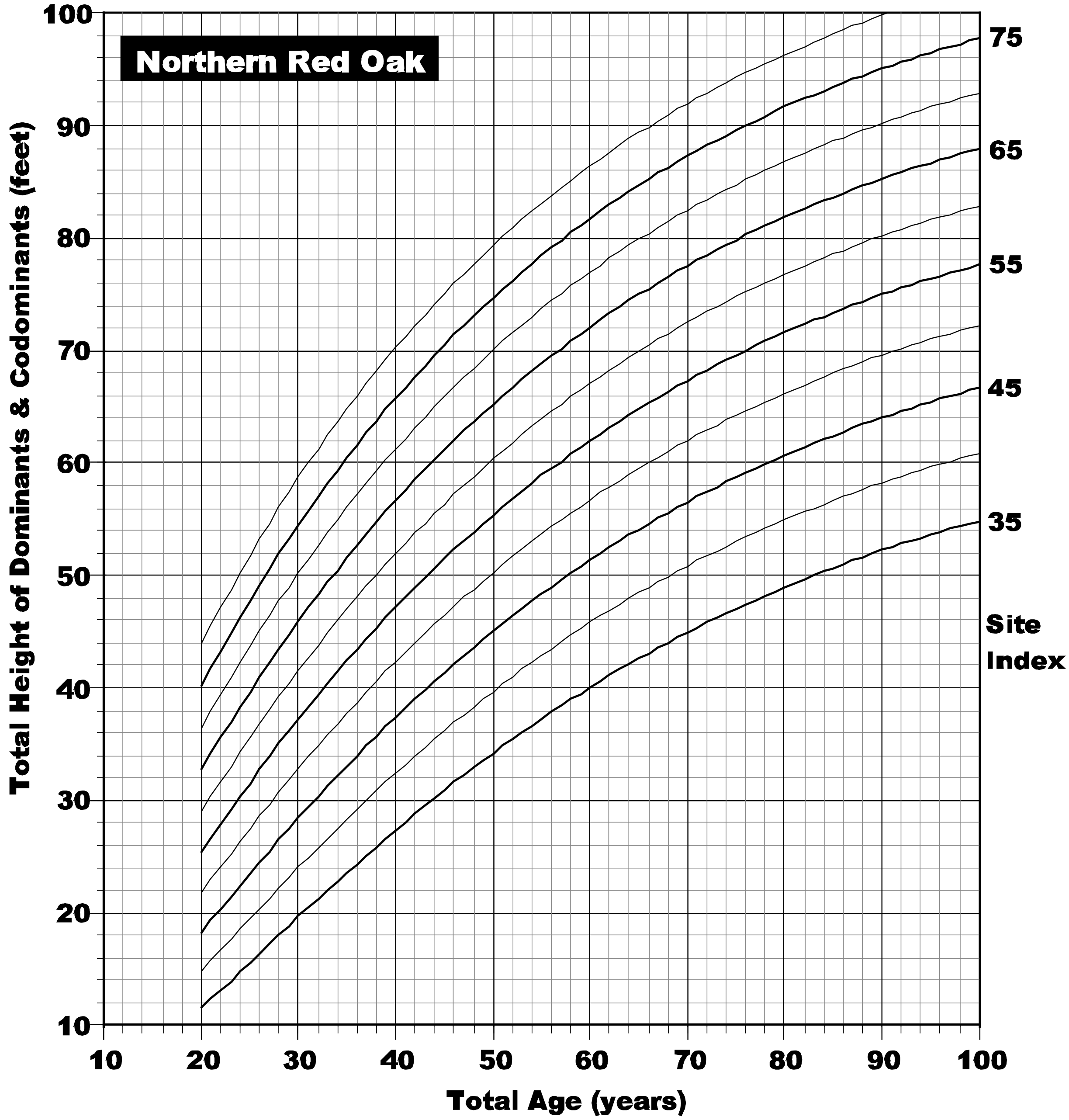
Figure 41.12. Stocking guide for northern red oak stands (average dbh 10-20" in Wisconsin (McGill et al. 1999).

The Northern Red Oak Stocking Guides (Figure 41.11 and Figure 41.12) display the relationship between basal area, number of trees, mean stand diameter, and stocking percent. They provide a statistical approach to guide stand density management (see Chapter 23).

- To utilize the stocking guides, statistically accurate estimates of at least two stand variables must be obtained, including basal area per acre, number of trees per acre, and/or mean stand diameter. For the oak stocking guides, these variables are measured only for main canopy trees (dominant, codominant, and intermediate crown class trees)
- The area between the A-line and B-line indicates the range of stocking where optimum stand growth and volume yield can be maintained.
    - The A-line represents maximum stocking. Maintaining stocking levels near (but below) the A-line will produce comparatively more trees, but of smaller diameter.
    - The B-line represents minimum stocking. Maintaining stocking levels near (but above) the B-line will produce larger diameter trees faster, but comparatively fewer trees.
- When designing and implementing a thinning regime for a stand, do not reduce stand density to below the B-line or allow it to surpass the A-line.
- Thinning can occur at any time as long as stand density is maintained between the A-line and B-line. The A-line is not a thinning “trigger.” When to thin depends on management objectives, stand conditions, and feasibility.

Typically, thinning is implemented when average stand stocking is halfway or more between the B-line and A-line. Stocking is reduced to slightly above the B-line. Crop tree concepts are applied to retain and focus growth on desirable trees, and order of removal concepts are applied to select which trees will be cut to achieve stand management objectives.

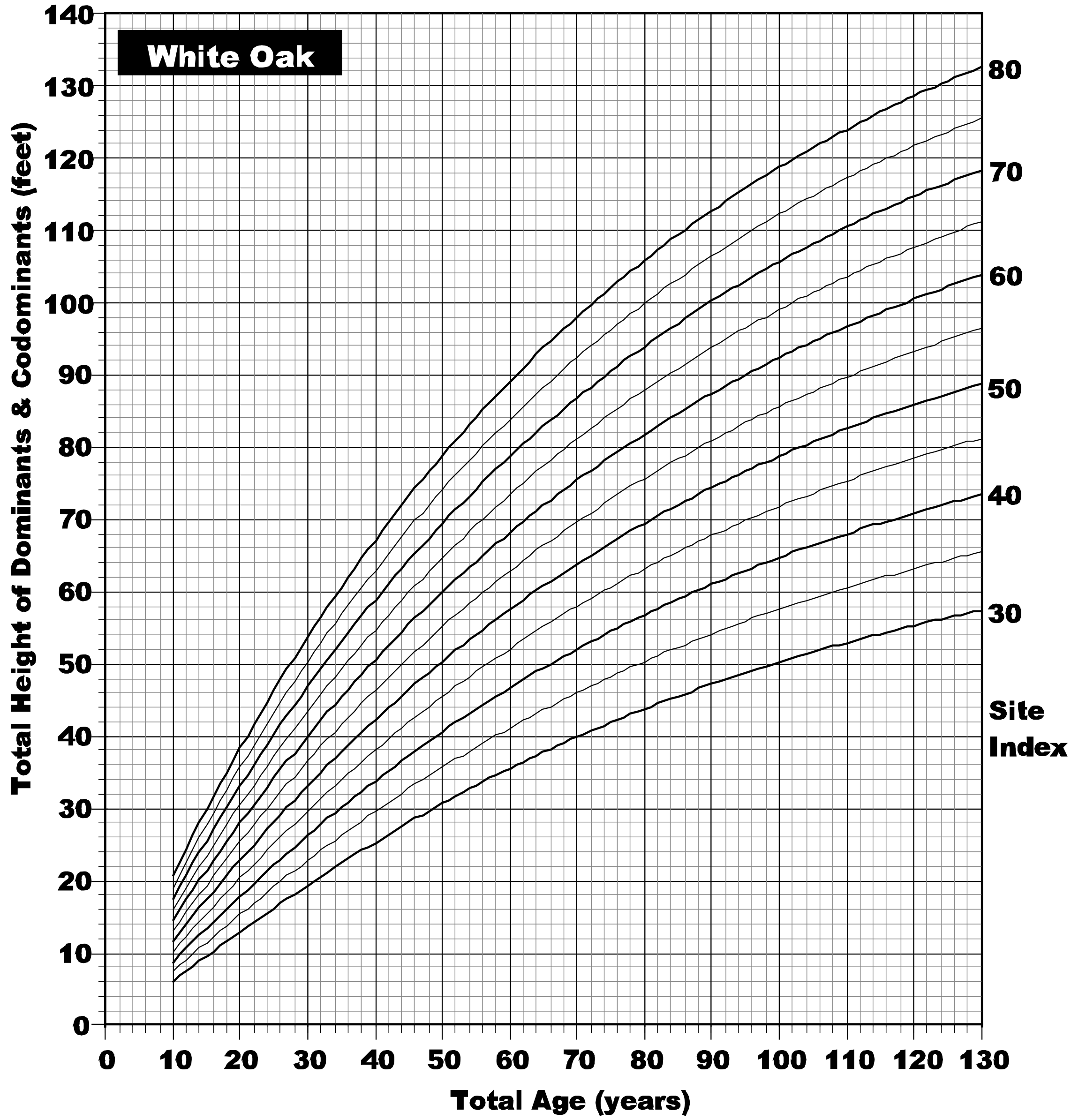
In overstocked stands, thin lightly and frequently, with increasing intensity, for the first several thinnings, to safely develop tree crown vigor and stem strength, and until target residual densities (near the B-line) are achieved. A general rule of thumb is do not remove >33% of the basal area in any one thinning operation.



Northern Wisconsin and Upper Michigan
37 plots having 136 dominant and codominant trees
Stem analysis, nonlinear regression, polymorphic
Add 4 years to DBH age to obtain total age (BH=0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE difference	Maximum
H	6.1785	0.6619	-0.0241	25.0185	-0.7400	0.99	1.32	4.9
SI	0.1692	1.2648	-0.0110	-3.4334	-0.3557	0.97	2.09	7.8

Figure 41.13. Site index curves for northern red oak (Carmean 1971, 1972).

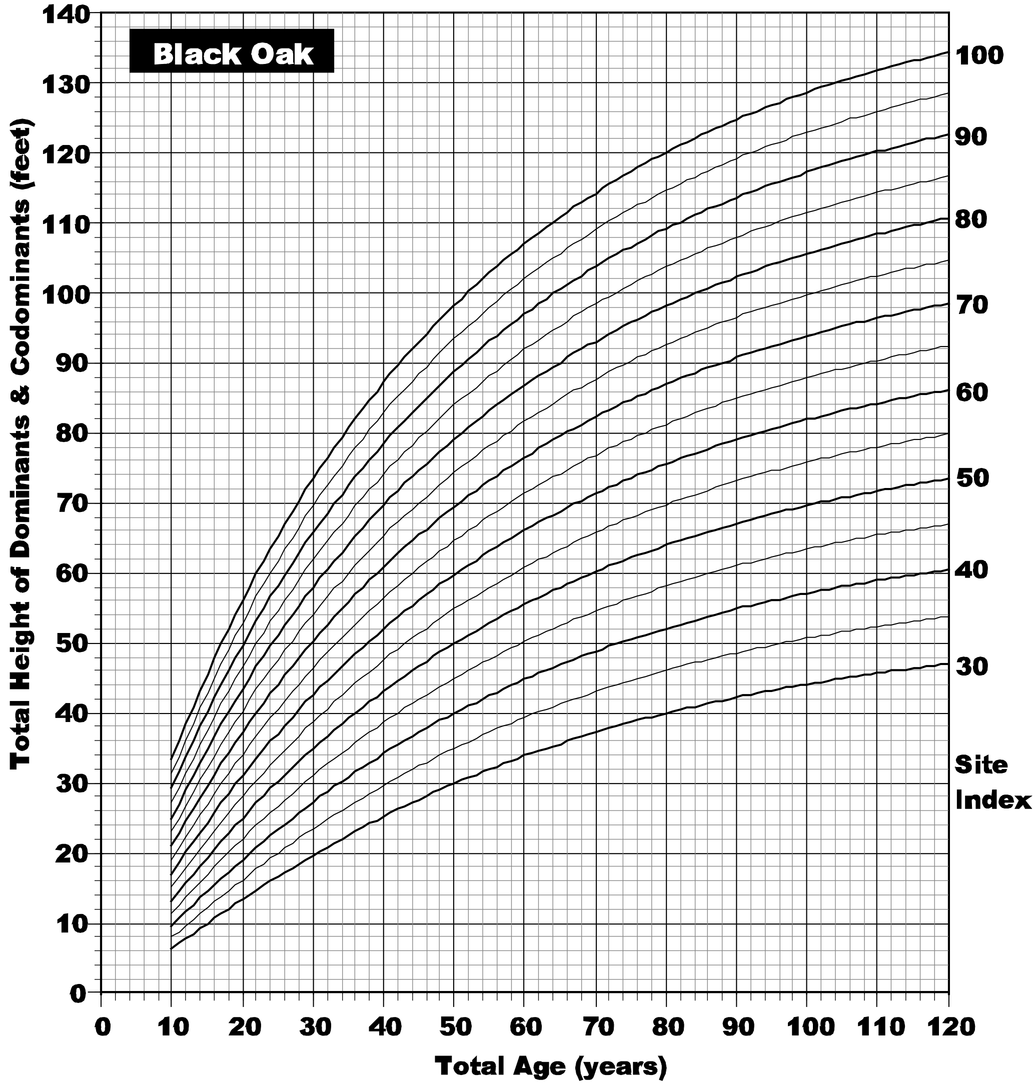


Unglaciated uplands of southeastern Ohio, eastern Kentucky, southern Indiana, southern Illinois, and southern Missouri; 41 plots having 112 dominant and codominant trees, Stem analysis, nonlinear regression, polymorphic. Add 3 years to DBH age to obtain total age (BH=0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	4.5598	0.8136	-0.0132	2.2410	-0.1880	0.99	2.69	(x)
SI	0.3387	1.0135	-0.0076	-0.9644	-0.0176	0.99	2.90	(x)

(x) Value not calculated because model was fitted to original data rather than to site index curves.

Figure 41.14. Site index curves for white oak (Carmean 1971, 1972).



Unglaciated uplands of southeastern Ohio, eastern Kentucky, Southern Indiana, southern Missouri
120 plots having 300 dominant and codominant trees
Stem analysis, nonlinear regression, polymorphic
Add 3 years to DBH age to obtain total age (BH=0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	2.9989	0.8435	-0.0200	3.4635	-0.3020	0.99	4.09	(x)
SI	0.2598	1.1721	-0.0107	-2.3272	-0.2825	0.99	4.42	(x)

(x) Value not calculated because model was fitted to original data rather than site index curves.

Figure 41.15. Site index curves for black oak (Carmean 1971, 1972).

8.1 Evaluation of Acorn Crops

A ranking system has been developed to help quantify the size of the acorn crop. Natural oak regeneration treatments (e.g., harvesting, mechanical and/or chemical site preparation, fire) should be timed with a good to bumper crop of acorns to maximize oak regeneration. Evaluating the size of the mature acorn crop is best done in August, when the acorns can be seen with the use of binoculars or a spotting scope. Since acorns in the red oak group require two years to mature, seed crops can be estimated after the first year of development to allow time for pre-planning of regeneration treatments. Developing ovules (i.e., acorns) are located on the current year's growth of the upper crown. The small 1-year ovules are 1/32-1/8" in size, singly or in clusters, on a short stalk. This early evaluation alternative can be misleading however if there are significant losses during the 2nd year of acorn development or if the sampled trees (i.e., cut tree from a nearby timber sale) are significantly different than the stand of trees to be regenerated, therefore the acorn crop should be verified again shortly before the regeneration treatment.

Procedure for evaluating acorn crops:

1. For fully developed acorns (i.e., August, second year for red oak group), binoculars or a spotting scope may be used to observe the acorns in the crown. For early estimates of 1-year developing red oak acorns, choose a nearby timber sale that was cut during the current fall or winter that is representative of the stand you wish to regenerate. Red oak ovules are too small to view from the ground, so you need to make these counts from representative trees that have been recently felled.
2. Randomly select at least three terminal branches from the upper one third of the crown on a dominant oak.
3. Count all the mature or developing acorns on the last 24" of each terminal (including all lateral branchlets). See Figure 41.16 (Early Evaluation of Acorn Crops from the Red Oak Group). Calculate the tree average from the three branches.
4. Due to tree to tree variation, repeat the procedure on several trees and then average all trees sampled on a site.
5. Determine the seed (acorn) crop rating from Table 41.13.

Table 41.13. A ranking of acorn production for individual trees (Johnson 1994).

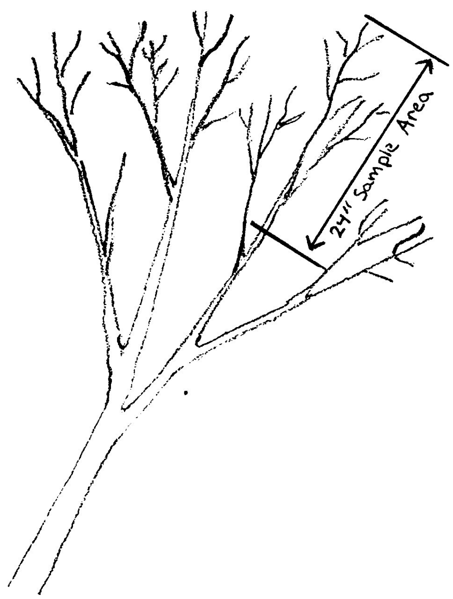
Ranking	White Oak Group	Red Oak Group
	Average number of acorns per branch[1]	
Excellent or Bumper	18+	24+
Good	12-17	16-23
Fair	6-11	8-15
Poor	<6	<8

[1]Based on the terminal 24" of healthy branches in the upper one-third of the crown.

According to Grisez (USFS Res. Pap. NE-315, 1975) the following table can serve as a guide to classifying next fall's crop. Remember, this is an estimate. These developing acorns are still susceptible to heavy insect losses and drying during a summer drought.

Seed Crop Rating	Average Number of Acorns Per 24-inch Branch Tip
Bumper	>24
Good	17-24
Fair	9-16
Poor	4-8
Trace to None	<3

Terminal Branch Sample Area:



First Year Red Oak Acorns:

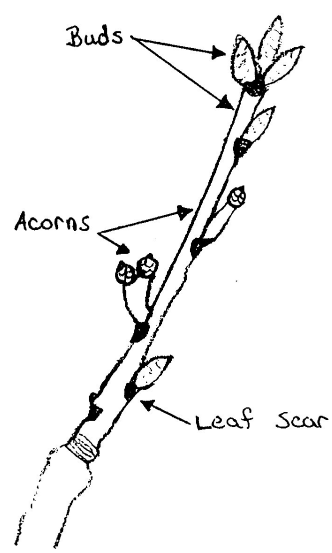


Figure 41.16. Early evaluation of acorn crops from the red oak group.

8.2 Evaluating the Adequacy of Oak Reproduction and Stump Sprouting

Adapted from Managing Oak in the Driftless Area, Jacobs and Wray 1992; Sander et al. 1984

To determine the potential ability of an oak stand to reproduce, conduct an inventory of the advance reproduction and the overstory oaks. If the advance reproduction does not meet the minimum stocking standards, the overstory inventory is used to determine whether there will be enough stump sprout potential to make up the difference.

The advance reproduction is evaluated in terms of the potential contribution of understory stems, after release, to stand stocking at age 20-25. The potential contribution of an individual stem is rated according to its height; this rating is called Stocking Value (SV). Ratings range from SV 1 for stems less than 1 foot tall to SV 30 for stems more than 4' tall:

Table 41.14. Stocking value by height.

Height		Stocking value of each stem	Adequate stocking (no. of stems)
(Class)	(Feet)		
A	<1.0	1	30
B	1.1-2.0	5	6
C	2.1-4.0	15	2
D	4.1+	30	1

An aggregate stocking value (SV) of 30 for stems in any combination of height classes in a reproduction plot indicates adequate stocking for that plot. For example, 3 class B stems (3 stems x 5 SV = 15) plus 1 class C stem (1 stem x 15 SV = 15) total 30.

An SV of 30 for all reproduction plots sampled indicates a potential minimum stocking of 220 4.5" dbh dominant or codominant oak stems per acre. However, a stocking of 154 dominant and codominant trees per acre (70% of reproduction plots stocked) is considered adequate. Although this is less than B-level stocking (30% stocked), if the trees maintain their crown position, either naturally or by thinning, there will be enough stems to reach B-level stocking when the average diameter reaches 9" and A-level when average diameter is 12". Presumably, total stocking will include the projected stocking of dominant and codominant oaks as well as other species and additional oaks in the subordinate crown classes.

A less or more restrictive minimum standard for oak reproduction can be set depending on the management objective for the stand. For example, if other desirable species (e.g., walnut, maple, and basswood) are present and, in combination with oak advance reproduction, meet the suggested minimum standard, fewer oaks may be acceptable as long as oaks represent 50% of the SV. Moreover, if competition remains under control after establishment of the seedlings, acceptable stocking value can be reduced by half to SV 15. This means that a reproduction plot can be considered stocked if it contains at least one oak 2' or more in height, at least three oaks 1' or more, or at least 15 oaks less than 1' tall.

<u>Field procedures</u>

1. Inventory all oaks 1.6” dbh and larger on 10 or more 1/20-acre plots (26.3’ radius). Record these data by species and size class on the “plot tally” lines of the Oak Overstory Tree Inventory form (Figure 41.17). This information may be used to determine stump sprouting potential. Also record the ages to the nearest 20 years of both the overstory (dominant and codominant crown classes) and the understory (intermediate and suppressed) oaks and enter the oak site index.
2. Select the number of 1/750-acre plots (4.3’ radius) reproduction plots required from Table 41.15 according to the acreage of the stand being examined:

Table 41.15. Reproduction plots needed by stand acreage.

Stand area (acres)	No. 1/750-acre plots
<10	25
10-30	40
30-50	60

3. Distribute the reproduction plots uniformly throughout the stand. On each plot, count the advance reproduction and record by height on the Advance Reproduction Inventory form (Figure 41.19).
4. For each reproduction plot, determine the aggregate SV for oaks. If it is 30 or more, check column E on the Advance Reproduction Inventory form (Figure 41.19).
    a) To simplify the procedure:
        i. Begin with the tallest stems (column D). If at least one stem of this size is present (SV 30; see SV at the head of columns A-D), record as stocked in column E and look no further (see example). If no column D (4.1’+) stems are present, go to column C; two stems this size indicate a stocked reproduction plot. And so on. Check column E when SV totals 30 or more. Also record the number of stems by height class, which together provided the SV 30 sum.
        ii. If the SV for oak is less than 30 (but at least 15) and other species are acceptable to the owner, repeat the above process for the other desirable species. When SV is 30 or more for the combination of species, including oak, check column F.
        iii. If undesirable vegetation is preventing the establishment of desirable reproduction or hindering its growth, enter in column G:
            - F for ferns,
            - S for shrubs and trees less than 6 feet tall, and
            - T for taller shrubs and trees.
            - Use judgment in evaluating potential competition – look for an understory “canopy layer” or the potential for one developing after the stand is opened up. Base your decision on density, height, and vigor of interfering vegetation.

Example (based on the sample data in Figure 41.20)

Assume the inventory has resulted in the entries shown in Figure 41.20. We see reproduction plot 1 has 1 tree taller than 4'. This immediately gives plot 1 an SV of 30, so check column E and go on. Plot 2 has 1 tree in the 2.1-4.0' class with an SV of 15. It also has more than 3 trees (3+) in the 1.1-2.0'class. Three times the SV for that class (5) is 15. The total for plot 2 is at least 30, check column E again and continue in a similar manner throughout the form.

CALCULATIONS

1. Determine the potential stocking from advance reproduction by adding the entries in columns E (and F, if used) and dividing by the number of reproduction plots sampled. If 70% or more of the plots are stocked, advance reproduction is adequate and no further calculations are needed.
2. If fewer than 70% of the reproduction plots are stocked, stump sprouts are needed to supplement the advance reproduction. Calculate the projected stocking from advance reproduction by multiplying the percent of reproduction plots stocked by 220 (100% stocking). Subtract the result from 154 to find the number of stump sprouts needed to bring projected stocking up to minimum.
    a) Referring back to the example (Figure 41.17), divide the total number of entries in column E (12) by the number of reproduction plots (20) for a stocking percent of 60. Multiply 60% by 220 = 132 projected stems per acre, 22 less than the 154 needed for minimum stocking. Thus, the stand will be inadequately stocked with advance reproduction and at least 22 stump sprouts will be needed to bring stocking up to minimum.
3. The number of sprouts available to supplement advance reproduction is calculated from the "plot tally" data on the Oak Overstory Tree Inventory form (Figure 41.17). For each species and dbh class, convert the plot tally to number of trees/acre by dividing the plot tally sum by the area sampled. Determine the number of potential sprouts by applying the appropriate percentages from Table 41.16 to the stems/acre figures. Total the resulting numbers to get the number of sprouts/acre.
4. Add the projected number of stump sprouts to the projected stocking from advance reproduction. If the sum is >154, the stand has adequate oak regeneration potential; if < 154 take steps to recruit additional oak reproduction or consider planting to supplement natural oak regeneration.

Example (based on the sample data in Figure 41.18)

a. Assume 10 1/20-acre plots, site index 60, understory age 20, and overstory age 90.
b. Divide the red oak plot tally for 2-5" dbh trees (14) by the area sampled (1/2-acre) to get 28 stems per acre.
c. Multiply this number by the appropriate percentage for trees less than 60 years old from Table 41.16 (86) to find the number of stumps expected to produce dominant or codominant trees at age 20, i.e., 28 x 86% = 24 (rounded to the nearest whole number). Record this number in the appropriate cell in Figure 41.18.
d. Compute the corresponding numbers for the other species and diameter classes (age greater than 60 years).

e. Add the numbers across for each species and then add the sums for a grand total of 29 expected stump sprouts per acre.

To determine whether the number of stump sprouts is adequate to bring stocking up to minimum, add this number to the projected stocking (132) based on the Advance Reproduction Survey form (Figure 41.20). The result is 161, more than 154, so stocking is adequate.

Table 41.16. Percentage of stumps that will produce at least one codominant or larger stem at age 20-25 years (Sander et al. 1984).

Species	Site Index	Age Class (years)	dbh (inches)			
			2-5	6-11	12-16	17+
			%			
Red oak	All	< 60	86	86	86	86
		> 60	49	46	38	24
Black oak	50	all	30	10	3	2
	60	all	45	15	5	2
	70	all	60	20	7	2
White oak	50	40	47	18	6	0
		60	25	10	4	2
		80	12	6	3	1
		100	5	3	2	1
	60	40	63	26	9	0
		60	38	16	7	3
		80	19	9	5	2
		100	8	5	3	2
	70	40	81	36	15	0
		60	55	25	11	5
		80	31	16	8	4
		100	15	9	6	4

(Trees 1.6+ inches DBH)

1/20 Acre Plots (26.3-foot radius) Age: Understory oaks: _________
Overstory oaks: _________
Number of Plots ___________ Site Index: Oaks ________

	DBH Class-inches				
	2-5	**6-11**	**12-16**	**17+**	**Total**
Red Oak **Plot tally**					
Stems/acre					
Sprouting%					
Sprouts/acre					
White Oak **Plot tally**					
Stems/acre					
Sprouting%					
Sprouts/acre					
Black Oak **Plot tally**					
Stems/acre					
Sprouting%					
Sprouts/acre					
Other Oak **Plot tally**					
Stems/acre					
Sprouting%					
Sprouts/acre					
Other Oak **Plot tally**					
Stems/acre					
Sprouting%					
Sprouts/acre					
All Oaks **Sprouts/acre**					

Figure 41.17. Oak overstory tree inventory.

Previous View

(Trees 1.6+ inches DBH)

1/20 Acre Plots (26.3 foot radius)

Number of Plots 10

Age: Understory oaks: 20

Overstory oaks: 115

Site Index: Oaks 60

	DBH Class-inches				
	2-5	6-11	12-16	17+	Total
Red Oak Plot tally	(14)	(3)	(3)	(1)	21
Stems/acre	28	6	6	2	
Sprouting%	86%	46%	38%	24%	
Sprouts/acre	24	3	2	0	29
White Oak Plot tally					
Stems/acre					
Sprouting%					
Sprouts/acre					
Black Oak Plot tally					
Stems/acre					
Sprouting%					
Sprouts/acre					
Other Oak Plot tally					
Stems/acre					
Sprouting%					
Sprouts/acre					
Other Oak Plot tally					
Stems/acre					
Sprouting%					
Sprouts/acre					
All Oaks Sprouts/acre	24	3	2	0	29

Figure 41.18. Oak overstory tree inventory example.

1/750 Acre Plot (4.3-foot radius)

	Column						
	A	B	C	D	E	F	G
Plot Number	Height Class – Feet				Plot Stocking		
	<1.0	1.1-2.0	2.1-4.0	4.1+			
	Stocking Value (SV)				Oak	Desirable Species	Understory Competition
	1	5	15	30			
	Number of Stems measured						
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Figure 41.19. Advance reproduction inventory.

Calculations

1. Percent stocking: no. of plots stocked ÷ total no. of plots x 100.

2a. If **more** than 70% of plots are stocked, no further calculations are needed; there is adequate regeneration potential.

2b. If **fewer** than 70% of plots are stocked, continue calculations.

3. Projected stocking from advance reproduction: 220 x % stocking.
Projected number of stump sprouts from Oak Overstory Tree Inventory: ______.
Total projected stocking: ______.

4a. If total is greater than 154, there is adequate regeneration potential.

4b. If total is less than 154, supplemental natural or artificial oak reproduction is needed.

Column

	A	B	C	D	E	F	G
Plot Number	Height Class – Feet				Plot Stocking		
	<1.0	1.1-2.0	2.1-4.0	4.1+			
	Stocking Value (SV)				Oak	Desirable Species	Understory Competition
	1	5	15	30			
	Number of Stems measured						
1				1	✓		
2		3+	1		✓		
3					X		
4			2+		✓		
5		6+			✓		
6	5				X		
7					X		
8	15+	3			✓		
9			2+		✓		
10		3+	1		✓		
11					X		
12	15+		1		✓		
13					X		
14				1	✓		
15	2				X		
16		3+	1		✓		
17		3+	1		✓		
18					X		
19		6+			✓		
20			1		X		
21							
22							
23							
24							
25							

Calculations;

1. Plots Stocked: 12 ÷ total no. of plots: 20 x 100 = Percent of plots stocked: 60.

2a. If **more** that 70% of plots are stocked, no further calculations are needed; there is adequate regeneration potential.

2b. If **fewer** than 70% of plots are stocked, continue calculations. ✓

3. Projected stocking from advanced reproduction: 220 x percent stocking (1) 60 = 132.
   Projected number of stump sprouts from Oak Overstory Tree Inventory = …………… 29.
   Total projected stocking …………………………………………………………………… = 161.

4a. If total is greater than 154, there is adequate regeneration potential. ✓

4b. If total is less than 154, supplemental natural or artificial oak reproduction is needed.

Figure 41.20. Advance reproduction inventory example.

8.3 Forest Health Guidelines - Forest Health Protection (FHP)

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
DEFOLIATING INSECTS			
Fall cankerworm – Alsophila pometaria Occasional outbreaks of repeated heavy defoliation in early spring may cause twig/branch dieback and mortality.	Oaks	Maintain healthy forests through proper forest management	https://fruit.webhosting.cals.wisc.edu/wp-content/uploads/sites/36/2011/06/Deciduous-Tree-Disorder-Cankerworms-1.pdf
Oak leafroller – Archips semiferanus The larva rolls one leaf and ties it with strands of silk to feed and rest within the rolled leaf. It is a spring defoliator.	Northern red, black, northern pin, scrub oaks	Maintain healthy forests through proper forest management	https://www.forestpests.org/acrobat/oakleaf.pdf https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5347803.pdf
Oak leaf tier (Oak leaf shredder) – Croesia semipurpurna The larva ties two or more leaves together with strands of silk to feed and rest between the leaves. It is a spring defoliator.	Oaks	Maintain healthy forests through proper forest management	https://www.forestpests.org/acrobat/oakleaf.pdf

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
Spongy moth – *Lymantria dispar* Feeding occurs from mid to late May through late June to early July. Widespread heavy defoliation occurs periodically at intervals of 5-15 years. Two or more years of heavy defoliation may stress trees to allow secondary pests, such as Armillaria root rot or two-lined chestnut borer to attack and kill trees. HAZARD ZONE: South of Eau Claire, Wausau, Marinette. HIGH RISK SITES: Upland, droughty sites with favored food trees in low-vigor, open-grown stands.	Oaks	ON HIGH RISK SITES: 1. Reduce oak and favored component to 25% or less. 2. Convert to unfavored type or non-timber type. 3. Accept risk of defoliation. ON LOW RISK SITES: 1. Maintain proper stocking levels. 2 Remove "wolf" trees. Monitor high-risk sites for rising populations. Spray rising populations to prevent outbreak. Allow population to rise and spray to protect foliage. Accept defoliation and monitor for decline	Spongy Moth (Lymantria dispar) | | Wisconsin DNR
Forest tent caterpillar – *Malacosoma disstria* Feeding occurs in May through early June. Widespread heavy defoliation occurs periodically at intervals of 5-15 years. An outbreak usually lasts 2-5 years.	Oaks	Maintain healthy forests through proper forest management During an outbreak, insecticide applications can be an option to minimize the damage on highly valuable stands.	Forest Tent Caterpillar | | Wisconsin DNR
Late season defoliators **Oak skeletonizer – *Bucculatrix ainsliella*** **Orange-striped oakworm – *Anisota senatoria*** **Red-humped oakworm – *Symmerista canicosta***	Oaks	Maintain healthy forests through proper forest management No chemical control is necessary	Oak skeletonizer https://www.forestpests.org/vd/105.html Orangestriped oakworm https://www.forestpests.org/vd/95.html

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
Variable oak leaf caterpillar – *Heterocampa manteo* Infrequent outbreaks of late summer defoliation seldom last more than one year. Normally late season defoliation does not damage trees significantly. However, complete defoliation may initiate branch dieback and decline of low-vigor trees, especially on droughty sites.			Variable oak leaf https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev2_043565.pdf Redhumped oakworm https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev2_043103.pdf
FOLIAGE DISEASES			
Anthracnose – ***Apiognomonia quercina (Gnomonia quercina)*** The fungus causes irregular dead blotches on the leaves. Heavily infected leaves prematurely fall, and cause growth reduction. Heavy infection may occur during wet cool spring.	Oaks	Direct control is impractical and usually unnecessary. Silvicultural measures to encourage air circulation may reduce infection.	https://hortnews.extension.iastate.edu/files/qa/files/howtorecognizecommondiseasesoaks.pdf
Tubakia leaf spot – *Tubakia dryina (Actinopelte dryina)* The fungus produces circular, reddish-brown spots on the leaves. Severely infected leaves fall prematurely. It occurs in late summer, and usually does not affect the health of trees significantly. However, recently, dieback and mortality of bur and white oaks, associated with	Oaks	Maintain healthy forests through proper forest management	https://hort.extension.wisc.edu/articles/tubakia-actinopelte-leaf-spot/

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
Tubakia leaf spot and other disease/insect factors, have been reported in Wisconsin (see Oak Decline below).			
Oak tatters – cause unknown It affects expanding new leaves in early spring. Affected leaves appear lacy or tattered. The causal agent is not determined, though frost, cold temperatures, and herbicides are among suspected.	Primarily the white oak group (bur, white, swamp white oaks) Red oaks are occasionally affected	Direct control is impractical and usually unnecessary.	https://hort.extension.wisc.edu/articles/tatters/
SCALE INSECTS			
Lecanium scale – *Parthenolecanium spp.* Adult females are circular to ovoid, and reddish to dark brown. This insect sucks plant juice, causing twig and branch dieback, and growth loss.	Oaks	Chemical control is impractical, and usually unnecessary.	Scale Insects of Trees and Shrubs. R. Wawrzynski and M. Ascerno. 1999. Univ. Minn. Ext. FO-01019. https://hort.extension.wisc.edu/articles/scale-insects/
Kermes scale – *Kermes spp.* Adult females are globular or gall-like, and yellow to light brown. This insect sucks plant juice, causing twig and branch dieback, and growth loss.	Oaks	Chemical control is impractical, and usually unnecessary.	https://extension.umn.edu/yard-and-garden-insects/scale-insects
CANKERS/CANKER ROT			
Nectria canker – *Nectria cinnabarina*	Oaks	Silvicultural control measures are based on percent of	https://hort.extension.wisc.edu/articles/nectria-

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
Trunk deformity and growth loss (all ages). Although it rarely causes mortality, a tree may break off at the point of canker.		infected trees in stand (see reference). Most infections occur when trees are 12-20 years old. Conduct improvement cut after age 20.	canker/#:~:text=Nectria%20canker%20is%20caused%20by,brown%20or%20black%20with%20age
Strumella canker – *Strumella coryneoieda (Urnula craterium)* Trunk deformity and growth loss (all ages). Although it rarely causes mortality, a tree may break off at the point of canker.	Oaks	Avoid wounding. Cankered trees should be considered for removal during thinning	https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev2_025759.pdf
Botryosphaeria twig dieback and canker – *Botryosphaeria quercuum* The fungus attacks tips of twigs and causes twig flagging. The disease may progress to a branch or to a stem and cause a branch dieback and tree decline.	Oaks	Since the fungus appears to attack stressed trees more often, maintain healthy forests through proper forest management	https://hortnews.extension.iastate.edu/files/qa/files/howtorecognizecommondiseasesoaks.pdf
WILT DISEASES			
Oak wilt – *Ceratocystis fagacearum* The fungus attacks trees' vascular system to induce plugging of the vessels. Leaves of an infected tree will wilt and prematurely fall and an entire tree may die. Once wilting symptoms become visible, a tree in the red oak group (northern red, northern pin, black,	Oak wilt symptoms progress much more quickly with trees in the red oak group compared to trees in the white oak group.	Avoid thinning, harvesting, or wounding oaks during critical time of oak wilt overland infection (for site-specific oak harvesting guidelines, refer to XXX). Cut root with a vibratory plow or trencher and remove trees of the same group within the root graft barrier.	Oak Wilt | | Wisconsin DNR

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
scrub oaks) dies within a month. The disease spreads through insect vectors (overland spread) or through connected root system (underground spread). Wilting occurs most often in July and August, and occasionally in spring or fall.		Consider conversion to alternate species if valuable species such as red or white pines are growing under oak.	
WOOD BORERS			
Two-lined chestnut borer – *Agrilus bilineatus* The larva feeds on nutrient and water conducting tissues beneath the bark and girdles and kills a branch or an entire tree. Dieback usually starts at the top and progresses downward. Trees may be killed within a year or in 2-3 years. This insect mainly attacks trees that are already stressed from defoliation, drought, or some other causes.	Oaks	Maintain healthy forests through proper forest management. Maintain well-stocked stands. Consider insecticide applications to reduce the damage from outbreaks of a defoliating insects	https://hort.extension.wisc.edu/articles/two-lined-chestnut-borer/
Other borers			
Red oak borer – *Enaphalodes rufulus* **White oak borer – *Goes tigrinus*** The young larva feed on phloem and sapwood, and the second-year larvae tunnel into heartwood.	Oaks	Maintain healthy forests through proper forest management.	Red Oak Borer. USDA FS FIDL 163. 1980. (https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev2_042855.pdf)

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
ROOT DISEASE			
Armillaria root disease (Shoestring root rot) – *Armillaria spp.* Stringy white rot. Dieback and mortality, especially during drought years or following 2 or more years of defoliation (all ages).	Oaks	Maintain stand in healthy condition. Harvest declining trees before mortality and decay take place.	https://widnr.widen.net/view/pdf/2tldne12ae/undefined
ABIOTIC and MECHANICAL DAMAGE			
Storm damage Limb and trunk breakage. Decay and discoloration through wounds.	Oaks	Add FHP Table for specific recommendations related to impact?	Storm Damage to Forests | | Wisconsin DNR
Cold injury Cold injury occurs when the winter temperature falls to approximately -35° F or colder. Species' sensitivity varies. Injury is typically manifested by patches of dead (brown and black) cambium. In spring, affected trees will have reduced bud break and may have epicormic sprouts.	Oaks	Monitor for dieback in upper and outer crown. If more than 50% of the crown dies, expect decline to continue to mortality.	Storm Damage to Forests | | Wisconsin DNR
Late spring frost damage This phenomenon is unpredictable and occurs when temperatures dip	Oaks	In frost pockets, expect injury to new expanding growth	Storm Damage to Forests | | Wisconsin DNR

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
below freezing during bud expansion, break and when foliage is just emerging. Foliage turns black and wilts. Twig dieback can occur. New lateral buds can break within 4 weeks after damage.		during years with late spring frost. Monitor for dieback in upper and outer crown. If more than 50% of crown dies, expect decline to continue to mortality.	
Drought Symptoms of drought include premature defoliation, thin crowns, subnormal leaf size and in severe cases, wilting foliage. If drought persists for more than one year, dieback of the upper and outer crown may occur.	Oaks	Monitor for dieback in upper and outer crown. If more than 50% of crown dies, expect decline to continue to mortality. Hardwoods take longer to recover from drought than conifers. Improvement in crown may not be noticeable for a year after normal precipitation returns.	Storm Damage to Forests | | Wisconsin DNR
Iron deficiency/chlorosis Interveinal yellowing of leaves of one branch or entire tree caused by inability of roots to take up iron because of high soil pH, soil disturbance, or root damage. Seriousness varies year to year. Some growth loss is common, and in extreme cases branch and tree mortality occur. Older trees are more susceptible.	Oaks, especially on northern pin oaks	Chemical control is impractical in forests, and usually unnecessary. In extreme cases, convert to a less susceptible type.	Chlorosis – Wisconsin Horticulture Storm Damage to Forests | | Wisconsin DNR

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
Logging damage Wounds. Limb and trunk breakage. Decay and discoloration through wounds.	Oaks	Careful felling/skidding, directional felling techniques, careful harvest plan layout. Limit harvest activities to times when soil is frozen or dry enough as to minimize soil compaction. See FHP Table 2 for specific recommendations related to impact.	
DECLINE			
Oak decline It is considered to be caused by a complex of environmental, insect and disease factors. Trees are stressed by frost, drought, insect defoliations, foliar diseases, etc., then later attacked by opportunistic pests, such as two-lined chestnut borers and/or Armillaria root rot.	Oaks	Maintain healthy forests through proper forest management. Monitor stands for possible salvage.	Oak decline. 1983 USDA FS FIDL 165 https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev2_043214.pdf

INVASIVE PLANT SPECIES	Conditions	Prevention, Mitigation Options	References*
Autumn olive – *Elaeagnus umbellate* A small shrub or tree introduced to the U.S. for landscaping and wildlife. Once established can be highly invasive and can disrupt native plant communities.	Disturbed areas, open woods and forest edges. Oak and red pine forests.	Young plants and seedlings can be pulled. Herbicide application with glyphosate or triclopyr via cut stump treatment is effective.	Autumn olive | (Elaeagnus umbellata) | Wisconsin DNR
Black locust – *Robinia pseudoacacia* A deciduous tree in the Legume family which was introduced extensively for soil erosion control. Dense stands can shade out native vegetation and is suspected of producing chemical compounds that prevent other plants from growing.	Forest, pastures, roadsides also found in canopy gaps of oak and red pine forests.	Cutting without herbicide application can result in sprout and spread. Basal bark application with triclopyr herbicide or cut stump treatment with glyphosate. When treating with herbicide, all stems must be treated.	Black locust | (Robinia pseudoacacia) | Wisconsin DNR
Burning bush – *Euonymus alatus* An ornamental deciduous shrub from Asia. Spreads by seeds and sprouts.	Forest edges, within oak, maple, and pine forests.	Cut stump treatment with Glyphosate or triclopyr herbicides can be effective. Avoid impacts to non-target vegetation.	Burning bush or winged euonymus | (Euonymus alatus) | Wisconsin DNR
Bush honeysuckles – (*Lonicera spp.*) Forms dense shrub thickets that outcompete and displace other flora. Seeds are spread by birds and in mud on equipment.	Oak forests and open lands.	Monitor to ensure early detection. Clean equipment before entering the forest. Small plants: eradicate by hand pulling Large shrubs: mechanically remove or cut and stem-treat. Foliar spray with glyphosate in spring, prior to native plants emergence. In high water table areas, use herbicides labeled for over water.	Tatarian honeysuckle | (Lonicera tatarica) | Wisconsin DNR Japanese honeysuckle | (Lonicera japonica) | Wisconsin DNR Morrow's honeysuckle | (Lonicera morrowii) | Wisconsin DNR Amur honeysuckle | (Lonicera maackii) | Wisconsin DNR

INVASIVE PLANT SPECIES	Conditions	Prevention, Mitigation Options	References*
Common buckthorn and smooth (glossy) buckthorn – (*Rhamnus cathartica* and *R. frangula*) Tall shrubs form dense thickets that outcompete and displace other flora. There is some evidence that they are also allelopathic. Seeds are spread by birds, and in mud on equipment.	Oak forests and open lands.	Monitor to ensure early detection. Clean equipment before entering the forest. Small plants: eradicate by hand pulling and prescribed burning. Large shrubs: mechanically remove, cut and stump-treat, or control with basal bark application. Restrict foliar sprays to fall months when buckthorn is actively growing but other species are dormant, to avoid impacts to non-target vegetation. Triclopyr may be more selective than glyphosate. In areas with high water tables, use herbicides labeled for use over water. Continued monitoring and follow-up are needed for several years after initial treatment.	Common buckthorn | (Rhamnus cathartica) | Wisconsin DNR Glossy buckthorn | (Frangula alnus) | Wisconsin DNR
Dames rocket – *Hesperis matronalis* Dame's rocket is a showy, short-lived perennial. Dame's rocket is planted as an ornamental, but quickly escaped\ cultivation because of its prolific seed production. Invasive success is attributed to wide distribution in "wildflower" seed mixes.	Forest edges, openings, cultivar escape. Found in oak and maple forests.	Plants can be pulled in the spring before going to seed. For larger infestations, use glyphosate foliar spray.	Dame's rocket | (Hesperis matronalis) | Wisconsin DNR
Field bindweed – *Convolvulus arvensis*	Oak forests.	Little is known about control in forests. Herbicide or hand-pulling on a regular basis (perhaps only	https://ipm.ucanr.edu/PMG/PESTNOTES/pn7462.html

INVASIVE PLANT SPECIES	Conditions	Prevention, Mitigation Options	References*
A Wisconsin state-listed "noxious weed" that can outcompete and displace other flora.		once per year), may be used where control is needed.	
Garlic mustard – *Alliaria petiolata* A major invasive plant that outcompetes herbaceous flora and tree seedlings. There is evidence of allelopathy to beneficial mycorrhizae. Small seeds spread easily on equipment and clothing, and on animal fur.	Oak forests. One of the few invasive understory plants to thrive in full shade.	Use preventative measures; clean equipment and clothing before entering the forest. Monitor to ensure early detection. Small infestations can be eradicated by hand pulling. Spray with glyphosate in spring or fall to kill basal rosette; avoid non-target species.	Garlic mustard | (Alliaria petiolata) | Wisconsin DNR
Japanese barberry – *Berberis thunbergii* Has potential to limit forest regeneration as it becomes more abundant. With a concerted effort, potential remains to suppress this species. It can outcompete and displace other flora. Its thorns make it difficult to work or recreate in an infested area.	Forests and semi-open areas, including oak forests. Tolerates full shade.	Mechanical removal in early spring is recommended for small infestations. Wear thick gloves. Glyphosate or triclopyr herbicides can be effective. Avoid impacts to non-target vegetation.	Japanese barberry | (Berberis thunbergii) | Wisconsin DNR
Japanese knotweed – *Polygonum cuspidatum* Outcompetes and displaces other flora. Early emergence, height, and density allow it to shade out other vegetation and limit tree regeneration. Not yet widespread in Wisconsin. Difficult to eradicate once established.	Oak forests, riparian forests, open lands with mesic or wet-mesic conditions.	Foliar treat late summer after flowering, do not cut unless necessary. Aminopyralid and Imazapyr are both effective herbicides. Continue monitoring as follow-up treatments are likely.	Japanese knotweed | (Fallopia japonica or Polygonum cuspidatum) | Wisconsin DNR

INVASIVE PLANT SPECIES	Conditions	Prevention, Mitigation Options	References*
Multiflora rose – *Rosa multiflora* Forming dense thickets that exclude other vegetation. Seed remains viable for up to 20 yrs. Spreads by stolons, shoots and seed.	Old fields, pastures and oak forests, full or partial sun.	Mowing and controlled burns. Cut stump and treat with glyphosate or basal bark spray stem with triclopyr.	Multiflora rose | (Rosa multiflora) | Wisconsin DNR
Oriental bittersweet – *Celastrus orbiculatus* A perennial vine that can climb and overtop trees. Reduces photosynthesis, causes breakage due to additional weight, increases susceptibility to wind and ice damage, and can girdle trees. Birds spread seeds. Closely resembles the native American bittersweet (C. scandens), with which it hybridizes; Oriental bittersweet has fruits originating from leaf axils, while American bittersweet fruits are borne at branch tips.	Oak and other forests.	Cut vine and pull up small infestations. Treat cut stem with triclopyr herbicide.	Oriental bittersweet, Asian bittersweet | (Celastrus orbiculatus, Celastrus loeseneri) | Wisconsin DNR
Siberian elm – *Ulmus pumila* This small to medium-sized tree has an open, round crown of slender, spreading branches. The fruits develop quickly and are disseminated by wind, allowing the species to form thickets of hundreds of seedlings in bare ground. Seeds germinate readily and seedlings grow rapidly.	Forest edge and within oak, maple and pine forests.	Young plants and seedlings can be pulled. Herbicide application with glyphosate or triclopyr via cut stump treatment is effective	Siberian elm | (Ulmus pumila) | Wisconsin DNR

Interfering Vegetation	Conditions	Prevention, Mitigation Options	References*
Pennsylvania sedge – *Carex* This native sedge can impact northern hardwood regeneration by forming impenetrable mats on the forest floor. Physical impedance is the mechanism by which damage occurs. Past management may have contributed to development of existing sedge mats; increases in size and density after opening the forest canopy have been observed.	Oak and mesic forests.	There is limited information on control. Herbicide, scarification, or tilling (particularly on roadbeds or landings) may be effective in some situations.	https://www.fs.usda.gov/database/feis/plants/graminoid/carpes/all.html

DEFECT	High Probability of Mortality or Failure (high risk)	High Probability[1] of Degrade due to Defect
Canker Localized area of dead bark and cambium; wood behind canker may or may not be decayed. Commonly caused by fungi. Fungal cankers are a source of spores that may infect healthy trees.	• Canker affects >50% of the stem's circumference or >40% of the stem's cross section. Common canker diseases on oak: Botryosphaeria canker (*Botryosphaeria quercuum*); Nectria canker (*Nectria cinnabarina*); Strumella canker (*Urnula craterium*) Strumella canker pathogen decays wood behind the cankers. • Horizontal crack on a canker face.	• Decay associated with large canker (affects >50% of stem's circumference). Fruit body visible in the canker's face. Extent of decay and discoloration will vary depending on organisms involved.
Wounds Any injury to tree that exposes the cambium or wood beneath cambium.		• >2 large (>5") branches broken close to the stem. • Codominant ripped from stem. • Fire scars affecting ≥ 20% of tree's circumference (red oak)
Decay Wood that is missing or structurally compromised. Canker rot fungi are not compartmentalized and will cause significant decay.	• Decay in main stem results in <1" of sound wood for every 6" in diameter; must have 2" of sound wood for every 6" dbh if there is also a cavity present. • Decay or cavity affects >40% of the stem's cross-section. • Tree infected with a canker-rot fungus (see next column).	• Tree infected with a canker-rot fungus including but not limited to: *Cerrena unicolor* *Phellinus everhartii* *Inonotus hispidus* *Spaniels' paydown (Ripe molly's)*

DEFECT	High Probability of Mortality or Failure (high risk)	High Probability[1] of Degrade due to Defect
Canker Localized area of dead bark and cambium; wood behind canker may or may not be decayed. Commonly caused by fungi. Fungal cankers are a source of spores that may infect healthy trees.	• Canker affects >50% of the stem's circumference or >40% of the stem's cross section. Common canker diseases on oak: Botryosphaeria canker (*Botryosphaeria quercuum*); Nectria canker (*Nectria cinnabarina*); Strumella canker (*Urnula craterium*) Strumella canker pathogen decays wood behind the cankers. • Horizontal crack on a canker face.	• Decay associated with large canker (affects >50% of stem's circumference). Fruit body visible in the canker's face. Extent of decay and discoloration will vary depending on organisms involved.
Cracks Open crack: A split through the bark, extending into the wood approximately 1 or more inches. Wood fibers are not fused. Stems or branches with open cracks cause the affected area to act as 2 or more separate beams, weakening mechanical support. Open cracks are more likely to be associated with decay and discoloration. Closed crack: A split through the bark that has fused back together.	• Open crack goes completely through a stem or is open for >4' (length). • Two open cracks occur on the same stem segment. • The stem has an open crack in contact with another defect such as decay, a canker, or weak union.	• >1 face with open or closed crack • open or closed spiral crack.

[1] There is a high probability that the defect will cause a significant reduction in value over a 15-year period; rate of decay/stain development varies by species. Defect may be limited to localized area.

DEFECT	High Probability of Mortality or Failure (high risk)	High Probability[1] of Degrade due to Defect
Galls Abnormal growths on stems and branches. Galls are typically sound but may cause degrade in a localized area around the gall.		• Galls on main stem (Phomopsis galls)
Weak Union Union with ingrown bark between stems; wood fibers are not fused. Weak unions are characterized by an acute angle between stems.	• Stump sprouts joined above ground in V-shaped union and associated with a crack, showing failure has already begun.	• Large (>8” diameter stems) tight union that is either cracked or decayed or associated with another defect. Could result in failure; stain/ decay will vary.
Structural Compromise Unusual form typically initiated by storm damage.	• Leaning tree with recent root lifting. • Leaning tree with a horizontal crack, long vertical crack, or buckling wood on the underside of the tree. • New leader formed in response to a dead or broken top. Risk increases as top gets larger and stem decays at break point.	
Root Defects Loss of structural support due to root rot, wounding, severing or any other factors that cause root mortality.	• More than 33% of roots severed, decayed or otherwise compromised. • Stump sprouts with a tight union where root structure is not sufficient to support stems.	• >3 root wounds within 4’ of the main stem; each wound encompasses >30% of root diameter.

DEFECT	High Probability of Mortality or Failure (high risk)	High Probability[1] of Degrade due to Defect
Crown Density/Dieback/Leaf Condition Crown symptoms are often showing a response to poor root health, stress such as defoliation or drought or infestation by cambium-mining beetles. Large dead branches/tops/codominants keep wound "open"; decay will advance more rapidly with an open wound. Failure of dead wood is unpredictable. Could cause damage upon failure.	• 50% of the crown dead unless loss of crown is due to stem breakage. • 75% of leaves subnormal in size or abnormal in color. (excluding iron chlorosis.) • Signs of cambium miners such as the two-lined chestnut borer.	• Multiple large (>5" diameter) dead branches, dead top or codominant (>10" diameter).

[1] There is a high probability that the defect will cause a significant reduction in value over a 15-year period; rate of decay/stain development varies by species. Defect may be limited to localized area.

Summary of principles related to discoloration and decay development

1. Wounding: the death of large branches, sprouts or codominants; and any activity that exposes the cambium to air and moisture initiate discoloration in trees with naturally white wood throughout.
2. After wounding, discoloration may be caused by bacteria, oxidation of phenolic compounds and degradation of the cells by fungi.
3. Discoloration and decay typically do not move throughout a tree as it ages but are compartmentalized and limited to tissue present at the time of wounding. Known exceptions to this include trees that are infected with canker-rot fungi.
4. Discoloration tends to form in vertical columns, tapered at the ends.
5. The further the wound or breakage is from the main stem, the lower the chance discoloration and decay will occur to the main stem.
6. Discoloration resulting from a broken top or split stem will progress downward and be limited to the diameter of the tree at the time of wounding. Rate of spread is variable; approximately 4 inches per year has been noted in sugar maple if wound is significant (> 40% of circumference).
7. Wounds initiated in the spring will form callus more quickly than wounds initiated in the fall but if the wounds are the same size, the discoloration resulting from both wounds will likely be similar after 3 years.
8. The presence of prior defects appears to influence the rate of formation (hasten) of additional discoloration from newer wounds.
9. Trees with lower starch content (i.e., defoliated) tend to be more negatively impacted by wounds, as there is a reduced rate of callus formation. Vigorous trees may slow or halt the discoloration/decay process more readily than trees of poor vigor.
10. Decay and discoloration are more likely and more extensive in wounds that remain open; decay and discoloration moves more slowly after wounds are closed.
11. Volume of discoloration and decay increases with increasing wound width; wound area is a good indicator of value loss.
12. Wounds are initiation points for cracks.
13. Factors such as site, genetic controls, wound type, frequency of wounding, host species and microorganisms present all potentially influence wound closure and in turn the rate and severity of discoloration and decay development.

Table 41.17. Summary of guidelines related to fire scars and decay development.

Issue	Species	Rule of Thumb
Wound size associated with fire scars	Black oak Northern red oak	Dormant season fire - Wound height = Height of bark scorch x 0.9; Wound width = Width of bark scorch x 0.6 Growing season fire - Wound height = Height of bark scorch x 1.2; Wound width = Width of bark scorch x 0.7
Wound size associated with fire scars	White oak	Dormant season fire - Wound height = Height of bark scorch x 0.7; Wound width = width of bark scorch x 0.6 Growing season fire - Wound height = Height of bark scorch x 1.0; Wound width = Width of bark scorch x 0.7
Decay associated with fire scars		Fire scars are common entries for decay fungi. Ten years after fire injury, decay may extend .5 – 1 foot above the top of the fire scar. Avg. rate of decay development = 1.25'/ decade.

Oaks (both red and white oaks) tend to decay at a slower rate with less discoloration with a same wound size/severity (see the diagram below).

Slower decay → **Faster decay**

Hickory, Sugar Maple, White, Red Oak — **Ash** — **Red Maple, Black Oak** — **White Birch, Basswood** — **Yellow Birch, Beech, Aspen**

Less discoloration (with same wound size/severity) → **More discoloration**

Hickory, Ash, Oak — **Basswood** — **White Birch** — **Sugar Maple** — **Red Maple, Yellow Birch**

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Chapter 43

Aspen Cover Type

Last Full Revision: 1/3/2019
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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Last Full Revision: 1/3/2019
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1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand Composition
Aspen comprises more than 50% of the basal area in sawtimber and poletimber stands or more than 50% of the stems in sapling and seedling stands. Principal species are bigtooth aspen (*Populus grandidentata*) and trembling aspen (*P. tremuloides*). Aspen will refer to both trembling and bigtooth in this chapter, unless otherwise noted. Balsam poplar (*P. balsamifera*) will also be discussed in this chapter.

Associated Species
Aspen grows with a variety of trees and shrubs over its extensive range, either as a dominant or an associate. Within the aspen cover type, the predominant associates in Wisconsin currently are (1996 FIA): red maple (*Acer rubrum*), paper birch (*Betula papyrifera*), balsam fir (*Abies balsamea*), red oak (*Quercus rubra*), and white pine (*Pinus strobus*). Most other major tree species occurring in Wisconsin can be found as occasional associates in aspen stands.

In Wisconsin, balsam poplar is found mainly in mixed stands where other species dominate.

1.2 Silvical Characteristics[1]

Trembling aspen is a medium-sized, fast-growing, short-lived tree. Typically, mature trees are 66-82 feet tall and average 6-12 inches dbh. On mesic and dry-mesic sites, trembling aspen may attain 120 feet and 22 inches dbh. Stands often begin to deteriorate near age 55-60 years. Growth continues in older stands but loss from decay and rot increase rapidly. Single clones typically occupy one-tenth to one-fifth acre, occasionally up to four acres.

Bigtooth aspen is a medium-sized, fast-growing, short-lived tree. Typically, mature trees are 60-80 feet tall and average 8-16 inches dbh. On the best sites, bigtooth aspen can reach 120 feet and 30 inches dbh. Height growth is rapid for the first 20-30 years and slows markedly thereafter. Stands often begin to deteriorate at age 40-45 years on wet-mesic to wet and very dry to dry sites and at age 50-70 years on more productive sites. Individual trees more than 100 years old have been found. Bigtooth aspen appears to be more resistant to disease than trembling aspen.

Balsam poplar is a medium to large, fast-growing, short-lived tree. Typically, mature trees are 75-100 feet tall and average 14-28 inches dbh. In Wisconsin, on mesic to wet-mesic sites, balsam poplar can reach 80 feet and 20 inches dbh. Stands can persist for up to 100 years.

Aspen is a “pioneer” tree species generally growing in even-aged stands regenerated following a major disturbance. Aspen often outgrows other associated species and can form nearly pure stands. Two-aged stands are the result of suckering after partial cutting or partial loss from natural disturbance events like wind or fire. In undisturbed stands, more tolerant associates will replace aspen through natural succession.

[1] Information compiled mostly from Fowells (1965), Burns and Honkala (1990), Perala (1977,1984), and Peterson (1992)

All three species are intolerant of shade, suffer stem mortality after fire, and are sensitive to mechanical injury to the root system and soil compaction. This is important when implementing aspen thinning and harvesting. Aspen is a vulnerable species because of its thin bark and is susceptible to many biotic and abiotic agents causing mild to moderate damage. There are only a few diseases that seriously damage or kill aspen trees (Ostry, 1982).

Aspen is well adapted to regenerating after fire via suckering and seeding. Thin bark predisposes aspen to mortality from fire. Root sucker response to the top kill of stems can enable aspen to assert dominance following catastrophic fire, even when it was merely an associate previous to stand disturbance. Aspen is a prolific seed producer, and its wind-disseminated seed can travel many miles. Catastrophic fires can create an ideal mineral seedbed for the germination of seed and early growth of seedlings, facilitating the colonization of sites by aspen.

After an aspen stand is disturbed by harvest, windthrow, or fire, root suckers generally sprout. Typically 10,000 to 30,000 suckers per acre are regenerated after a simple coppice regeneration harvest. Most suckers develop the first growing season following harvest and stand density gradually declines in succeeding years. Suckering is controlled both by growth regulating compounds (auxins/hormones), and by soil conditions (temperature and aeration). Aspen will not sucker when root temperatures are maintained below 55° F or when soils are saturated (Bates et al. 1990).

The time of year cutting is conducted affects the number of suckers and their vigor. Harvesting aspen stands during the dormant season generally produces the most abundant and vigorous sucker crops, while summer harvests generally produce less abundant and vigorous crops. The number of suckers produced is also related to the degree of cutting, with the greatest number occurring after cutting of all trees. Young suckers cut or destroyed by browsing for three successive years usually will not resprout. As far as is known, the aspen type can be maintained indefinitely by simple coppice. The presence of viruses in some clones may gradually deteriorate some stands.

Aspen responds to intensive management. In one study, production of thinned stands for a 50-year rotation, including thinnings removed at ages 10, 20, and 30, was about 57 cords/acre (1.14 cords/acre/year). This was about 42% greater than for similar unthinned stands.

Aspen produces abundant viable seed, but the seed typically remains viable for less than one week. Germination and initial growth require moist bare mineral soil. The major deterrents for managing reproduction by seed are the short duration of seed viability and the ease of coppice regeneration.

Balsam poplar regenerates by seed, stump sprouts, root suckers, and buried branches. Balsam poplar seeds are well adapted to flood plain conditions as the seeds disperse easily by water and require moisture to germinate. Germination can occur under water, and even mild water deficits reduce germination. Most balsam poplar seeds die within several weeks of dispersal, but some remain viable for 4-5 weeks.

Table 43.1. Summary of selected silvical characteristics.

	TREMBLING OR BIGTOOTH ASPEN	BALSAM POPLAR
Flowers	Dioecious, but some trees bear perfect flowers. Flowers emerge early in the growing season before leaves (March-April depending on location).	Dioecious. Flowers emerge early in the growing season before leaves (April-June depending on location).
Fruit Ripens	May and June (4-6 weeks after flowering, and before the leaves are fully expanded). Capsule with many small brown seeds, each surrounded by tufts of long, white silky hair.	May and June. Each small seed is attached to a tuft of long, silky hair.
Seed Dispersal	Wind and water for both species. 2.5-3 million seeds per pound. Transported many miles.	Wind and water. Relatively warm, dry weather causes rapid dispersal.
Good Seed Years	Every 4 or 5 years with light crops in most intervening years.	Every year.
Seed Bearing Age	Trembling: Significant production begins between age 10 and 20. Bigtooth: 20 years for vigorous trees	8-10 years with large seed production every year.
Seed Viability	High viability but short duration (typically 3-4 days or as long as 2-4 weeks). When stored properly, 97% germination after one year may be attained.	Seeds can remain viable for 4-5 weeks. Viability is dependent on temperature and moisture; cooler, drier conditions prolong viability.
Germination	No dormancy. Germination occurs in 1-2 days if seed lands on moist soil and temperature ranges between 32–95° F. Germination can occur in water.	No dormancy. Germination occurs between 41-95° F. if moisture is adequate. Germination can occur under water. Even moderate moisture deficits reduce germination.
Seedling Development	Primary root develops slowly during first few days. Bare soil required; young seedlings roots are unable to penetrate deep or dry leaf litter. Initial root hairs are delicate and need a moist soil surface. After primary root develops, seedlings remain highly susceptible to heat, drought, and fungi. In the first year, seedlings will grow 12 inches in height and will develop 8-10 inch taproots. Lateral roots develop in the second-to-third year.	Moist mineral soil surfaces are optimal seedbeds. Seeds germinate on moist organic seedbeds, but seedling survival is poor. Development depends on photosynthesis soon after germination.

Vegetative Reproduction	Vigorous root suckers from lateral roots 3-4 inches below the soil, root collar sprouts less vigorous, and stump sprouts least vigorous. Warm temperature (opt. 74° F.) stimulates sucker formation, while light is necessary for continued vigorous development. Time of harvest influences number of suckers, summer often produces fewer stems. Suckering usually ceases if suckers are destroyed for 3 successive years.	Balsam poplar reproduces vegetatively via branches, root and stump sprouts. On wet sites reproduction is greatest from buried branches sprouting root systems. Summer harvests result in less reproduction. Stump sprouts are generally short lived.
	CHARACTERISTICS ACROSS COVER TYPE	
Growth	Growth is rapid for the first 20-30 years, then slows. Dominant suckers may grow 4-6 feet in height the first year; seedlings in contrast may grow only 6-24 inches. High mortality typical with rapid natural thinning. First accelerated mortality occurs at age 5.	
Shade Tolerance	Intolerant; aggressive pioneer species; pronounced ability to express dominance.	
Diseases	Hypoxylon canker (*Entoleuca mammata*) is one of the most serious diseases affecting aspen by girdling and killing the tree or causing stem breakage. Well-stocked stands are less susceptible than poorly stocked stands. Bigtooth aspen is attacked less frequently. Consider harvesting infected, poorly stocked stands early to improve stocking through root sucker formation. Site treatment under advisement of the forest pathologist is recommended to encourage good regeneration. White Trunk Rot (*Phellinus tremulae)* causes more volume loss in aspen than any other disease. Primarily a problem in stands approaching maturity. Harvest stands damaged by fire or weather early. Maintain well-stocked stands to minimize infection sites.	
Insects	Forest tent caterpillar (*Malacosoma disstria Hubner*) and large aspen tortrix (*Choristoneura conflictana*) are defoliators which reduce aspen diameter growth if defoliation occurs for several successive years. No actual mortality is attributed to these defoliations, but attacks weaken trees making them susceptible to secondary insect and disease problems. Spongy moth (*Lymantria dispar*) (formerly called Gypsy moth) a severe hardwood defoliator, is responsible for attacking over a million acres of forestland in the eastern US since 1980. Repeated defoliation increases susceptibility to secondary attacks.	
Herbivory	Beaver, snowshoe hare, and other bark-eating mammals can impact aspen stands on a local level. Deer browse new shoots and rub antlers on stems.	

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

Management objectives should be identified in accordance with landowner goals within an ecosystem management framework, which gives consideration to a variety of goals and objectives within the local and regional landscape. The silvicultural system described below is designed to promote the optimum vigor of aspen stands. Pulpwood production is the objective for most sites; however sawlog production can be considered on productive sites (dry-mesic to wet-mesic). This silvicultural system may be modified to satisfy other management objectives, but aspen vigor and growth potential may be reduced. The habitat type is the preferred indicator of site potential.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.1 Landscape Considerations

The aspen forest type provides significant social and ecological benefits, but there are also concerns about effects at landscape and regional scales. Considerations are related to the total amount of aspen and its spatial distribution, which can benefit some species while negatively affecting others.

3.1.1 Historical Context

When the General Land Office surveys were conducted in Wisconsin (1832-1866), forests dominated by aspen or aspen-white pine occupied about 3.5 to 4.3 percent (approximately 680 to 835 thousand acres) of the area within Province 212 in northern Wisconsin according to data interpretations by Schulte et al. (2001). Fire disturbance was a historic factor in development of aspen forests, and native Americans were undoubtedly instrumental in setting some of the fires that led to aspen regeneration. Fire frequency was significantly greater in sandy outwash areas than in the loamy moraines (Mladenoff 2000). Aspen forests typically developed where fire regimes were moderate, such as in transitional areas between outwash and moraines, or where till materials are intermingled with outwash sands. Fire disturbance regenerated aspen clones and exposed mineral soils for seed germination. Aspen that developed after fire would have had a patchy distribution, often as a component of mixed stands. Some aspen clones would have been perpetuated in very young or sparsely forested conditions, leading to more variable aspen densities and age classes than are typically found in coppice-regenerated stands.

After the Cutover, very hot slash fires occurred extensively over northern Wisconsin. The repeated fires eliminated seedlings of many tree species, at the same time as harvesting reduced seed sources. Aspen, because of its abundant wind-dispersed seed, was able to invade large areas (Mladenoff 2000). FIA records show that aspen-birch reached a historic maximum of about 5.3 million acres in the 1930’s; net acreage has decreased since then through natural succession to other cover types. In 1996, the aspen-birch forest type group occupied about 16 percent (approximately 3 million acres) of land area in northern Wisconsin (Province 212) (Schmidt 1998). Although the proportion of aspen-birch forest has declined since the 1930’s, it still occupies a much larger area than it did 100-150 years ago.

3.1.2 Current Context

Age-Class Distribution

Maintaining a desirable aspen age-class distribution is a landscape-level consideration. A relatively stable age class structure in aspen maximizes its benefits to wildlife by providing a full range of age and structural conditions. Economic interests that depend on aspen products prefer to have an even flow in supply. Because aspen regenerated all over Wisconsin at about the same time after the Cutover, there were dramatic peaks and valleys in the supply of mature aspen for many years. These fluctuations appear to have diminished at a statewide level, based on comparisons of age-class distributions from 1983 and 1996 (Schmidt 1998, Spencer et al. 1988), but maintaining the distribution requires management attention. The following chart shows that aspen in the 0-20 age class decreased by 9.6% in 1996 as compared with 1983, but the greatest decrease was in the 41-60 age class. Age classes 61 years and older have the same distribution in both inventory cycles.

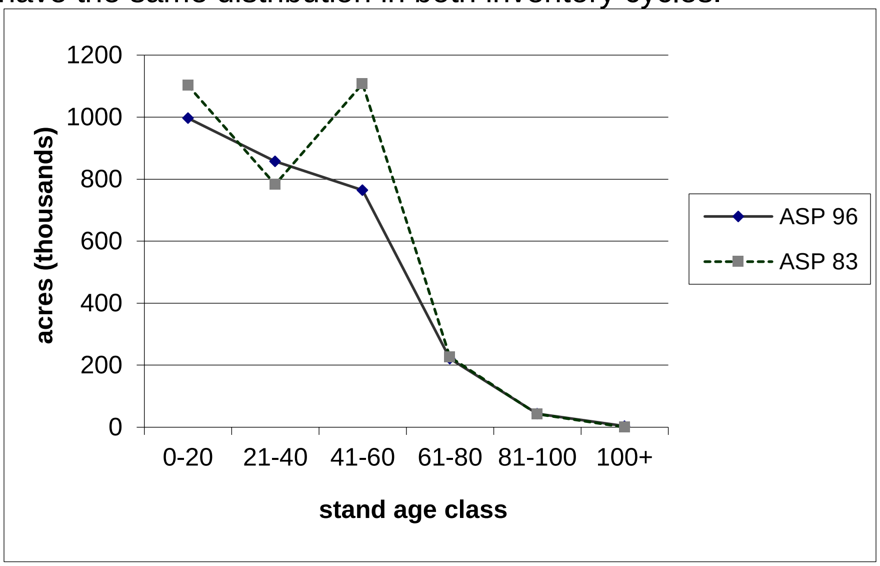


Figure 43.1. Aspen age-class distribution in 1983 and 1996.

3.1.4 Summary of Landscape Considerations

When deciding whether to regenerate an aspen stand or convert another forest type to aspen, assuming the habitat type is suitable, consider the following factors:

- What are the characteristics of the broader-scaled ecological unit (LTA or Subsection) around the stand?
- Is the ecological unit in northern or southern Wisconsin? In some parts of southern Wisconsin, permanent fragmentation from agricultural, residential, and urban land uses is so prevalent that habitat fragmentation due to aspen conversion is a minimal effect. However, if managing a relatively large forest patch in southern Wisconsin, fragmentation and edge considerations regarding NTMBs still apply.
- Is the ecological unit already fragmented by either habitat or permanent fragmentation or by “natural fragmentation” (a heterogeneous landscape that contains a wide variety of Habitat Types, wetlands, and/or water bodies)?

- Consider the dominant natural disturbance in the surrounding LTA. If fire, consider managing for a large patch of aspen. If wind, consider regenerating aspen as a component of a northern hardwood forest, emulating the small sized patches characteristic of gap disturbance.
- Aggregating individual cuts will reduce the amount of edge.
- Are there NTMBs of concern in the surrounding LTA, which ones are they, and how will the proposed management affect them?
- Is the area around the stand a large patch of northern hardwood forest? Large forest patches with older age-class structure are scarce, and managing for interior NTMBs may be an important consideration.
- What are the local and regional issues surrounding deer density (e.g. car-deer collisions, hunting opportunities, local economy)? Are there issues with herbivory in the surrounding LTA (e.g. lack of regeneration of hemlock, yellow birch, cedar, or Canada yew; excessive browsing of lilies and orchids)?
- What is the age class distribution of aspen in the broader-scaled ecological unit?
- Aspen can attract deer into a local area. If cedar, hemlock, yellow birch, or Canada yew is present, it may not be advisable to manage aspen in the same area because of the potential impact on these declining species. If the deer herd were predicted to be dramatically lower for at least a ten-year period, foresters may wish to consider cedar and hemlock regeneration.

3.2 Site and Stand Considerations

3.2.1 Soils

The aspen type occurs on a wide range of soil conditions, from sand to clay and from dry to wet. Best growth is demonstrated on dry-mesic and mesic sites with well-drained loamy soils, but growth potential is good for all sites, except dry, excessively drained sands, poorly drained wet sites, and heavy clays. Although both species can be found across the full range of site conditions, bigtooth aspen occurs predominantly on very dry to dry-mesic sites, whereas trembling aspen occurs predominantly on dry-mesic to wet sites. Balsam poplar generally occurs on wet sites, such as river floodplains, stream and lake shores, moist depressions, and swamps, but will also grow on drier sites.

Potential impacts on long-term productivity is a consideration when maintaining aspen through multiple regeneration and harvest cycles on the same site. Management activities that remove organic matter have been associated with declines in site productivity. Concern has been expressed regarding potential nutrient losses from repeated aspen coppice harvests. Effects of multiple long-term coppice harvests on site productivity are unknown. Nutrient replacement following a typical harvest at full rotation age is relatively quick (less than 20 years for N, P, K, Mg and Ca) (Gordon, 1981).

- In one study, whole tree harvesting had no significant effect on soil nutrition levels 5 years after logging (Alban and Perala 1990).
- In another study on aspen productivity (Stone et al. 1999, Stone and Elioff 2000, Stone 2001), total tree harvesting of aspen on clay and loam soils had no negative effects on 5

year growth and productivity. In contrast, total tree harvesting on sand soils was associated with reduced 5 year aspen growth and productivity. Results indicate potential declines in aspen productivity with repeated total tree harvesting on sands. Retention of organic matter appears to be an important consideration to sustain long-term productivity of aspen stands on sand soils. Limbing at the stump and retaining logging slash on site is recommended to decrease nutrient removal on sandy sites.

Management activities that compact soil have been associated with declines in site productivity.

- In studies on aspen productivity (Stone et al. 1999, Stone and Elioff 2000, Stone 2001), compaction treatments that increased soil bulk density by 15% and 30% had no consistent negative effects on 5-year aspen growth and productivity. In further operational studies, excessive compaction at landings and rutting by careless logging operations significantly reduced sucker density and growth on fine textured soils.
- The physical effects of soil compaction, increased bulk density and decreased soil porosity, are long-term.
- Snow cover does not protect soils from compaction and rutting; frozen soil conditions do. Recommendations to protect soils from excessive compaction and rutting when logging in deep snow include: 1) plow and pack snow on skid trails and allow to freeze before use, and/or 2) delay skidding for 1-4 weeks following felling.

On wet to wet-mesic soils (poorly drained and somewhat poorly drained), removing only commercial wood (retain some hardwoods and conifers) can result in less rutting and compaction. Harvesting on these sites on frozen or dry ground will minimize rutting. Rutting can impede water flow and alter existing drainage. Also, reserve trees can help avoid significant water table rises.

3.2.2 Site Quality

3.2.2.1 Range of Habitat Types

The aspen cover type has the potential to develop on all upland habitat type groups and most habitat types in Wisconsin, but actual distribution and potential productivity are variable. Although bigtooth and trembling aspen are similar, there are individual differences in distribution and productivity across site types.

Aspen Cover Type

Acreage Distribution: The aspen cover type occupies approximately 18% of Wisconsin forest land acreage as estimated by the 1996 Wisconsin Forest Inventory and Analysis (FIA).

a. Northern Habitat Type Groups: About 87% of the total statewide aspen acreage occurs associated with the northern habitat type groups. These groups are:

N. Very Dry to Dry (VD-D)	N. Dry to Dry-mesic (D-DM)	N. Dry-mesic (DM)
N. Mesic (M)	N. Mesic to Wet-mesic (M-WM)	N. Wet-mesic to Wet (WM-W)

The aspen cover type occurs on all northern groups, with its greatest acreage on M-WM, and the least acreage on WM-W (Figure 43.3).

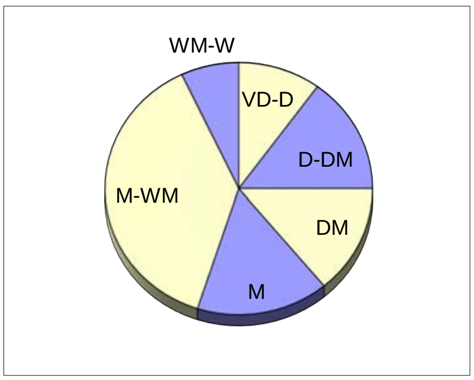


Figure 43.2. Aspen cover type acreage by habitat type group, as a percent of total aspen acreage in northern Wisconsin.

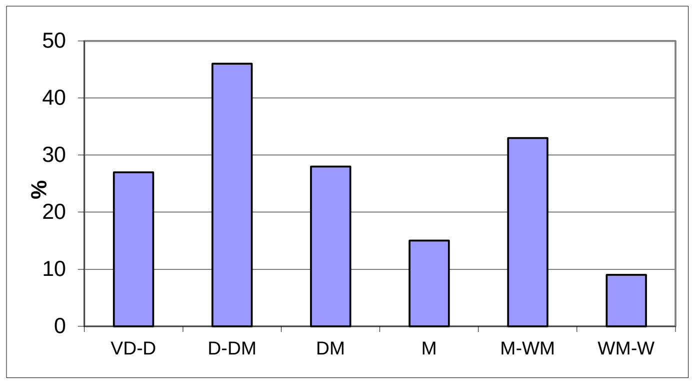


Figure 43.3. Aspen cover type acreage as a percent of total forest land acreage within each northern habitat type group.

Within habitat type groups, the aspen cover type is of common occurrence (>10% of total group acreage) on all the northern habitat type groups except WM-W. It is most common within the D-DM group where it occurs on approximately 46% of all D-DM habitat type acres (Figure 43.2). The aspen type is common on most northern habitat types, with the notable exception of the driest, most nutrient poor habitat types, and some mesic, nutrient rich types.

b. Southern Habitat Type Groups: The other 13% of statewide aspen cover type acres occur on southern habitat types, which are grouped as:

S. Dry (D)	S. Dry-mesic	S. Dry-mesic to Mesic	S. Dry-mesic to Mesic
S. Mesic (M)	S. Mesic Phase [M(P)]	S. Mesic to Wet-mesic (M-WM)	S. Wet-mesic to Wet (WM-W).

The aspen cover type occurs on most southern habitat type groups. However, over one-half of all the aspen acres associated with the southern groups occur on Dry sites (centered in the Central Sands region). Other southern habitat type groups with notable aspen type acreages are DM and M (X).

Within the individual southern habitat type groups, aspen stands are of common occurrence (>10% of total group acreage) only on the D group; elsewhere the cover type is of minor occurrence (Figure 43.5). The southern habitat types with major aspen acreage are PVRh, PVHa, PVGy, PVG, ArCi-Ph, and ATiSa-De.

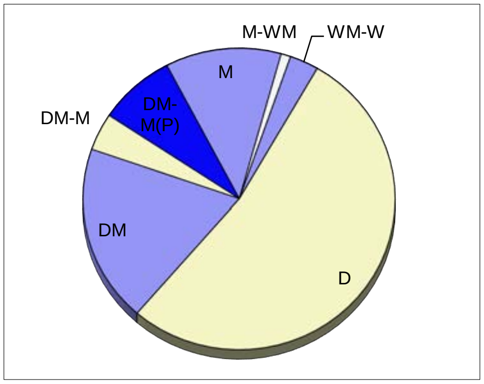


Figure 43.4. Aspen cover type acreage by habitat type group, as a percent of total aspen acreage in southern Wisconsin.

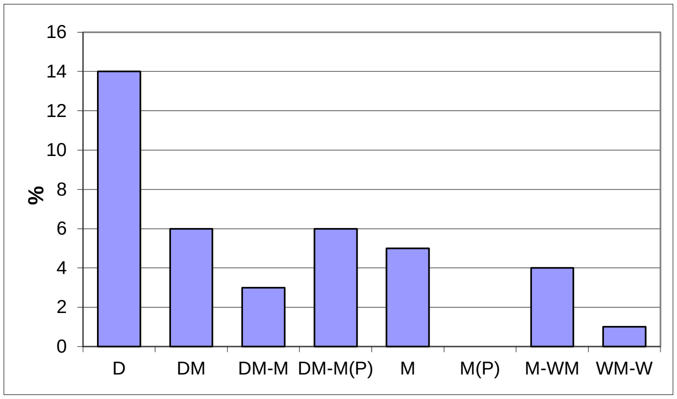


Figure 43.5. Aspen cover type acreage as a percent of total forest land acreage <u>within</u> each southern habitat type group.

Volume Per Acre: Potential stand growth and volumetric productivity of the aspen cover type vary across habitat type groups and habitat types. Figure 43.6 shows the aspen type's average standing volume per acre for selected habitat type groups (1996 FIA). Highest average standing volumes are associated with northern M, DM, D-DM, and southern DM habitat type groups. Although the northern WM-W group supports the greatest aspen type acreage, these stands are maintaining lower average volumes. The lowest volumes are associated with the driest and wettest sites.

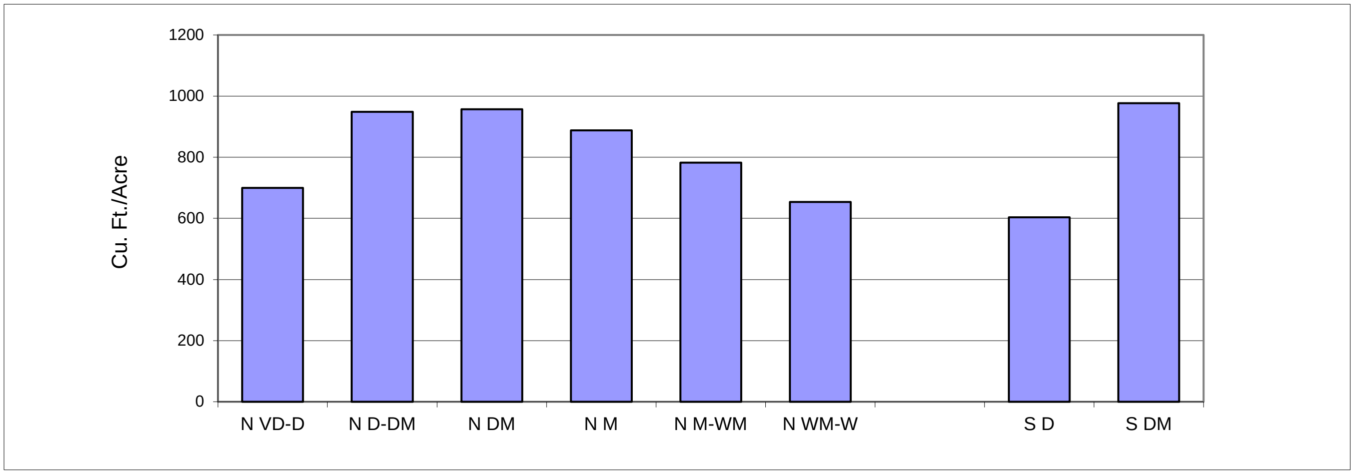


Figure 43.6. Aspen cover type average growing-stock volume per acre (cubic feet per acre) on forest land by each habitat type group

Associated Species: Within the aspen cover type in northern Wisconsin, red maple is the predominant associate (based on the percent of total number of trees greater than 5" dbh). It is an important associate within all habitat type groups, but is particularly abundant within the D-DM, DM, and M-WM habitat type groups. Balsam fir is a major associate on WM-W, M-WM, and to some extent on M sites. White birch is an abundant associate on D-DM, DM, and to some extent on M sites. Sugar maple is a somewhat abundant associate only on M sites. Within the VD-D habitat type group, red oak is the most abundant associate in aspen stands. In terms of regeneration and natural succession potentials, red maple and balsam fir are the most common and abundant saplings occurring in aspen stands. Sugar maple saplings are predominant only on mesic sites.

<u>Aspen Species</u>

Volume Distribution: The 1996 FIA estimates the two aspen species combined account for approximately 13% of the net growing-stock volume on forest land in Wisconsin. Trembling aspen accounts for 9% and bigtooth aspen for 4%.

a. Northern Habitat Type Groups: About 88% of trembling aspen volume occurs on northern habitat type groups. This species occurs on all northern groups, with the most volume on M-WM, and the least on VD-D (Figure 43.7).

About 61% of bigtooth aspen volume occurs on northern habitat type groups. This species occurs on all northern groups, with the most volume on DM, and the least on WM-W (Figure 43.8).

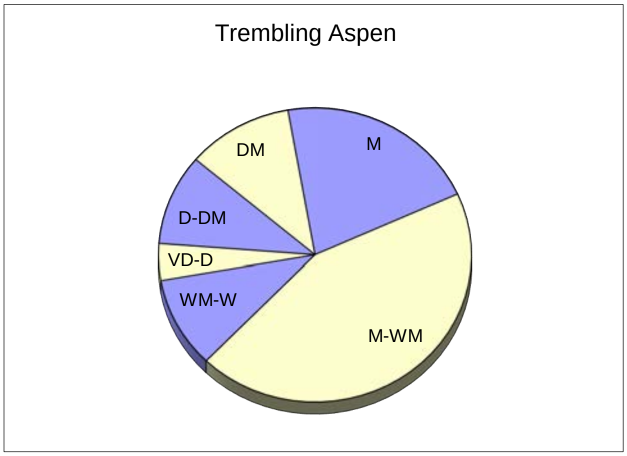


Figure 43.7. Representation of trembling aspen across the northern habitat type groups, as a percent of the total volume of trembling aspen in northern Wisconsin.

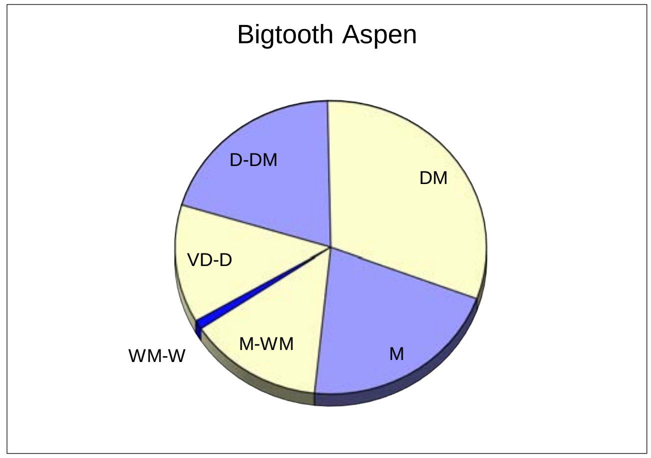


Figure 43.8. Representation of bigtooth aspen across the northern habitat type groups, as a percent of the total volume of bigtooth aspen in northern Wisconsin.

Within the northern habitat type groups, the aspen species combined are common (>10% of total group volume) on all groups except WM-W. Aspen accounts for nearly 25% of total group volume on D-DM and M-WM groups, but only 8% on the WM-W group. Trembling aspen represents significantly larger proportions of total group volume than does bigtooth aspen on the WM-W, M-WM, and M groups. Both species are fairly similar in volume representation on DM, D-DM, and VD-D northern habitat type groups (Figure 43.9).

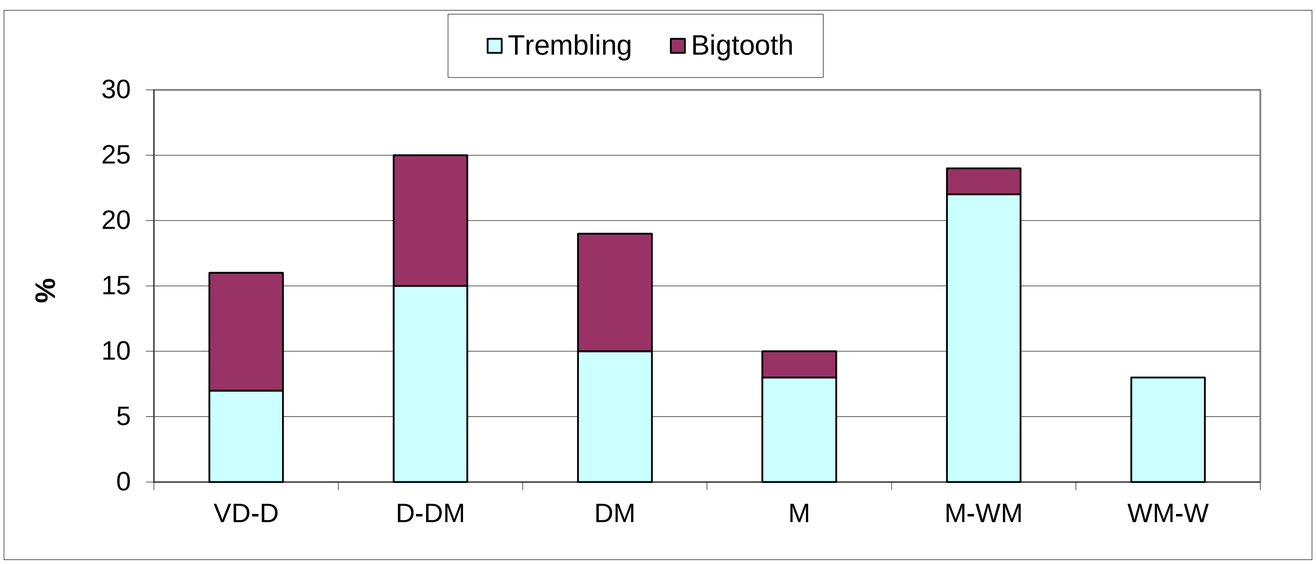


Figure 43.9. Trembling and bigtooth aspen individual and combined volumes as a percent of total net growing-stock volume on forest land within each northern habitat type group.

b. Southern Habitat Type Groups: About 12% of trembling aspen volume occurs on southern habitat type groups. This species occurs on all southern groups, with the most volume on D, and the least on M (P) (Figure 43.10).

About 39% of bigtooth aspen volume occurs on southern habitat type groups. This species occurs on all southern groups, with the most volume on DM, and only minuscule volumes on M (P), M-WM, and WM-W (Figure 43.11).

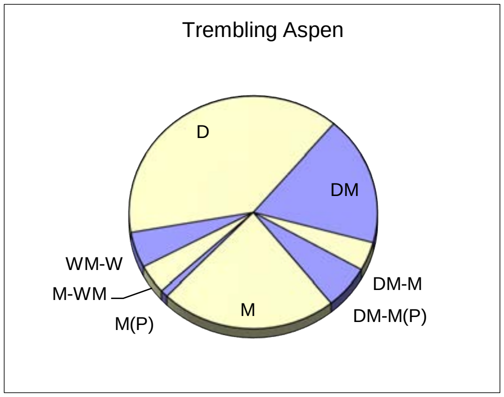


Figure 43.10. Representation of trembling aspen across the southern habitat type groups, as a percent of the total volume of trembling aspen in southern Wisconsin.

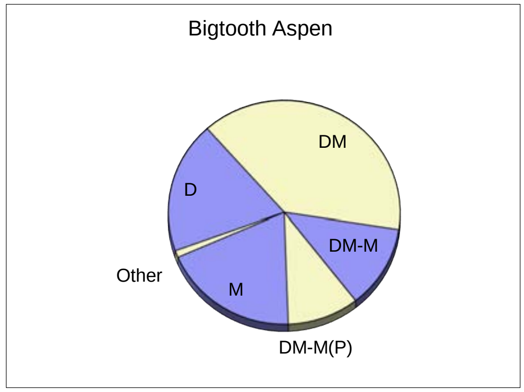


Figure 43.11. Representation of bigtooth aspen across the southern habitat type groups, as a percent of the total volume of bigtooth aspen in southern Wisconsin.

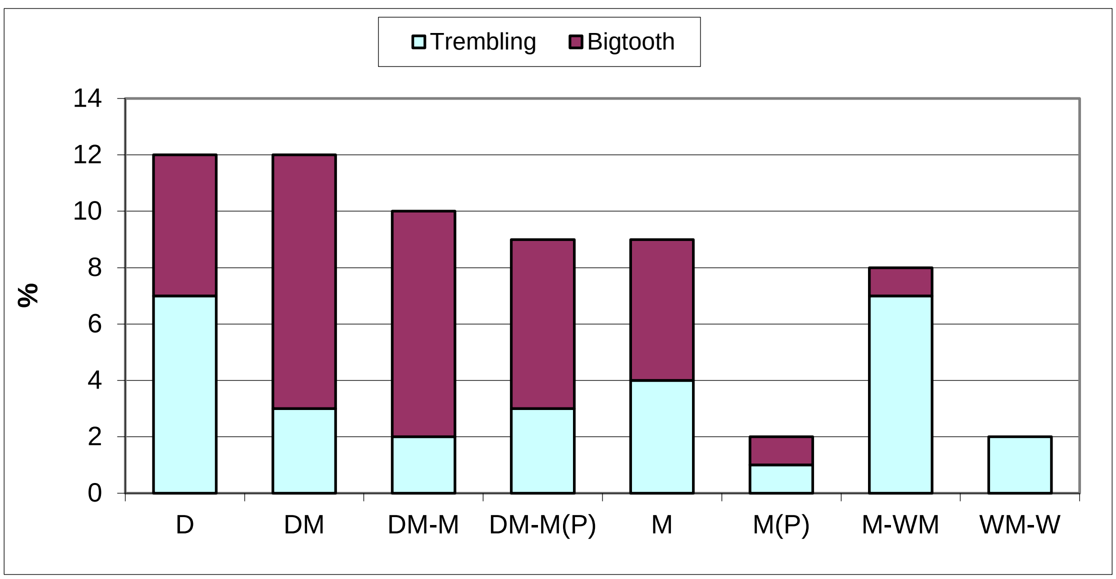
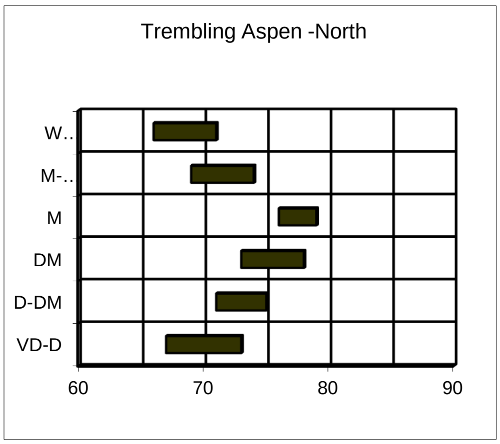


Figure 43.12. Trembling and bigtooth aspen individual and combined volumes as a percent of total net growing-stock volume on forest land within each southern habitat type group.

Within the southern habitat type groups, the aspen species combined are common (>10% of total group volume) only on the D and DM groups. Within each of these two groups, aspen accounts for about 12% of total group volume. In contrast, aspen accounts for only 2% of group volume on the M (P) and WM-W groups. Trembling aspen represents significantly larger proportions of total group volume than bigtooth aspen on the WM-W and M-WM groups. Both species are fairly similar in volume representation on M(P), M, and D groups. Bigtooth aspen represents significantly larger proportions of total group volume than trembling aspen on the DM, DM-M, and DM-M (P) southern habitat type groups (Figure 43.12).

Site Index: Average site index for trembling and bigtooth aspen varies across northern habitat type groups (Figure 43.13). Site index ranges within groups and patterns across groups are similar for both species. In general, average site index increases from very dry to mesic, then decreases from mesic to wet.



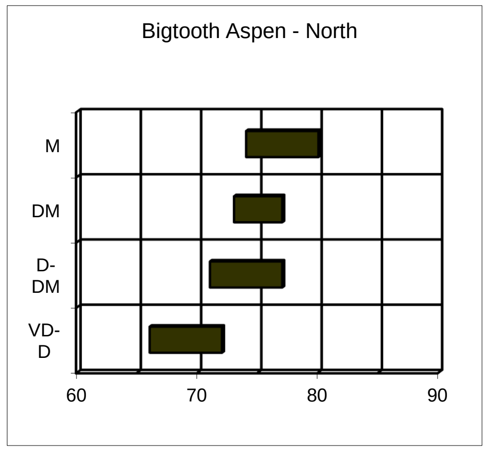


Figure 43.13. Site index for trembling and bigtooth aspen for northern habitat type groups. Bars indicate the 95% confidence limits for the mean. Non-overlapping bars indicate significant differences.

Data for southern habitat type groups are limited, but site index trends probably are similar to northern groups.

Potential Productivity: Using information on average aspen (cover type) volume per acre, with species average site indices and per tree volumes across northern habitat type groups, it is possible to estimate relative potential productivity.

In general, for northern habitat type groups and for both aspen species, relative growth potentials are:
very good: M
good to very good: DM
good: D-DM and M-WM
moderate to poor: VD-D and WM-W
Data for southern habitat type groups are limited, but growth potential trends probably are similar to northern groups.

Balsam Poplar Cover Type

The balsam poplar cover type occupies only approximately 0.2% of Wisconsin forest land acreage (1996 FIA). Most of this acreage is distributed among two northern habitat type groups: WM-W and M-WM (about one-half of this M-WM balsam poplar occurs on the Superior Clay Plain).

3.2.5 Wildlife

Aspen forests are critical to abundant populations of ruffed grouse, American woodcock, and beaver and important to many other species of Wisconsin wildlife. White-tailed deer and elk populations in northern Wisconsin use aspen for cover and forage. Wolves, fishers, goshawks, and other northern predators dependent on prey species, benefit from aspen forests. Black bear, snowshoe hares, and many songbirds use aspen. Some songbirds dependent on early-successional forests have experienced significant population declines both range-wide and in Wisconsin. Aspen forests in the Great Lakes region show evidence of being important for some species on a continental scale. For example, some early-successional breeding birds, such as golden-winged warbler, chestnut-sided warblers, and American woodcock, were identified by Howe et al. (1992) as being core/source species in northern Wisconsin. The group of species so identified has the core of their range centered on forests of the northern Lake States and/or provides a surplus of young, which may be important in maintaining populations elsewhere.

Aspen is used for cover and food from the seedling/sapling stage to the old-growth stage. Because of the short lifespan of aspen, examples of all life stages are present in Wisconsin and management for wildlife benefits from each stage is possible. Aspen bark, twigs, buds, and leaves are used by many herbivores in the northern forest. The decay characteristics of aspen make it particularly suitable for primary and secondary cavity nesting species of wildlife. The light-admitting canopy tends to allow development of understory plants and a diverse shrub layer. This expands the utility of an aspen stand to a large variety of wildlife.

Forty-seven species of Wisconsin birds use pioneer deciduous forests for breeding habitat (Robbins, 1990). Additionally, many species, which Robbins lists as preferring shrub/savanna habitats (e.g. American woodcock), use young aspen extensively. Breeding birds found in aspen forests include several warblers, all of the northern woodpeckers except the black-backed, woodland hawks and owls, and a variety of representatives of other groups. Bird species richness and total population size peaks at 2 age classes in aspen forests. One occurs shortly after regeneration and includes ground foragers such as robins, flickers, and rufous-sided towhees. Sparrows and some warblers are also present early in the life of the stand. The other peak is at stand maturity when the understory has fully developed. Species groups found during this second peak include thrushes, warblers, and cavity-nesting birds (Probst et al, 1992).

American woodcock begin using regenerating aspen in the first spring following harvest for display grounds and night roosting areas. Nesting and brood-rearing takes place in regenerating aspen and in older aspen with well-developed shrub understories. Aspen was important as diurnal resting cover in a study conducted in northern Wisconsin (Gregg, 1984). Many of the aspen stands identified during this study were either very young or poorly stocked due to site characteristics. Alder, either alone or in association with aspen, was nearly as important to woodcock. Over 80% of the diurnal resting sites identified in this study occurred in one of these two cover types. Structure of the cover was important but soil characteristics which affected food availability also played a role in selection of the habitat. Management for woodcock must emphasize early-successional habitats. Openings are important for breeding and night roosting. Dense vertical stem density provides cover for broods and for birds in daytime resting covers. Leaf mulch from aspen and alder contributes to the desirability of these covers for woodcock because it is a preferred food for earthworms.

Ruffed grouse selected aspen over all other habitat types in a study conducted in central Wisconsin (Kubisiak, 1985). Grouse use in regenerating aspen was highest in stands between 6 and 25 years of age. As with woodcock, the presence of alder as a component of the understory of the stand was associated with an increase in grouse use. Grouse use of aspen stands 26 years of age and older declined but was still high if a shrub understory was present. Older aspen is important to grouse as a food source in the winter months. Ruffed grouse drumming sites are also associated with mature aspen. Management direction in aspen for ruffed grouse should emphasize retention of the aspen type. Complete clearcuts, which result in a residual basal area of less than 15 $ft.^2$ per acre will provide the necessary vegetative structure for optimum ruffed grouse habitat. Small cuts of less that 5 acres may not provide adequate aspen regeneration due to suppression of aspen suckers. Large cuts of 40 acres or more may be acceptable but careful planning of the cut may be necessary. If large cuts are necessary, they should be rectangular so as to minimize the distance to older aspen. Alternatively, large cuts can be improved for ruffed grouse by retaining older aspen either in clumps of 30-50 trees within each 10-acre block or widely scattered mature aspen (2-9 per acre) throughout the cut. Optimum production of grouse will be attained where 30% - 35% of the aspen is in the sapling stage.

Habitat suitability for beaver is enhanced by aspen associated with water. Aspen is a favored food of beaver and an abundance of aspen contributes to high beaver populations. Beaver dams create habitat beneficial to many other species and mitigate peak flows that cause flooding. Beaver populations rose in the early 1990’s and then declined. Lowest populations in the mostly forested northern part of the state are in the northeast in beaver management zone B where population control measures are most prevalent (Kohn et al, 1999).

Some small mammal populations reach high numbers in early-successional forests in Wisconsin and the eastern United States. Representatives of these are cottontail rabbits and snowshoe hares. Because these two species are extremely important to predators, their abundance can affect a range of species. Productivity and survival of snowshoe hares in central Wisconsin is higher in habitats with high stem density deciduous cover and young aspen stands provide the best hare cover in the area. Snowshoe hares and cottontail rabbits are vulnerable to predation when dispersing through areas without heavy cover. Good interspersion of young, high-density aspen stands provides the best opportunity for high populations of these species.

Carrying capacity of deer within management units in Wisconsin is closely tied to the percentage of early successional habitats within the unit. Aspen, oak, jack pine, and openings are all desirable habitats for deer. Deer trails used as an index to deer use in central and northern Wisconsin indicate that aspen and jack pine are consistently preferred habitats, and the presence of tall shrubs or deciduous saplings increase the value of almost all habitats (Kubisiak and Rolley, 1997). Deer are valued by hunters and non-hunters as an emblematic resident of the forest. Deer also play a role in supporting other valued wildlife species in the state. Wolves, bear, coyotes, bobcat, and a host of scavengers feed on deer or deer remains in Wisconsin. Habitat management for deer should include early-successional types such as aspen.

Habitat management for wildlife in the aspen forest should include a diversity of age classes reflective of the wildlife values derived from each stage of aspen. Young and old aspen stands produce conditions that are favorable to high populations of some species and to a diverse array of wildlife. Wildlife species assemblages change with growth stage in all northern forest types. In aspen, these changes occur relatively rapidly due to the short lifespan of the tree. Maintaining aspen in a variety of age classes in conjunction with other northern forest types will ensure a diverse wildlife community.

Effects of Aspen Management on Neotropical Forest Migrants

During the past 20 years, there have been a number of studies conducted to generate explanations for the decline of many neotropical migrant bird species (NTMB) associated with forested landscapes. One segment of this research investigates the impact of edges and fragmentation, generated by forest management, on these species.

Landscapes like those of southern Wisconsin were the focus of many NTMB studies conducted during the 1980's. These areas have relatively high levels of permanent fragmentation brought about by agricultural and urban land uses. Most of this fragmentation creates "hard" edges, or abrupt changes between habitat types, such as woodlands adjoining farm fields. Bird populations within these fragmented woodlots are heavily impacted by nest predation and by high levels of nest parasitism by brown-headed cowbirds. These populations are generally "sink" populations because they are maintained by recruitment of individuals from other "source" populations.

Northern Wisconsin forests are more important for aspen management, and have different levels and types of fragmentation. The amount of edge within this landscape is determined primarily by timber management, and secondarily by permanent fragmentation associated with development. The hard edges generated by even-aged management are slowly transformed to "soft" edges, or areas of more gradual change between habitats, as forest regenerates.

Forests and associated wetlands of the northern Lake States support some of North America's highest densities and most diverse assemblages of breeding birds (Howe et al. 1996). This region is also thought to contain source populations of many NTMBs. Edge and fragmentation studies in the 1990's have focused more on these forested landscapes. Most researchers tested whether hard edges would affect avian productivity as they did in agricultural landscapes. Predictably, edge effects in forested landscapes are much more complex and local than those found in agricultural landscapes. Interspecific competition and predation rates are much more important than parasitism in forested landscapes. Cowbird abundance is much lower in northern Wisconsin because most areas lack agricultural or large open areas.

Studies focusing on the northern forest have found that principles applicable to agricultural landscapes cannot be extrapolated. Nest predation, not nest parasitism, is the most important demographic factor limiting nesting success in the northern Lake States forests. These predators include fisher, skunks, raccoons, foxes, crows, blue jays, a variety of other birds, and assorted small mammals. Predator species, abundance, and behaviors are different than those of southern Wisconsin. Fenske and Neimi (1996) found that predation rates extending into a mature aspen forest from hard edges (defined as vegetation less than 2 meters high next to medium age or older forest) were lower than predation rates at soft edges (vegetation 2-8 meters high) in Minnesota. This phenomenon warrants further study but may indicate that edge effects are more prolonged than believed. Flaspohler et al. (2001a) studied edge effects generated by clearcuts (6 years or less) adjacent to large stands of older deciduous forests in Wisconsin. Hermit Thrush and Ovenbird, forest interior species that nest on the ground, had lower nest success within 300m of hard edges generated by clearcuts. Forest interior birds that nest in the canopy nested at lower densities within 50 meters of clearcuts, but at higher densities between 50 and 300 meters. American Robin and Rose-breasted Grosbeak, species known to be less sensitive to edge, had higher nest densities near recent clearcuts. Predation was the leading cause of nest failure for both ground and canopy nesting birds. A related study of Ovenbirds determined that while nest density was similar between edges and interior, predation and mean clutch size were both highest near edges. Therefore, net productivity was similar. We do not know whether this result applies to other species. More research is needed in this region to better understand local predator populations and how they affect nest success of NTMB's.

Aspen management can also have direct and indirect effects on competition among bird species. Creation of edge and fragmentation in a landscape often benefits generalist bird species, which are adapted to a variety of habitats. Many of these species (e.g. House wren, Gray catbird, American crow, Blue jay) are egg predators, but their effects on local bird populations are not well known. Hamady (2000) found that Black-throated blue warblers, a forest gap-dependent species associated with shrub layers, declined in Upper Michigan landscapes with increasing habitat fragmentation, because of competition with forest generalist species.

Current research also suggests that vegetation patterns in forest-dominated landscapes can affect the composition of avian communities within individual forest stands. In northeast Wisconsin, forested stands in landscapes with greater amounts of upland open land, as well as higher levels of fragmentation as indicated by measures of landscape pattern, had a lower abundance of edge-sensitive NTMBs (McRae 1995). Amounts of open land were correlated with landscape pattern measures, making it difficult to study these effects separately. Pearson and Niemi (2000) sampled mature aspen stands in Minnesota to determine whether both within-stand habitat characteristics and landscape patterns influenced breeding bird abundance in a forested landscape. They found that habitat specialists (Blackburnian warbler and Magnolia warbler) were found in aspen if there was a conifer component retained in the stand and also a large conifer component in the surrounding landscape (up to 1/3 mile radius). Forest generalists (veery and ovenbird) were least influenced by landscapes. Retaining appropriate habitat in the landscape for certain habitat specialists as well as maintaining more diverse aspen stands may prove beneficial to regional populations of some NTMB's.

The overall effect of habitat fragmentation and edge on NTMBs in northern Wisconsin is not clear. Population estimates suggest that this region is a source population for many NTMBs and other bird species. Generation of excessive amounts of edge and habitat fragmentation within a landscape will be beneficial to some generalist NTMBs but may prove detrimental to source populations of forest interior NTMBs, many of which are of higher conservation concern. Local research results are difficult to extrapolate, appearing to vary by ecosystem type. Additional local research is needed to determine how aspen management affects patterns of interspecific competition and nest predation in the northern forests.

Fragmentation and Edge Effects

Fragmentation is a term used to describe certain kinds of landscape structure. Inherent fragmentation describes landscapes that are naturally heterogenous due to characteristics of the physical environment, such as an area with numerous small lakes and wetlands dispersed throughout a pitted outwash plain. Permanent fragmentation refers to long-term conversion of forest to urban, residential, or agricultural uses. Habitat fragmentation is defined as a disruption of habitat continuity, caused by forest harvesting or natural disturbance, which creates a mosaic of successional stages within a forested tract. This kind of fragmentation is shorter-term, affecting species while the forest regrows, and is a consideration in aspen management in northern Wisconsin. Aspen regeneration is generally accomplished through the use of evenaged management, and dispersion of clearcuts throughout the forest creates differences in forest structure that are a type of habitat fragmentation.

In Wisconsin and elsewhere, the loss of forest habitat has a larger impact on species than shorter-term habitat fragmentation. However, area of habitat loss is often correlated with measures of fragmentation (e.g. patch size, distance between patches, cumulative length of patch edges, etc), making it difficult to quantify their separate effects. Habitat loss may result from second homes, or urban and industrial expansion. A drastic change in land cover, such as that which occurs after a clearcut harvest, represents a short-term loss of habitat for some species and a gain for others. Dispersal can be affected if species or their propagules cannot cross or get around the open land and cannot find suitable habitat within it. Other concerns about habitat fragmentation are related to edge and area effects.

3.2.5.1 Deer and Herbivory Effects

Contribution to Deer Carrying Capacity

In the northern forest the abundance of aspen, oak, upland brush, grass, and other early successional habitats contribute significantly to carrying capacity for white-tailed deer. Poorer habitat units are made up of pole and larger-sized maples, dense conifers, and swamps (McCaffery 1984). Deer are a keystone species because they directly or indirectly affect many other plants and animals in the ecosystem. These effects are apparent at stand, landscape, and regional scales.

There are positive impacts from the large deer herd, including:

- social and economic benefits

- recreational opportunities for hunting and viewing deer
- food source for wolves, eagle, crows, bear, chickadees, and other predators

There are also negative impacts from the large deer herd. The Deer 2000 report (Wisconsin Conservation Congress 2000) has noted:

- damage to natural, agricultural, and urban vegetation
- reduced regeneration and growth of some tree species, and changes in species composition (possible economic impact in areas of high deer abundance)
- local extirpation of some plant species
- reduction of habitat diversity
- effects on other wildlife that depend on understory plants and shrubs
- economic and social impacts of car-deer collisions
- food source for predators, which can lead to increased predation on other desirable species

3.2.6 Endangered, Threatened and Special Concern (ETS) Species

Most aspen management would have no effect on Endangered Resources (species listed in the Wisconsin Natural Heritage Inventory [NHI] Working List). Twenty-six species on the NHI working list occur regularly in aspen stands. Most of these twenty-six species are found in a variety of habitats and use aspen primarily for foraging. Several other species use aspen as breeding habitat, but also use many other habitats. None of these twenty-six species are obligates to the aspen habitat.

Wide-ranging species that utilize aspen areas for foraging are:

> Timber wolf (*Canis lupis*), northern myotis (*Myotis septentrionalis*), eastern pipistrelle (*Pipistrellus subflavus*), woodland vole (*Microtus pinetorum*), Arctic shrew (*Sorex arcticus*), pygmy shrew (*Sorex hoyi*), water shrew (*Sorex palustris*), bobcat (*Lynx rufus*), great gray owl (*Strix nebulosa*), sharp-tailed grouse (Tympanuchus phasianellus), Cooper's hawk (Accipiter cooperii), Swainson's thrush (*Catharus ustalatus*), veery (*Catharus fuscescens*), wood thrush (*Hylocichla mustelina*), and eastern kingbird (*Tyrannus verticalis*).

The remaining species use aspen as breeding sites and can be more directly influenced by stand management decisions. Only one species (DeGraaf et al. 1996) is considered to have aspen as preferred habitat, Nashville warbler (*Vermivora ruficapilla*). The Special Concern Nashville warbler prefers young (1-20 year-old) aspen stands, but also prefers young upland conifers, swamp conifers and old jack pine. Aspen stand management can add some benefit to this species.

Twelve species utilize aspen but have other preferred habitat. These species can be affected by harvest. When present, stand harvest may have benefits (from one to twenty years afterwards) for 4 species that utilize young aspen stands. A shifting mosaic of young stands can accommodate these species:

- The Special Concern black-throated blue warbler (*Dendroica caerulescens)* prefers dense understory in hardwood stands, but uses aspen coppice.

- The Special Concern golden-winged warbler (*Vermivora chrysoptera)* prefers dense shrubs along alder-lined streams or bog edges, and also uses young aspen (1 – 20 years after harvest). Additional discussion concerning this species is provided below.
- The Special Concern large-flowered ground-cherry (*Leucophysalis grandiflora)* can occasionally be found in aspen stands that regenerate following fire.
- The Special Concern Canada mountain-ricegrass (*Oryzopsis canadensis)* can be found in aspen clones in barrens areas.

When present, stand harvest could have negative impacts on eight species, because they utilize mature stands. Consideration of extended rotation ages for aspen may lessen the impacts of harvest on these species:

- Three Special Concern species occasionally use old aspen trees as nest sites: northern goshawk (*Accipiter gentilis),* common goldeneye (*Bucephala clangula),* and common merganser (*Mergus merganser).* When present, consideration for maintaining aspen to the top end of the extended rotation could benefit these species.
- The Special Concern woodland jumping mouse (*Napaeozapus insignis)* prefers northern hardwoods,but will utilize older aspen.
- The Special Concern yellow-billed cuckoo (*Coccyzus americanus)* forages for caterpillars in oak and northern hardwoods but will use older aspen for nesting and foraging.
- The Special Concern Hooker's orchid (*Platanthera hookeri)* is most often found in old red and white pine forests,but will grow in old aspen stands with the same habitat types as the pines.
- The Special Concern large roundleaf orchid (*Planthera orbiculata)* has similar habitat requirements, as Hooker's orchid.
- The Special Concern Indian cucumber-root (*Medeola virginiana)* can be found in aspen stands adjacent to its preferred beech forest habitat.

Golden-winged warbler is listed as special concern by the Wisconsin DNR, and a priority species for management concern by Partners in Flight. This warbler regularly occupies regenerating aspen stands and occasionally pole-sized aspen stands. A bird preferring early succession habitats, the golden-winged warbler is found most frequently in alder/tamarack swamps, alder-lined stream corridors, regenerating spruce/fir forest and shrubby sedge meadows. This warbler is also found in lower frequencies in many other forest cover types (and most age and size classes) as well as old fields.

The diversity of forest types used by golden-winged warbler requires management planning efforts focused on landscape attributes and wintering grounds in Central America and northern South America. Commonly cited factors limiting populations are: (1) loss of breeding habitat, especially conversion of early successional habitats in northeast U.S. to more mature forest and suburban development; (2) brown-headed cowbird parasitism; (3) competition from and hybridization with blue-winged warbler; and (4) loss of winter habitat (Confer 1992).

Aspen management can supply habitat for golden-winged warbler, although a decline of 9.6% in the acres of young aspen (0 – 20 years) between 1983 – 1996 (FIA data) is not correlated to a decline in golden-winged warbler population (0.0 trend in WI) during the same period. Some researchers have speculated that golden-winged warblers have higher productivity in young aspen near wetlands, than in upland situations. Additional research is needed to clarify habitat (stands and landscapes) preferences, threats, and management needs.

Other rare species may occur in aspen stands considered for harvest. Many of these species will be found in specialized habitats such as rock outcrops, cliffs, ephemeral ponds, and seeps. If an NHI occurrence or species verification is identified, contact the appropriate person according to the Department protocol. Information on species and habitat can be found at the Forestry web site: https://dnr.wisconsin.gov/topic/forestry.

4 STAND MANAGEMENT DECISION SUPPORT

4.2 Key/ Checklist for Evaluating Cover Type Stand Management Options

Note: The following recommendations assume the management objective is to regenerate aspen, maximizing growth and yield.

1. Aspen maintenance	**2**
1. Conversion to aspen	**5**
2. Primary timber management objective is produce pulpwood	**3**
2. Primary timber management objective is produce sawtimber on dry-mesic to wet-mesic sites with site index > 70	**4**
3. Wet, poorly drained soils	Aspen management NOT recommended.
3. Wet-mesic, somewhat poorly drained soils	Harvest at rotation age, using simple coppice or coppice with standards regeneration methods. To avoid rutting and compaction, operate on dry or frozen ground only. Consider maintaining reserve and immature hardwoods and conifers if water tables can potentially rise and kill regeneration.
3. Very Dry to Mesic sites	Harvest at rotation age, using simple coppice or coppice with standards regeneration methods.
4. Stand older than 30 years	Harvest at recommended or extended rotation age, using simple coppice or coppice with standards regeneration methods. Consider two-age aspen management at age 30-40 years based on management objectives.

4. Stand 16-30 years old	Thin at age 30. Commercially thin from below. If possible, cut narrow strips into stand for machine access, alternating with wide leave strips, and operate equipment only in cut strip on slash mat to minimize rutting and compaction. Reduce basal area to approximately 65 square feet per acre in leave strips. Leave DOMINANT TREES, spaced about 10-11 feet apart (400 trees/acre). (NOTE: Thinning could result in increased defect and mortality to residual trees if care is not taken to minimize mechanical damage).
4. Stand 15 years or younger **and** mesic site	Pre-commercially thin at age 15 only if residual stems will not be damaged. Leave 550-600 trees per acre (9 X 9 foot spacing). Felling by hand is desirable to prevent mechanical damage to residual stems. **OR** Mechanically flatten or chip 6-8 ft wide strips at a spacing of 6-10 ft.
5. At least 50 well-spaced aspen per acre present	Harvest at aspen rotation age, using simple coppice or coppice with standards regeneration methods.
REGENERATION BY SEED **5.** Not as in “5” above, but with a suitable aspen seed source adjacent to the stand.	Cut all trees on area to be regenerated to aspen (reserve trees can be retained). Create a suitable seedbed by prescribed burning or by mechanical scarification. Results will depend on seed crop, prevailing winds, and available moisture.
ARTIFICIAL REGENERATION **5.** Not as in “5” above, but suitable aspen site.	Plant with aspen seedlings (see Artificial Regeneration chapter).

5 SILVICULTURAL SYSTEMS

Management of aspen is usually on an even-age basis. Rotation ages are based on site productivity as defined by the habitat type classification system. Recommended regeneration methods include:

- Simple coppice (total tree harvest).
- Coppice with standards. Retain standards (reserve trees) at 5-15% crown cover or stand area; these trees are not harvested during the coppice rotation (see Chapter 24).

5.2 Intermediate Treatments

5.2.3 Thinning

5.2.3.1 Non-Commercial Thinning and Improvement

A **pre-commercial thinning** at age 15 can dramatically improve sawtimber yields on exceptional sites (mesic sites, site index ≥80) with a rotation age of 60 years. Growth of young aspen is particularly rapid for the first 20 years. Pre-commercial thinning has been conducted on a relatively large-scale basis. Blandin Paper Company in Grand Rapids, Minnesota has mechanically thinned about 16,250 acres in the past decade. Their prescription for 8- to 10-year-old aspen sapling stands calls for flattening 6-8 feet wide strips at a spacing of 6-10 feet (David et al. 2001). More recently chipping has been tried to reduce the tangle created by just pushing stems over and to improve access for hunters. Significant growth responses in the residual trees have been observed. **NOTE:** TAKE EXTREME CARE TO PREVENT DAMAGE TO RESIDUAL STAND. Pre-commercial thinning has been found to increase internal defect in residuals by up to 10 times versus control stands. Partial harvest of aspen was observed to increase mortality in residuals due to canker diseases associated with logging wounds, as well as damage from sunscald and woodboring insects (Ostry 1982).

5.2.3.2 Commercial Thinning and Improvement

Thinning has been demonstrated to reduce the length of pulpwood rotations (Jones et al. 1990), increase volume increment (Weingartner and Doucet 1990), and increase sawtimber output up to 40% and veneer output up to 140% (Perala 1977). Thinning also can be an effective means of eliminating poor clones from a stand, provided residual densities are heavy enough to retard suckering. To maximize aspen sawtimber production on dry-mesic to wet-mesic sites, commercially thin at age 30 (Perala 1977). This thinning will capture some of the natural mortality that occurs as the stand matures as well as release crop trees. NOTE: thinning at age 30 can result in increased defect and mortality to residual trees if care is not taken to minimize mechanical damage during the harvest.

5.3 Natural Regeneration Methods

5.3.1 Even-Age Regeneration Methods

<u>Management Recommendations</u>

- To maximize stand growth and vigor, aspen should be grown in full sunlight in a fully stocked condition. Optimum stocking is 12,000 well-spaced suckers per acre the first year, 6,000 suckers per acre is a minimum. Regeneration by simple coppice produces 10,000 to 30,000 suckers per acre (Graham et al. 1963).
- Retain some hardwoods and conifers on wet to wet-mesic soils when regenerating aspen. This maintains a portion of the normal evapotranspiration and nutrient cycling processes (Navratil et al. 1994), allowing for partial aspen regeneration in areas that may become non-forested due to a rise in the water table if all trees are cut.
- **Balsam poplar** can be regenerated from seeds, stump sprouts, root suckers, and buried branches.

Management Alternatives[2]

- The **aspen reserve management** method may reduce aspen sucker density and increase early aspen sucker growth, while maintaining species diversity (Stone et al. 2000). This method leaves 7-15 dominant or co-dominant aspen per acre at a uniform spacing of 50-66 feet in the regeneration area (10-12 square feet reserve basal area). In a study of the first full growing season following an aspen reserve harvest, sucker density was reduced 41% compared to the control. Moreover, suckers on these sites had a greater mean diameter (28% greater) and greater height growth (33% taller) than the simple coppice control site. This suggests carbohydrate and/or nutrient reserves in the parent root systems are channeled to fewer suckers, thereby increasing their early growth as postulated by Ruark (1990).
- **Two-age aspen management** was proposed by Ruark (1990). This method allows for sawtimber production while maximizing aspen pulpwood production. It is recommended only for dry-mesic and mesic sites. Although this method has not been validated, the proposed two-age management of aspen is: (1) Conduct a harvest at age 32 (maximum mean annual increment (MAI) for aspen pulpwood) leaving 10-20 scattered dominant aspen per acre in the initial cut. (2) Grow the regenerated stand for another 32 years. At that time, all 64-year old stems and most 32-year old aspen stems (all but 10-20 dominants per acre) are harvested. Care must be taken to not damage residual stems. No more than 20-30 mature trees per acre should remain standing following harvest. This amount of residual will not exceed the 30 square feet maximum reserved basal area per acre recommended in a coppice and standards regeneration method. This residual still allows enough light for aspen sucker development.

5.5 Rotation Lengths and Cutting Cycles

Rotation Definition

In even-aged silvicultural systems a rotation is defined as the period between regeneration establishment and final cutting. The length of rotation may be based on many criteria, including culmination of mean annual increment (CMAI), target size, attainment of a physical or value growth rate, and biological condition.

Choosing an Appropriate Rotation Age

Selecting when to rotate a stand is based on multiple considerations, including landowner goals, stand condition, and expected future growth. The rotation ages provided are guidelines based on literature, empirical data, and professional experience. In application, foresters will need to regularly review stands in the field and exercise professional judgment concerning tree vigor and mortality and stand growth and productivity. Different rotation lengths can result in increased production of some benefits and reduced production of others, and landowner goals will help inform the evaluation of the benefits and costs (ecological, economic, and social) associated with different forest management strategies. Below are aspen rotation length

[2] Management practice that may have potential for application in managing aspen but has not been widely utilized and tested.

guidelines based on three different management emphases to accommodate a variety of landowner goals.

Flexibility in Rotation Length Guidelines

The recommended rotation ages presented here are appropriate for most stand conditions and landowner goals encountered in aspen stands. Foresters may modify these guidelines to accommodate specific stand conditions and management objectives. Modifications to these guidelines should always be scientifically sound. Some of the more common modifications include early rotations due to significant stand health concerns, modifications to regulate a species' age class distribution at the property/landscape level, and accommodations due to operability issues. In addition, aspen rotations are sometimes modified to create age class diversity for ruffed grouse management.

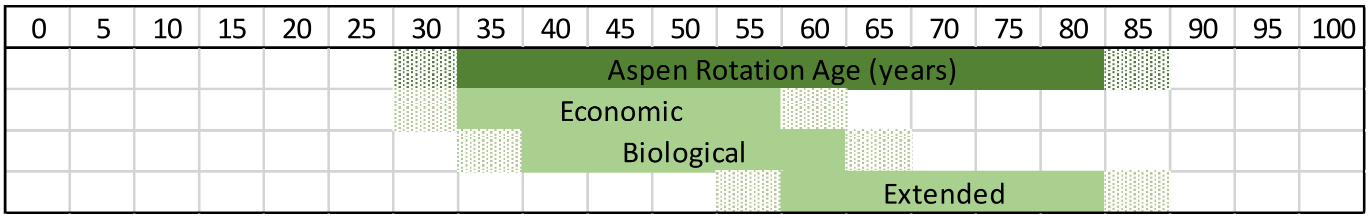


Figure 43.14. Economic, biological, and extended rotation length recommendations for aspen.

5.5.1 Economic Rotation

The economic rotation age seeks to maximize the net present value of the stand. It may only include financial (monetary) aspects but could also include non-timber benefits. The inclusion of non-timber benefits may shorten or lengthen the rotation age depending on the non-timber benefits included. For more details on the factors that affect economic rotation age, please refer to the Economics Chapter (Chapter 62). Landowners who choose economic rotation ages generally want to maximize the financial performance of the stand. Economic rotations will vary depending on the target discount rate and factors such as estimated costs and revenues (Minnesota DNR 2013; Steigerwaldt 2016). In practice, there can be significant overlap between economic and biological rotations, especially on higher quality sites. Current aspen markets in Wisconsin favor pulpwood and composite products. The density of aspen wood is low, making it less valuable for biofuel production. The majority of aspen sawtimber in Wisconsin is classified as lower grade. Bigtooth aspen is more likely to be of higher grade than quaking aspen. There are regional variations in aspen with the highest quality aspen generally found in northeast and northwest Wisconsin.

5.5.2 Biological Rotation

The biological rotation seeks to maximize long-term sustained yield, or volume production. In this guideline, the range in rotation ages is defined at the lower end by the age at which maximization or culmination of mean annual increment (CMAI) growth occurs and at the upper end by the average stand life expectancy. The recommended rotation to maximize average annual volume growth (CMAI) is 40-60 years, with CMAI generally occurring sooner on very dry or wet habitat types and later on rich habitat types. The better the site, the higher the potential to maintain high growth rates for a longer period; however, disease may cause significant declines in timber value in older stands. Bigtooth aspen has the potential to maintain vigor and growth longer than quaking aspen and is typically found on higher quality sites. Ecological benefits of biological (and economic) rotations can include more abundant coppice regeneration and maintenance of early successional wildlife habitat.

5.5.3 Extended Rotation

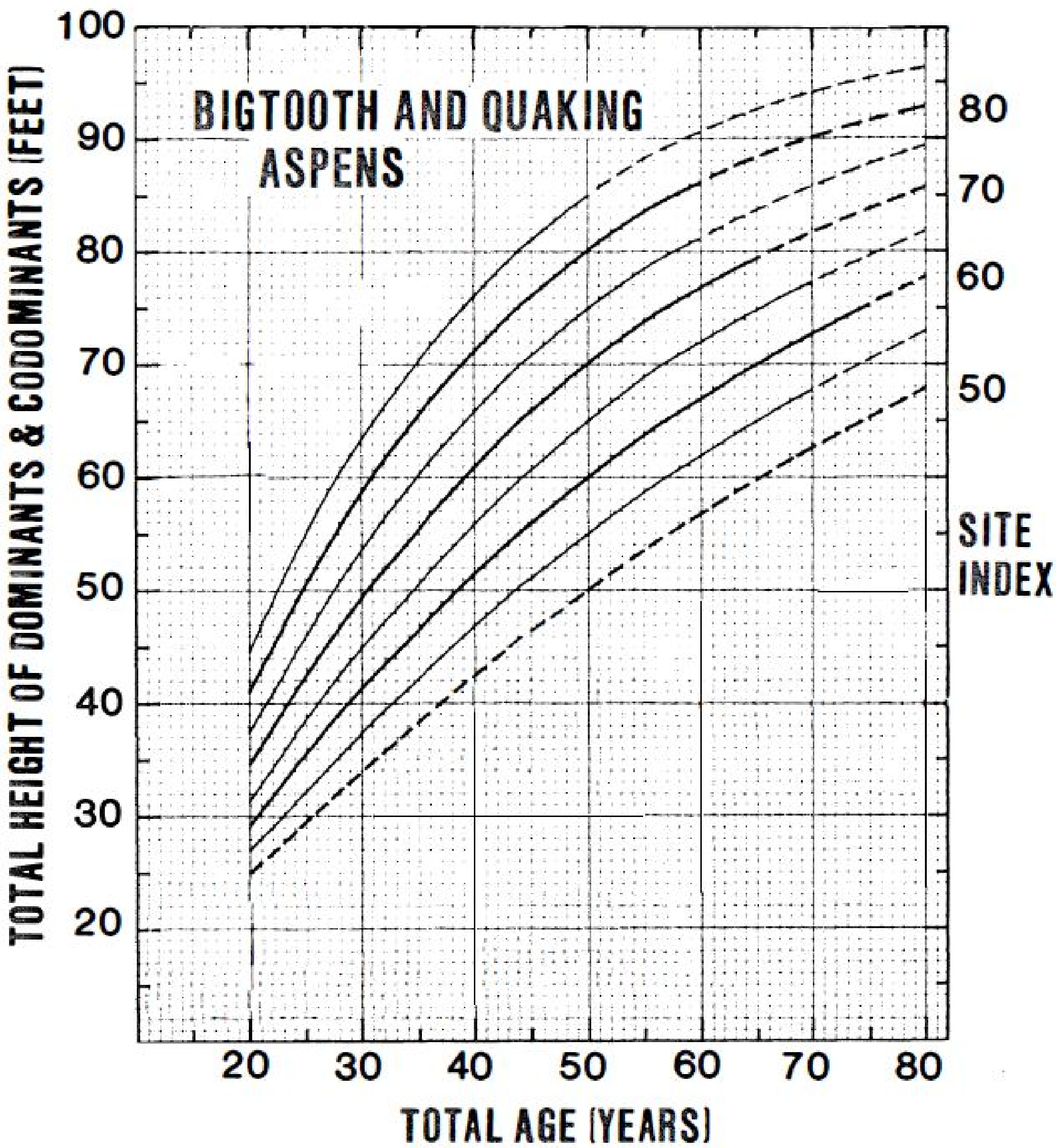
Extended rotation involves growing stands beyond typical biological rotation ages yet younger than average tree life expectancy, with the objective of managing for both commodity production and the development of some ecological and social benefits associated with older forests. Ecological benefits of extended rotations can include an abundance of large trees, more diverse vertical structure, and greater levels of standing snags and coarse woody debris that support organisms associated with these structures.

5.6 Other Silviculture Considerations

5.6.2 Cover Type Conversion

Conversion to aspen requires either an adequate aspen component in the overstory OR a suitable seedbed with an adjacent seed source. On well drained sites, coppice regeneration with as few as 50 trembling aspen per acre will normally create a fully stocked stand of suckers (Perala 1977). To establish aspen regeneration from seed, a continuously moist mineral soil seedbed is essential. Successful seeding has occurred on a seedbed scorched with a hot fire or scraped bare with a dozer blade so the seedbed has mineral soil fully exposed to the sun and soil conditions are firm. Firm soil (not compacted) increases the moisture retention needed for seed germination (Gullion 1984).

8 APPENDICES



Bigtooth and quaking aspens (Carmean 1978)
Northern Wisconsin and Upper Michigan
13 plots having 42 dominant and codominant trees Stem analysis, nonlinear regression, polymorphic Add 4 years to d.b.h. age to obtain total age (BH = 0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	5.2188	0.6855	-0.0301	50.0071	-0.8695	0.99	1.58	4.5
SI	0.0612	1.4390	-0.0050	-3.9080	-0.4350	0.99	1.90	10.4

Figure 43.15. Site index curves for bigtooth and trembling aspens in northern Wisconsin and upper Michigan (Carmean et al., 1989).

8.1 Forest Health Guidelines - Forest Health Protection (FHP)

PEST MANAGEMENT GUIDELINES FOR ASPEN AND HYBRID POPLAR

Disturbance Agent and Expected Mortality or Damage	Options for Minimizing Mortality or Preventing Disease	References
ROOT DISEASE		
Armillaria Root Disease - *Armillaria* sp. Armillaria root disease is more of a threat if aspen is managed under frequent, short (less than 13 years) rotations. This disease is also more prevalent when aspen is stressed from defoliation or drought. 1. Sucker stands: mortality usually scattered, acting as a thinning agent. 2. 45-55 year-old stands: mortality can occur in pockets and develop rapidly following defoliation or drought. 3. In stands with frequent (2 or more) short (<13 years old) rotations, stem and root decay degrade root systems to a point where they are unable to support sprout growth.	1. No prevention necessary 2. Monitor stands > 40, every 5 years; more often when stands are over 55. If > 15% of the stems are infected, consider harvest. 3. Avoid repeated short rotations.	A Guide To Insects, Diseases, and Animal pests of Poplars. M.E. Ostry. 1989. USDA FS Agr. Handbook 677. Armillaria root rot in aspen stands after repeated short rotations. G.R. Stanosz and Patton, R.F. 1987. Can. J. of For. Research. 17:1001 - 1005.
STEM DISEASES		
Hypoxylon Canker - *Entoleuca mammata* Hypoxylon canker causes stem and branch cankers, top breakage, girdling and mortality. Mortality more common on	1. No action necessary 2. Harvest the stand early; treat to encourage good regeneration.	A Guide To Insects, Diseases, and Animal pests of Poplars. M.E. Ostry. 1989. USDA FS Agr. Handbook 677.

Disturbance Agent and Expected Mortality or Damage	Options for Minimizing Mortality or Preventing Disease	References
young (10 years) trees. Stain and decay enter trees through cankers. Trembling aspen is most susceptible native aspen. 1. Sucker stands with 30,000-40,000 stems/acre: Hypoxylon kills an average of 1-2% of the stems/ year, acting as a thinning agent. Stand can suffer up to 7.5% mortality/ year and still yield 1,500 stems at 40 years. 2. If 15-25% of the stems are infected: 3. If more than 25% of the stems are infected.	3. Harvest the stand as soon as possible and convert to other species or convert to a less susceptible clone.	Hypoxylon Canker of Aspen. R.L. Anderson, G.W. Anderson and A.L Shipper. 1979. USDA FS FIDL #6.
Other Cankers *Cryptosphaeria populina* *Nectria galligena* *Ceratocystis fimbriata* *Encoelia pruinosa* Typically infecting through a wound, these canker-causing fungi can cause a reduction in tree quality through stem deformity, stain and stem breakage. Mortality can occur but is rare.	Avoid wounding and sunscald. Harvest trees before cankers reduce quality or yield potential.	A Guide To Insects, Diseases, and Animal pests of Poplars. M.E. Ostry. 1989. USDA FS Agr. Handbook 677. Identification of Aspen Cankers. M. Albers and J. Campbell. 1988. MN DNR leaflet.

Disturbance Agent and Expected Mortality or Damage	Options for Minimizing Mortality or Preventing Disease	References
Cankers more serious in plantations and nurseries *Cytospora, chrysosperma Phomopsis macrospora,* *Cryptodiaporthe populea* These canker diseases are more prevalent in plantations and nurseries and on trees that are declining from some other cause. Cankers cause dieback, branch mortality, bark necrosis and cankers on branches and main stems of native/introduced poplars. Susceptibility to these fungi varies	In plantations and nurseries: Plant cuttings and seedlings during periods of favorable moisture and temperature to minimize stress. Plant on the best poplar sites. Control weeds, irrigate and fertilize. Plant trees far enough apart to minimize competition for light, moisture and nutrients. Plant clones resistant to *Melampsora, Septoria* or *Marssonina* leaf diseases. Plant cuttings from only disease-free	A Guide To Insects, Diseases, and Animal pests of Poplars. M.E. Ostry. 1989. USDA FS Agr. Handbook 677. How To Identify and Prevent Injury to Poplars Caused by Cytospora, Phomopsis and Dothichiza. M.E. Ostry. 1982. USDA FS HOW TO.
FOLIAGE DISEASES		
Septoria Leaf Spot and Canker - *Septoria musiva* Can be a serious pathogen of aspen as the disease causes premature defoliation and cankers on the twigs and main stem. Other canker fungi often infect Septoria canker and cause further injury, twig and stem girdling and decay.	Plant only uninfected nursery stock. Harvest highly susceptible trees and replant using disease resistant clones.	A Guide To Insects, Diseases, and Animal pests of Poplars. M.E. Ostry. 1989. USDA FS Agr. Handbook 677. Biology of *Septoria musiva* and *Marssonina brunnea* in hybrid Populus plantations and control of Septoria canker in nurseries. M.E. Ostry. 1987. European J. of For. Pathology. 17:158-165.

Disturbance Agent and Expected Mortality or Damage	**Options for Minimizing Mortality or Preventing Disease**	**References**
Leaf Rust - *Melampsora medusae, M. abietis-canadensis* Trees defoliated early in the growing season can experience growth loss. Repeated years of defoliation can cause a higher susceptibility to other diseases and environmental stress. M. medusae alternate host is eastern larch; alt. host for M. abietis-canadensis is eastern hemlock.	Plant disease resistant clones. Do not plant poplars adjacent to hemlock, red or jack pine or eastern larch. Some hybrid larches also act as alternate hosts. Space trees far apart (1.5m) to reduce rust severity on moderately susceptible clones. Wide spacing will not protect highly susceptible clones.	Diseases of trees and shrubs. W. Sinclair, Lyon and Johnson. 1987. Cornell University Press. How To Identify Leaf Rust of Poplar and Larch. A.Shipper, K Widin and B. Anderson. 1978. USDA FS. HOW TO.
Leaf Spots - *Phyllosticta, Ciborina, Marssonina, Septotinia* Heavily infection can cause premature defoliation and a reduction in growth rate.	Remove, bury or otherwise destroy infected leaf debris in fall or early spring to minimize new infections in the spring. Plant resistant clones.	How to Identify and Control Marssonina Leaf Spot of Poplars. M. Palmer. 1980. USDA FS HOW TO. How to Identify Septotinia and Phyllosticta leaf Spots of Poplars. M. Ostry. 1980. USDA Forest Ser. HOW TO.
Leaf Bronzing - Viruses, Phytoplasmas, Rickettsia, Spiroplasmas These pathogens can initiate decline and dieback, and cause a reduction in growth. These pathogens have not been extensively studied in aspen and are difficult to diagnose.	Plant only vigorous, disease-free stock.	A Guide To Insects, Diseases, and Animal pests of Poplars. M.E. Ostry. 1989. USDA FS Agr. Handbook 677.

Disturbance Agent and Expected Mortality or Damage	Options for Minimizing Mortality or Preventing Disease	References
SHOOT BLIGHT CANKER ROT/DECAY		
Venturia macularis, V. populina, V. tremulae Venturia shoot blight is most severe in young aspen stands and hybrid poplars. Infected shoots and leaves become black and curled. Death of the terminal can deform small trees and cause a shrubby tree form. Saplings, after repeated attack may die.	Disease susceptibility varies among hybrids. Plant resistant clones.	A Guide To Insects, Diseases, and Animal pests of Poplars. M.E. Ostry. 1989. USDA FS Agr. Handbook 677. How To Identify Shoot Blight of Poplars. M.E. Ostry. 1980. USDA FS HOW TO.
SHOOT BLIGHT CANKER ROT/DECAY		
White Trunk Rot - *Phellinus tremulae* Known as "white trunk rot", this canker rot causes significant volume loss in aspen in the Lake States. Advanced decay and discoloration reduce the value of trees as fiber sources. This pathogen becomes more serious with stand age.	Monitor stands over 40 years, every 5 years; more often over 55. Look for signs (fruiting bodies) of decay. Harvest aspen before decay becomes extensive. Harvest stands damaged by fire or weather early as these stands are more susceptible to infection. Make regeneration cuts in overmature stands. Manage aspen to achieve uniform, well-stocked stands so natural pruning will minimize infection sites.	A Guide To Insects, Diseases, and Animal pests of Poplars. M.E. Ostry. 1989. USDA FS Agr. Handbook 677. How To Identify and Minimize White Trunk Rot of Aspen. A. Shipper, R. Anderson. 1978. USDA FS. HOW TO.
TWIG PESTS		
Poplar-Gall Saperda - *Saperda inornata* Tunneling and gall formation in twigs may result in heavy loss of twigs, stem deformity, and entry of canker diseases.	Avoid establishing new aspen stands in heavily damaged areas. Maintain well-stocked sucker stand.	How to Identify and Prevent Injury by the Poplar-Gall Saperda. L.F. Wilson. 1980. USDA FS, NCFES.

Disturbance Agent and Expected Mortality or Damage	Options for Minimizing Mortality or Preventing Disease	References
FOLIAGE PESTS		
Spongy Moth – *Lymantria dispar* Periodic heavy defoliation can be expected at intervals of 5-15 years. Impacts should be similar to those of forest tent caterpillar, but outbreaks should be of shorter duration.	No prevention necessary. Manage by maximizing tree vigor in order to minimize mortality. OR Convert to alternate species (less susceptible species).	Gypsy Moth. M. McManus et al. 1980. USDA Forest Insect and Disease Leaflet 162. Gypsy Moth Silvicultural Guidelines for Wisconsin. C. Brooks and D. Hall. 1997. DNR PUB-FR-123
Forest Tent Caterpillar - *Malacosoma disstria* Periodic widespread outbreaks of defoliation in spring in northern 1/3 of Wisconsin lasting up to 3 years. Three years of defoliation can reduce growth by 90%. 1. On most sites, mortality is limited to a few suppressed trees. 2. On wet or excessively dry sites mortality may be heavy.	No prevention necessary. Convert to alternate species.	A Guide to Insect, Disease, and Animal Pests of Poplars. M. Ostry, . 1989. USDA FS Handbook 677.
Large Aspen Tortrix - *Choristoneura conflictana* Occasional outbreaks of spring defoliation seldom lasting more than one or two years. Little or no mortality, some growth loss.	Prevention or control unnecessary.	A Guide to Insect, Disease, and Animal Pests of Poplars. M. Ostry, . 1989. USDA FS Handbook 677.
Aspen Blotch Miner- *Phyllonorycter tremuloidiella (*Braun*)*.	Prevention or control unnecessary.	A Guide to Insect, Disease, and Animal Pests of Poplars.

Disturbance Agent and Expected Mortality or Damage	Options for Minimizing Mortality or Preventing Disease	References
Occasional outbreaks of late summer defoliation. No growth loss or mortality has been observed.		M. Ostry, . 1989. USDA FS Handbook 677.

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Chapter 44

Paper Birch Cover Type

WISCONSIN
DEPT. OF NATURAL RESOURCES

Last Full Revision: 1/9/2015
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand Composition
White birch (*Betula papyrifera*) comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands.

Associated Species
In stands dominated by white birch, the most common associates are aspen (*Populus* spp.) and red maple (*Acer rubrum*). Other common associates include: red oak (*Quercus rubra*), white oak (*Quercus alba*), balsam fir (*Abies balsamea*), white pine (*Pinus strobus*), red pine (*Pinus resinosa*), white cedar (*Thuja occidentalis*), and sugar maple (*Acer saccharum*). Many other species occur as occasional associates.

1.2 Silvical Characteristics[1]

White birch is a widespread boreal and northern species adapted to cold climates. Occurrence in Wisconsin is at the southern limits of its range. Across its broad range, white birch exhibits a diverse and very plastic gene pool; hybridization among birch varieties and species is common. One variant, *Betula cordifolia*, is occasionally found in the northern part of the state identified by its heart shaped leaves, white to pinkish bark and ascending catkins.

In Wisconsin, white birch is an early successional species adapted to colonize sites following severe disturbance; near complete canopy removal (e.g. fire, wind, logging) and fire (for seedbed preparation and competition control) provide a conducive environment for the development of stands of white birch.

White birch is monoecious. Flowers are borne in catkins clustered at the ends of twigs and lateral shoots. Catkins bearing staminate flowers are pre-formed in late summer; by winter they average about one inch long and are clearly visible. The male flowers mature the following spring and the catkins grow to 1.5 to 4 inches long. Catkins bearing pistillate flowers appear in the spring and grow to 1 to 2 inches long. Flowering occurs April through May. Catkins disintegrate when mature. Fruits are tiny, light winged nutlets 0.06 inches long and 0.03 inches wide.

Seeds generally ripen August to September, and most are dispersed September to November (some dispersal can occur throughout the year). Stands of white birch produce seed most years, with good seed crops every two years, and bumper crops about every 10 years; seed production can range from 1 million to over 35 million seeds per acre. During extremely heavy bumper seed crops, tree crown deterioration and stunted growth can occur. The abundance of male catkins in the fall can indicate potential seed production the following year. Seed viability typically ranges from 53% to 86%, and is best when seeding is most prolific (best seed years). The seeds remain viable for up to 2 years. Optimum seed bearing age is 40 to 70 years, although trees often begin production around age 15.

[1] Safford et al. 1990

Seeds are dispersed by wind. Most seed falls within the stand where it was produced, and within 100 to 200 feet of the parent tree. Although seed can be blown across the snow for long distances, the quantity of dispersed seed declines rapidly with distance from stand edge. Seed catch in clearcut openings can be reduced by 90% at 165 feet from the edge of a stand of white birch. It has been estimated that a stand needs to produce about 2 million seed per acre to regenerate an adjacent opening 165 feet wide.

Germination begins once environmental conditions (moisture, temperature, and light) are suitable. Ideal germination temperature is 68^0F to 86^0F. The ideal seedbed to facilitate germination is moist mineral soil. Germination is moderate on humus and poor on undisturbed litter. Seed germinates well on coarse woody debris that has been incorporated into the soil. Shade facilitates germination by moderating moisture and temperature. Following stand disturbance, most established seedlings develop from seed that was disseminated the previous fall and germinates the first spring. Some seed can remain dormant for a year or more. Fire can create ideal site conditions for germination, survival, early growth, and establishment.

Newly germinated seedlings are very fragile (small seed and shallow roots), and are sensitive to variations in moisture, temperature, light, and seedbed condition. Root development is enhanced with coarse woody debris such as stumps and down logs. Seedlings experience high levels of mortality in the first 2 years after germination since they are sensitive to desiccation and inadequate light. Although germination is reduced on humus, early height growth is significantly improved (moisture and nutrients). Early height growth may be best under about 50% full sunlight; severe shade limits height growth by limiting light, and full sunlight can limit height growth owing to high temperatures and reduced soil moisture availability. Seedlings often grow only 2 to 5 inches tall the first year. Competition from other vegetation (e.g. *Rubus* spp.) can limit early survival.

White birch trees can produce stump sprouts. Sprouts can be abundant and vigorous in young stands (<50years), especially with stump heights of 6 to 12 inches; sprouting can be significantly less in older stands (>100 years). Although stump sprouts can be abundant following cutting, mortality during the first several years can be high; deer browsing can be a significant limiting factor especially on stump sprouts. Intensive site preparation, including prescribed fire, can reduce sprouting abundance. Sprout origin trees tend to develop into poorer quality trees (timber) and have shorter life spans than seed origin trees. Although seed origin regeneration provides the primary regeneration in most stands, stump sprouts can supplement regeneration.

White birch is relatively shade intolerant. In Wisconsin, it is an early successional species. Dominance is expressed early during stand development. Stem diameter of seedlings and saplings can be an indicator of growth potential, with larger diameters indicating greater potentials. During stem exclusion, density dependent self-thinning can be heavy, with high mortality rates, particularly among smaller crowned and suppressed trees. In associations with aspen, birch often falls behind and loses vigor, and stand level representation becomes diminished (release from aspen competition may be needed to maintain significant representation).

White birch tends to develop a relatively shallow root system. Most roots occur in the upper 2 feet of soil, and there is no taproot. Rooting depth varies with genetics and soil conditions.

White birch is considered a medium sized, relatively fast growing tree species. It exhibits a relatively long period of seasonal height growth, beginning while minimum temperatures are still below freezing, and ending in response to day length. Maximum height growth rates occur in June. In contrast to height growth, birch exhibits a relatively short period of diameter growth, requiring warmth and moisture.

Young trees grow most rapidly, and rates decline with age. A DBH of 8 inches at 30 years age is common. At rotation, trees typically average 10-12 inches DBH and 70 feet in height. Yields at rotation (60-80 years) on good sites (SI>60) typically average 2500-4000 ft^3/acre; on poorer sites (SI 40-60) with similar rotations, yields typically average 1000-3000 ft^3/acre. On excellent sites, older trees can surpass 30 inches DBH and 100 feet in height.

White birch is a relatively short-lived tree species. Trees are often considered “mature” at 60-80 years, when height growth is generally complete. Depending on environmental conditions, stand deterioration generally occurs sometime between 70 and 120 years. Individuals rarely live more than 140 years, but trees over 200 years old have been documented.

Table 44.1. Summary of selected silvical characteristics of white birch.

White (Paper) Birch (*Betula papyrifera*)	
Flowers	Monoecious. April to May. Borne in catkins.
Fruit (seed)	Winged nutlets 0.06 inches long and 0.03 inches wide. Seeds generally ripen August to September.
No. of seeds/lb	1.4 million seed per pound
Seed Dispersal	Mostly September to November. Dispersed by wind. Most seed falls within the stand where it was produced, and within 100 to 200 feet of the parent tree.
Good Seed Years and Seed Production	Stands of white birch produce seed most years, with good seed crops every two years, and bumper crops about every 10 years. Seed production can range from 1 million to over 35 million seeds per acre.
Seed Viability	At stand level, seed viability typically ranges from 53% to 86%, and is best when seeding is most prolific (best seed years).
Seed Bearing Age	Optimum seed bearing age is 40 to 70 years, although trees often begin production around age 15

Germination	Epigeal. Germination begins once environmental conditions (moisture, temperature, and light) are suitable.
Seedbed Requirements	The ideal seedbed to facilitate germination is mineral soil. Germination is moderate on humus and poor on undisturbed litter. Seed germinates well on coarse woody debris. The best seedbed for germination and growth is mixed mineral and organic soil (the presence and incorporation of coarse organic debris, >1 inch diameter, is beneficial).
Seedling Development	Recently germinated seedlings are very fragile, and are sensitive to variations in moisture, temperature, light, and seedbed condition. Droughty surface soil conditions anytime during the first growing season can result in high seedling mortality. Although germination is reduced on humus, early height growth is significantly improved. Early height growth may be best under about 50% full sunlight; near full sunlight maximizes growth once established.
Vegetative Reproduction	Stumps sprout. Sprouts can be abundant and vigorous when young, vigorous trees are cut with stump heights up to12 inches. Sprout mortality can be high. Sprout origin trees tend to develop into relatively poor quality, short-lived trees.
Shade Tolerance	Intolerant
Maximum Tree Longevity	Stand deterioration generally occurs sometime between 70 and 120 years. Individuals rarely live more than 140 years, but trees over 200 years old have been documented.

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

Stand management objectives should be identified in accordance with landowner property goals, and within a sustainable forest management framework on a local and regional landscape. The silvicultural systems described herein are designed to maximize tree vigor and growth to optimize productivity (quantity and quality) for a variety of timber products (e.g. pulpwood, boltwood, sawlogs) as well as to successfully regenerate the stand.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.1 Landscape Considerations

3.1.1 Historical Context

When the General Land Office Public Land Surveys (PLS) were conducted in Wisconsin (1832-1866), white birch was a strong associate in red and white pine dominated stands.

White birch dominated stands were found in small to large patches throughout the Northern Highlands Pitted Outwash (subsection 212 Xb), and less frequent in adjacent subsections and on mesic sites along Lake Superior and Lake Michigan. However, it was widespread as a component of several forest types (Schulte et al, 2002; Curtis, 1959).

White birch grows in climates ranging from boreal to humid and tolerates wide variations in precipitation patterns. It grows at the northern limit of tree growth in arctic Canada and Alaska, in boreal spruce woodlands and forests, in montane and subalpine forests of the West, in wooded draws of the northern Great Plains, and in coniferous, deciduous, and mixed forests in Wisconsin and the other Lake States. It is shade-intolerant, and abundant on burned-over and cut-over lands, but generally restricted to openings in older forests. White birch is most abundant on rolling upland terrain and alluvial sites but grows on a wide variety of soils and topography, including rugged slopes, open slopes, rock slides, muskegs, and borders of bogs and swamps (Uchytil, 1991).

White birch is adapted to disturbance and opportunistic with respect to fire but it is not fire-dependent. In mixed stands, it burns at intervals of several decades and in pure stands, it burns only during unusually dry conditions at longer intervals. The bark of white birch is both thin and highly flammable, which renders trees highly susceptible to top-killing. However, in trees less than 50 years old it sprouts vigorously from the root collar. White birch is an abundant producer of lightweight, wind-dispersed seeds which readily germinate on mineral seedbeds created by fire and prescribed fire can be used to prepare seedbeds for regeneration (Uchytil, 1991).

White birch was a historically important species to the Native American cultures throughout its range, including the Ojibwe Tribes of Wisconsin. White birch bark was made into baskets, storage containers, mats, baby carriers, moose and bird calls, torches, household utensils, and canoes. The strong and flexible wood was made into spears, bows, arrows, snowshoes, sleds, and other items (Holloway & Alexander, 1990; Kindscher & Hurlburt, 1998).

3.1.2 Current Context

Today white birch grows in a wide variety of habitats throughout Wisconsin and a few stems can be found just about anywhere trees are successfully growing, from boggy sites with Tamarack to dry uplands with Jack Pine. Nearly 75% of white birch acreage is located in northern Wisconsin with lesser amounts in the southwest and central parts of the state (WDNR, 2012). Nearly 50% of the white birch is found within the Forest Transition, North Central Forest, and Northern Highland Ecological Landscapes (Table 44.2). Most white birch is part of the aspen / birch forest type and, to a lesser extent, the maple / basswood type. In southern and central Wisconsin, it’s also a part of the oak / hickory forest type.
The volume of white birch has decreased significantly since 1983. This is a result of both natural succession and increased mortality. The numbers of seedlings and saplings have also decreased suggesting that white birch will play a less prominent role in the future (Figure 44.7). In the last 23 years, growth rates have decreased and are currently negative (mortality exceeds growth). White birch has the highest ratio of mortality to growth and the lowest ratio of

growth to volume of all species in the state. Whereas white birch makes up about 2.5% of all volume of trees in Wisconsin, it accounts for 10% of total mortality (Figure 44.2) (WDNR 2012).

Table 44.2. Acres of timberland by ecological landscape – white birch forest type (FIA 2012).

Ecological Landscape	Area of timberland-acres
Central Lake Michigan Coastal	5,990
Central Sand Hills	13,375
Central Sand Plains	5,086
Forest Transition	46,348
North Central Forest	82,148
Northeast Sands	8,749
Northern Highland	45,874
Northern Lake Michigan Coastal	10,657
NW Lowlands	18,663
NW Sands	20,157
Southeast Glacial Plains	3,770
Superior Clay Plains	27,854
Western Coulees and Ridges	63,793
Western Prairie	4,160
Total	**356,624**

Maintaining a desirable age-class distribution is a landscape-level consideration. A relatively stable age class structure, including all developmental stages, maximizes benefits to wildlife by providing a range of structural conditions. It also contributes to diversified economic interests by supplying different types of materials, including pulp, poles, sawlogs, and veneer. The amount of white birch on the landscape has declined significantly since 1983. However, the age class structure has remained fairly steady with a majority of acreage in the middle age classes and fewer acres in the youngest and oldest age classes. Today there are more acres of white birch in the older age classes than there were in 1983, even though the amount of white birch overall has declined (Figure 44.1). The current trend is a decline in the younger white birch stands. White birch in the 0-19 age class has declined by 50% since 1983 (Figure 44.1). In addition, the number of growing stock trees in the youngest age class is very low, indicating the possibility of further decline of the birch resource in Wisconsin (Figure 44.2).

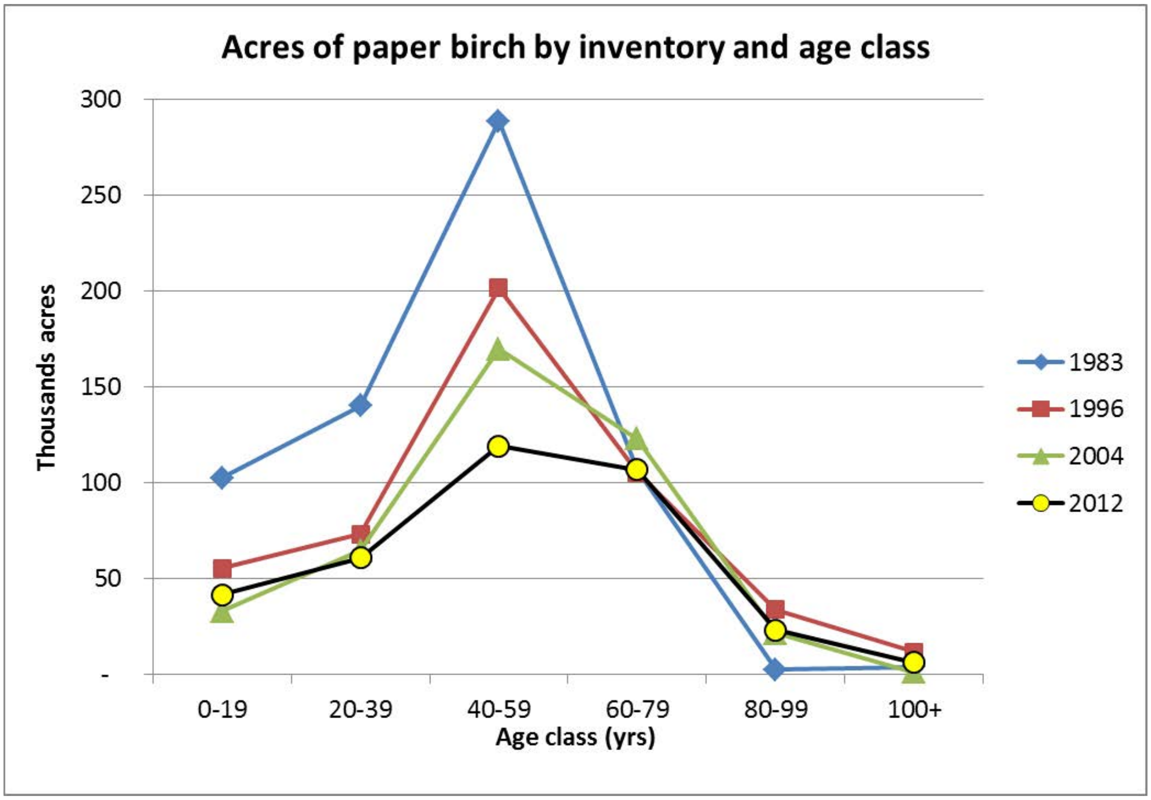


Figure 44.1. Forest age-class distribution for white birch cover type in Wisconsin (FIA 2012)

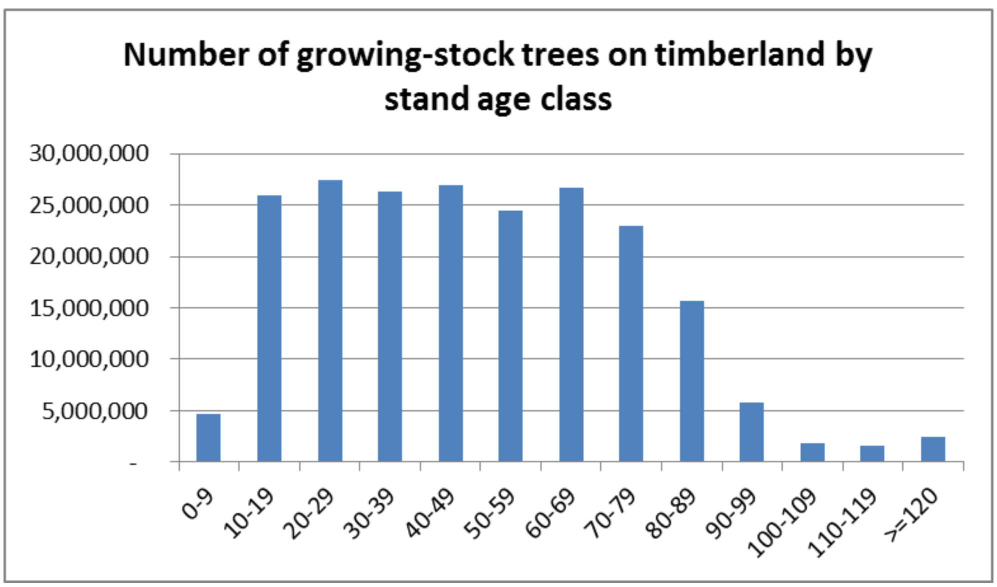


Figure 44.2. Growing stock trees on timberland by age class (FIA 2012).

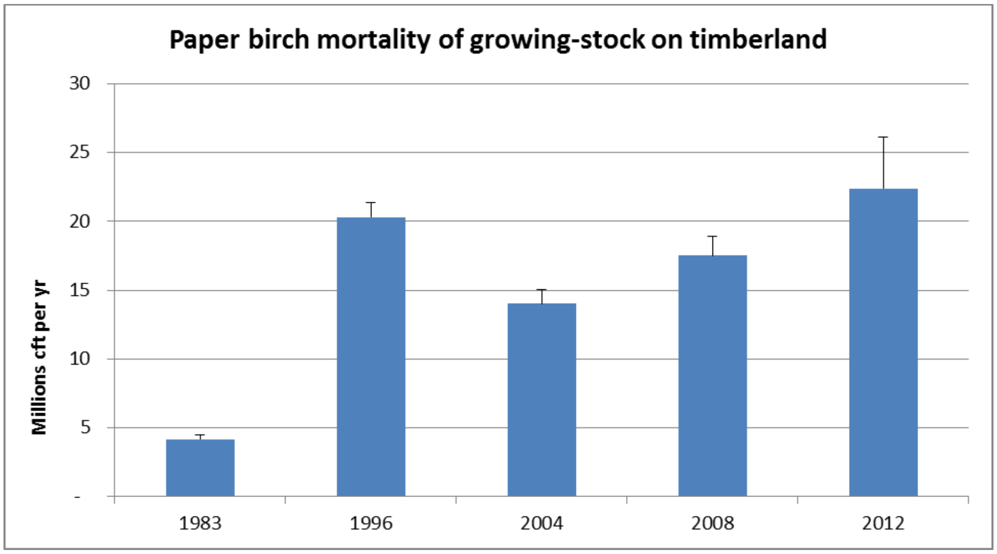


Figure 44.3. White birch growing stock mortality on timberland (FIA 2012).

3.1.3 Climate Change

White birch is a northern species adapted to cold climates, with its northern range extending to the limit of tree growth. It is seldom found growing naturally where average July temperatures exceed 70° F. Current modeling of tree response to climate change under high and low emissions scenarios predict that white birch abundance will decline in Wisconsin's forests and the optimum latitude/suitable habitat will move north perhaps out of the United States (Iverson & Prasad, 2002; Landscape Change Research Group, 2014). Currently, white birch occupies about 20% of the land area in the eastern US, that extent is predicted to decline to between 0% and 8% of land area by 2100. Under some conditions white birch is predicted to be extirpated as a major component of forests in Wisconsin (Iverson & Prasad, 2002; Scheller & Mladenoff, 2005; Iverson et al, 2008).

3.1.4 Forest Simplification

Forest simplification refers to a loss of species diversity and structural diversity, and an increased dominance of fewer species. The increase in sugar maple dominance that is occurring in northern hardwood forests is an example of simplification, as is the lack of features like large woody debris and tip-up mounds. At the landscape level, simplification and homogenization occur when forested patches become similar in size, shape, and composition. Land uses have led to homogenization and reduction of patch sizes, and creation of patch shapes that are less complex (Mladenoff *et al*. 1993). The cumulative effects of stand-level simplification make composition similar among patches. This is unlike the mosaic of forest patches found in remnant old growth forests, where white birch would have occupied large and small gaps created by disturbance (Crow *et al*. 2002). As an opportunistic early successional, intolerant species, white birch is dependent on the structural diversity of forest stands created by disturbance to maintain itself as a component of the forested landscape.

3.1.5 Landscape Pattern, Fragmentation and Edge Effects

Fragmentation describes certain kinds of landscape structure. Inherent fragmentation describes landscapes that are naturally heterogeneous due to the physical environment, such as landscapes with numerous small lakes and wetlands dispersed throughout a pitted outwash plain. Permanent fragmentation refers to long-term conversion of forest to urban, residential, or agricultural uses. Habitat fragmentation is defined as a disruption of habitat continuity, caused by forest harvesting or natural disturbance, which creates a mosaic of successional stages within a forested tract. This kind of fragmentation is shorter-term, affecting species while the forest regrows, and is a consideration in white birch management in northern Wisconsin, since white birch is an opportunistic species and relies on this mosaic of successional stages in a natural system. White birch regeneration is generally accomplished through the use of even-aged management, and dispersion of clearcuts throughout the forest creates differences in forest structure that are a type of habitat fragmentation.

In Wisconsin and elsewhere, the loss of forest habitat has a larger impact on species than shorter-term habitat fragmentation. However, area of habitat loss is often correlated with measures of fragmentation (e.g. patch size, distance between patches, cumulative length of patch edges, etc), making it difficult to quantify their separate effects. Habitat loss may result from second homes, or urban and industrial expansion. A drastic change in land cover, such as that which occurs after a clearcut harvest, represents a short-term loss of habitat for some species and a gain for others, including white birch. Dispersal can be affected if species or their propagules cannot cross or get around the open land and cannot find suitable habitat within it. The light winged white birch seeds are dispersed by wind and can travel great distances. Though seed fall drops off rapidly with distance from stand edge or clearcut opening. Seed dispersal and shade-intolerance make white birch somewhat tolerant of disturbance and fragmentation in the short term, though if habitat is lost due to permanent land use changes or fragmentation disrupts the disturbance mosaic, white birch will decline.

3.1.6 Incorporating Complexity into White Birch Management

Forest management generally simplifies forest structure and composition with some negative impacts in terms of biodiversity and resilience. Thus, maintaining structural and ecological complexity is increasingly an objective of sustainable forest management. The integration of complexity into forest management would involve designing harvest operations that maintain or enhance the capacity of forests to adapt to changing conditions, like climate change. Operationally, managing for complexity involves protecting or restoring complex patterns in forest structure. White birch is adapted to taking advantage of small and large canopy gaps created by disturbance. Management regimes which maintain complexity by mimicking natural disturbance and creating gap habitat within the forested landscape will be beneficial to maintaining white birch as a component of the forest resource.

3.1.7 Summary of Landscape Considerations

- White birch is a medium-sized, fast-growing tree that develops best on well-drained, sandy loams on cool moist sites. The species is commonly found in the mixed hardwood-conifer forests but may form nearly pure stands where they colonize areas disturbed by fires, logging, or other disturbance. White birch has declined and is declining in acreage.

- White birch is classed as a shade-intolerant tree. In the natural succession of species, white birch usually lasts only one generation and then is replaced by more tolerant species. Whenever possible manage maintain white birch stands instead of converting them to other cover types.
- White birch tends to be more abundant on the dry sites than on the wet or poorly drained soils. Where white birch and aspen *(Populus tremuloides)* occur in mixed stands, birch predominates on the cooler, moister sites, and aspen on the warmer, drier sites. Maintaining ecological complexity on the landscape will help maintain the white birch component.
- White birch is an early successional opportunistic species adapted to disturbance. It is opportunistic with regard to fire but is not fire-dependent. Fire can also seriously harm established stands. Because the bark of white birch is thin and highly flammable, even large trees may be killed by moderate fires.
- White birch is adapted to cold climates and models indicate that suitable habitat may decline in Wisconsin under climate change.
- White birch is an important source of food for birds. The redpoll, pine siskin, and chickadee feed on seeds; the ruffed grouse eats male catkins and buds.

3.2 Site and Stand Considerations

3.2.1 Soils

White birch grows on a wide range of soils, across most textural and drainage classes. In general, best development and growth occurs on loamy soils that are well to moderately well-drained. Comparatively poor development and growth are exhibited on dry (excessively drained) and wet (poorly drained) sites.

3.2.2 Site Quality

Site productivity is an important consideration when selecting a silvicultural prescription for regenerating white birch.

<u>Very Dry to Dry-Mesic Habitat Type Groups</u>
Birch regeneration on these sites is prone to desiccation, and as a result the only prescriptions likely to succeed are those that provide adequate shading, which aids in holding soil moisture and reducing soil temperature. Narrow strip clearcuts (less than 100 feet wide), and shelterwood harvests with 30-60% crown cover are the only two methods with potential to successfully regenerate birch on these sites. Deer browse may hinder regeneration in narrow strip clearcut areas because of small treatment areas. Depending on strip orientation, sunlight may be a limiting factor as well.

<u>Mesic to Wet-Mesic Habitat Type Groups</u>
Strip clearcuts up to 200 feet wide, shelterwood harvests with 30-60% crown cover and seed tree harvests with up to 20% crown cover have potential application. Birch will successfully regenerate, but competition from other species (especially aspen) can cause mortality. Unless

birch are released from competition, wider strip clearcuts and seed tree harvests will likely result in a mixed stand.

3.2.2.1 Range of Habitat Types

See Chapter 12 – Forest Habitat Type Classification System for information summarizing the system and the habitat type groups.

Within Wisconsin, the white birch cover type occupies about 3% of statewide forest land acres, and contains about 3% of net growing stock volume (FIA 2012). Approximately 77% of white birch cover type acres occur on northern habitat types, and 23% on southern habitat types. White birch as a species represents about 5% of statewide net growing stock volume on forest land (FIA 2012). Approximately 81% of white birch volume occurs on northern habitat type groups, and 19% on southern groups. Statewide, only about 33% of white birch species volume occurs within the white birch cover type. The northern hardwood type contains about 31% of white birch volume. Other cover types with significant white birch volume are aspen and oak.

Northern Wisconsin Habitat Types
In northern Wisconsin, the occurrence and relative growth potential of the white birch cover type varies by habitat type groups and habitat types (Table 44.3 and Figure 44.4).

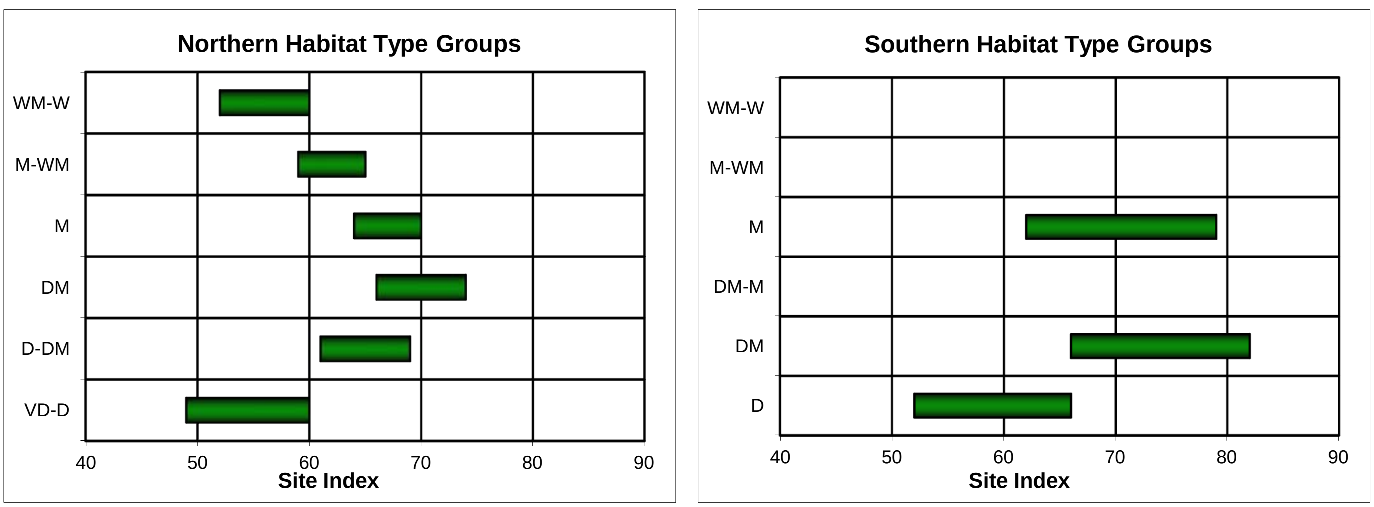


Figure 44.4. Site index for white birch by habitat type group (from FIA 2012). Bars indicate the 95% confidence limits for the mean. FIA data was insufficient to develop site index values for all habitat type groups.

Table 44.3. White birch cover type – estimated relative growth potential by northern habitat type group and habitat type.

Northern Habitat Type Groups	Estimated Relative Growth Potential for White Birch Cover Type[1]			
	Poor	Fair	Good	Excellent
Very Dry to Dry	PQE[2] PQG[2] PQGCe[2]	PArV PArV-U PArVAo[2] QAp[2]		
Dry to Dry-mesic			PArVHa PArVAm PArVAa PArVAa-Vb PArVAa-Po PArVPo[2]	
Dry-mesic				TFAa AVCl AVVb AVb-V AVDe ACl AVb AAt ATFPo
Mesic				AFVb[2] ATM ATFSt ATFD[2] ATD[2] ATDH[2] AAs AHVb[2] AFAd[2] AFAl[2] ACaCi AOCa[2] AH[2]
Mesic to Wet-mesic			PArVRh ArVRp ArAbVCo ArAbVC ArAbSn ArAbCo[2] TMC AAtRp ASnMi AAtOn[2] ASal[2] ACal[2] AHI[2]	
Wet-mesic to Wet	Lowland habitat types not defined region wide.			

1 – Estimation of relative growth potential for white birch cover type based on:
white birch cover type average volume/acre, white birch site index, and potential tree vigor and form.
2 – Currently, the white birch cover type rarely occurs. The species may occur as a rare to common associate.

The white birch cover type is a common cover type on all northern habitat type groups, representing 2-6% of group acres, and 1-9% of group volume.

- Approximately 37% of white birch northern cover type acres occur on mesic to wet-mesic sites; 20% on dry-mesic; 12-13% on dry to dry-mesic, mesic, and wet-mesic to wet; and 7% on very dry to dry sites.
- Approximately 35% of white birch northern cover type net growing stock volume occurs on mesic to wet-mesic sites; 23% on dry-mesic; 18% on dry to dry-mesic; 8-11% on mesic and wet-mesic to wet; and 5% on very dry to dry.

<u>Southern Wisconsin Habitat Types</u>
In southern Wisconsin, the occurrence and relative growth potential of the white birch cover type varies by habitat type groups and habitat types (Table 44.4 and Figure 44.4).

The white birch cover type is a somewhat common cover type on most southern habitat type groups, representing 1-3% of group acres, and 1-3% of group volume; the exceptions are mesic (phase) and mesic to wet-mesic where white birch is uncommon.

- Approximately 35% of white birch southern cover type acres occur on dry-mesic sites.
- Approximately 46% of white birch southern cover type net growing stock volume occurs on dry-mesic sites.

Table 44.4. White birch cover type – estimated relative growth potential by southern habitat type group and habitat type.

Southern Habitat Type Groups	Estimated Relative Growth Potential for White Birch Cover Type[1]		
	Poor to Fair	Good	Excellent
Dry	PEu[2] PVGy[2] PVCr[2] PVG	PVHa	
Dry-mesic			ArDe-V ArDe[2] AArVb[2] AArL[2] ArCi ArCi-Ph AQVb-Gr[2]
Dry-mesic to Mesic (includes Phases)			ATiFrCi[2] AFrDe[2] AFrDe(Vb)[2] ATiFrVb(Cr)[2] ATiDe(Pr) ATiCr(O) ATiCr(As) ATiDe-Ha[2] ATiDe-As[2] ATiDe ATiFrVb[2] AFrDeO[2]

Southern Habitat Type Groups	Estimated Relative Growth Potential for White Birch Cover Type[1]		
	Poor to Fair	Good	Excellent
Mesic (includes Phases)			ATiSa[2] ATiSa-De ATiFrCa(o)[2] ATiAs(De)[2] ATTr[2] AFTD[2] AFH[2] AFAs[2] AFAs-O[2] ATiFrCa[2] ATiH[2] ATiCa ATiCa-La ATiCa-Al[2]
Mesic to Wet-mesic		PVRh	
Wet-mesic to Wet	Lowland habitat types not defined		

1 – Estimation of relative growth potential for the white birch cover type based on:
white birch cover type average volume/acre, white birch site index, and potential tree vigor and form.
2 – Currently, the white birch cover type rarely occurs. The species may occur as a rare to common associate.

White birch height growth on good sites is moderate compared to other species such as aspen, cottonwood or balsam poplar. First year birch seedling can reach 18 inches on good sites but average about 5- 6 inches. Rapid early height growth is common; however, growth dramatically slows after 50 years. Through much of its range mature stands average 12 inches dbh and over 70 feet in height. Table 44.3 and Table 44.4 suggest growth potential and Figure 44.4 indicates site index on various habitat types with Wisconsin. The northern and southern dry-dry mesic and mesic habitat type groups tend to have better growth potential for this species.

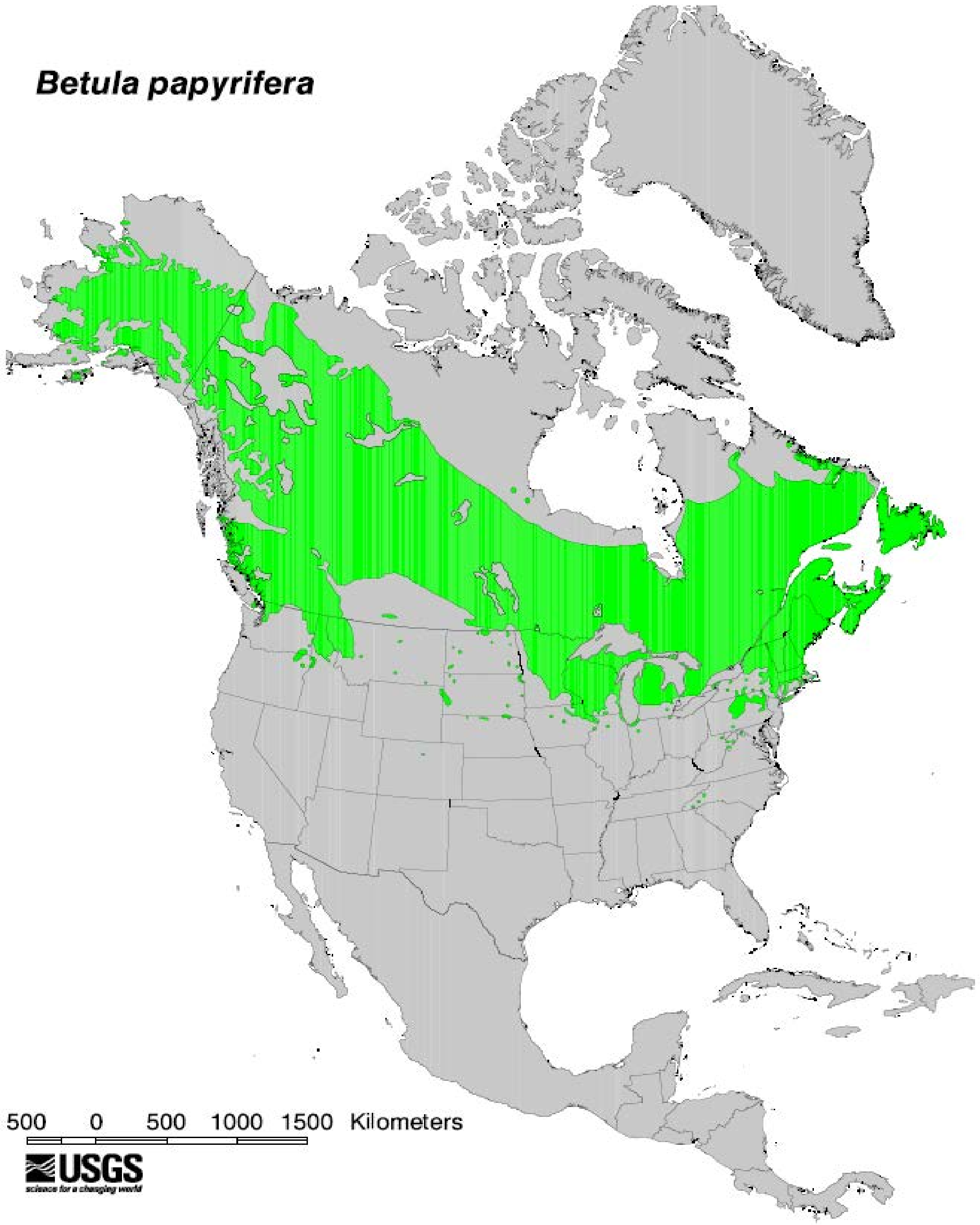


Figure 44.5. Native range of white birch (USGS map).

The range of white birch closely follows the northern limit of tree growth from Newfoundland and Labrador west across the continent into northwest Alaska; southeast from Kodiak Island in Alaska to British Columbia and Washington; east in the mountains of northeast Oregon, northern Idaho, and western Montana with scattered outliers in the northern Great Plains of Canada, Montana, North Dakota, the Black Hills of South Dakota, Wyoming, Nebraska, and the Front Range of Colorado; east in Minnesota and Iowa, through the Great Lakes region into New England. White birch also extends down the Appalachian Mountains from central New York to western North Carolina.

White birch is distributed across Wisconsin in many counties with the most cubic feet volume represented in Buffalo, Burnett, Douglas and Vilas counties (Figure 44.6). The counties with more cubic feet volume represented above have better growth potential reflected in the soils and habitat type.

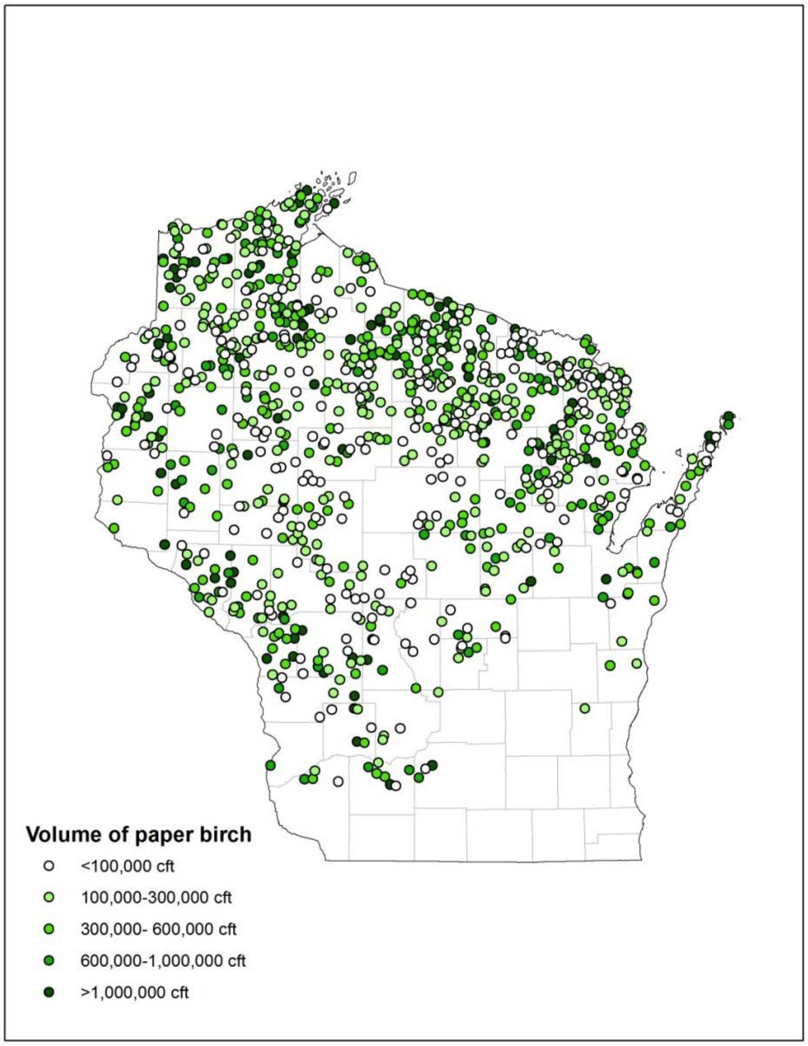


Figure 44.6. Volume of white birch from Wisconsin FIA plots (2012 data).

3.2.5 Wildlife

White birch stands make up a relatively small proportion of the northern forest and no wildlife species are exclusively associated with this cover type. However, white birch is a common associate in many timber types and it is a valuable wildlife tree regardless of its proportion in the stand. White birch is used for both food and shelter by a wide variety of wildlife. Most accounts of wildlife use are in the northern range of white birch. However, white birch provides important resources to a wide variety of wildlife species throughout its Wisconsin range. Maintaining white birch stands or as a component of other types will benefit wildlife throughout Wisconsin.

White birch foliage, twigs, and bark is palatable to browsing and gnawing mammals. Snowshoe hares, deer, and porcupines all feed heavily on white birch bark and twigs in winter months and browsing on leaves in summer and fall is important to deer.

White birch is a consistent seed producer with relatively regular large seed crops. Seed fall occurs in late summer and early fall but some seed falls during winter months. This is periodically an important food source for winter-resident songbirds such as black-capped chickadees and northern juncos. Small mammals also feed on the seeds of white birch.

The buds and catkins of white birch are important winter foods for all three of Wisconsin’s grouse species. White birch flowers early in the spring and attracts insects which are utilized by migrating songbirds.

White birch is a short-lived tree with soft wood. It rots rapidly after death. In some instances, the bark is more resistant to rot than the wood and the resulting snag may be a cylinder of bark around rotted wood. Bark characteristics sometimes produce areas where small mammals or birds can shelter under flaking bark. White birch bark is also used as nest material by some birds. These characteristics of white birch make it important for nesting and shelter by small cavity-dependent species and a number of bird species which are not cavity nesters.

Maintaining white birch in a variety of age classes will provide the full spectrum of wildlife benefits. No special management beyond maintaining vigorous white birch is called for by wildlife. In seed tree treatments, the residual left for regeneration purposes should be allowed to die and provide snags for wildlife. White birch can be maintained as reserve trees during regeneration harvests. Large-crowned or open-grown trees are the best candidates for retention. Retained trees can be individuals or within retention clumps. White birch tends to have high mortality when retained after stand harvest but dead and dying trees benefit wildlife species as snags and foraging sites.

3.2.6 Endangered, Threatened and Special Concern (ETS) Species

There are no Wisconsin Endangered, Threatened, or Special Concern species (ETS) known to rely, exclusively, on white birch. However, white birch can be found in a variety of forest types, and rare species can be found in examples of any of these types. Although white birch is not often the dominant species in a stand, it can contribute to stand diversity and provide cavity trees, snags, and other habitats.

Boreal forest is the natural community type perhaps most strongly associated with white birch, at least for forests where white birch is co-dominant or even dominant. These forests, found in the northernmost parts of the state and Door County, represent the southern extent of a forest type that is much more common further north in Canada. Some of these forests in Wisconsin were once dominated by white pine or other conifers, but they are largely composed of aspen now. A variety of rare species can be associated with boreal forest, including several bird species. For example, northern goshawk can nest in older white birch trees. Many boreal forest species utilize conifers, so maintaining or increasing the now greatly diminished conifers from these stands can benefit a variety of rare or uncommon species such as Canada warbler and northern flying squirrel; the latter also benefits from cavities, especially larger examples. Allowing some of these stands to succeed to conifers and grow older, especially near ravines, may benefit some rare plants such as spreading woodfern (*Dryopteris expansa*) and ram's-head lady's-slipper (Cypripedium arietinum) on some sites. Other rare plants include Chilean sweet cicely (*Osmorhiza berteroi*), white Mandarin (*Streptopus amplexifolius*) and broad-leaved twayblade (*Listera convallarioides*).

White birch is a less-abundant associate in other natural community types such as Northern Mesic Forest (northern hardwood or hemlock cover types) and Northern Dry-mesic Forests (white pine, red pine, and pine-oak forests). Here, white birch can add to the overall diversity of the site and provide ecological values. For example, large birch trees can provide excellent cavities and later become coarse woody debris, a feature that can be in short supply in stands managed for timber production. Users of this handbook are encouraged to learn more about these community types and their associated rare species at the Wisconsin DNR web site (https://dnr.wisconsin.gov/topic/EndangeredResources).

Whether a white birch stand is likely to support rare species will depend on certain stand characteristics, including its location in the state, the composition of the surrounding landscape, stand age, stand species composition, stand structural complexity, and whether certain microhabitats are present. For example, climbing fumitory (*Adlumia fungosa*) is commonly found near white birch on rocky or sandy slopes in northern forests. There are a number of other rare species associated with white birch mainly because they are found on rocky ledges in northern forests - e.g., large-leaved sandwort (*Moehringia macrophylla*) and narrow false oats (*Trisetum spicatum*). Often microhabitats that support rare species in forests can be accommodated without precluding active timber management in the majority of the stand; examples include moist or dry cliffs, ponds and small wetlands, seeps or other aquatic features, and pockets with prairie or barrens vegetation that can support rare plants and, sometimes, associated rare invertebrates like butterflies or moths.

Handbook users are encouraged to submit sightings for species on the NHI Working List (https://dnr.wisconsin.gov/topic/NHI). Electronic forms are available for this purpose.

3.2.7 Economic Issues

Most white birch is utilized by primary wood-producing industries as a pulpwood or biomass product, as trees are typically smaller in diameter at the time of harvest. Some higher quality sites may be capable of growing trees that are utilized for boltwood or sawtimber. Production of white birch veneer logs is limited to higher-quality sites with a site index of 60 or greater (Marquis et al 1969).

Secondary wood-producing industries favor white birch for turning because of the smooth texture of the wood, straight grain, and the ease with which it can be machined. Most hardwood users in the industry consider birch a part of their acceptable species mix. Some industries, on the other hand, are very dependent on the birch resource with birch being a greater percentage of the pulp mix. White birch is critical to the pulping process, primarily for the sugar and lignin properties therefore being important in the composition of pulp product.

Concerns on the availability of white birch have been raised by the forest products industry. The total volume of growing stock for white birch has gradually decreased over the inventory years from approximately 850 million cubic feet to 550 million cubic feet (Figure 44.7). The changes in the growing stock reflect the issues of maintaining white birch. These issues include forest health concerns, competition from undesirables, replacement by other desirable species; lack of disturbance to maintain the species and market demand for other species.

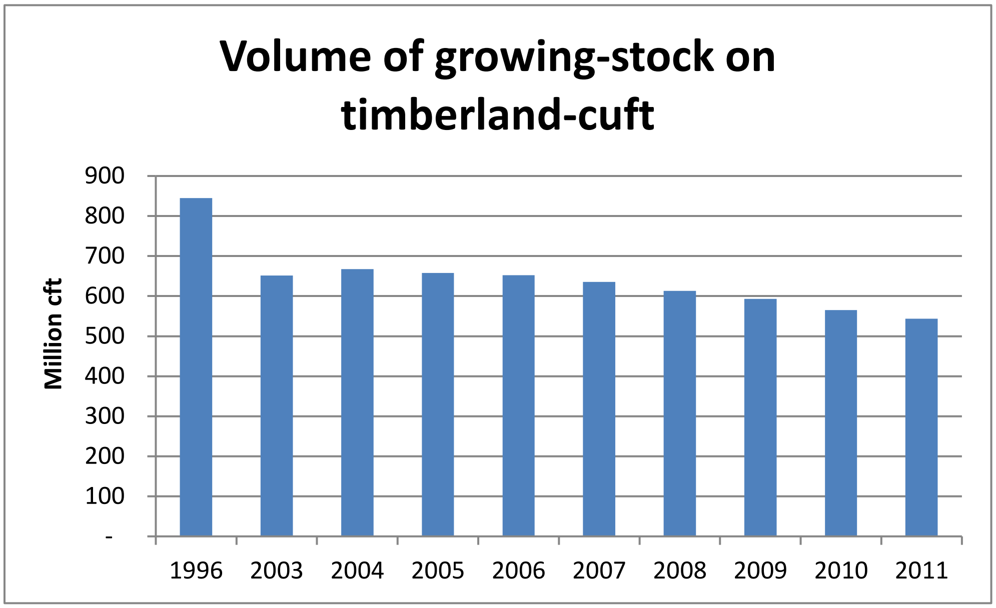


Figure 44.7. Volume of white birch growing stock in each inventory year.

3.2.7.1 Non-Timber Uses and Objectives

Although the predominant use of birch is by forest industry, non-timber uses of white birch may be the primary management goal on some parcels of land and have potential to be compatible with timber management.

Wiigwaas, or “white birch bark”, is known as a “cultural keystone species” to the Great Lake Ojibwe. Primarily the bark is the main use of the tree, however, many other parts of the tree are harvested such as branches, leaves, roots and sap. Bark is gathered in the spring and early summer and is used for crafts, shelters, medicines, ceremonial purposes and for food sources. The Great Lake Indian Fish and Wildlife Commission (GLIFWC) that represents 11 Ojibwe tribes of the Upper Great Lakes region has expressed concerns about the continued availability of the birch resource in the ceded territories. Concerns rise from the findings of a collaborative effort between GLIFWC and the USDA Forest Service FIA program (2004-2006) that has shown a decline in the white birch supply across the ceded territories. These findings may be due to insect and disease, drought, deer herbivory, cover type conversion and impacts from climate change. A report written in 1997 by GLIFWC personnel outlines management recommendations and highlights the need to perpetuate birch on appropriate habitat types (Lynch 1997).

Birch sap

Birch sap has been harvested for centuries in northern latitudes of Europe and North America. The sap is harvested in April and early May in a similar fashion as maple sap. Typically, sap is consumed straight from the tree, but also can be boiled down into syrup. Birch sap contains a much higher sap to syrup ratio than maple – about 100 gallons of sap are needed to make one gallon of birch syrup compared to 30 to 40 gallons of sap to make one gallon of maple syrup. The primary birch syrup production area of the United States is Alaska; however, very little birch syrup is produced commercially in the United States.

Birch bark

Both the outer bark and inner bark of birch trees have traditionally been used by Native people for crafts, medicines and for ceremonial purposes. The inner bark is typically boiled – either alone or with other plants – for medicinal purposes and has been used for dying cloth. Outer bark is utilized in sheets, strips, or pieces for a plethora of uses – including basketry, shoes, knife handles and sheaths, boxes, canoes, mats, and more recently as a medium for art projects.

The effect of outer bark removal on wood quality is not well documented. On trees where outer bark was removed with little damage to the inner bark, lumber quality does not appear to be affected, but veneer quality could be diminished due to light staining.

Branches, Twigs, Roots, & Leaves

Depending on the size, branches and twigs can be utilized from anything to furniture and decorative trim to whisk-brooms and crude ropes. Roots are typically used in basketry, but this use has historically been limited to northern Scandinavia. Root bark was used as medicine in Ojibwe culture. Little has been documented on the use of birch roots in North America. Leaves were traditionally used to make medicinal infusions, but leaf extracts are now commonly used in dyes and cosmetics.

4 STAND MANAGEMENT DECISION SUPPORT

4.1 Stand Inventory

Prior to development and implementation of silvicultural prescriptions, landowner property management goals must be clearly defined and stand conditions accurately assessed. Identifying objectives will determine the importance of white birch retention to the landowner as well as an individual site's ability to regenerate white birch.

White birch stand assessment should include quantifying variables such as:

- Present species composition

- Canopy, shrub, and ground layers
  - Sources of regeneration
  - Potential competition
- Stand structure
  - Size class distribution and density
  - Age class distribution
- Stand and tree quality
- Site quality - The habitat type is the preferred indicator of site potential. Other indicators of site potential include site index, soil characteristics, and topographical characteristics. Site has a strong influence on volume growth, potential yield, and regenerative capacity.
- Seed availability, soil scarification, moisture
- Stand and site variability
- Wildlife habitat

5 SILVICULTURAL SYSTEMS

A silvicultural system is a planned program of vegetation treatment during the entire life of a stand. The silvicultural system for white birch includes three basic components: harvesting, scarification, and regeneration. With the goal of regenerating white birch, even-aged management is the preferred method while addressing site-specific and species-specific conditions. The even-aged regeneration method generally accepted and supported by literature is:

- Shelterwood with scarification

Conditional (alternative) management recommendations include methods such as:

- Clearcut with standards
- Progressive strip clearcut
- Overstory removal and seed tree (based on a set of conditions that will ensure successful regeneration of this cover type). This section is discussed later in this chapter.

5.1 Seedling / Sapling Stands

Once established, white birch seedlings and saplings exhibit optimal vigor (growth and health) when exposed to (near) full sunlight. Crop trees that are maintained in free-to-grow conditions have the greatest potential to survive and to maximize growth and productivity. When stand is between 25-35 years, white birch stocking should be maintained at approximately 100 to 150 crop trees per acre (Safford 1983). This will provide enough crop trees to form a fully stocked stand when the trees reach merchantable size.

Following establishment, white birch seedlings and saplings can be outcompeted by other tree species resulting in birch mortality and reduced stocking and representation well into the poletimber stage. When aspen reproduces as an associate it often assumes dominance. On mesic sites, other hardwoods (e.g. red maple and white ash) can limit and outcompete white birch representation but are not nearly as significant competitors as aspen.

In instances of aspen or other species competition, release operations will generally be required to control competition and maintain tree vigor. Release operations are best implemented before desirable stems are physically suppressed and while there are still many individuals to choose from. Seedlings and saplings generally respond to release with significant increases in vigor, height and diameter growth. Release operations should be implemented early in the life of the stand, typically at 8-10 years of age. Release at an earlier or later stage will not have the same beneficial effect.

The recommended process is to select 50-200 crop trees per acre. A 10-foot release on all sides is sufficient but will likely require a second release 10-15 years later due to competing vegetation (Ave'Lallemant, 2013). For a single release to be adequate throughout the birch's lifespan, 20 feet on all sides is recommended.

5.2 Intermediate Treatments

5.2.2 Thinning

Commercial thinning may begin as soon as the stand attains merchantable size. Individual white birch designated for release should be vigorous, high quality dominant and co-dominant crown class. Although thinning birch is not readily applied, in the aspen cover type, it has been demonstrated to reduce the length of pulpwood rotations, increase volume increment, and increase sawtimber output. Thinning is an option on better quality sites with higher site index; sawtimber as one objective; vigorous trees with full crowns and/or aesthetic situations.

Intermediate treatments in birch pose some concerns, however. Thinning can cause mortality to some crop trees. The mortality is primarily because birch is shallow rooted and heavy equipment used during harvest will damage roots. Opening the stand may cause surface drying and stress crop trees. Nonetheless, considerations and timing of harvest can make thinning a viable option.

5.3 Natural Regeneration Methods

Table 44.5. Generally accepted and conditionally recommended practices.

Shelterwood	Clearcut with standards	Seed tree	Overstory removal	Strip clearcut
GAP	CR	CR	CR	CR

Note: GAP - Generally accepted practice; CR – Conditionally recommended practice

Note: The following recommendations assume the management objective is to maximize tree vigor and stand growth to optimize productivity (quantity and quality) of a variety of timber products. These methods may not be successful on all sites and may require artificial regeneration (direct seeding or other) if natural regeneration fails.

Important considerations when managing white birch include the following:

- Site quality
- Soils
- Uniform spacing of leave trees
- Timing – with seed dispersal and a good seed crop
- Scarification – mixing soil and organic material

- Maximize area scarified
- Harvest in snow free conditions and/or whole tree skidding timed with the harvest

The preferred regeneration method is **Shelterwood with Scarification**.

Other silviculture alternatives include **Clearcut with Standards**, **Seed Tree with Scarification** and **Progressive strip cut**; however, these methods can be less successful especially with the following limitations:

- Very dry, nutrient poor sites
- High temperatures hinder seed germination
- Desiccation
- Intense competition from undesirable vegetation
- Mortality of scattered, residual birch
- Deer browse especially on coppice regeneration
- Age of stand

5.3.1 Even-Age Regeneration Methods

5.3.1.1 Shelterwood with Scarification

The shelterwood method is an even-aged regeneration method designed to manipulate the overstory and understory to create conditions favorable for the establishment and survival of desirable tree species. The residual overstory serves to modify understory conditions, create a favorable environment for reproduction, and provide a seed source. The method is characterized by a preparatory cut of aspen (optional), seeding cut(s), and overstory removal over a period of time. At each cut, the most vigorous, dominant/co-dominant trees are normally retained and less vigorous trees removed.

Key aspects of applying shelterwood system in birch are optimizing seed availability uniformly throughout the stand, scarification to expose mineral soil, retaining partial shade to prevent desiccation, and controlling competing vegetation. Modifying light and understory conditions can enhance seed germination and seedling establishment. Exposing mineral soil through scarification techniques is essential to enhance germination success.

The shelterwood regeneration method is the recommended method to regenerate stands of white birch. In most cases there will be two cutting treatments: a seeding cut with scarification and the final overstory removal. Typically, this two-step shelterwood is implemented with a 2-4 year cutting interval, however, the interval can be extended longer if necessary to ensure the establishment of desirable regeneration. Follow-up release of regeneration may be necessary to maintain a fully stocked stand of white birch as described previously for seedling/sapling stands.

<u>Seeding Cut with Scarification</u>
Recommended process:

- Remove trees to create uniform, residual high crown cover of 30-60% of predominately well distributed, dominant/co-dominant birch. This shelterwood density will allow sufficient sunlight for germination and early growth while providing partial shade to maintain soil moisture and limit the growth of some competing species. On dry to dry-mesic sites, it may be important to maintain the upper recommended range of crown cover to provide some shade and prevent desiccation.

- Retain vigorous, high quality (best phenotypes) dominant and co-dominant white birch trees to serve as seed sources. The residuals should be retained uniformly throughout the stand to provide optimum seeding potential.
- Remove poor quality trees and less desirable species. If aspen is present as an associate do not cut aspen in order to minimize sprouting. Red maple stump sprouting may need to be assessed to determine the degree of competition. However, red maple stump sprouts appear to be less significant than aspen sprouts.
- Scarify – use the best available technique to expose mineral soil. See Scarification section below.

Overstory Removal Cut

The overstory removal cut is the final removal of overstory trees to release abundant, well-distributed, established regeneration and enable vigorous growth of the new stand. Following germination, allow white birch seedlings 2-3 growing seasons under the shelterwood overstory and then be liberated by the overstory removal cut. Typically, the overstory removal cut occurs approximately two years following the seeding cut but can be later depending on specific treatments applied. Seedling size and number are important to monitor. In some cases, overstory mortality can be significant, particularly if trees are retained for more than two years following the initial seeding cut. The residual trees are prone to desiccation, crown dieback and windthrow.

The adequacy of white birch regeneration (number, size, distribution) and potential competition should be evaluated after two growing seasons. Acceptable regeneration can generally be defined as a minimum of 2000 well distributed seedlings per acre that are vigorous and free-to-grow, ideally at least 1 foot tall (Perala 1989). Release of seedlings may be required to achieve a free-to-grow condition (soon after establishment); stump sprouts may benefit from thinning the clump to 1-2 stems.

During the overstory removal cut, care should be taken to preserve as much of the desired advance regeneration as possible. Protecting established regeneration can be attained through various methods such as winter logging through deep snow, harvest design, or type of equipment used during harvest. Retain only desirable regeneration and reserve trees. Excessive deer browsing is a significant deterrent to the establishment of young white birch, especially for stump sprouts.

Scarification

A scarified seedbed is critical to the successful regeneration of white birch. Attempting white birch regeneration without adequate soil scarification has led to many failed attempts. Germination and survival of white birch seedlings depend greatly on the condition of the seedbed. Mineral soil provides the best moisture and temperature conditions for germination and initial survival. However, nutrient elements are most available from the organic material (woody debris) in the forest floor. For establishment and early growth of the seedlings, it is important for the organic material to be preserved in the seedbed. Treatments such as scarification, discing, or burning help provide the best seedbeds for establishing white birch.

Scarification of the soil by breaking up surface organic horizon and mixing with surface mineral soil provides ideal seedbed conditions for germination and establishment of white birch seedlings. Logging with modern logging equipment during seasons with no snow and unfrozen soil may provide adequate scarification. For example, under these conditions, whole-tree skidding of trees with branches attached has the potential to adequately scarify the site with minimal residual slash. For this option to be successful, the skidding must cover as much surface area as possible while not damaging residual overstory birch trees. Also, following Best Management Practices for water quality and woody biomass guidelines are important considerations during this process.

Consider the timing of harvests relative to the production of good seed crops, seed dispersal and germination, and site preparation operations. Stands of white birch produce seed most years, with good seed crops every two years. The abundance of male catkins in the fall can indicate potential seed production the following year. Most seed are dispersed September to November. Germination begins once environmental conditions (light, temperature, and moisture) are suitable, generally the following spring. Following stand scarification most established seedlings develop from seed that was disseminated during fall and germinated the first spring thereafter (i.e. stored seed usually is not a major contributor, and seed disseminated following the initial recruitment and growing season usually results in little additional establishment).

When mechanically scarifying the site, maximizing the adequate amount of area scarified is critical or the result will be an understocked stand. Scarifying at least 50 % or more of the stand area is the recommendation from various birch trials in Wisconsin. Costs are variable depending on the site and operator's skill.

There are many different types of site preparation techniques including manual, mechanical, chemical, and burning. It is important to understand the site characteristics and match the site preparations accordingly. Manual is rarely used as it is appropriate for only the smallest plantings or most difficult sites. Burning has some logistical challenges but can be an option. Mechanical is the most reliable method to adequately prepare a site for natural regeneration of white birch. The method and extent of site preparation implemented can leave long lasting effects, impacting future management decisions.

Mechanical site preparation includes blading, raking, plowing, ripping, mixing, chopping, scalping, mounding, discing, dragging, trenching and rotovating. If done properly, using the appropriate equipment and timing, mechanical site preparation will provide the best prepared site for natural regeneration of white birch. The best time to conduct site prep work is usually July-November (prior to freeze up). It is even more beneficial if you can time the site prep with a good seed crop. Although a lot of birch seed will fall in the winter when there is snow cover, thousands will fall from August-November. A well-prepared site prior to seed fall is vital to successful natural regeneration of white birch.

Blading with the use of an angled blade on a dozer, with an attached salmon blade or brush rake, or dragging an anchor chain to scarify the soil prior to or following a harvest have been the most successful scarification methods used in Wisconsin. Whole tree skidding has been successful; however, close supervision of the skidding pattern may be needed to ensure successful scarification. In some trials, herbicide has been used to treat undesirable vegetation (aspen) after scarification but is not commonly done throughout the state.

5.3.1.2 Clearcut with Standards

The clearcut method is used to regenerate a stand by the removal of all woody vegetation during harvest and leaving some patches of birch or other species as standards. Regeneration can occur from natural seeding from adjacent stands or from trees harvested. Clearcutting is not a generally accepted practice for the regeneration of white birch because of certain variables such as desiccation, deer browse, site quality, and age of birch. If this regeneration method fails, supplemental planting or direct seeding would be recommended. Stump sprouting cannot be relied on to achieve a fully stocked stand due to deer and small mammal herbivory. In Wisconsin, the successful clearcut trials in birch have relied on late summer/early fall, presale scarification (salmon blade). These birch trials had site conditions suitable for this method including sandy loam soils with larger reserve areas of white/red pine and oak for seeding as well. Relying on seeding, timing of harvest and scarification in this method are important considerations.

5.3.1.3 Seed Tree with Scarification

Seed tree method is an even-aged regeneration method designed to encourage seed origin regeneration by leaving enough trees singly or in groups to naturally seed the area with adequate stocking of desired species. This method is also considered conditional management alternative because of certain variables such as soils and desiccation, deer browse, site quality, and age of birch. In this method only a few trees (typically 3 to 10 per acre) of the original stand are left, and this residual stocking is not sufficient to protect, modify, or shelter the site in any significant way. Seed trees may be removed after establishment or retained indefinitely. In Wisconsin, this method has been successful in areas where the soils hold more moisture (sandy loam to silt loam) and in better nutrient habitat types (ACl and AVCl; AVDe; AAT and other habitat types mentioned in (Table 44.3).

The seed tree regeneration method is often recommended to regenerate white birch in other regions (e.g. New England and Alaska). In the Lake States, the method has often failed because of two major reasons postulated: 1) frequent summer droughts (maintenance of soil moisture throughout the first growing season is critical to birch seedling survival), and 2) competition from aspen (Perala 1989). This method can be successful at times, but limitations include:

- Germination and establishment could be limited by high temperatures and lack of moisture
- Intense competition from other vegetation
- Scattered white birch trees often exhibit relatively rapid mortality (2-3 years) following stand harvest, thus limiting future options if initial regeneration attempt fails.

In white birch, the seed tree regeneration method most accurately applies to summer harvests (June to September). Seed trees retained will provide seed that will disperse in the fall (September to November); a good seed crop is required. Seeds germinate the following spring, and most regeneration should become established during the first growing season.

Recommended Process
At rotation, when a white birch stand is harvested, retain 3 to 10 dominant/co-dominant trees (with well-developed crowns) per acre. Scarification, timing with a good seed crop, is recommended. White birch reserve trees often decline and die within a few years providing snags. If possible, also retain other longer-lived tree species to develop into large living trees. If selecting this method, consider the limitations and species that have better success.

5.3.1.4 Progressive Strip Clearcut with Scarification

Clearcut is an even-aged regeneration method used to regenerate a stand by the removal of most or all woody vegetation Progressive strip clearcut is a variation of the clearcut method. In this method, the stand is removed using a series of strips harvested over 2-3 entries, usually covering an equal area on each occasion. The entire stand level strip removal process is completed within a period of time not exceeding 20% of the intended rotation (creating an even-aged stand). Typically, the uncut area serves as the primary seed source. Additional regeneration can come from seed previously dispersed and from trees during harvest operations, natural seeding from nearby stands, and sprouting. Regeneration is established during or following stand removal.

This method can be successful at times, but as with the seed tree method, limitations include:

- Germination and establishment could be limited by high temperatures and lack of moisture
- Intense competition from other vegetation especially in narrow strips.
- Deer browse has been observed as a significant factor in this silviculture method since the strip creates a pathway for deer to follow.

Recommended Process

- Cut narrow strips approximately 50-100 feet wide and retain 50-foot wide uncut strips. Ideally strips should be cut perpendicular to prevailing winds to aid in seed dispersal and desiccation. Retain only exceptional reserve trees if present.
- Scarify cut strips as described in “Scarification” section of this chapter. Scarification may be adequate from harvest operations alone.
- Allow 2-3 growing seasons to accurately assess regeneration success.
- Once adequate regeneration is present in the cut/scarified strips, a second harvest should be implemented in the remaining strips as described above. Leave individual birch seed trees or clumps of 6-7 seed trees every 100 feet to provide the seed source for these final cut strips.

5.4 Artificial Regeneration Methods

5.4.1 Direct Seeding and Planting

If white birch seed-producing trees are completely lacking or if harvest is done during a poor seed year and supplemental seeding is needed, it may be necessary to employ direct seeding (or planting) to obtain white birch regeneration. If direct seeding is a consideration, it is imperative that the seed be sown on a suitable seedbed by using scarification technique described previously. Scarification can be done prior to seeding. In some cases, seeding has been done during the late fall or in the winter to take advantage of the moisture from the snow to ensure germination in the spring.

5.5 Rotation Lengths

In even-aged silvicultural systems, the rotation is defined as the period between regeneration establishment and final cutting. The length of rotation may be based on many criteria, including culmination of mean annual increment (MAI), mean size, age, attainment of particular minimum physical or value growth rate, and biological condition. Ideally, the rotation length range would be defined by the maximization of MAI at the lower end and the average stand life expectancy at the upper end. However, growth and mortality rates vary among stands and can be affected by many variables, including site factors, silvics, stocking, silvicultural methods, insect and disease and units of measure.

Rotation age is defined as the age when environmental, economic, or cultural factors (such as site limitations, natural mortality, insect and disease issues, MAI, and management objectives) determine when regeneration efforts should be considered. The rotation ages provided are guidelines based on literature, empirical data, and professional experience. In application, foresters will need to regularly review stands in the field and exercise professional judgment concerning tree vigor and mortality and stand growth and productivity.

The option to rotate stands at the lower end of rotation age can be based on many conditions such as the stand occurring on drier, nutrient poor sites; disease and defoliation, and low vigor. Documenting the site and stand conditions are important when determining rotation age of the applicable stand.

Since forests provide a variety of benefits, different rotation ages can result in increased production of some benefits and reduced production of others. Landowner goals and objectives will provide the framework for rotation age determination. See the discussion under management considerations in the following sections to evaluate some benefits and costs (ecological, economic, social, and cultural) associated with different forest management strategies.

- **50 to 80 years** recommended rotation for timber management
    - Down to 50 years for poorer nutrient xeric sites and sites outside the natural range.
    - Up to 80 years for exceptional, nutrient rich mesic sites where higher value products such as saw logs and veneer can be grown through longer rotations given careful consideration of tree vigor and site capability.

- Extended rotation is not recommended for this short-lived, early successional species. However, some **vigorous** stands and vigorous individual trees on good sites could potentially be managed to 100 years or more.

8 APPENDICES

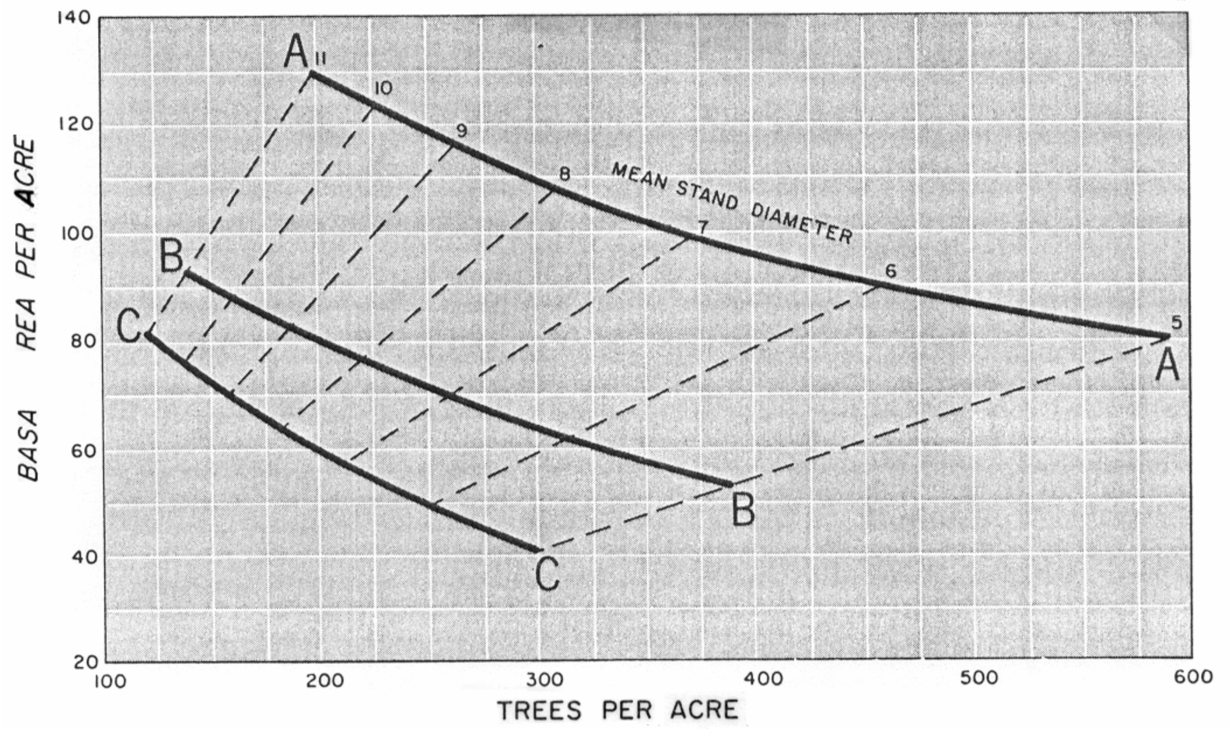


Figure 44.8. Stocking chart for white birch stands (Marquis et al. 1969).

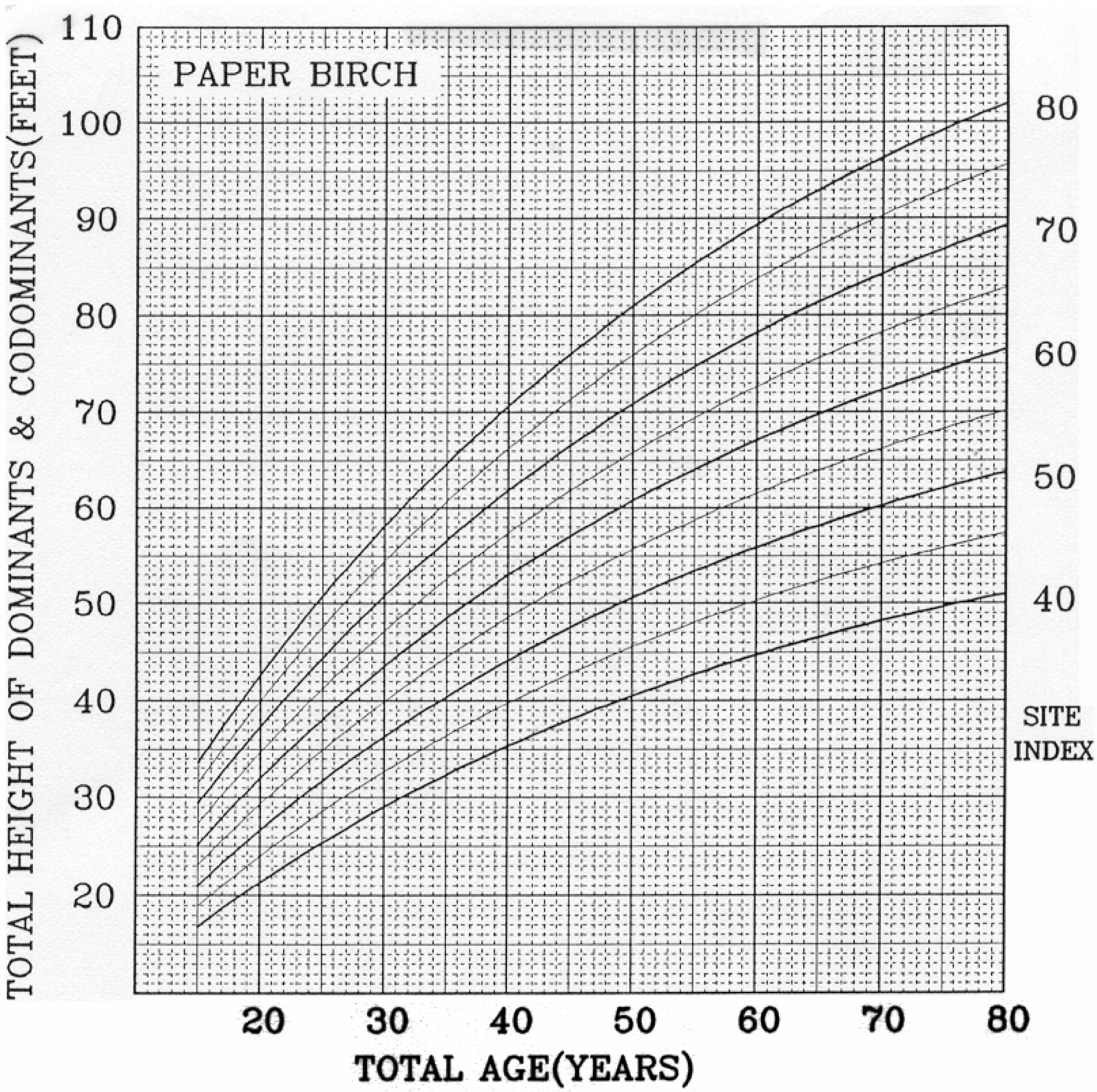
Stocking chart for white birch, displaying the relationship between basal area, number of trees, and mean stand diameter. The area between the A-line and B-line indicates the range of stocking where trees can fully occupy and utilize the site (fully stocked stand).

The stocking chart provides a statistical approach to guide stand density management (see Chapter 23).

- To utilize the stocking guide, statistically accurate estimates of at least two stand variables must be obtained, including basal area per acre, number of trees per acre, and/or mean stand diameter. For the birch stocking guide, these variables are measured only for main canopy trees (dominant, codominant, and intermediate crown class trees)
- The area between the A-line and B-line indicates the range of stocking where optimum stand growth and volume yield can be maintained.
    - The A-line represents maximum stocking. Maintaining stocking levels near (but below) the A-line will produce comparatively more trees, but of smaller diameter.
    - The B-line represents minimum stocking. Maintaining stocking levels near (but above) the B-line will produce larger diameter trees faster, but comparatively fewer trees.
    - The C-line shows the limit of stocking necessary to reach the B-line level in 10 years on average sites.
- When designing and implementing a thinning regime for a stand, do not reduce stand density to below the B-line or allow it to surpass the A-line.

- Thinning can occur at any time as long as stand density is maintained between the A-line and B-line. The A-line is not a thinning “trigger.” When to thin depends on management objectives, stand conditions, and feasibility.

Typically, thinning is implemented when average stand stocking is halfway or more between the B-line and A-line. Stocking is reduced to near but above the B-line. A general rule of thumb is do not remove >35% of the basal area in any one thinning operation. Crop tree concepts are applied to retain and focus growth on desirable trees, and order of removal concepts are applied to select which trees will be cut to achieve stand management objectives.



Paper birch (Cooley 1958, 1962)
Northern Wisconsin (104 plots); Upper Michigan (4 plots)
108 plots, number of dominant and codominant trees not given
Total height and age, anamorphic, equation not given
Add 4 years to d.b.h. age to obtain total age (BH = 0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	1.5980	1.0000	-0.0198	0.9824	0.0000	0.99	0.32	0.6
SI	0.6258	1.0000	-0.0198	-0.9824	0.0000	0.99	0.32	0.6

Figure 44.9. Site index curves for white birch in northern Wisconsin and upper Michigan (Carmean et al. 1989).

8.1 Forest Health Guidelines - Forest Health Protection (FHP)

Insect/ Disease/ Disturbance	Loss or Damage	Prevention, Minimizing Losses, Management Alternatives	References
		Foliage Insects	
Birch Leafminer *Fenusa pusilla*	Periodic outbreaks cause leaf destruction in early summer. All age and size classes are susceptible. Injury can cause growth loss. Combined with drought or other stress factors, birch may sustain branch dieback and become more susceptible to attacks by the bronze birch borer.	No direct controls are practical in a forest stand. Monitor heavily defoliated stands for birch dieback.	Conklin, James G. 1969. Insect enemies of birch. In: The birch symposium: proceedings; 1969 August 19-21; Durham, NH. Res. Pap. NE-146.Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 151-154.
Birch Skeletonizer *Bucculatrix canadensisella*	Periodic outbreaks cause leaf destruction in late summer. Late-summer leaf injury typically has minimal impact on tree health yet injury can cause growth loss. All age and size classes are susceptible. Combined with drought or other stress factors, birch may sustain branch dieback and become more susceptible to attacks by the bronze birch borer.	No direct controls are practical in a forest stand. Monitor heavily defoliated stands for birch dieback.	http://www.forestpests.org/vermont/birchskeletonizer.html
Forest Tent Caterpillar *Malacosoma disstria*	Periodic outbreaks cause defoliation in spring on aspen that may also defoliate nearby birch, basswood and oak. Outbreaks typically last 2-5	A natural enemy, *Sarcophaga aldrichi*, is a native parasite of the pupal stage that can significantly contribute to mortality of	https://www.fs.usda.gov/foresthealth/docs/fidls/FIDL-09-ForestTentCaterpillar.pdf

Insect/ Disease/ Disturbance	Loss or Damage	Prevention, Minimizing Losses, Management Alternatives	References
	years. Combined with drought or other stress factors, birch may sustain branch dieback and become more susceptible to attacks by the bronze birch borer.	FTC. Monitor heavily defoliated stands for birch dieback. Although aerial application of pesticides is not typically practical, this is an option. Information is available from your DNR regional forest health specialist.	
Spongy Moth ***Lymantria dispar***	Widespread heavy defoliation occurs at intervals of 5-15 years, outbreaks lasting 2-5 years. Attacks a wide variety of tree species including white birch.	Various parasitoids/predators and fungus, virus that kill larvae. Aerials spraying of Bt is control measure.	Gypsy moth Silvicultural Guidelines for Wisconsin. C. Brooks and D. Hall. 1997. DNR PUB-FR-123.
Main Stem and Root Pests			
Bronze Birch Borer *Agrilus anxius*	Larvae damage trees by feeding on the phloem and cambium, disrupting the flow of water and nutrients. Trees stressed by drought or defoliation are more likely to become infested and sustain dieback or die.	Management practices that cause stand disturbance during drought or heavy defoliation events, can make trees more susceptible to infestation by bronze birch borer. Monitor stands for birch dieback.	Conklin, James G. 1969. Insect enemies of birch. In: The birch symposium: proceedings; 1969 August 19-21; Durham, NH. Res. Pap. NE-146.Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 151-154.
Ambrosia Beetles	Adults tunnel into the sapwood, distributing a fungus that may result in stain and degrade of wood products. Tunneling is typically only in stressed trees.	No direct controls are practical in a forest stand.	Conklin, James G. 1969. Insect enemies of birch. In: The birch symposium: proceedings; 1969 August 19-21; Durham, NH. Res. Pap. NE-146.Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 151-154.

Insect/ Disease/ Disturbance	Loss or Damage	Prevention, Minimizing Losses, Management Alternatives	References
Yellow-Bellied Sapsuckers *Sphyrapicus varius*	Yellow-bellied sapsuckers cause very small wounds on the main stem as they feed on sap. Wounds typically close quickly and the trees compartmentalize stain and decay to a very small area. May cause degrade in wood products.	Consider leaving attacked trees in place, as sapsuckers tend to return to the same trees for feeding.	How to identify and control sapsucker injury on trees. M. Ostry, et al. 1976. USDA Forest Service.
Canker Rots *Inonotus obliquus*	Decay of wood. Canker rots are not compartmentalized, thus decay can be extensive.	Infection occurs most often through dead branch stubs, thus there is no practical way to minimize infection. During intermediate harvests, remove infected trees.	http://forestry-dev.org/diseases/ctd/Group/Canker/canker6_e.html
Armillaria Root Disease *Armillaria* spp.	Typically infects roots of trees stressed by drought, defoliation or bronze birch borer. Infection may cause decay of roots and/or the root collar. Infection further stresses trees, initiating decline and potentially mortality.	Management practices that cause stand disturbance during drought or heavy defoliation events, can make trees more susceptible to infection by Armillaria.	Shaw, Charles G. and Kile, Glen A. 1991. Armillaria Root Disease. USDA Forest Service Agriculture Handbook No. 691.
Dieback	Dieback or upper crown twig and branch mortality may occur in response to stress from one or a combination of several factors including drought, defoliation, infestation by the	If more than 25% of the crown is dead or dying, the tree will probably die within the next 5 years.	

Insect/ Disease/ Disturbance	Loss or Damage	Prevention, Minimizing Losses, Management Alternatives	References
	bronze birch borer or infection by Armillaria spp.		
Cankers ***Nectria galligena***	Causes a target-shaped canker, typically on the main stem. Wood behind canker is discolored but typically not decayed. Stem becomes more susceptible to breakage at canker face as canker deforms the stem beyond its normal size.	Infection occurs most often through dead branch stubs, thus there is no practical way to minimize infection.	

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Chapter 45

Black Walnut Cover Type

WISCONSIN
DEPT. OF NATURAL RESOURCES

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1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand Composition
The black walnut type is defined as having stand composition of 50 percent black walnut (*Juglans nigra*). However, it is present in southern Wisconsin to a very limited extent and is seldom abundant. Black walnut grows in many mixed mesophytic forests or less commonly forms pure stands along the forest edge.

Associated Species
Eastern red cedar (*Juniperus virginiana*), white oak (*Quercus alba*), red oak (*Q. rubra*), shagbark hickory (*Carya ovata*), American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), white ash (*Fraxinus americana*), black cherry (*Prunus serotina*), basswood (*Tilia americana*), American elm (*Ulmus americana*), hackberry (*Celtis occidentalis*), boxelder (*A. negundo*), and green ash (*F. pennsylvanica*). In general where white ash or red oak grows well, black walnut also thrives.

1.2 Silvical Characteristics*

Table 45.1. Summary of selected silvical characteristics.

Species	Black walnut
Flowers	Monoecious. Male -- catkins; female -- erect terminal spikes. Depending on latitude, flowers appear between April 10 and June.
Fruit	Spherical fruit, 1 to 2 inches in diameter, with a thick, semi-fleshy husk enclosing a woody, corrugated nut and an edible sweet, oily seed. Fruit ripens in September or October and drops shortly after leaf fall.
Seed Dispersal	By gravity and animals.
Good Seed Years	Irregular, perhaps twice in five years. Open-grown trees may begin producing fruit as young as 4 to 8 years., but the minimum seed-bearing age for commercial quantities of seed is about 12 years. Best seed production begins at 30 years of age and continues for about 100 years.
Germination	Many seedlings germinate from the nuts buried by squirrels. Normal freezing and thawing usually break dormancy the following spring, but germination is often delayed until year 2. Seedlings emerge in April or May of the first or second spring.
Seed Viability	Up to four years if stored in outdoor pits. Losses to squirrels and other rodents severely limit the success of direct seeding unless mechanical barriers are used to protect seeds.
Seedling Development	On deep, rich, moist soils, young seedlings may grow as much as 3 ft. the first year and double in height the following year. Growth is not as rapid as that of white ash but surpasses growth of the oaks. Height growth peaks in late April to May and ends by middle July to early August.
Growth	On the best sites, young trees grow 2 to 3 ft. per year. On less favorable sites, trees can attain heights of 30 to 40 ft. and diameters of 5 to 8 inches in 20 years. Trees 130 ft. tall and 100 inches in diameter have been reported in Wisconsin. Black walnut matures in 150 yrs. but may live to 250.

Vegetative Reproduction	Stumps usually sprout freely, but sprouts will develop heart rot or other decay from parent trees if they originate high on older stumps.
Shade Tolerance	Intolerant
Root Zone Antagonism	The growth of many species is inhibited in the root zone of black walnut. This effect is attributed to a toxic substance, juglone, which is present in walnut leaves, roots, and nut hulls. This compound is known to affect tomatoes, alfalfa, and conifers.
Major Pests	Black Walnut Pest Management Guidelines are included at the end of this chapter.

* From Fowells (1965).

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

The management objective should be identified in relation to other land management objectives and be based on site potential. Possible alternatives include managing to produce the maximum quantity and quality of veneer and sawtimber, maintaining black walnut where it exists, and expanding the type within ecological limits.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.2 Site and Stand Considerations

3.2.1 Soils

Good soil is perhaps more important for black walnut than for any other species. The most important soil characteristics are texture, depth, and drainage.

The best walnut sites are deep loams, loess soils, and fertile, well-drained alluvial deposits. Good agricultural soils are generally the most favorable sites. Soils should be deep (preferably four feet or more to bedrock or water table), well-drained, moist (either floodplain, or northerly or easterly aspect), fertile, and nearly neutral in pH.

Other limiting characteristics include solum depth, and the presence of sand and gravel or clayey layers. Soils that are somewhat poorly to poorly drained are not suitable. External factors such as frost hazard, slope, aspect, and possibility of prolonged flooding are also important in site selection.

3.2.2 Site Quality

A general method (in the absence of known habitat types) for determining site quality is the use of site index curves (See Chapter 15 of this Handbook). The site index for black walnut can be determined from if walnut trees 15 years of age or older are present in the stand of interest. Do not manage for walnut if the site index is less than 40.

5 SILVICULTURAL SYSTEMS

5.2 Intermediate Treatments

5.2.1 Stem Quality

Pruning: Open-grown trees, as well as forest-grown trees, can always benefit from lateral pruning. Pruning should start before branches are two inches in diameter but should be suspended in closed stands as branches grow larger than three inches. Since a larger pruning wound can be tolerated by open-grown walnuts because of their faster growth, branches up to four inches in diameter may be pruned on open-grown trees. Dead branches of all sizes may be removed at any time.

5.2.2 Thinning

Release: Any walnut tree that is healthy, has a bole likely to make veneer or a high-quality log, and is small enough that it can be left to grow for at least ten more years should be considered for release. Three-fourths of the released crown should be at least five feet from the crowns of adjacent trees. The crowns of released trees, as well as the surrounding crowns, should be expected to expand rapidly.

Bole sprouting should also be expected on released trees. However, most of the sprouts will occur above the butt log so little extra pruning will be required.

5.3 Natural Regeneration Methods

<u>Managing Natural Stands</u>

Regeneration: If the walnut trees to be harvested are scattered individuals in a mixed forest, the recommended regeneration methods for the specific forest type should be followed.

If the soil type appears adequate for good walnut growth, planting should be done the year following the regeneration cut. Fifty seedlings per acre should be sufficient.

If walnut is to be harvested from a pure stand or plantation, the surest way to regenerate is by planting seedlings. Not enough is known yet about regenerating a pure stand or plantation by other methods to ensure success. Natural or planted seedlings must be released from shade after a few years, otherwise the number of surviving seedlings will decrease by two-thirds each year.

Fertilization: Research on this subject is not completely consistent, but in general:

a. release often increases diameter growth as much as fertilization does, if not more, and

b. nitrogen stimulates diameter growth more than phosphorous or potassium does.

If fertilizing is mandated, select sawlog-sized trees (greater than 15 inches) and spread 10 pounds of urea around the base of the tree over an area about 10 yards in diameter.

Treatments can be repeated at five-year intervals. Several similar trees should be left unfertilized to verify that the fertilized trees are responding to treatment.

Harvesting: Timing of the final harvest depends on market conditions and the potential increase in value if harvesting is deferred.
Most black walnut is grown to produce veneer and sawlogs. There are no standardized specifications for veneer trees. Veneer buyers have their own systems for selecting and evaluating potential trees. The seller can obtain a fair market value for his timber through competitive bidding, but there is no objective procedure for assessing market value of walnut veneer logs. Sawlogs can be evaluated more objectively using standard tree grades and current selling prices.

Although black walnut matures in about 150 years and may live to 250 years of age, economic maturity is the consideration for private landowners.

a. Slow-growing trees should be harvested as soon as they reach sawlog size (12 to 14 inches DBH).

b. Trees with average growth rates on medium sites (estimated at 8 to 12 rings per inch) should be left until they are greater than 16 inches DBH.

c. On good sites (estimated at 3 to 8 rings per inch), diameters of 20 to 24 inches DBH can be achieved. Leaving trees to grow larger than 24 inches DBH does not appear to be economically feasible for a reasonable return on a landowner's investment.

5.4 Artificial Regeneration Methods

In plantations, even-age management with periodic thinnings based on crown competition factor (CCF) control. In natural stands, single tree selection.

<u>Managing Plantations</u>
Most plantations have been disappointing due to poor growth or quality of the trees. This may be partly due to off-site planting or overstocking, but livestock grazing has also contributed to plantation failure, especially in the Midwest (Fowells, 1965).

Seed Source: Studies have shown that walnut trees from seeds originating south of the plantation site grow for a longer period during the growing season than those of local or northern origin. Seed sources located up to 200 miles south of the intended plantation site should be used (Schlesinger and Funk, 1977).

Seedling Selection: Only large, vigorous, well-balanced seedlings should be planted. Large seedlings outgrow small ones on a wide variety of sites. Seedlings 1/4-inch or larger in diameter (measured above the root collar) are recommended. The root may be pruned to 8-10 inches prior to planting but this step is not essential.

Site Preparation: In old fields, it is neither necessary nor desirable to destroy all herbaceous vegetation before planting. Strips mowed at the same spacing as the intended planting will expedite the planting job and create strips of weeds providing wind protection for developing seedlings. In brushy fields, however, brush should be removed before planting.

For grass and weed control, an herbicide may be used. Confirm your choice of herbicides with the state herbicide specialist before beginning, however. Be aware of the dangers in using herbicides. Read and follow label directions. Keep post-emergent herbicides off trees.

Planting Methods: Several planting methods are suitable for planting walnut seedlings. The KBC planting bar, a 12-inch tractor-mounted post hole auger, or a standard tree planting machine can be used. Care must be taken in all cases to ensure that seedlings are planted at the proper depth (the root collar should be about one inch below ground line). All seedlings should be checked after planting to make sure they are upright. Spring planting is recommended to aid in controlling competing vegetation around newly planted seedlings.

a. Spacing: In plantations intended for timber and veneer production, trees should be planted on a 10 ft. x 10 ft. grid. Plantations established at this initial spacing can be thinned from 436 to 23 trees per acre through a sequence of five thinnings (Figure 45.2. Black walnut stocking per acre for tree 8 to 25 inches in diameter (Schlesinger and Funk, 1977).

b. (Table 45.2). Irregular spacings such as 8 ft. x 12 ft., 6 ft. x 8 ft., or 7 ft. x 9 ft. may be preferable in some situations.

c. Interplanting: Other trees or shrubs may be interplanted with walnut for any number of reasons: to meet aesthetic goals, to provide wildlife cover or food, to yield an intermediate crop such as Christmas trees, or to serve as trainers or nitrogen-fixing species to stimulate black walnut growth.

White pine appears to be best suited for forcing height growth and providing an intermediate Christmas tree crop.

Maintenance:

a. Weed Control: After site selection, weed control is the next most important factor in establishing walnut plantations. Weeds and grasses must be controlled around each walnut seedling for the first 3 to 5 years to increase survival, promote faster growth, and to prevent insect and meadow vole damage. Walnut trees grow faster when weeds are controlled by herbicides rather than by mulching or cultivation.

b. Corrective Pruning: Corrective pruning should not be confused with lateral pruning; the latter is intended to develop knot-free wood, whereas the former is to help the tree develop a strong central leader and grow upright with few forks. Corrective pruning is needed when terminal damage has occurred from late spring frosts, insects, or deer browse.

Corrective pruning is best done during the dormant season after late spring frosts and winter deer browse. Some pruning in June or July may be done to remove multiple stems. The guiding principle when pruning is overall tree balance. Any leader at the same height as the central leader will force the central leader away from it. When the competing leader is removed, the central leader has the opportunity to adjust and regain balance.

c. Lateral Pruning: To produce a stem free of knots, it is necessary to periodically remove lower branches as the walnut tree increases in height until 17 ft. of bole are limb-free. Branches should be pruned before they are 2 inches in diameter to minimize damage and promote rapid healing. Pruning wounds made during the dormant season tend to heal more rapidly and sprouts from dormant buds are less likely to develop. If sprouts do develop, they should be promptly removed.

Lateral pruning should begin when the trees are 10 ft. in height. Prune approximately 100 potential crop trees per acre. No more than 25 percent of the live crown should be removed in a single year. The live crown/length ratio should be maintained at no less than 50 percent.

d. Thinning Objectives:
   i. to maintain rapid growth of all potential crop trees for as long as possible while the trees intended for the final harvest are being selected, and
   ii. to grow the trees that will be removed in thinning operations to a size sufficient to yield saleable intermediate products.

The rules for thinning black walnut are based on the Crown Competition Factor (CCF), a measure of competition that integrates tree size and the number of trees per unit area. Management objectives for timber and veneer production should maintain a CCF near 110. For optimum growth of individual trees on dryer sites, lower stocking levels may be required.

In using CCF to guide the thinning decision, the manager must select upper and lower CCF levels between which the plantation stocking will be maintained. When the upper level is reached, the plantation should be thinned back to the lower level. The difference between the upper and lower levels determines how often thinnings will be required (Figure 45.1 and Figure 45.2).

Use CCF to determine when to thin and how many trees to leave. The selection of crop trees must be made on-the-ground. In contrast to initial conifer thinning strategies, strict mechanical spacing for black walnut would defeat the purpose of leaving the best possible crop trees for eventual harvest. Thinning should also be planned so that each remaining crop tree will have had at least one competing neighbor removed.

For mixed stands, and for overstocked plantations (i.e., CCF = 160 or more), stocking guide thinnings are not appropriate. The better approach for both mixed stands and overstocked plantations is crop tree release following the guidelines for single tree culture (see below, "Natural Stands - Release"). The reason for this precaution is that reducing the stocking level to the lower CCF in one operation may result in epicormic branching. After overstocked plantations have been thinned, they can be brought under the stocking guide procedure.

e. Fertilization: On high quality sites, soil nutrients are not usually limiting to walnut growth. On mediocre sites, tree growth may be increased by fertilization, but the results may not be worth the investment. As a rule, fertilizing walnut plantations is not recommended.

8 APPENDICES

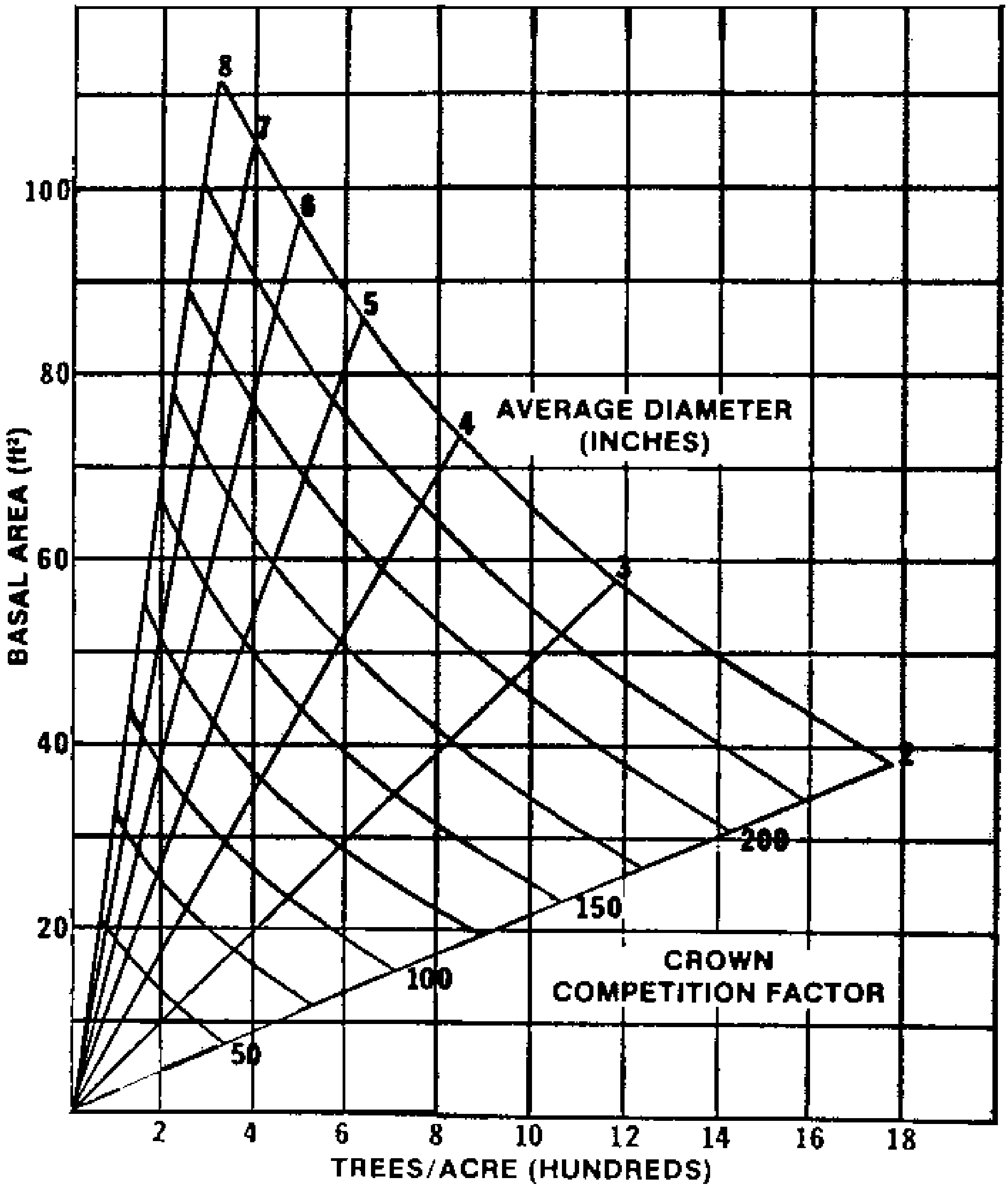

Figure 45.1. Black walnut stocking per acre for trees 2-8 inches in diameter (Schlesinger and Funk 1977).

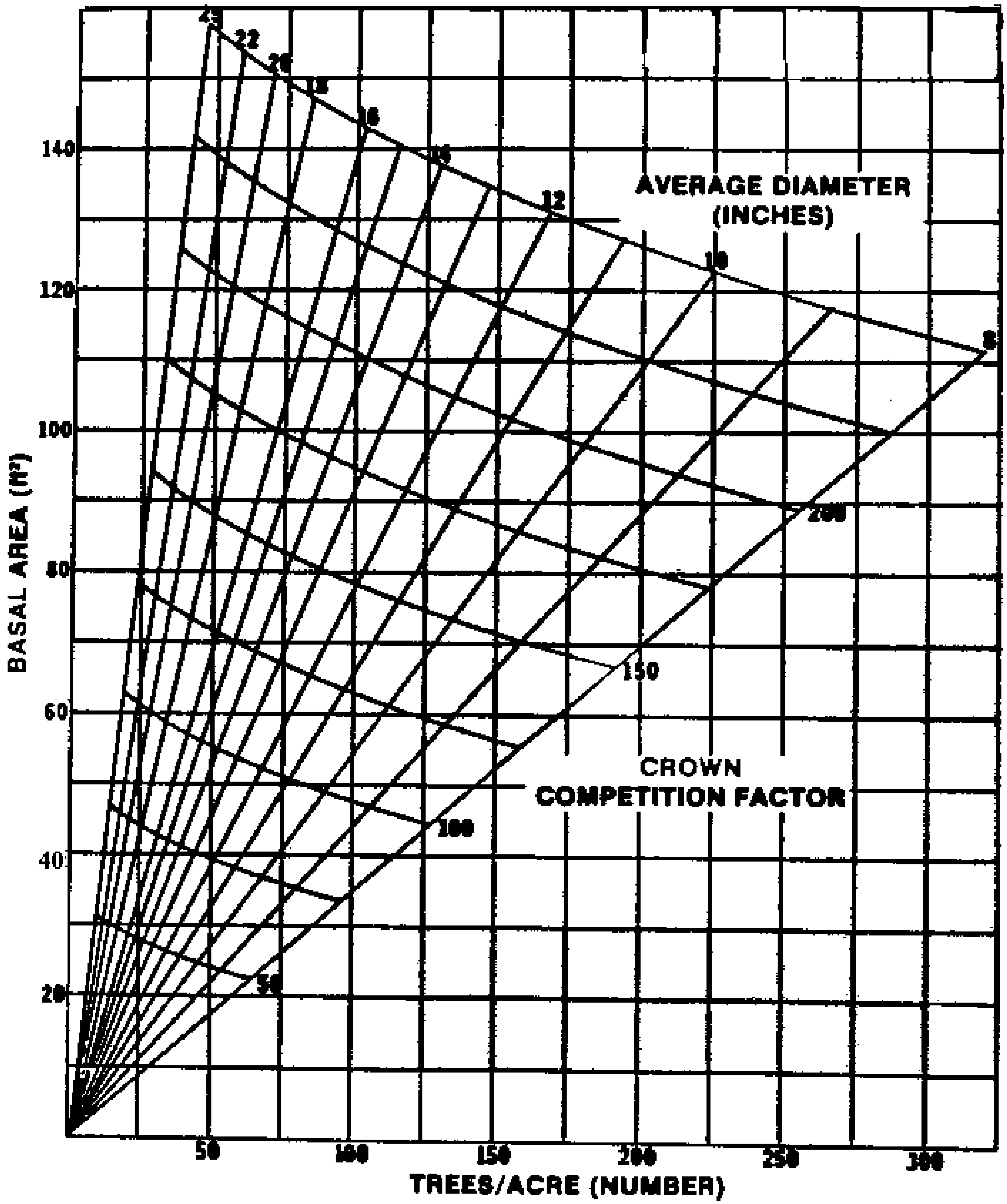

Figure 45.2. Black walnut stocking per acre for tree 8 to 25 inches in diameter (Schlesinger and Funk, 1977).

Table 45.2. Black walnut thinning schedule for timber and veneer production.*

	Before thinning Trees/acre (number)	Average DBH (inches)	After thinning Trees/acre (number)	Average DBH (inches)
1st Thinning	436	3.5	235	4.0
2nd Thinning	235	5.6	131	6.2
3rd Thinning	131	8.4	73	9.1
4th Thinning	73	12.1	41	13.0
5th Thinning	41	16.9	23	18.0
Harvest	23	23.4	---	---

* For timber and veneer production, an upper CCF of 110 and a lower CCF of 70 appear best. Assuming a 10 ft. x 10 ft. spacing at time of planting the above thinning schedule would be applied. The first two thinnings will most likely be non-commercial (fuel wood or possible home use). The third thinning could be used for small specialty products.

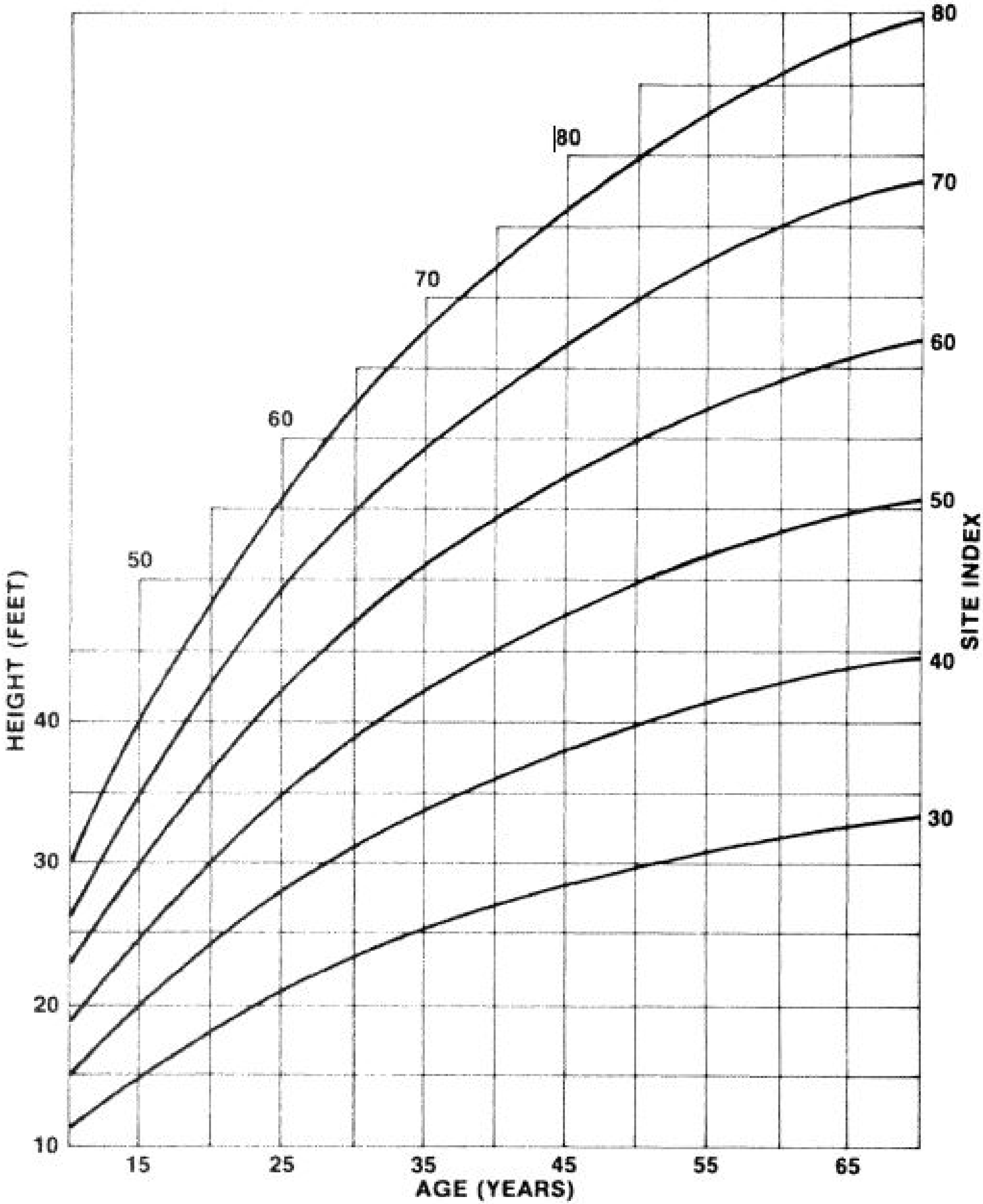

Figure 45.3. Site index curves for black walnut (Schlesinger and Funk 1977).

8.1 Forest Health Guidelines - Forest Health Protection (FHP)

HAZARD	LOSS OR DAMAGE	PREVENTION, MINIMIZING LOSSES AND CONTROL ALTERNATIVES	REFERENCES
Walnut caterpillar	Late summer defoliation. Normally an individual branch may be defoliated by a single colony and little growth loss occurs. During outbreaks, heavy defoli-ation may occur in closely spaced sap-lings and in individual, large open-grown trees, but seldom in closed natural stands. Heavy growth loss and twig dieback may occur. Following seed crops may be stunted. Trees heavily defoliated 2 years may die.	1. Do nothing and accept defoliation. 2. Clip off twigs with colonies or larvae. 3. Scrape caterpillars off molting mat on tree trunk. 4. Spray small larvae with the biological insecticide, ***bacillus thuringiensis***. 5. Spray medium to large larvae with chemical insecticide.	How to Identify and Control the Walnut Caterpillar. M. Farris, et al. 1978. USDA Forest Service.
Fall webworm	Mid- and late-summer defoliation of individual branches. Seldom serious.	1. Do nothing and accept defoliation. 2. Pull webs off branches. 3. Spray with chemical insecticide.	How to Diagnose Black Walnut Damage. B.C. Weber, et al. 1980. USDA Forest Service. Gen. Tech. Rep. MC-52.
Walnut Anthracnose and ***Mycosphaerella*** Leafspot	Discoloration and loss of foliage in mid and late summer. Causes growth loss and reduces nut quality.	Control is seldom required. In stands with repeated heavy damage, consider: 1. Nitrogen fertilization. 2. Disking down leaves in autumn (fungus overwinters in leaf stems). 3. Interplant walnut with autumn olive or Russian olive. 4. Control weeds when trees are young to reduce humidity.	How to Identify and Control Leaf Spot Diseases of Black Walnut. W.M. Black, et al. 1977. USDA Forest Service. How to Identify and Control Black Walnut Mycosphaerella Leaf Spot. K. Kessler. 1985. USDA Forest Service NCFES.

BUD, SHOOT AND TWIG PESTS			
Case bearers (***Acrobasis*** sp.)	Destruction of buds and shoots in spring cause main stem deformity, height growth loss of saplings, and loss of nut crop.	1. Do nothing; accept deformity. 2. Apply corrective pruning to improve form. 3. Plant at close spacing (or interplant with another species) to force trees to grow straight regardless of shoot damage. 4. Apply chemical insecticide shortly before bud break in late April.	Walnut Insects and Diseases. Workshop Proceedings. USDA Forest Service. 1979. Gen. Tech. Rep. NC-52. 100pp.
Tree hoppers	Egg laying under bark may kill twigs. Normally not serious; occasional heavy damage causes stunting of saplings.	Control seldom necessary.	How to Diagnose Black Walnut Damage. B.C. Weber, et al. 1980. USDA Forest Service. Gen. Tech. Rep. NC-52.
White-tailed deer	Browsing causes deformity and height growth loss of seedlings and young saplings.	1. Intensive hunting. 2. Repellents (variable success). 3. Corrective pruning to improve form. 4. Remove heavily damaged stems during thinning. 5. Use protective tubes.	Deer. Scott Craven. 1983. In: Prevention and Control of Wildlife Damage. Univ. Neb. Ext. Publ.
Frost damage	Late frosts in low lying areas. Kills foliage and new shoots causing growth loss and deformity of main stem.	1. Avoid establishing walnut stands in known frost pockets. 2. Apply corrective pruning to improve form. 3. Establish dense stand to force trees to grow straight regardless of shoot damage.	How to Diagnose Black Walnut Damage. B.C. Weber, et al. 1980. USDA Forest Service. Gen. Tech. Rep. NC-52.

Previous View

MAIN STEM PESTS			
Stem canker	Canker on main stem, usually kills whole tree or top. Sprouts develop below canker. Canker usually more prevalent on bottomland sites than upland. Outbreaks may cause severe mortality.	1. Remove diseased material. 2. Prune trees when dormant. 3. Prune dead branches as well as live. Do not allow dead branches to remain on tree. Dead limbs may provide an entry point for canker infection. 4. Inter-plant with other species.	How to Diagnose Black Walnut Damage. B.C. Weber, et al. 1980. USDA Forest Service. Gen. Tech. Rep. NC-52.
Perennial target canker (***Nectria***)	Canker on main stem causes wood defect, stunting or mortality of sapling to sawlog sized trees.	Cut and remove infected material from stand including other infected hardwoods before April 1.	How to Diagnose Black Walnut Damage. B.C. Weber, et al. 1980. USDA Forest Service. Gen. Tech. Rep. NC-52.
Yellow-bellied sapsucker	Wounding of thin bark of saplings and pole-sized trees causes wood defect. May kill tree directly, may allow entry of canker or decay fungus.	Leave attacked tree in place. Birds will attack same tree repeatedly and limit damage to one tree at a time.	How to Identify and Control Sapsucker Injury on Trees. M. Ostry, et al. 1976. USDA Forest Service.
Meadow vole/meadow mouse	Gnawing on bark at base of tree during winter results in mortality of trees up to 5 years old. Heavy grass concentra-tions support population build-up and may result in heavy tree mortality.	1. Control grass and weeds first 5 years after planting. 2. Apply rodenticide baits.	Meadow Mouse Control. Scott Craven. 1981. Univ. Wisc. Ext. Leaflet A2148.

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Chapter 46

Swamp Hardwood Cover Type

WISCONSIN
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1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand Composition
Any combination of black ash (*Fraxinus nigra*), green ash (*Fraxinus pennsylvanica*), red maple (*Acer rubrum*), silver maple (*Acer saccharinum*), swamp white oak (*Quercus bicolor*), and elms (*Ulmus spp.*) comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands. This type occurs on wetlands characterized by periodic inundation (fluctuating water table near or above the soil surface) and nearly permanent subsurface water flow.

Swamp hardwood stands are often composed of relatively pure black ash, although mixed stands are commonly found. Black ash with its rapid growth rate initially, dominates the structure and composition in this cover type. In old growth black ash stands, an uneven age structure with gaps is usually exhibited depending on the natural disturbance regime at the site (wind throw and flooding).

Northern and Southern Hardwood Swamp are the plant communities mentioned in the Endangered Resources section of this chapter. The latter tends to be more represented in the southern part of the state having more green ash and silver maple as a component within the forest.

Similar but distinct community types are:

- Bottomland hardwood forests occur on floodplains and some terraces mostly in southern part of the state. Defining species are silver maple, green ash, swamp white oak, American elm, river birch (*Betula nigra*), and cottonwood (*Populus deltoides*).
- On uplands with somewhat poorly drained to moderately well drained mineral soils, some stands can be dominated by species typical of the swamp hardwood cover type (red maple, black ash and elm), however these are not swamps. In comparison, trees on these sites generally exhibit significantly improved vigor and productivity.

Associated Species
Associates in swamp hardwood communities include: aspen (*Populus spp*.), white birch (*Betula papyrifera*), yellow birch (*Betula alleghaniensis*), balsam fir (*Abies balsamea*), northern white cedar (*Thuja occidentalis*), hemlock (*Tsuga canadensis*),white pine (*Pinus strobus*), white spruce (*Picea glauca*), black spruce (*Picea mariana*), and tamarack (*Larix laricina*).

Differences in species composition are dependent on variation in site, soils and duration of high water. Black ash-dominated swamps are adapted to more stagnant water with reduced oxygen content whereas, green ash is more likely to occur with moving, oxygen rich water. Due to the presence of emerald ash borer (EAB) in the upper Midwest, the domination of black and green ash on swamp hardwood sites is expected to decline.

1.2 Silvical Characteristics

1.2.1 Black Ash

Black ash is a relatively small, slow growing tree of northern swampy woodlands. Black ash grows most commonly on peat and muck soils in bogs, along streams or in poorly drained areas which are often seasonally flooded. Black ash can tolerate semi-stagnant conditions but best growth occurs when water is moving through the soil so that the soil remains aerated even though it is saturated. Black ash has a shallow and fibrous root system well adapted to high soil moisture conditions. It has the ability to tolerate intermediate to high levels of shade when older but the seedlings are somewhat shade-intolerant. Studies in Minnesota have indicated tolerance to prolonged periods of suppression (D'Amato personal communication).

Commonly, the largest trees reach 60-70 feet tall and 12-24 inches dbh. Maximum life expectancy ranges from 150 to 320 years. In many stands the largest trees are only 8-10 inches dbh. Growth rates are slow with site index at base age 50 years ranging from 50 to 80 feet in northern Wisconsin and Michigan. In many stands black ash is often outgrown by its associates, especially balsam fir, red maple and northern white cedar.

Black ash is polygamous and flowers in May and June during or just prior to leaf out. Seeds disperse from July through October. Good seed crops occur infrequently. Seeds remain dormant during their first year and must undergo a period of warm followed by cold stratification. Seeds normally germinate in their second year but may remain viable in the seed bank for more than 8 years. Black ash seedlings exhibit slower growth than associated species such as red maple.

Black ash regenerates from seed, readily stump sprouts, and is reported to produce root suckers following cutting. However, Tardif and Bergeron (1999), state that root suckering in black ash has never been quantified nor are there any references with empirical data.

Black ash is very tolerant of low oxygen levels but is intolerant of flooding well into the growing season. Massive dieback of overstory and sometime understory can result from extended periods of high water. An adaptation to this occurrence is the long dormancy period of black ash seeds. Other adaptations include hypertrophied lenticels (oversized pores on woody stems that foster gas exchange between and plants and atmosphere) and rapid stomatal closure. Flooding extent has even been found to dictate the mode of regeneration for black ash and can lead to reduced levels of radial growth in years following prolong flooding (Tardif 1997). Heavy flooding usually results in vegetative reproduction by stump sprouting, whereas seed origin regeneration is usually fostered with less prolonged flooding.

1.2.2 Green Ash

Green ash is the most widely distributed of the American ashes. In Wisconsin it occurs most often in the eastern counties bordering Lake Michigan. Green ash grows naturally on moist bottom lands and stream banks. However, it is widely planted and is also a very popular ornamental tree.

Green ash may be the most adaptable of all the ashes growing on sites ranging from frequently flooded clay soils to sandy soils with limited moisture availability. However, it is found most commonly on alluvial soils along rivers and streams and less frequently in swamps. Green ash is less tolerant of flooding.

Green ash is dioecious. A high percentage of the male and female trees flower annually and many of the female trees produce seeds each year. Seeds ripen in late September or early October. Seeds are dispersed by wind short distances from the parent tree and may germinate in the spring following seed fall or lie dormant in the litter for several years. Under ideal open grown conditions seedlings grow rapidly with reports of 12" height growth the first year and another 18" the second year. Green ash may also reproduce vegetatively. Stumps of sapling and pole sized tree sprout readily.

Little data exists for growth rates under natural stand conditions. In the northern part of its range green ash can reach 50-60 feet tall and 18-24" DBH. Maximum life expectancy is about 175 years.

In Wisconsin green ash varies from intolerant to moderately tolerant of shade. It is usually an early successional species. However, some studies in the southern part of its range have shown that advanced reproduction can be maintained in the understory for more than 15 years and responds well to release.

1.2.3 Red Maple

Red maple, commonly referred to as soft maple in Wisconsin, is one of the most widespread tree species of eastern North America. It reaches the western and northern extent of its range in Wisconsin. Red maple grows on a wide range of soil types, textures and moisture regimes. It is common in swampy areas, on slow draining flats and depressions and along small slow flowing streams. Red maple can occur in almost pure stands on moist soils and swamp borders.

Red maple flowers from March through May and is a prolific seed producer yielding between 12,000 and 91,000 seeds per tree. A seed crop occurs nearly every year and a bumper crop once every two years. Seeds ripen quickly and begin dispersing during April through July. Seeds are dispersed by wind and may begin germinating immediately after ripening. Given proper temperature and moisture conditions red maple seeds can germinate with very little light. Second year germination is common if the overstory canopy is too dense. Moist mineral soil is the preferred seed bed.

Red maple seedlings are moderately tolerant to tolerant of shade and are often very abundant. Seedlings respond well to overstory disturbance such as disease, windthrow and harvesting. Red maples also stump sprout vigorously especially in stumps less than 12" diameter. Under favorable conditions seedlings can grow 1 foot in the first year and up to 2 feet per year for the next few years. Stump sprouts can grow as much as 3 feet in the first year but soon slow down to the same rate as seedlings.

Red maple is a short to medium lived tree, maturing in 70-80 years and seldom living longer than 150 years. An average red maple tree may reach 60-90 feet tall and 18-30" DBH.

Red maple is a pioneer or subclimax species and is more shade tolerant and longer lived that other early successional species. Seedlings are more shade tolerant than larger trees and can exist in the understory for several years. These seedlings respond rapidly to release and can occupy over-story space before being replaced by longer lived more shade tolerant species.

1.2.4 Silver Maple

Silver maple is a medium lived, rapidly growing tree common in the eastern U.S. Maximum life expectancy is about 130 years. Its native range covers most of Wisconsin except for the far north and northwestern parts of the state. Silver maple is most commonly found on stream banks, flood plains and lake edges where it grows best on better drained, moist alluvial soils. It is only occasionally found in swamps, gullies and small depression of slow drainage. Silver maple seedlings are adapted to survive long periods of inundation in bottom lands where flooding is common.

Silver maple begins to flower as early as February and continues flowering into May. Seeds ripen and disperse beginning in April and ending by June and are most often dispersed by wind and occasionally by water. Seeds may begin germinating immediately after dispersal. Moist mineral soil with considerable organic matter is the preferred seed bed. Initially, seedlings grow rapidly, 12-36” in the first year, but cannot compete with overtopping vegetation in subsequent growing seasons. First year seedling mortality is high if they are not released.

Prolific sprouting from root collars and lower stems is characteristic of silver maple. Stumps of 12” diameter or less sprout readily.

Depending on site quality and location the shade tolerance of silver maple ranges from moderate to very intolerant. In general it is considered tolerant on good sites and intolerant on poor sites.

1.2.5 Swamp White Oak

Swamp white oak is a midsized, rapidly growing tree occurring on lowlands, along edges of streams and in swamps subject to flooding. In Wisconsin its native range includes approximately the south half of the state where it is more common in swamps. Swamp white oak is long lived and may reach 300 to 350 years of age.

Swamp white oak is typically found on poorly drained mineral soils, organic soils ranging from muck to peat or alluvial soils. These soils are found in areas which are periodically inundated. However, it is not found where flooding is permanent.

Swamp white oak reach seed bearing age at about 20 years. The trees flower from May through June with acorns maturing in about 1 year. Acorns fall during September and October and begin germinating soon after. Good seed crops occur every 3-5 years. Seedlings develop best on better drained lowland soils. Swamp white oak will also sprout very well especially when stump diameter is less than 11 inches.

Swamp white oak is a midsized tree averaging 60-75 feet tall and 24-36 inches DBH. It usually grows in a mixture with other bottom land species and is only abundant locally.

The tree is of intermediate shade tolerance and seedlings will become established under moderate shade.

1.2.6 American Elm

American elm (*Ulmus americana*) is most notable for its susceptibility to the wilt fungus, Dutch elm disease. Because of the disease American elm comprise a much smaller percentage of large diameter trees than in the past. Dutch elm disease has virtually eliminated elm from future silvicultural considerations. Although elm is no longer significant as an overstory tree, it can still make up a significant part of the understory and seedling layers. American elm may be perpetuated for generations even though the average life of the trees is likely to be reduced.

American elm is found throughout eastern North America. It is found most commonly on flats and bottom lands but is not restricted to these sites. In the Lake States it is also found on plains and morainal hills as well as bottom lands and swamp margins.

American elm grows best on well drained loams. However, it grows on many different soil groups including well drained sands, organic bogs and poorly drained clay. Soil moisture greatly influences growth rates. Growth is poor in well drained sands and where the summer water table is less than two ft below the soil surface.

Flowering begins in April and May in the Lake States. Seeds ripen and fall by mid-June. American elm are prolific seed producers after about 40 years of age. Seeds are dispersed by wind and most fall within 300 feet of the parent tree.

Seeds usually germinate within 6-12 days after they fall. Germination is best with temperatures between 68-86 degrees F on a mineral soil seed bed, but can also become established on moist litter, moss and decayed logs or stumps.

Seedlings grow best with about 1/3 to full sunlight conditions. Seedlings can withstand flooding in the dormant season but die if flooding is prolonged into the growing season. Compared to other lowland tree species elm is only intermediately tolerant to complete inundation.

Moderately shade tolerant as a seedling but it becomes very intolerant as a sapling and pole-sized tree. Without release, vigor declines dramatically once trees are more than 2-4 DBH. Isolated trees are growing into sawtimber size classes on somewhat poorly drained soils.

American elm seldom grows in pure stands and there is no information on stand yields. On wet soils elm may grow to 40-60 feet tall and live for 175 – 300 years if not infected with Dutch elm disease. If infected, some trees can live for about 30-40 years before the tree is severely stressed and dies. Elm is of intermediate shade tolerance and responds well to release.

Table 46.1. Summary of selected silvical characteristics[1].

Species	Black Ash	Green Ash	Red Maple	Silver Maple	Swamp White Oak	American Elm
Flowers	May - June Polygamous	April-May Dioecious	March - May Polygamo-dioecious	Feb. - May Dioecious	May to June Monoecious	April – May Perfect
Fruit Ripens	June – Sept. single samara	Sept.-Oct Single samara	April - June Double samara	April - June 1 seeded samara	Sept- Oct. Acorn	April – June Winged samara
No. of seeds/lb	7000 samaras/lb	17,200 seed/lb	22,800 seed/lb	10,000 seed/lb	120 seed/lb	71,000 seed/lb
Seed Dispersal	July – Oct. Wind dispersed >300 feet.	Late Sept - Winter. Wind > 300 feet	April - July. Wind.	Early Summer. Wind and Water	Sept – Oct. Animal	Mid June Wind
Good Seed Years	Every 1-8 yrs	Annually	Annually	Annually	Every 3-5 years	2-3 yrs.
Seed Bearing Age	30-40 yrs.	20 yrs.	12-15 yrs.	11 years.	20 yrs.	15-40 yrs
Seed Viability	8 yrs.	1-7 yrs	good	poor	poor	poor
Germination	Warm/cold stratification to break dormancy – germination in 2nd year. Rate:7%	Cold stratification – dormant embryo until 2nd yr. Rate:80%	Early summer soon after dispersal Rate: 77%	Immediately after maturity Rate: 99%	Soon after falling Rate: 50-90%	Soon after falling. Rate:65%

[1]Information extracted from Burns etal 1990 and USDA 2008

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

Management objectives should be identified in accordance with landowner goals within a sustainable forest management framework, which gives consideration to a variety of goals and objectives within the local and regional landscape. The silvicultural systems described herein are designed to promote the optimum quality and quantity of swamp hardwood timber products. Modifying these silvicultural systems to satisfy other management objectives could potentially result in reduced vigor, growth and stem quality. The habitat type is the preferred indicator of site potential. Other indicators of site potential include site index, water table and soil characteristics. It is recommended not to rely on site index alone.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.1 Landscape Considerations

Deciduous hardwood swamps occur on lake plains, glacial tills, and flat to pitted glacial outwash where the surface falls at or below the water table and, as a result of their topographic requirements, tend to be distributed as scattered, discrete bodies on the landscape, rarely covering extensive contiguous areas. These stands are seasonally inundated with water at or near the surface much of the year. Soils have relatively high organic matter and generally consist of a shallow layer of muck or peat over mineral soil. Though swamp hardwoods can also be found on fine sands and loams underlain by clays (Dunn & Stearns 1987; Christensen et al, 1959; Wright, 1965).

3.1.1 Historical Context

When the General Land Office Public Land Surveys (PLS) were conducted in Wisconsin (1832-1866), black ash dominated wetland forests were approximate 4% of the landscape. Prior to the introduction of Dutch elm disease in the 1950's, American elm was a major component of the swamp hardwood community type, especially in southern Wisconsin. Today, elm is much less abundant, comprising only about 5% of total stems in these communities (Dunn, 1985).

A recent analysis was conducted of species historically present in our current swamp hardwood stands. State and county forest reconnaissance data from November 2011 were intersected with data from the US General Land Office's Public Land Survey of the mid-1800s. There were 3,898 stands typed as swamp hardwood (SH) that intersected with 1319 "witness trees" at 606 survey posts. Although there are limitations to using the witness tree data (e.g., see Schulte and Mladenoff, 2001), some inferences can be drawn when the data are examined across a broad, statewide perspective.

As with many locations in the north, it appears the representation of conifers in these stands is much less than it was historically. Cedar and tamarack were the most commonly reported species at these 606 survey posts, followed by hemlock, then roughly equal numbers of yellow birch and black ash trees (Figure 46.1).

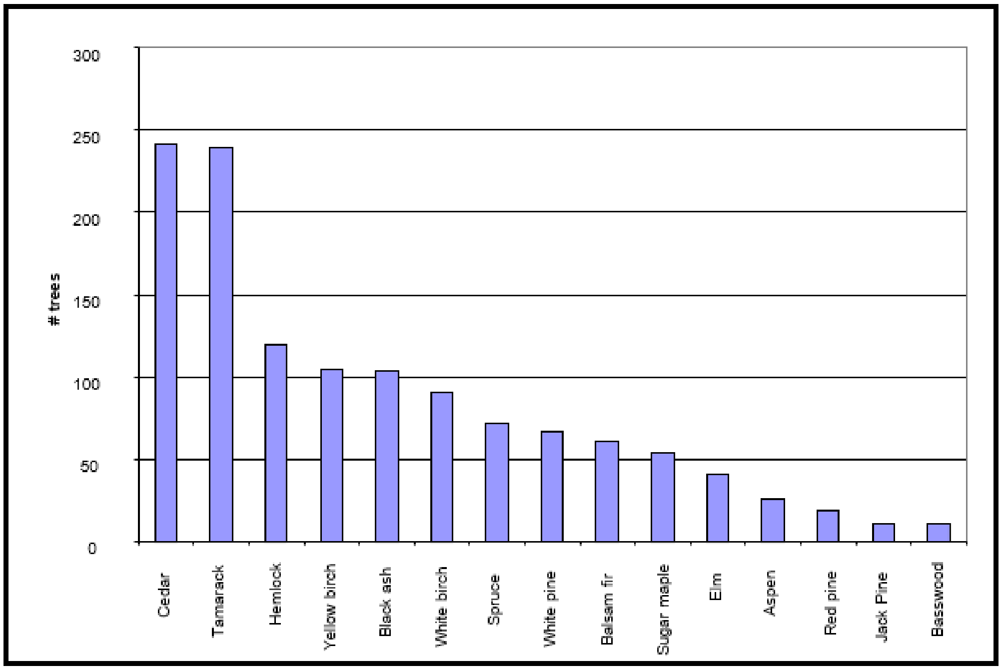

Figure 46.1. Witness trees by species that intersect with swamp hardwood stands on state and county lands from November 2011 recon data. Only species with 10 or more trees are shown (comprises 96% of the 1,319 trees).

Summarizing trees that were present at the time of Euro-American settlement can be useful for exploring the ecological capabilities of an area. This information can be helpful if there is a desire to restore an area of swamp hardwoods, especially given the anticipated impacts of emerald ash borer on black ash, the current canopy dominant in the majority of these stands. Unfortunately, some of the major species that were present historically are now difficult to regenerate in almost any conditions. For example, hemlock and yellow birch appear to have been present in many of these stands in the North Central Forest, similar to many parts of that Ecological Landscape. These species were reported much less often in the Northwest Lowlands Ecological Landscape, where cedar was most often reported. Table 46.2 describes the distribution of the witness trees by Ecological Landscape.

Table 46.2. Witness trees by Ecological Landscape that intersect with swamp hardwood stands on state and county lands from November 2011 reconnaissance data. Only tree species with five or more total witness trees and only the 13 Ecological Landscapes with swamp hardwood stands in the November 2011 reconnaissance data are shown.

Species	# Witness Trees	Central Lake Michigan Coastal	Central Sand Hills	Central Sand Plains	Forest Transition	North Central Forest	Northeast Sands	Northern Highland	Northern Lake Michigan Coastal	Northwest Lowlands	Northwest Sands	Southeast Glacial Plains	Superior Coastal Plain	Western Coulees and Ridges
Aspen	26		3			3	4		2	5	4	1	4	
Balsam fir	61				7	25	6			12	6		5	
Basswood	11		1		1	2				1		3	3	
Black ash	104	2		2	3	22	20	1	4	30	12	7	1	
Black oak	6		6											
Bur oak	8		1		2					3		2		
Cedar	241	12	0	0	8	93	34	2	19	49	7	2	15	0
Elm	39					8	5		1	4	2	11	5	3
Hemlock	119	1			9	94	12		3					
Jack Pine	11			1			5			3	2			
Pine (undifferentiated)	6					6								
Red pine	19						12				7			
Spruce	72				3	19	9		2	23	6	1	9	
Sugar maple	54				1	27	5			15	2	2	2	
Tamarack	239	4	2		5	51	47	9	9	60	30	19	3	
White ash	5		1			3						1		
White birch	90	1			3	30	16		2	24	3		11	
White cedar	51					12				33	6			
White oak	5		4									1		
White pine	67			1	9	12	19			19	7			
Yellow birch	105				8	65	5	2	6	14	2		2	1

3.1.1 Current Context

Today the black ash\American elm\red maple forest type accounts for about 5% of the all the forest land in Wisconsin. Although this forest type can be found in lake plains, stream terraces, and depressional areas throughout Wisconsin, more than 80% of these stands are located in northern Wisconsin, primarily in the North Central Forest and Forest Transition Ecological Landscapes (USDA 2009) (Figure 46.2).

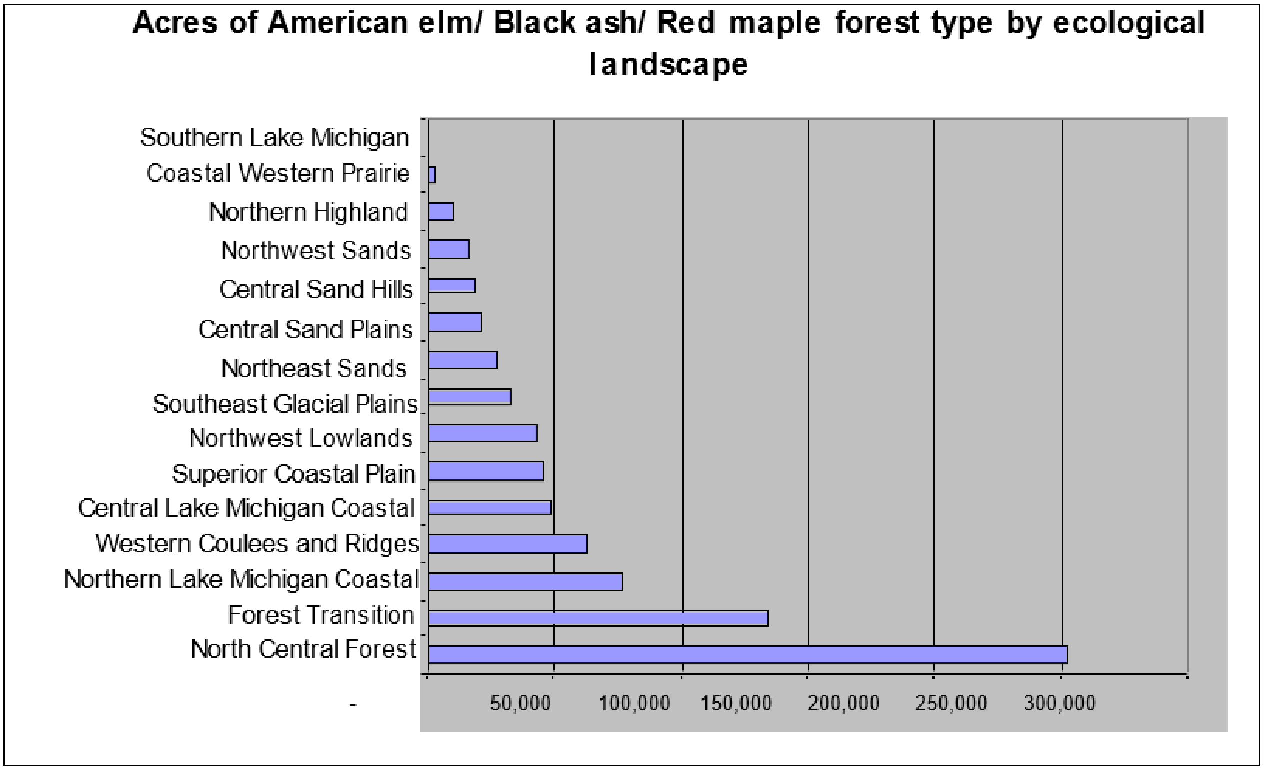

Figure 46.2. Acres of swamp hardwood cover type by ecological landscape.

Maintaining a desirable age-class distribution is a landscape-level consideration. A stable age-class structure that includes all developmental stages maximizes benefits to wildlife by providing a range of structural conditions and economic interests by supplying a range of materials such as pulp, fuel wood, and sawlogs. While the average age of swamp hardwood forests in Wisconsin increased slightly between 2004 and 2009 as a result of increased acreage in the oldest age classes, the majority of swamp hardwood acreage is still concentrated in the middle age classes (Figure 46.3).

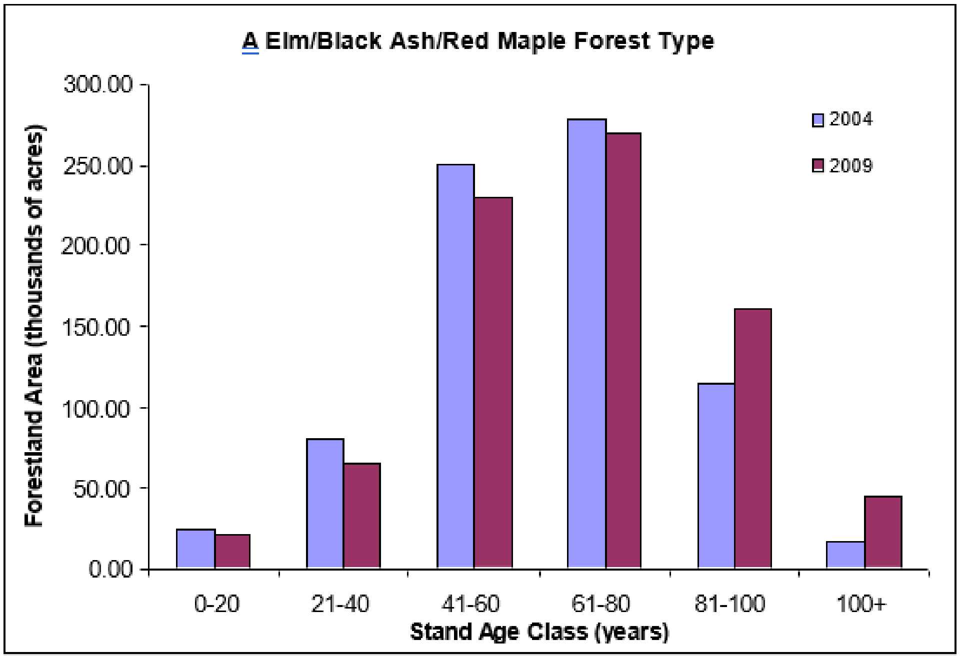

Figure 46.3. Forest age-class distribution for the elm/black ash/red maple cover type in Wisconsin, 2004 and 2009 (USDA 2009).

3.1.3 Hydrology

In swamp hardwoods, it is important to understand the hydrology and water flow. A watershed is made up of surface drainage (streams) and underlying subsurface geologic framework (aquifer) that constitute the terrestrial portion of the hydrologic cycle. Water is constantly moving through a watershed with inflow from precipitation and outflow by evapo-transpiration and discharge into basin outlets. Flowing from high hydraulic heads to areas of low hydraulic heads creates the groundwater pump. In this hydrologic process, trees facilitate the process by uptake of water through their root system and transpiring through their leaves. If there is complete or even partial removal of the trees at a given site, the water cycle is impacted.

Concerns about impacts from harvesting in forested wetlands can be addressed by first understanding the characteristics of this cover type. Swamp hardwood sites are different than bottomland hardwood sites in that the hydroperiod has a very predictable pattern associated with spring thaw and prolonged storm events. They are often hydrologically open, connected to a wetland matrix (other wetlands) and are somewhat dependent on overland water flow for nutrients. It is also helpful to understand the climate, surrounding geology and landform, soils, and aquifer type before applying the silvicultural prescription. Recommendations regarding hydrology considerations are outlined in the Management Considerations section of this chapter.

3.1.4 Disturbance Regime

Seasonal flooding is the primary disturbance in hardwood swamps. Standing water is usually present in the spring and drained by late summer. Flooding extent has been found to influence the mode of regeneration for black ash whereby heavy flooding usually results in vegetative reproduction by stump sprouting, and sexual reproduction is found with less prolonged flooding (Tardif et al., 1994). In addition, black ash has adapted to stagnant water and low oxygen levels associated with swamp depressions but is intolerant of flooding well into the growing season. Massive dieback of understory and sometimes overstory vegetation can result from extended periods of high water in hardwood swamps. An adaptation to these extended periods of high water is the long dormancy period (up to eight years) of black ash seeds (Wright and Rauscher, 1990).

Drought disturbance also impacts hardwood swamps. While drier periods that expose the saturated organic soils are essential for regeneration, xeric stress is harmful to shallow rooting black ash seedlings (Tardif et al. 1994). As a result, swamp hardwood communities are relegated to depressions, and low-level terrain near rivers, lakes, or wetlands, which experience seasonal flooding and where because of the high water-retaining capacity of peat soils, soil moisture is maintained throughout the growing season.

Other large-scale disturbances were most likely infrequent. In Minnesota, large windthrow and fire events in northern hardwood swamps had a rotation of 370 and 1,000 years, respectively (MNDNR 2003). However, small-scale windthrow events are common in these systems due to shallow rooting in muck soils. The uprooting of individual trees creates microtopography that results in fine-scale gradients of soil moisture and increases floristic diversity. In addition, beaver activity is a localized source of periodic disturbance in these systems. Dam-building activities alter hydrology by causing either prolonged flooding or lowering of the water table depending on the location of the forest in relation to the dam (Curtis 1959, Heinselman 1963, Jeglum 1975). Beaver can also generate canopy gaps in these systems by cutting down large trees.

In general lowland forests have received somewhat less human disturbance than many upland forest types because their economic potential as sources of lumber is relatively low compared to other forest types. However, many of the southern lowland forests have been cut and drained for agriculture. In the north there were few attempts at drainage for agriculture, and logging and fire were the primary human caused disturbances (Curtis, 1959).

3.1.5 Summary of Landscape Considerations

- Monitor and control invasives. Continue and support biological control research to manage invasives that are present and prevent spread of additional invasives.
    - Use Best Management Practices and other sustainable forest community management practices to prevent detrimental soil and water impacts.

- Use adaptive management techniques to restore forest structure and composition; monitor and share results.
- Manage recreational uses so they do not harm the environment.
- Protect significant areas from hydrological changes from road construction and development. Restore hydrology where needed and/or appropriate.
- Preserve large blocks of habitat in a matrix of other forest types
- Consider opportunities to increase a diversity of tree species in this type

3.2 Site and Stand Considerations

3.2.1 Soils

The swamp hardwood cover type occurs on forested wetlands (swamps) characterized by periodic inundation (fluctuating water table near or above the soil surface) and nearly permanent subsurface water flow. Seasonal and yearly fluctuations in depth of saturation can be considerable. Soils are poorly drained to very poorly drained and are subject to ponding. These soils commonly have a “depth to water table” of zero inches and can occur in basins, depressions, flats, and drainage ways.

Typical soils are mucks of highly variable thickness (several inches to several feet) over mineral soil of any texture. In some cases, the surface can be mucky mineral soil, and other soils may include mucky peat. Nutrient availability can be highly variable among sites and has a strong influence on community development and potential productivity. Nutrient availability is influenced by type of substrate, degree of decomposition of organic materials, run-off from adjacent stands and groundwater flow. In general, growth and productivity are improved by mineral soil of finer texture closer to the surface; greater decomposition of organic materials; better drainage; flowing and aerated water; and adjacent landform/soils. Although swamp hardwoods, particularly black ash, can tolerate semi-stagnate water flow and relatively nutrient poor conditions, the type does not generally develop on nutrient poor, acid peatlands (dysic histosols).

Harvesting practices need to be properly implemented when removing timber products from a swamp hardwood stand. Poor skidding technique and seasonal timing can reduce stem quality, root health, and soil productivity. When roots are damaged, the potential for windthrow may increase. Bole and branch damage can reduce log quality and grade and may also lead to decay.

When swamp hardwoods occur on muck soils, the area is susceptible to soil displacement and rutting when wet and to soil compaction when dry. Soil displacement, rutting, and compaction have been shown to decrease seedling and sapling growth in many soil types, although specific effects depend on soil moisture and content (NCASI 2004). Driving over the root system with heavy equipment can also cause root damage potentially causing severe dieback of residual trees. Harvesting when the soil is frozen or firm can reduce the potential for soil displacement, rutting, and compaction.

The total area devoted to landings, roads, and skid trails should be minimized to limit the loss of productive area. Designate skidding routes and landing areas to limit the total area affected by vehicle traffic. Primary skid trails should be reused in future entries, whenever possible.

Recommendations in the Wisconsin Forest Management Guidelines and Wisconsin Forestry BMPs for Water Quality Field Manual (WDNR 2010) should be used to minimize impacts of roads, landings, and skid trails on surface and sub-surface hydrology. In addition, the BMPs can help minimize soil erosion and sedimentation from roads and other forest management activities.

3.2.2 Site Quality

3.2.2.1 Range of Habitat Types

As defined here, forested wetlands generally occur on poorly drained to very poorly drained soils (as classified by NRCS). The substrate can be mineral or organic and is influenced by a fluctuating water table or periodic flooding. Seasonal and yearly fluctuations in depth of saturation can be considerable. Nutrient availability can be highly variable among sites, and has a strong influence on community development, growth and productivity, and habitat type classification. Forested wetland ecosystems comprise about 2,670,000 acres or 17% of Wisconsin's forest lands (USDA 2009). About 77% of these forested wetlands occur in northern Wisconsin.

Within Wisconsin, the swamp hardwood cover type represents approximately 25 to 30% of forested wetlands and occupies about 4 to 5% of statewide forest land acres (slightly over one million acres). In northern Wisconsin, swamp hardwood stands tend to be strongly dominated by black ash, with red maple often playing an important role. In southern Wisconsin, swamp hardwood stands tend to be dominated by green ash, silver maple and red maple, with black ash, American elm and swamp white oak often represented.

Forested wetland habitat types are being developed for Wisconsin and have been defined for Northern Region's 1-4. These sites are all grouped into the wet-mesic to wet habitat type group. Therefore, the swamp hardwood cover type only occurs on the wet-mesic to wet habitat type group (stands of similar composition can be found on the mesic to wet-mesic habitat type group, but the sites are better drained).

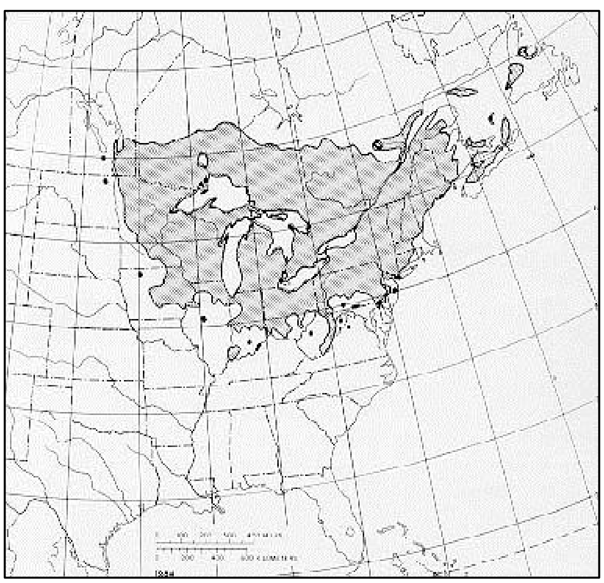

Figure 46.4. Black ash range map.

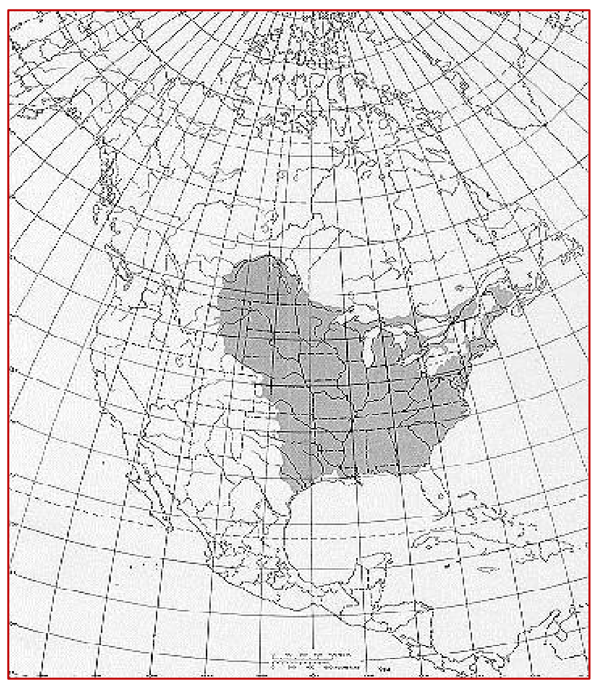

Figure 46.5. Green ash range map.

The dominant swamp hardwood species are most productive on nutrient medium to rich upland habitat types in the mesic and mesic to wet-mesic habitat type groups (moderately well drained and somewhat poorly drained soils). Table 46.3 presents average site index values for several swamp hardwood species on northern mesic to wet-mesic and wet- mesic to wet sites.

Within the wet-mesic to wet habitat type group (swamps), the occurrence and relative growth potential of the swamp hardwood cover type varies by habitat types. In general, as nutrient availability decreases the frequency of swamp hardwood occurrence and potential productivity also decrease. This is reflected in the understory vegetation component, hydrology, parent soil and depth of organic layer. Adjacent landform and soil substrate influence the habitat type also.

Table 46.3. Site index for some swamp hardwood species on wet sites (swamps) and wet- mesic uplands in northern Wisconsin (FIA 1996). Range represents the 95% confidence limits for the mean, and number in parenthesis is the number of observations.

Tree Species	Habitat Type Group	
	North Wet-mesic to Wet	North Mesic to Wet-mesic
Black Ash	47-51 (119)	59-66 (25)
Red Maple	54-61 (42)	64-67 (146)
Green Ash	60-67 (48)	64-72 (27)

Nutrient medium habitat types named after ashes, maples, and/or elms (e.g. FnArI or Fraxinus nigra-Acer rubrum/Impatiens capensis in region 3 and FnUB or Fraxinus nigra Ulnus Boehmeria in region 4) are commonly dominated by the swamp hardwood type and generally exhibit relatively better productivity. In comparison, swamp hardwood communities sometimes develop on nutrient poor to medium habitat types (e.g. AbFnThOs) but tend to exhibit relatively poor productivity. Nutrient poor to very poor sites (acid peatlands or dysic histosols) generally do not support swamp hardwood communities.

Other poor to medium nutrient habitat types in region 3 and 4 that are associated with swamp hardwood include:

- FnThAbAt (Fraxinus nigraThugaAbiesAthyrium)
- FnAbArOn (Fraxinus nigraAbiesAcer rubrumOnoclea)
- ThAbFnC (ThujaAbies Fraxinus nigraCoptis)
- AbFnThIx (AbiesFraxinus nigraThujaIlex)
- AbFnThOs (Abies balsamea-Fraxinus nigra-ThujaOsmunda)
- AbFnThAs (Abies balsamea-Fraxinus nigra-ThujaArisema)

3.2.3 Forest Health

Prior to the detection of emerald ash borer (EAB) in the upper Midwest, black ash was a commonly favored species in single tree selection regeneration harvests on swamp hardwood sites (Erdman et al. 1987; Tardif and Bergeron 1999). However, EAB is a potential threat to black ash stands. Managing for other associated species on swamp hardwood sites (e.g. balsam fir, yellow birch, red maple, hemlock, northern white cedar, etc.) may be a consideration due to the possibility of forest loss from EAB. As long as EAB persists without adequate biological control agents or effective management tactics, black ash may not be the optimal tree species especially in quarantined counties. Currently both Wisconsin and Minnesota are coordinating silviculture trials to further investigate options to build site level resiliency and reduce potential impacts. For more information, please refer to the EAB silvicultural guidelines.

With the emergence of EAB, conversion from black ash dominated swamp hardwood stands to another cover type may be a good alternative. Consult the EAB guidelines to determine appropriate management options. Stands with a large proportion of ash (such as a bottomland, swamp, or plantation) will be heavily impacted by EAB unless the ash component is drastically reduced. When planning harvesting activities, consider two alternatives: reducing the rotation age and changing what is considered a crop tree. If practical, reduce the ash component during regularly-scheduled stand entries, keeping the stand adequately stocked. Individual trees of other species may also be removed at the same time as EAB management activities if appropriate for the stand's management plan. Multiple stand entries may be needed to bring the ash component down to a suitable level where feasible. If the ash-dominated stand is at or near rotation age, consider regenerating the stand with a reduced proportion of ash**.**

3.2.5 Wildlife

Swamp hardwood stands are made up of a variety of tree species. The composition of the stand and resultant wildlife use is influenced by site characteristics. Wildlife benefits from swamp hardwoods include food from mast, twigs, and bark. In addition, some of the trees found in swamp hardwood host large numbers of insects which are a food source for birds and small mammals. The ground-layer vegetation is an important food source for browsers, particularly in the spring. This cover type is an important contributor of cavities as many of the trees found in swamp hardwoods are large and the dead wood of these trees are relatively rot-resistant. Bobcat, fisher, and pine marten use swamp hardwoods for foraging and for resting or den sites. Large stands of mature swamp hardwoods are suitable nesting habitat for forest raptors like northern goshawk and red-shouldered hawks. Poorly stocked or newly regenerated swamp hardwood stands provide important habitat for golden-winged warblers. Shallow rooted trees contribute to windthrow and openings in the forest canopy and increased vertical structure resulting from these openings benefit some wildlife species.

Invasive species are a concern for wildlife in this type. Reed canary grass can be present, particularly in a poorly stocked stand, and can be favored by management activities (WDNR 2009). Reed canary grass can dominate the ground-layer community to the exclusion of more valuable native species. It can also inhibit regeneration of the stand and establishment of understory shrubs. Cryptic invasion by buckthorn can take place over a number of years. Both of these invasives are difficult to remove and both can be favored by management. The utility of swamp hardwood stands for wildlife is diminished by invasive species and management practices that minimize or reduce invasive species will benefit wildlife.

This cover type can provide winter forage for white-tailed deer and other browsing species. While not primary food source, swamp hardwood species particularly willow are utilized by beaver. Most use of bark and twigs takes place in young stands. Canada warblers are ground-nesting insectivores associated with understory thickets. Management that increases understory woody material will benefit this species and other neotropical migrants.

Recommendations:

- Maintain diversity of tree species within stands and age classes within a landscape.
- Use best management practices to avoid hydrologic and soil compaction issues during silvicultural treatments.
- Monitor stands for invasive species and tailor silvicultural treatments to minimize the possibility of providing competitive advantages for these species. Currently, reed canary grass and buckthorns are major problems in some areas of the state.
- Maintain opportunities for green tree retention, snags, cavity trees, and coarse woody debris.
- Be aware of the possibility of forest raptor use of the stand. If nesting territories of SGCN species are identified, protection of nest trees and a modified marking and entry schedule might be warranted. WM or ER staff can provide recommendations on a site-specific basis. Because territories and nest trees can be used over a period of years, mapping these features is advised.

A list of opportunities, threats, priority conservation actions, and descriptions of rare plants and animals found in this type can be reviewed in the Northern Hardwood Swamp section of the Natural Communities listed in the Wildlife Action Plan. The Wildlife Action Plan is available on the WDNR website. The keywords “Wildlife Action Plan” in the search engine will take you to the appropriate webpage.

3.2.5.1 Deer and Herbivory Effects

White-tailed deer browse heavily on black ash seedlings and stump sprouts in swamp hardwood stands during the winter months. However, black ash can withstand moderate browsing (Erdmann et al 1987; Curtis, 1959). In the management section of this chapter the recommendation of established regeneration is 2 to 4 feet unless herbivory and hydrology issues are concerns.

3.2.6 Endangered, Threatened and Special Concern (ETS) Species

The swamp hardwoods cover type corresponds to the (northern) Hardwood Swamp and Southern Hardwood Swamp natural community types (Epstein et al. 2002). The distribution of these two types appears to correspond roughly with the Tension Zone, and their species composition can differ. Hardwood swamps contain many important structural characteristics and unique microsites and can support rare species. They are more susceptible to negative impacts than many other forest types due to their wet, mucky soils, as well as their frequent connections to other wetland habitats and aquatic features.

Landscape context is an important consideration if the goal is to maintain or enhance biodiversity and swamp hardwood forests occur in a wide variety of ecological contexts. Swamp hardwood stands are often located near other wetland types or aquatic features, and there can be important ecotones and hydrological connections among adjacent communities. Planning management beyond the individual stand to include nearby and adjacent features would be best, including avoidance of fragmentation and hydrological disruption.

Hardwood swamps are often quite structurally diverse, and they contain numerous microhabitats not typically found in most other northern forest cover types. Some stands include seepages or streams, and most stands contain pools of water for at least portions of the year. These pools, along with the presence of hummocks (small hills of mosses and/or sedges) and other structural features can be important for some species. Since these features are often abundant, spread throughout the stand, and frequently hydrologically connected, they cannot be as easily accommodated through routine prescriptions as the special features found in other types (e.g., vernal pools in northern hardwoods). Maintaining overall structural diversity in the stand including a component of large trees, standing dead cavity trees, and coarse woody debris whenever possible is an important biodiversity consideration.

Hydrology is critical in these forests. As mentioned throughout the chapter, some stands are at risk of developing a raised water table following harvest. This flooding could, essentially, deforest the stand and remove habitat for many of the associated rare species. In places where maintaining biodiversity is the most important consideration, retaining some large, contiguous unharvested areas would be a good option. Landscape-scale planning could be used to identify these areas.

Hardwood swamps are susceptible to invasive plant infestations, including reed canary grass (*Phalaris arundinacea*), and buckthorns (*Rhamnus* spp). These are especially problematic in certain areas of the state and can negatively impact habitats for rare plants and animals.

Rare plants in swamp hardwood forests are often associated with certain habitat features, and several broad considerations are more or less universally important to these species. Harvests should be designed to avoid known rare plant locations. Where locations are unknown, it would be best to design timber sales to avoid dramatic changes to microclimate and reduce the potential for swamping wherever possible. As mentioned, avoiding impacts to hydrology and microhabitats, such as hummocks, is important for maintaining species' habitats. Compaction caused by logging equipment, especially along skid trails and log yards, could be expected to negatively impact habitats for long periods of time, so logging should be done in conditions that will have the least impact to the site.

Certain species could actually benefit from additional light, so logging that does not negatively impact the site could be beneficial for those plants. However, light is not a limiting factor in many stands due to sparse canopy cover.

Table 46.4 includes a list of rare plants associated with swamp hardwoods in Wisconsin. Some of these species occur broadly across large portions of the state, while others are limited to only a couple of counties. Please consult the species and natural community web pages maintained by the Wisconsin DNR's Endangered Resources Program for more information (*https://dnr.wisconsin.gov* keyword "biodiversity").

Table 46.4. Select rare plant species that are associated with swamp hardwood stands, as well as their degree of association with the (northern) Hardwood Swamp or Southern Hardwood Swamp natural community types. Data are from the department's Endangered Resources Program, and scores are as follows: 3 = "significantly associated," 2 = "moderately associated" and 1 = "minimally associated." See the Wisconsin DNR web site for avoidance measures, management guidance, and other information on these species and natural communities (*https://dnr.wisconsin.gov*, keyword "biodiversity").

Common Name	Scientific Name	State Status	(Northern) Hardwood Swamp	Southern Hardwood Swamp
Ravenfoot sedge	*Carex crus-corvi*	END*		2
Rope dodder	*Cuscuta glomerata*	SC		1
Northern yellow lady's-slipper	*Cypripedium parviflorum* var. *makasin*	SC		2
Showy lady's-slipper	*Cypripedium reginae*	SC	2	
Clinton's woodfern	*Dryopteris clintoniana*	SC		3
Large-leaved avens	*Geum macrophyllum var.*	SC	2	
Butternut	*Juglans cinerea*	SC		1
Small forget-me-not	*Myosotis laxa*	SC	2	
Black tupelo	*Nyssa sylvatica*	SC		2
Bog bluegrass	*Poa paludigena*	THR**	3	
Northern wild-raisin	*Viburnum nudum var. cassinoides*	SC		2

* Known from two southeastern counties in Wisconsin
** Recommended for de-listing by the Endangered Resources Program, as of this writing.

Maintaining habitat for rare animals involves many of the previously discussed considerations. In addition, several of the species in Black ash stumpage values are typically lower due to market conditions and wetland harvesting operations. Stumpage values can be as much as 50% lower than mixed hardwood (maple) stumpage values depending upon current market conditions. Seasonal conditions (winter only harvests) can restrict wetland harvesting operations from year to year. In drought conditions, the soils may be dry and firm where harvest can occur. However, extreme caution and monitoring the site is necessary, and contract extensions may be needed for swamp hardwood stands.

Black ash is prone to ring shake. Ring shake is a splitting along the plane of the annual growth rings. Shake may be caused by an abrupt change in diameter growth rates such as when trees are released by a long-delayed thinning (Smith 1986). The presence of ring shake in a tree significantly degrades log quality. However, the possibility for ring shake should not preclude one from managing for high quality saw logs. Ring shake appears to be confined to the first 2-3 feet of the butt log and may be associated with the root flare or seams. The butt log should be given a generous amount of trim allowance so that shake may be "butted off" as needed (personal communications - Tim Lee – Log buyer et al).

3.2.7 Operational Considerations

Forests on sites that have a water table near the surface are sometimes subject to a rise in water tables after a harvest. The rise in water tables (also known as “swamping out”, “watering up”, or “wetting up”), occurs due to the loss of transpiration by trees, and the loss of direct evaporation that occurs when trees intercept precipitation. Plant roots and soil organisms are directly affected by the lack of oxygen that results from a water table rise. Increases in water table levels after harvests have been observed in many locations. Clearcutting in Quebec raised water tables on seven of eight study sites, with wetland/upland transition zones being more susceptible to rises (Dube et al. 1995), and another Quebec study found a correlation between the percent basal area removed and the amount of increase in water tables (Pothier et al. 2002; Erdman 1987).

Infrastructure (roads, skid trails, and landings) development and maintenance can have both immediate and cumulative impacts on forest soils and wetland hydrology. Studies have correlated these impacts with changes in hydrologic regimes, surface drainage patterns, and soil moisture (Jeglum 1975). The physical effects of soil compaction due to rutting can increase bulk density and impact the site hydrology.

Practices that will limit water table rises and compaction to some extent during forest management include:

- maintaining a partial tree canopy
- careful layout of skid trails and infrastructure to limit surface ponding
- retaining woody debris
- harvesting during frozen ground (pre-freezing skid trails)
- limit rutting by skidding over tops and debris and using high flotation equipment

rely on large blocks of forest, so keeping large, intact stands within a favorable context would provide the best habitat. In general, providing areas with mature forest, dense canopy cover, abundant cavities, and coarse woody debris would benefit numerous rare species associated with this forest type. Some of the species in Black ash stumpage values are typically lower due to market conditions and wetland harvesting operations. Stumpage values can be as much as 50% lower than mixed hardwood (maple) stumpage values depending upon current market conditions. Seasonal conditions (winter only harvests) can restrict wetland harvesting operations from year to year. In drought conditions, the soils may be dry and firm where harvest can occur. However, extreme caution and monitoring the site is necessary, and contract extensions may be needed for swamp hardwood stands.

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- limit rutting by skidding over tops and debris and using high flotation equipment

are only associated with swamp hardwood stands when certain features are present and in certain parts of the state. See the Bureau of Endangered Resources species and natural community Web pages for more information (*https://dnr.wisconsin.gov,* keyword “biodiversity”).

Table 46.5. Select rare animal species that are associated with swamp hardwood stands, as well as their degree of association with the (northern) Hardwood Swamp or Southern Hardwood Swamp natural community types. Data are from the Wisconsin Wildlife Action Plan, and scores are as follows: 3 = "significantly associated," 2 = "moderately associated" and 1 = "minimally associated." See the Wisconsin DNR web site for avoidance measures, management guidance, and other information on these species and natural communities (*https://dnr.wisconsin.gov*, keyword "biodiversity").

Common Name	Scientific Name	State Status	(Northern) Hardwood Swamp	Southern Hardwood Swamp
Birds				
American woodcock	*Scolopax minor*	SC/M	2	1
Black-billed cuckoo	*Coccyzus erythropthalmus*	SC/M	1	1
Blue-winged teal	*Anas discors*	SC/M		1
Blue-winged warbler	*Vermivora pinus*	SC/M		1
Canada warbler	*Wilsonia canadensis*	SC/M	3	
Golden-winged warbler	*Vermivora chrysoptera*	SC/M	2	1
Least flycatcher	*Empidonax minimus*	SC/M	2	1
Northern goshawk	*Accipiter gentilis*	SC/M	1	
Red-shouldered hawk	*Buteo lineatus*	THR	1	1
Rusty blackbird	*Euphagus carolinus*	SC/M		3
Solitary sandpiper	*Tringa solitaria*	SC/M		1
Veery	*Catharus fuscescens*	SC/M	3	1
Willow flycatcher	*Empidonax traillii*	SC/M		1
Wood thrush	*Hylocichla mustelina*	SC/M	1	1
Yellow-billed cuckoo	*Coccyzus americanus*	SC/M		2
Yellow-crowned night-heron	*Nyctanassa violacea*	THR		2
Herptiles				
Blanding's turtle	*Emydoidea blandingii*	THR*		2
Eastern Massasauga rattlesnake	*Sistrurus catenatus catenatus*	END		2
Four-toed salamander	*Hemidactylium scutatum*	SC/H	2	3
Gray ratsnake	*Pantherophis spiloides*	SC/P		2
Mink frog	*Rana septentrionalis*	SC/H	1	
Pickerel frog	*Rana palustris*	SC/H		2
Timber rattlesnake	*Crotalus horridus*	SC/P		2
Wood turtle	*Glyptemys insculpta*	THR	2	2
Mammals				
American marten	*Martes americana*	END	1	
Eastern red bat	*Lasiurus borealis*	SC/N	2	2
Gray wolf	*Canis lupus*	SC/P	2	1
Hoary bat	*Lasiurus cinereus*	SC/N	2	1
Moose	*Alces alces*	--	3	
Northern flying squirrel	*Glaucomys sabrinus*	SC/P	2	1
Northern long-eared bat	*Myotis septentrionalis*	THR	2	2
Silver-haired bat	*Lasionycteris noctivagans*	SC/N	2	1
Water shrew	*Sorex palustris*	SC/N	3	2
Woodland jumping mouse	*Napaeozapus insignis*	SC/N	2	2

* Recommended for de-listing by the Endangered Resources Program, as of this writing.

3.2.1 Economic Issues

Economic and operational conditions are important when managing in swamp hardwood. Although economics is important to consider, maintenance and protection of site productivity, optimum tree health and vigor, and encouraging diversity of species are very important in this cover type. The following considerations address log value and ring shake, water table, compaction and soil and site productivity.

Most swamp hardwood sites are dominated by small diameter material; although a very modest amount of high-quality saw logs are grown. Tree size and quality impacts the market and processing opportunities. Most of the swamp hardwood resource is a good fit for pulpwood, fuel wood/biomass and small diameter log markets.

Black ash stumpage values are typically lower due to market conditions and wetland harvesting operations. Stumpage values can be as much as 50% lower than mixed hardwood (maple) stumpage values depending upon current market conditions. Seasonal conditions (winter only harvests) can restrict wetland harvesting operations from year to year. In drought conditions, the soils may be dry and firm where harvest can occur. However, extreme caution and monitoring the site is necessary, and contract extensions may be needed for swamp hardwood stands.

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Infrastructure (roads, skid trails, and landings) development and maintenance can have both immediate and cumulative impacts on forest soils and wetland hydrology. Studies have correlated these impacts with changes in hydrologic regimes, surface drainage patterns, and soil moisture (Jeglum 1975). The physical effects of soil compaction due to rutting can increase bulk density and impact the site hydrology.

Practices that will limit water table rises and compaction to some extent during forest management include:

- maintaining a partial tree canopy
- careful layout of skid trails and infrastructure to limit surface ponding
- retaining woody debris
- harvesting during frozen ground (pre-freezing skid trails)
- limit rutting by skidding over tops and debris and using high flotation equipment

3.2.3 Ephemeral Ponds

Swamp hardwoods are wetlands with poorly drained to very poorly drained soils. Within swamp hardwoods, there may be inclusions of ephemeral ponds (also called vernal pools). Ephemeral ponds are small ponds of water that dry out seasonally. Ephemeral ponds provide important habitat for many amphibians and invertebrates. They also provide valuable habitat for many species of birds.

In swamp hardwoods, ephemeral ponds may occur as small open pools ringed by trees or as areas of open water with trees scattered through the pond. The frequency and distribution of ephemeral ponds influence their functional importance for maintaining or enhancing diversity.

Buffering ephemeral ponds can help to protect amphibian foraging and breeding habitat adjacent to ponds. When harvesting near ephemeral ponds, avoid felling trees into or skidding through these wetlands. Identifying these areas prior to harvesting can be helpful because ephemeral ponds may not be apparent at certain times of the year because of snow cover or lack of water.

3.2.4 Declining Stands

Concerns about black ash decline by forestry professionals in both Minnesota and Wisconsin have been noted. These stands exhibit trees with severe crown dieback, others with both dieback and epicormic branching. Field evaluation in Minnesota, showed that decline was greater on wetter sites, in stands of older trees, and in stands growing closer to roads (Palik et al 2009). A change in hydrology can permanently impact the growth and vigor in swamp hardwood stands and appears to severely impact black ash. Proper restoration of the impeded hydrology may improve the quality of these sites and should be considered.

4 STAND MANAGEMENT DECISION SUPPORT

4.1 Stand Inventory

In addition to clearly identifying landowner goals and objectives, in-depth and accurate stand assessment will facilitate discussion of management options and objectives in relation to realistic and sustainable management goals. Swamp hardwood stand assessment should include quantifying variables such as:

- Hydrology
- Present species composition

- Canopy, shrub, and ground layers
- Sources of regeneration
- Potential growth and competition
- Potential non-ash sources of regeneration

- Stand structure
  - Size class distribution and density
  - Age class distribution

- Stand and tree quality
- Site quality - The habitat type is the preferred indicator of site potential. Other indicators of site productivity include site index (should not be the only factor), soil characteristics, cubic ft./acre/year growth rate, and topographical characteristics. Site has a strong influence on volume growth and potential yield.
- Stand and site variability
- Invasive species – reed canary grass, phragmites, buckthorn and others
- Damaging insects, diseases
  - Proximity of known emerald ash borer (EAB) infestations

- Special considerations: watershed, BMPs, rare species, archaeology, landscape

4.3 Cover Type Decision Model

The swamp hardwood decision models below outline initial considerations in the development of a management plan and integrate the use of silvics, site capabilities (soil, habitat type, competition, regeneration, successional pathways), methods (timing/sequence), and timeline at growth stages under ideal conditions. Sustainable forestry practices must be based on compatible landowner objectives, the capability of each site and generally accepted silvicultural practices. Each of these factors should be considered when approaching these models. Included below are some observations from the Wisconsin swamp hardwood trials.

Not all swamp hardwood stands can or should be managed for timber production. Due to a raised water table, decreased transpiration, rare species, operability, invasive species, economic viability, and other concerns, each proposed stand should be carefully evaluated. To further evaluate sites for potential management, it is recommended to consider the characteristics or site conditions defined for low, medium and high-quality sites. Characteristics of low, medium and high-quality sites include, but are not limited to, soils, site index, lowland habitat type, stand vigor and hydrology.

Low Quality - Characteristics of low-quality sites may include SI< 40, impeded drainage, muck soils, poor to medium habitat types, and poor stand condition including top dieback, epicormic branching, and heart rot. These sites are prone to rising water table and competition. If management is still a consideration, consider stand age as a factor in deciding a silviculture method.

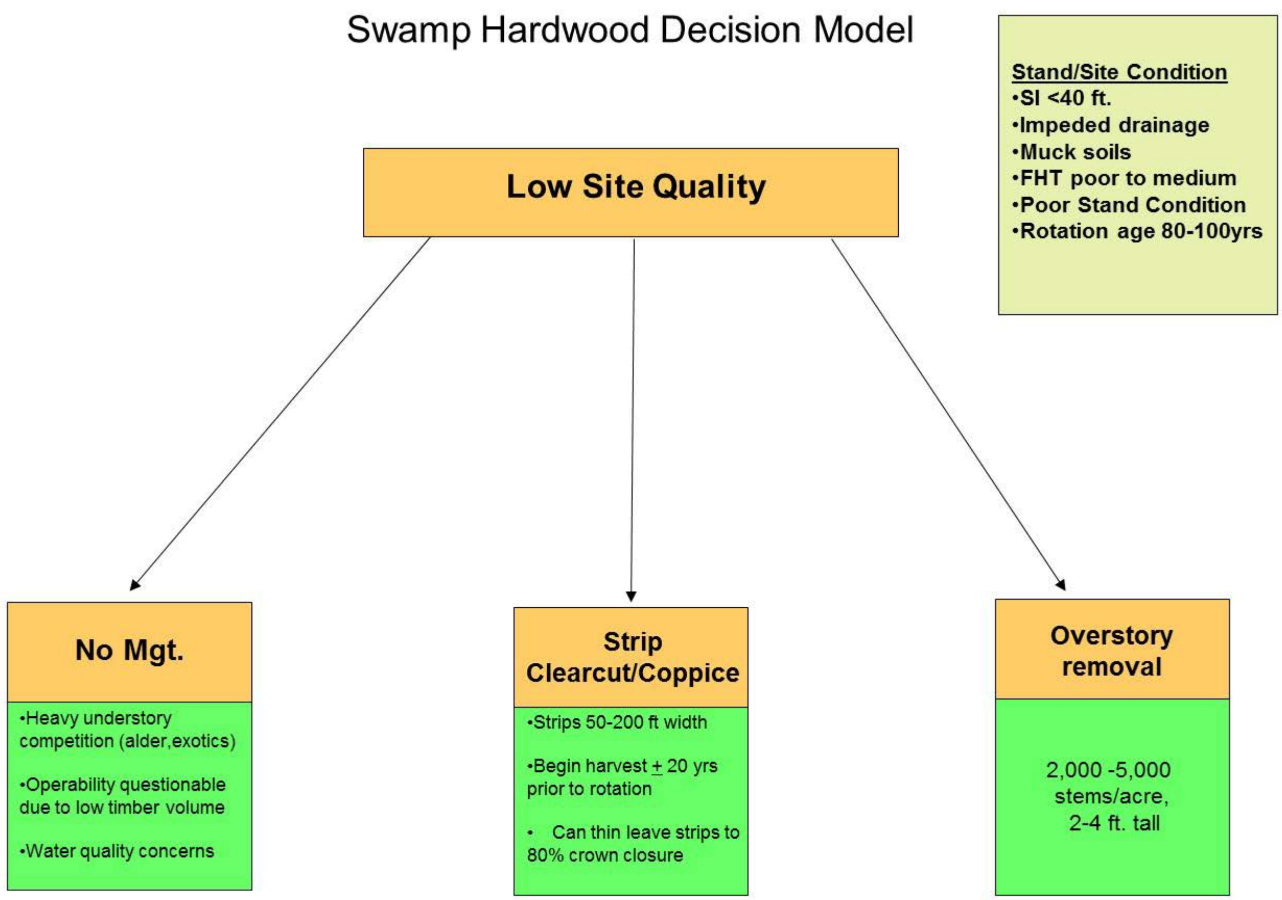
Medium Quality - On medium quality sites, characteristics may include SI 40-50, somewhat impeded drainage, muck over mineral or poorly drained mineral, poor to medium habitat types; and moderate stand condition. Many of these stands exhibit poor sawlog potential, the management consideration is for pulpwood production. On some sites there may be limited sawlog potential.

High Quality - On high quality sites, characteristics may include SI >50, good drainage to somewhat poorly drained mineral soil, medium to good habitat types and good stand condition. On these sites there is more potential to develop quality sawlogs but pulpwood production is still an option.

Even-aged silvicultural systems are commonly recommended for the management of low and medium quality stands to emphasize pulpwood rotation because sawlog potential is limited. It can be applied to high quality stands based on other objectives. The even-aged methods include shelterwood/overstory removal, strip clearcut/coppice and coppice with standards utilized for managing swamp hardwood on low to medium quality sites. As with these and any other methods, careful hydrology considerations should be applied when managing these sites.

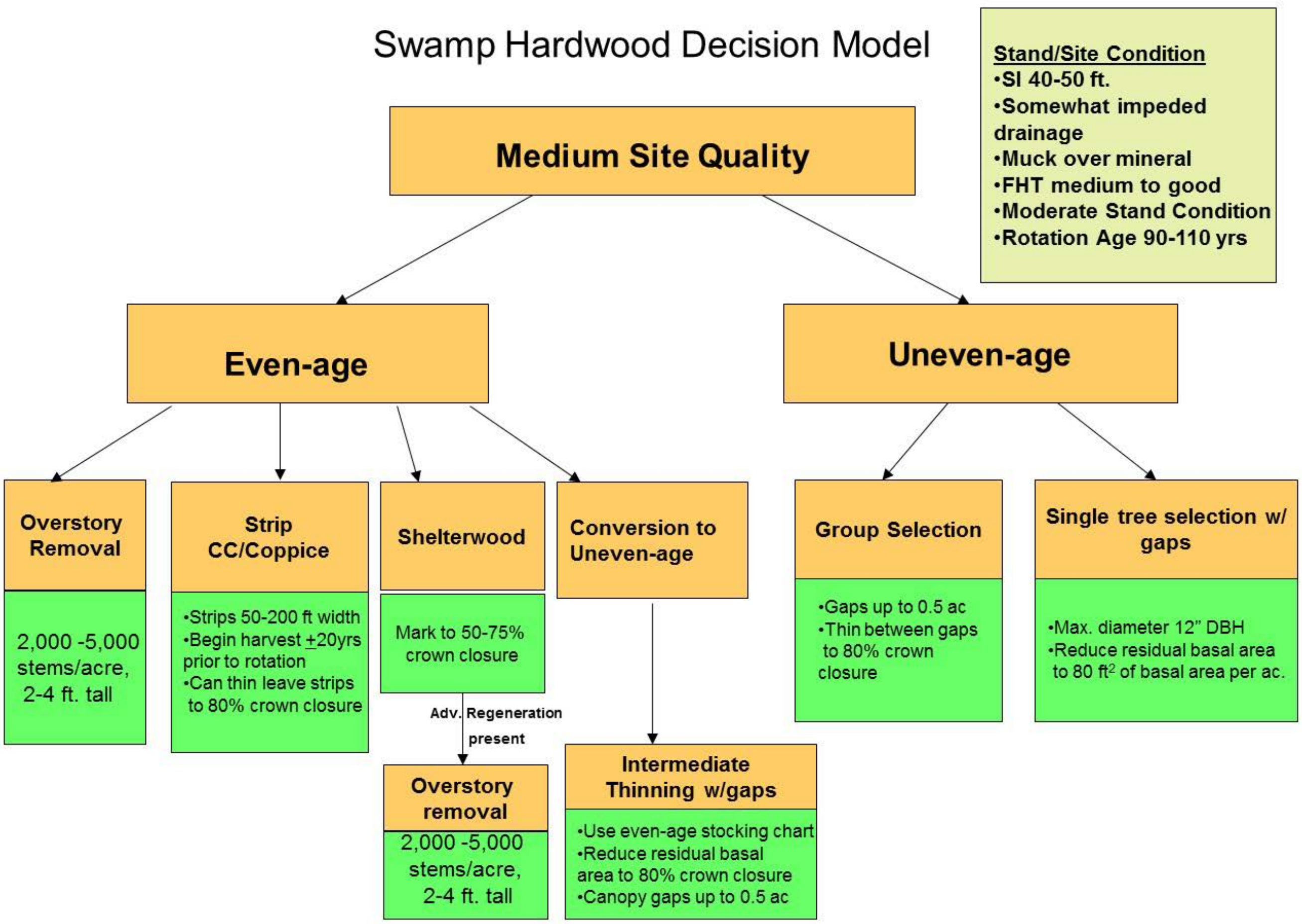
Uneven-aged silvicultural systems, such as single tree selection and group selection may also be utilized for the management of swamp hardwood stands on the medium and high-quality sites and can develop sawlog quality. Conversion from even-aged to uneven-aged structure using similar northern hardwood applications has been utilized on some sites also.

Across the spectrum of swamp hardwood stands in Wisconsin, there is a range of quality and condition observed. For instance, in the Northeastern region of the state the swamp hardwood mix of green/black ash can produce sawlog quality product on some sites. Also, in the Northern region there are some stands that have sawlog potential. However, for the most part, swamp hardwood stands in these regions have poor sawlog potential. There are 3 site quality categories to consider when assessing the proposed stand. This chapter offers management alternatives that can be applied to address this spectrum using either even-aged or uneven-aged (sawlog potential) methods.



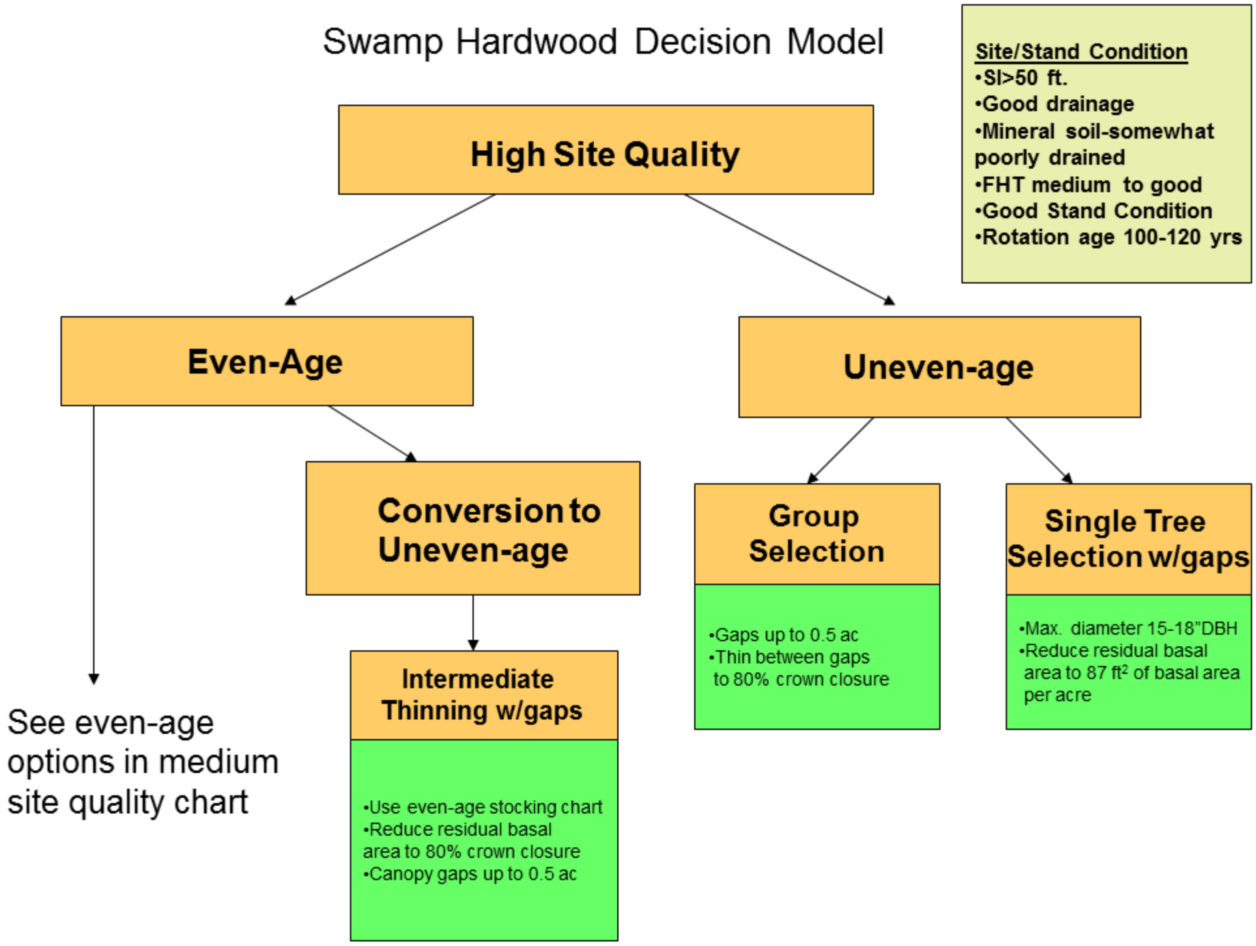
For low quality sites that are defined as having a site index of <40, impeded drainage, muck soils, poor to medium habitat types, and poor stand condition, options for management are even-aged management or no management. In some of these stands, tag alder may be dominant in the understory or other aggressive plants. Tag alder, although beneficial for wildlife, can be an aggressive competitor against tree regeneration. If tag alder, buckthorn, reed canary grass or other aggressive plants are the dominant understory >50%, they can take over the stand once released (Hoffman personal communication). In this case, either control of these species or no management should be considered.

In choosing one silviculture method over another, the forester should evaluate site conditions carefully. For example, a strip clearcut/coppice may be the method selected to minimize hydrology concerns while trying to increase regeneration. The overstory removal method may be used only if adequate advanced regeneration is present.



For medium quality sites that are defined as having a SI 40 – 50, somewhat impeded drainage, muck over mineral soils, poor to medium habitat types; and moderate stand condition, options for management are even-aged management through progressive strip clearcut or shelterwood or uneven-aged management through single tree selection or group selection. Medium site quality stands are quite prevalent in Northern Wisconsin and management trials have had some success. Uneven-age management may be an option in better quality stands or to minimize the spread of aggressive species such as tag alder, buckthorn, or reed canary grass (maintaining some canopy).

In choosing one silviculture method over another, the forester should evaluate site conditions carefully. For example, a strip clearcut/coppice may be the method applied to minimize hydrology concerns while trying to increase regeneration. The overstory removal method may be used only if adequate advanced regeneration is present. The shelterwood method may be applied when larger diameter trees are present and to increase regeneration.



For high quality sites that are defined as having a site index of SI>50, good drainage, mineral soils – somewhat poorly drained, medium to good habitat types, and good stand condition, options include either even aged or uneven-aged management. High quality stands have been observed in some parts of northern and northeastern Wisconsin. Characteristics of these high-quality stands include free flowing surface water (sheet flow), no impeded drainage (good culvert placement in road systems near the managed stands and no beaver dams), good annual diameter growth, vigorous crown, little or no epicormic branching. Most of the managed, high quality stands that were observed in the trials have been managed uneven-aged through single tree selection harvest.

In choosing one silviculture method over another, the forester should evaluate site conditions carefully. For example, a strip clearcut/coppice may be the method selected to minimize hydrology concerns while trying to increase regeneration. The overstory removal method may be used only if adequate advanced regeneration is present. For uneven-age methods, group selection may enhance tree diversity while single tree selection maintains tree vigor on higher quality sites.

5 SILVICULTURAL SYSTEMS

A silvicultural system is a planned program of vegetation treatment during the entire life of a stand. All silvicultural systems include three basic components: intermediate treatments (tending), harvesting, and regeneration. Very little information is available in the literature regarding silvicultural systems used in the swamp hardwood type. Much of the information in this section is adapted from case studies or silviculture trials in Wisconsin and incorporates some recommendations from the publication "Managing Black Ash in the Lake States" (Erdman et al. 1987). The case studies include 35 or more trials in swamp hardwood. Most trials were implemented on county forest lands, though a few are on state and private forest lands. The trials increase our understanding of ecological, silvicultural and hydrological impacts. Many of these trials are documented on the WDNR internet website:https://dnr.wisconsin.gov/topic/forestmanagement/silviculturetrials

5.1 Seedling / Sapling Stands

Once established, seedlings and saplings (especially black ash and red maple) exhibit optimal vigor (growth and health) when exposed to (near) full sunlight. Crop trees that are released to free-to-grow conditions have the greatest potential to survive and to maximize growth and productivity. Stocking should be maintained at 2,000 to 5,000 well distributed trees per acre (2 to 4 ft. tall) to ensure full stocking when pole-timber size is attained.

5.2 Intermediate Treatments

5.2.2 Non-Commercial Intermediate Treatments

5.2.2.1 Release

Release treatments may be implemented in young stands of swamp hardwoods to enhance growth on potential crop trees and to eliminate competition from undesirable species. Release treatments are probably not economically viable for swamp hardwoods, but if considering this method see the northern hardwood chapter.

5.2.3 Thinning

Intermediate treatments are generally designed to enhance individual tree growth, health, and quality, as well as stand composition, structure, and value. Thinning is a cultural treatment conducted in stands past the sapling stage to reduce stand density. It temporarily reduces stocking to concentrate growth on the more desirable trees. Thinning can impact stand growth, compositional and structural development, and economic yield. It provides the main method, implemented between regeneration and final harvest, to increase the economic productivity of stands. Normal thinning does not significantly alter the gross production of wood volume.

Thinning can be difficult, especially on wetter sites, due to operability concerns. When thinning is considered, implement when basal area stocking is above 100% crown cover. Reduce stocking to a density near 80% crown cover, choosing a residual basal area that will accommodate landowner objectives. A general rule of thumb is do not remove >35% of the basal area in any one thinning operation. Refer to the stocking chart (Figure 46.6) to help determine timing and level of thinning. When to thin depends on management objectives, stand conditions, and operability.

Intermediate thinning should be restricted to stands that are economically viable, at least 20 years prior to rotation and should contain at least 100 square feet of basal area. First, reduce the residual basal area to the prescribed stocking level (80 percent crown cover for first entry) using the even-aged stocking guide for black ash (Figure 46.6) The thinning is made from below and frees crop trees from poor quality main canopy competition as suggested below. Black ash has a narrower crown than other swamp hardwood species, thus a 5-foot crown release is recommended. Subsequent thinning to 90 percent crown cover should be delayed until crowns close and lower branches die on crop trees. Crop tree selection criteria and standard order of removal are defined below.

Crop tree selection criteria:

- Low risk of mortality or failure (main stem breakage)
- Good crown vigor
    - Dominant or codominant trees
    - Good silhouette and healthy leaves
    - Full concentric crown

- Good stem quality
- Desirable species

Trees may also be selected for retention to achieve other objectives, such as aesthetics or wildlife management.

Select trees to cut, following the standard order of removal.

Standard order of removal (with EAB imminent see EAB guidelines for order of removal especially in the quarantined counties):

- High risk of mortality or failure (unless retained as a wildlife tree)
- Release crop trees
- Low (lower) crown vigor
- Poor (poorer) stem form and quality
- Less desirable species
- Improve spacing

5.3 Natural Regeneration Methods

Note: The following recommendations assume the management objective is to maximize quality and quantity of swamp hardwood pulpwood and sawlogs. For declining stands or stands on poor quality sites see considerations discussion. If EAB is imminent, address management by referring to the EAB silviculture guidelines.

For landowners with the goal of maintaining shade intolerant to mid-tolerant species, even-aged management is the preferred method where hydrology is easier to control. The even-aged regeneration methods generally accepted and supported by literature are:

- Overstory removal
- Strip clearcut/coppice

- Shelterwood

Where maintenance of mid-tolerant species is a goal on medium to high quality sites, uneven-aged management may be suitable. The uneven-aged regeneration methods generally accepted and supported by literature are:

- Single tree selection
- Group or patch selection

5.3.1 Even-Age Regeneration Methods

5.3.1.1 Shelterwood

Even-aged management, using the shelterwood method, is implemented in medium- and high-quality swamp hardwood stands to enhance less shade tolerant species such as black ash, yellow birch, red maple and white pine (Erdmann 1986). While stands are maturing, intermediate even-aged thinning guidelines should be followed. Stand rotation is based on landowner objectives, species present, site quality, tree vigor and stand condition, and requires the presence of adequate established regeneration (see rotation length section). As with all methods, hydrology considerations should be a priority at these sites.

Regeneration is usually accomplished using a two-step shelterwood. Initial harvesting (seed cut) will provide proper crown closure and tree spacing depending on the preferred species composition leaving a high, uniform crown cover of 50 - 75 % in the residual shelterwood overstory. Retain vigorous, high quality (best phenotypes) dominant and codominant trees to serve as seed sources.

Consider timing of the shelterwood cut and site preparation operations relative to the production of good seed crops. Site preparation may be needed for regeneration to be successful. Site preparation on these sites can be difficult due to swamping, rutting potential and further development of swamp grass and other competitive species. Site preparation can be accomplished via mechanical or chemical methods, prescribed burning, or a combination of these techniques. The intent is to provide a moist, mixed seedbed of mineral soil and humus in addition to reducing competition. Complete the final removal and release established regeneration using the overstory removal methodology described below.

5.3.1.2 Overstory Removal

This even-aged method removes all or a portion of the canopy placing established, advanced regeneration in a free to grow position. Gradual or patch overstory removal may be necessary on wet sites to reduce the chance of raising the water table, causing damage or mortality to regeneration. Swamp hardwood regeneration is considered established when it reaches sufficient height, usually 2 to 4 feet tall, however, taller established regeneration may be needed to address deer browse and hydrology concerns. Sufficient established regeneration of 2,000 to 5,000 or more well, spaced seedlings and low stump sprouts per acre is optimum prior to considering overstory removal. Overstory removal operations should be conducted during the winter or fall during non-growing season and preferably with frozen or dry soil conditions in order to minimize the damage to the regeneration. Overstory removal is typically conducted when the canopy is at or near rotation age or in degraded stands with adequate advanced regeneration.

General considerations in the application of overstory removal method are: overstory health, condition and composition; potential risk of raising the water table on wet sites; adequate stocking, distribution, vigor; site capability; existing and potential competition including invasive species.

5.3.1.3 Progressive Strip Clearcut/Coppice

Clearcut is an even-aged regeneration method used to regenerate a stand by the removal of most or all woody vegetation during harvest creating a (nearly) completely open area leading to the establishment of an even-aged stand. Progressive strip clearcut is a variation of the clearcut method. The stand is removed using a series of strips harvested over two or three entries, usually covering an equal area on each occasion. The entire stand level strip removal process is completed within a period of time not exceeding 20% of the intended rotation (creating an even-aged stand). This method is recommended
when hydrology, regeneration and less frequent entries is a consideration

Typically, the uncut area serves as the primary seed source for regenerating the cut strip (and to maintain the water table). The clearcut strips are often oriented so that they are at right angles to the direction of seed-dispersing winds. Additional regeneration can come from previously dispersed seed, trees cut during each strip harvest operation, natural seeding from nearby stands, and stump sprouting (coppice). Regeneration is established during or following stand removal. There is the option of having the uncut strip harvested up to 80% crown closure so long as damage does not occur to the residual trees.

Recommended process:

1. Cut first ½ or 1/3 of stand in strips approximately 50 (to 200) feet wide. Strip orientation and width is dependent on road layout, stand shape, windthrow concerns, and hydrology. Wait until well established regeneration is 2 to 4 ft. tall and 2,000 – 5,000 stems per acre.
2. Cut next adjacent strip 50-200 feet wide. Cut strips should be located adjoining the previously cut strips.
3. Wait until well established regeneration is 2 to 4 ft. tall (unless there are browse or hydrology concerns) and at 2,000 – 5,000 stems per acre.
4. Cut final strips, retaining reserve trees for green tree retention.

<u>Strip management recommendations:</u>

- When the first and second strip cuts are implemented, remove all trees >1-inch dbh, and retain only exceptional reserve trees, if present, for green tree retention purposes.
- When the second and third strip cuts are implemented, care should be taken to protect the regeneration in the previously cut strips.
- When the third (last) strip cut is implemented, remove all trees >1-inch dbh, but consider retaining seed trees and reserve trees.
- Consider the timing of the strip cuts relative to the production of good seed crops, seed dispersal and germination, and site preparation operations.

5.3.1.4 Coppice with Standards[1]

An even-aged regeneration method is designed to naturally regenerate a stand using vegetative reproduction from stump sprouts. Standards or reserve trees of a desirable seed source (red maple, yellow birch, white pine, white spruce, tamarack and cedar where available) are left for several purposes such as maintenance of water table, wildlife considerations or to promote conversion to a different species composition. Leaving 20% crown cover or more for reserves in scattered or in aggregated patches are recommended for green tree retention purposes and to maintain hydrologic function and prevent swamping.

Considerations:

- This method should be carefully considered due to hydrology and regeneration concerns.
- Coppice regeneration harvests should occur fall to winter to encourage increased number and vigor of stump sprouts the following spring. During the coppice regeneration harvest, remove all trees >1-inch dbh; retain only desirable reserve trees.
- Sprouts can be abundant and vigorous when young, vigorous trees are cut with stump heights of less than 12 inches; sprouting can be significantly less in older stands (>100 years).
- Following cutting, stump sprouts can be abundant, but mortality during the first several years can be high; deer browsing can be a significant limiting factor.
- When necessary, herbicides can effectively control competing vegetation; of particular concern is the control of tag alder, buckthorn and reed canary grass. With these species, either no management or uneven-aged system may be applicable.
- Reserve trees may be susceptible to windthrow.

In many trials it has been documented that several swamp hardwood species (black and green ash, red maple, yellow birch, elm) produce abundant stump sprouts. Black ash has a fast growth rate from the stump and can put on as much as 5 feet in the first year (Schmidt personal communication).

5.3.2 Uneven-Age Regeneration Methods

Tardif and Bergeron (1999) and Erdman (1987) describe pure, uneven-aged black ash stands on wet, nutrient rich sites. They described the age and size distributions as an inverted “J” shape characteristic of old-growth forests at equilibrium or of self-sustaining “climax” populations. In Wisconsin, two-aged and multi-aged black ash stands are commonly observed in the field. Black ash appears to readily capture canopy gaps created as individual trees die off or groups of trees are windthrown. In fact, Tardif and Bergeron (1999) speculate that most black ash enter the canopy as a result of small disturbances – i.e. due to tree by tree replacement. Their data also shows that in old growth black ash stands seed and sprout reproduction is sufficient to result in self maintenance of the population following the mortality of mature trees. In addition, black ash advanced regeneration is often observed under a full black ash canopy. All of which seem to indicate that black ash may be more tolerant of

[1] Management practice that may have potential for application in managing swamp hardwoods but has not been widely utilized and tested.

understory conditions than previously thought and may lend itself to uneven-aged management on better quality sites.

5.3.2.1 Single-Tree Selection

Single tree selection may not be the best alternative for low and some medium quality sites depending on the landowner objective. Considerations in selecting this method may include economic feasibility and operability. With the single tree selection, regeneration is established by creating canopy gaps with each entry. Gaps (25-75' diameter) may be created by cutting large crowned trees or groups of low vigor/poor quality trees. All poor-quality residual stems larger than 2 inches DBH must be cut in these gaps so that vigorous regeneration can develop. Residual stand structure recommendations can be found in Table 46.8 and Table 46.9. The following recommended guidelines should be followed when using single tree selection (adapted from Erdman 1987):

- Follow basal area guidelines (Table 46.8 and Table 46.9). Recognize current and target structures. For medium sites use a 12" maximum tree size and on high quality sites use a 15-18" maximum tree size class (developed for black ash).
- In overstocked size classes cut the poorest trees to obtain the recommended density and release crop trees.
- Follow the recommended order of removal, as mentioned above.

Most second growth stands require about three periodic harvests to achieve desirable stocking and structure conditions before they are fully regulated to uneven-aged sustained yield and growth.

5.3.2.2 Group Selection

Group selection may also be utilized to produce regeneration in groups throughout a stand. Spatial distribution of groups may be irregular and dictated by small variations in stand conditions, such as the vigor, health, and size of individual and small groups of trees. Site quality will determine the potential for high quality products. Other considerations in selecting this method may include economic feasibility and operability.

The group selection regeneration method in swamp hardwoods is appropriate for promoting a higher preponderance mid-tolerant species including yellow birch, red maple or white pine. Groups of trees are selectively or systematically removed to create medium sized gaps in the canopy of swamp hardwood stands ranging from 0.1 acres up to approximately 0.5 acres in size. Factors affecting the size of the opening include stand management objective, structure, quality, vigor, and shade tolerance of desired regeneration species.

Group patches often require site preparation and release of preferred species of regeneration from competition. Site preparation on these sites can be difficult due to swamping, rutting potential and further development of swamp grass and other competitive species. This method may not be the best alternative if species such as buckthorn and reed canary grass is present. These species will quickly establish and dominate the gap. Site preparation can be accomplished via mechanical or chemical methods or a combination of these techniques. The intent is to provide a moist, mixed seedbed of mineral soil and humus in addition to reducing competition.

The number of groups and rotation length are dependent upon the landowner objectives and the size of the area being managed. In application, group openings are cleaned of all non-crop tree stems down to one inch in diameter. Groups of trees cut to create openings are those of poorest stem form, vigor and quality or are at rotation age. Consider location of gaps relative to existing advanced regeneration or in relation to where there is need for developing regeneration within the stand. During group opening creation, thinning and crop tree release occurs throughout the remainder of the stand. Refer to the northern hardwood chapter regarding this method.

5.3.2.3 Even-aged to Uneven-Aged Conversion Process

Stands that are even-aged or two-aged may be converted to uneven-aged management by combining crop tree release, thinning and canopy gap formation (conversion) techniques. The conversion to uneven-aged in swamp hardwood has not been well documented. This method suggested in the flowchart should be applied in high quality stands only. Crop tree release enhances growth and crown development on potential crop trees. Many even aged stands have closed canopy conditions which prevent or limit establishment and recruitment of multiple age classes. Installing canopy gaps will create proper growth conditions for regeneration and recruitment of new regeneration. Due to lack of information utilizing this method in swamp hardwood, the currently recommended procedure to convert even-aged stands to uneven-aged structure comes from the northern hardwood chapter and adapted from the Argonne Experimental Forest studies.

1. Crown release 40-60 crop trees per acre. Pole sized crop trees should receive a 4-sided, 5’ crown release (black ash). Sawtimber sized crop trees should receive a 1-3 sided crown release (see chapters 23 & 24).
2. Create canopy gaps for regeneration on approximately 10% (range of 5-15%) of the area at each entry. Canopy gaps can range in size from 30 to 60 ft. in diameter. The percentage of area in regeneration gaps is based on the frequency and size of gaps. Recommended targets for size and quantity of gaps are 4, 35’ gaps per acre (9% of stand area) or 6, 30’ gaps per acre (10%). Occasionally, larger gaps can be included to encourage the representation of mid-tolerant species (e.g. 1, 35’ gap and 1, 60’ gap occupy 9% of an acre). Gaps should be created by cutting groups of high risk or relatively poor-quality stems. Within the gaps all poor-quality stems >1” DBH should be cut to facilitate vigorous regeneration.
3. Apply even-aged thinning guidelines to the remainder of the stand; follow the order of removal.
4. Wait 15 to 20 years for the next entry. To facilitate the development of timber quality, the next cut should not be implemented until after crown closure and lower branch mortality occurs in crop trees.
    - If stand is predominantly pole to small sawtimber sized, then repeat the conversion process.
    - If stand is predominantly medium sawtimber sized, then apply target structure for uneven-aged single-tree selection guidelines. It is necessary to compensate for understocked size classes by maintaining stocking in other overstocked size classes to meet the total target goal of 80 sq ft/acre on medium quality sites and 87 sq ft/acre on high quality sites.

- It will probably require at least 3-4 cutting operations to develop a relatively well regulated and fully stocked (by size class) uneven-aged stand.

5.5 Rotation Lengths and Cutting Cycles

Even-Aged Silvicultural Systems

In even-aged silvicultural systems the rotation is defined as the period between regeneration establishment and final cutting. The length of rotation may be based on many criteria including culmination of mean annual increment, mean size, age, attainment of particular minimum physical or value growth rate, and biological condition. Ideally, the lower end of the rotation length range would be defined by the age at which maximization of mean annual increment (MAI) growth occurs. The upper end of the rotation length range would be defined by the average stand life expectancy. However, very little objective data exists identifying these endpoints in general and even less by site type.

Swamp hardwoods are usually managed to produce sawtimber on sites (see Table 46.8 and Table 46.9) where relative potential productivity is good (black ash SI>50). The recommended even-aged rotation to balance high quality development, high growth rates (vigor), and economic risk is 120 years. Rotations up to 150 years can be considered (on excellent sites), but volume growth rates may decline and economic risk will increase.

On poorer sites (black ash SI<50), recommended rotation ages may be somewhat shorter, because reduced vigor and growth will make managing for sawtimber products difficult. Individual trees and stands may maintain vigor longer or decline earlier than these rotation length guidelines indicate. In application, foresters will need to regularly review stands in the field and exercise professional judgment concerning quality, vigor, mortality, and merchantability. See Table 46.6 below to review site characteristics. The numbers provided are based on general data, empirical evidence, and the best estimations of the authors and other contributors.

Uneven-Aged Silvicultural Systems

In uneven-aged systems, the method is designed to regenerate and maintain uneven-aged stands by removing some trees at regular intervals. Trees are removed in various size classes, either singly or in small groups. An uneven-aged stand is maintained by periodically regenerating new age classes while manipulating the overstory structure to facilitate continual development of quality growing stock. Stand regeneration is achieved by periodically manipulating the overstory and understory to create conditions favorable for the establishment and survival of desirable tree species. Regeneration cuts, thinning, and harvesting usually occurs simultaneously. Generally, most regeneration is seed origin, although a component can be vegetative.

The selection of the appropriate stocking guide and cutting interval depends on site quality, species, growth rates, operational considerations, and landowner goals. On high quality sites where management goals attempt to achieve an optimal balance of sawtimber quality and quantity, the 15-18” inch maximum size class stocking guide is recommended (Table 46.8). If stocking in the maximum diameter class is too low or other poorer quality trees are present, then the vigorous, low risk, high quality trees should be retained even if well beyond the maximum diameter.

In stands managed under uneven-aged management, the cutting cycle re-entry interval generally ranges from 15 to 20 years based on landowner objectives, site quality, and growth. Shorter cutting cycles can maintain higher tree growth rates but operability (costs and benefits) must be considered. Shorter, more frequent re-entries may increase the potential for degrading stand quality through stem damage and soil compaction. Conversely, shorter cutting cycles will allow for capture of more high risk and low vigor trees succumbing to mortality. Longer cutting cycles can maximize tree quality and reduce negative impacts, such as damage to residual trees, soil compaction, aesthetic impacts (e.g. reduced slash), and ecological impacts (e.g. habitat disruption).

5.5.3 Extended Rotation

Management goals for extended rotations attempt to balance economic, social, and ecological management goals. While timber production is still an important value, increased emphasis is placed on other values, such as aesthetics, wildlife habitat, and biodiversity. Typically stocking guides utilize a 15-18-inch maximum tree size class (Table 46.8) or larger. Longer cutting cycles can be appropriate using ecological management techniques such as the retention of reserve trees, management of coarse woody debris (large snags and downed rotting logs), and the encouragement of coniferous associates (especially hemlock and white pine). The recommended extended rotation age is 100 – 150 years on sites where there may be a variety of objectives. On some green ash or mixed green/black ash sites observations in northeastern Wisconsin indicate that vigor can be maintained longer. On other sites there may be hydrology or rare species considerations where extended rotation is recommended.

Table 46.6. Review of site characteristics and rotation ages for low, medium and high-quality stands.

Low site quality	**Medium site quality**	**High Site quality**
Impeded drainage	Somewhat impeded	Medium to Good drainage
Muck soils	Muck over mineral soil	Mineral soil
Poor stand condition	Moderate stand condition	Good stand condition
Poor to medium habitat type	Poor to medium habitat type	Medium to good habitat type
Rotation age: 80-100 yrs	**Rotation age:** 90-110 yrs	**Rotation age:** 110-120

5.6 Other Silvicultural Considerations

5.6.2 Cover Type Conversion

When considering natural conversion evaluating the site conditions and potential are important. Knowledge of the site factors such as soils, lowland habitat type, existing vegetation and productivity potential will aid in deciding to use this method. Of high importance is the presence of a desired seed source. Some of the dominant species that maybe be considered in conversion include red maple, yellow birch, and tamarack. Other species that may be a component of these stands include white birch, white pine, swamp white oak, silver maple, and

American elm. These species respond well to large gaps in the canopy for regeneration recruitment. Group selection, variations of shelterwood harvests, coppice with standards, and wide strip clearcuts (50-200 feet wide) are all viable options for natural conversion.

Other species to consider for conversion include more shade tolerant species such as balsam fir, hemlock, and white cedar. Small gaps in the canopy can be used to recruit regeneration. Silviculture systems that may work well for regenerating these species include shelterwood harvests, narrow strip clearcuts (30-60 feet wide), coppice with standards and single tree selection. Regenerating some of these recommended species can be difficult but refer to each species cover type chapter when considering natural conversion. In extremely wet stands where tag alder is predominant in the understory, conversion to another cover type species will be very difficult to achieve.

With artificial regeneration, it's important to once again evaluate the site conditions such as soils, existing vegetation and site potential. Depending on the site evaluation, species to consider include tamarack, northern white cedar, red maple, yellow birch, hemlock, black spruce, and white spruce. Shallow rooted species will have the greatest growth and survival on these sites. Tamarack may be the best option because it grows well in wet conditions and is less likely to be browsed. Northern white cedar will require some form of protection from herbivory (mainly from deer). Red maple may work on mineral sites and sites that are not extremely wet. Black and white spruce may be a good option since they will not be browsed as heavily. Knowing the lowland habitat type will aid the manager in deciding what alternative cover type to promote. Site preparation may be needed in these stands when using artificial regeneration. Site preparation methods include alder shearing and harvesting operations to allow adequate conditions for seedlings. Due to the high planting costs and herbivory (deer) some species may not be viable options in all stands. Refer to the Artificial Regeneration chapter for more information on planting.

5.6.3 Diameter Limit Harvest

Diameter limit cutting is harvesting all trees above a set diameter regardless of the impact on stand structure, stand quality, tree quality, species composition, or regeneration needs. At times referred to as a "selective cut", the only consideration is diameter as opposed to specific criteria employed in a true single tree selection harvest under the uneven-aged silviculture system. Diameter limit harvesting usually removes the most vigorous and best seed producing trees. After a diameter limit harvest, the residual trees that were in a subordinate crown position are subjected to lower stem quality and epicormic branching (Fajvan, 2002). The few diameter limit harvest trials in swamp hardwood that were documented in the Wisconsin trials, appeared to "swamp out" as a result of the harvest and little tree regeneration remaining. The residual (suppressed) trees at these sites eventually died from stress. Diameter limit harvest is not considered a generally accepted silvicultural practice that results in sustainable forestry because of these considerations.

8 APPENDICES

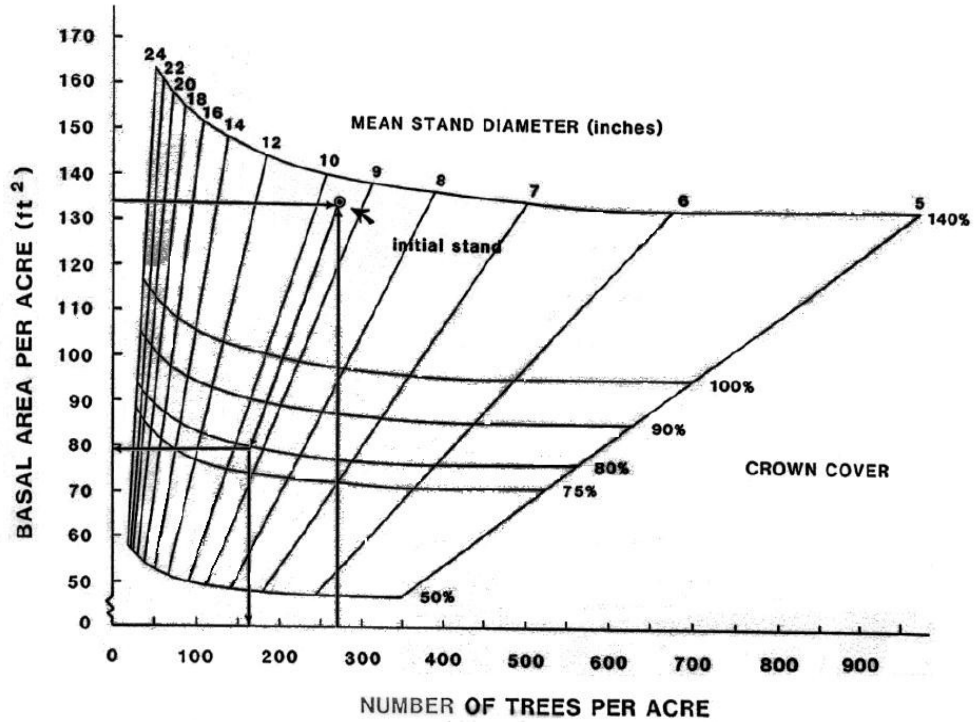


Figure 46.6. Even-aged stocking levels for black ash by crown cover, basal area and trees per acre for specific average stand DBH classes (Erdman et al. 1987).

Previous View

Table 46.7. Even-aged stocking level table for black ash by crown cover, basal area and number of trees per acre for specified DBH classes (Erdman 1987).

SU.nd (In.)	Crown cover (rcent of 43,560 tt2/A)									
	Trees No./A	SA Ft2/A	Trees tlo./A	IJA Ft2/A	Trees Wo./A	IJA Ft2/A	Trees No./A	I!A Ft2/A	Trees No./A	:II: Ft2/A
5	348	47.4	522	71.2	556	75.9	626	85.3	696	94.9
6	242	47.6	363	71.3	388	76.1	436	85.6	485	95.1
7	180	48.1	270	72.2	288	77.u	324	86.6	360	96.2
8	140	48.8	210	73.1	223	78.0	251	87.8	279	97.5
9	112	49.5	168	74.2	179	79.2	202	89.0	224	98.9
10	92	50.2	138	75.3	147	80.3	166	90.4	184	100.4
11	77	50.9	II6	76.4	123	81.5	139	91.7	154	!01.8
12	66	51.6	99	77.4	105	82.6	118	92.9	131	103.2
13	57	52.3	85	78.5	91	83.7	102	94.1	II3	104.6
14	50	53.0	74	79.4	79	84.7	89	95.3	99	105.9
15	44	53.6	66	80.4	70	85.8	79	96.5	87	107.2
16	39	54.2	58	81.3	62	86.7	70	97.6	7!;1	108.4
17	3:)	54.8	52	82.2	56	87.7	63	9II.7	70	109.6
18	31	55.4	47	83.1	50	88.6	56	99.7	63	110.8
19	28	55.9	43	83.9	45	89.5	51	100.7	57	III.9
20	26	56.5	39	84.7	41	90.3	47	I0l.6	52	112.. 9
21	24	57.0	36	85.5	38	91.2	43	102.6	47	114.0
22	22	57.5	33	86.2	35	92.0	39	103.5	44	115.0
23	20	58.0	30	87.0	32	92.7	36	104 . 3	40	115.9
24	19	58.4	28	87.7	30	93.5	33	105.2	37	116.. 9

!I Expected blacash crown area-7.6483 + 3.8952 d.b.h. I.7974 Where d.b.h. fs fn fnches; basis n = 37 forest!Jrown trl:!eS that have a d.b.h. at leastas large as the aerage sta.nd d.b.h.; R2•0.89. Values for the 20-inch and larger d.b.h. classes hdve been projected be.)'ond our data base.

Table 46.8. Desired residual stocking for high-quality sites after individual tree selection harvest, 15-18-inch maximum diameter class. Adapted from Erdman 1987 and T. Strong 2005.

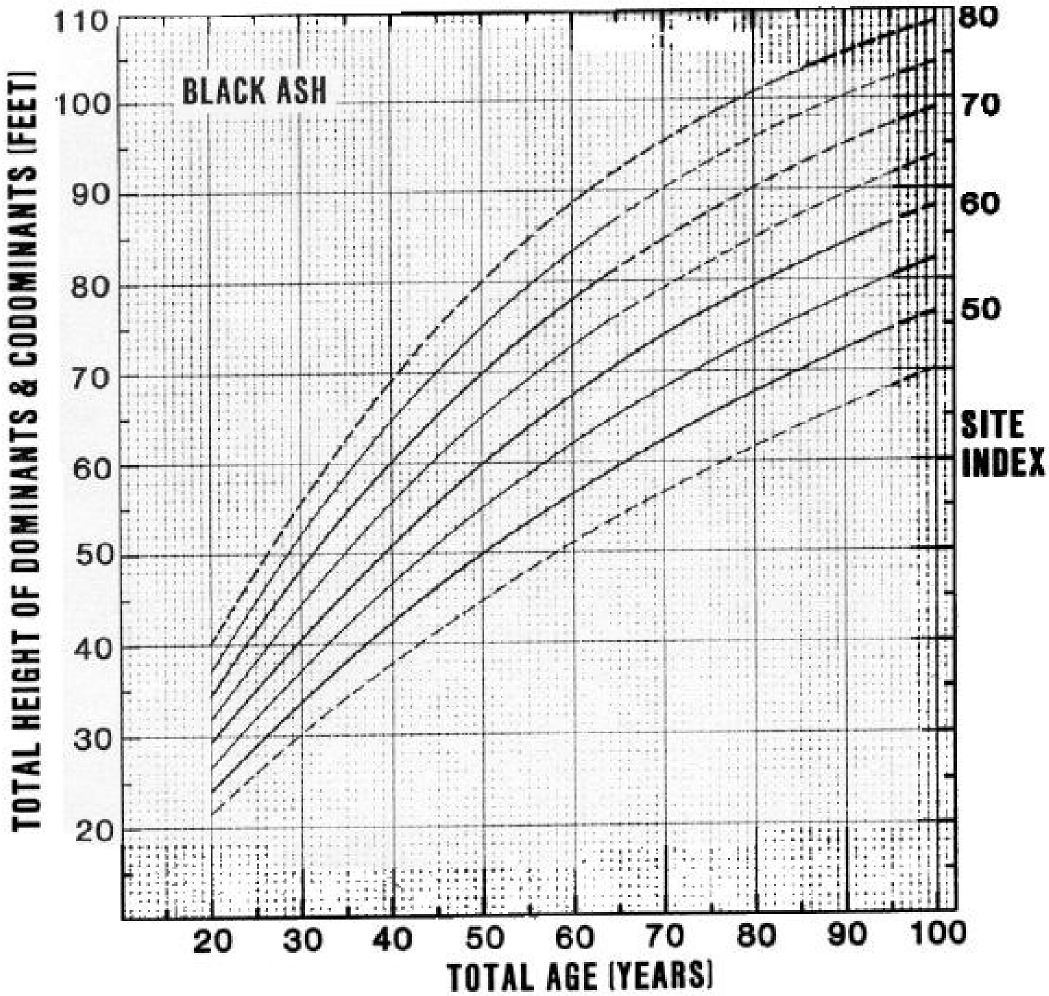
DBH Classes	Trees/Acre	Basal Area/Acre
	Poles	
5	22	3.0
6	19	4.0
7	17	5.0
8	15	5.0
9	13	6.0
Sub Total	86	23
	Small Saw	
10	11	6.0
11	10	7.0
12	9	7.1
13	8	7.4
14	7	8.0
Sub Total	45	36
	Med. Saw	
15	6	7.4
16	5	7.0
17	4	6.3
18	4	7.1
Sub Total	19	28
Total	150	87

Stocking recommendations are based on max tree size of 15-18” DBH, Q factor of 1.1, Residual crown cover of 80%.

Table 46.9. Desired residual stocking for medium-quality site after individual tree selection harvest, 12-inch maximum diameter class. Adapted from Erdman 1987.

DBH Classes	Trees/Acre	Basal Area/Acre
Poles		
5	69	9.3
6	53	10.3
7	41	10.8
8	31	10.9
9	24	10.6
Sub Total	218	51.9
Small Saw		
10	18	10.1
11	14	9.4
12	11	8.6
Sub Total	43	28.1
Total	261	80

Stocking recommendations are based on a max tree size of 12 inches at DBH, Q factor of 1.3, Residual Basal Area of 80 square feet for trees 4.6 inches at DBH and larger.



Black ash (Carmean 1978)
Northern Wisconsin and Upper Michigan
39 plots having 143 dominant and codominant trees
Stem analysis, nonlinear regression, polymorphic
Add 4 years to d.b.h. age to obtain total age (BH = 0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	4.2286	0.7857	-0.0178	4.6219	-0.3591	0.99	0.70	2.4
SI	0.2388	1.1583	-0.0102	-1.8455	-0.1883	0.99	0.99	3.4

Figure 46.7. Site index curves for black ash in northern Wisconsin and upper Michigan (Carmean et al. 1989).

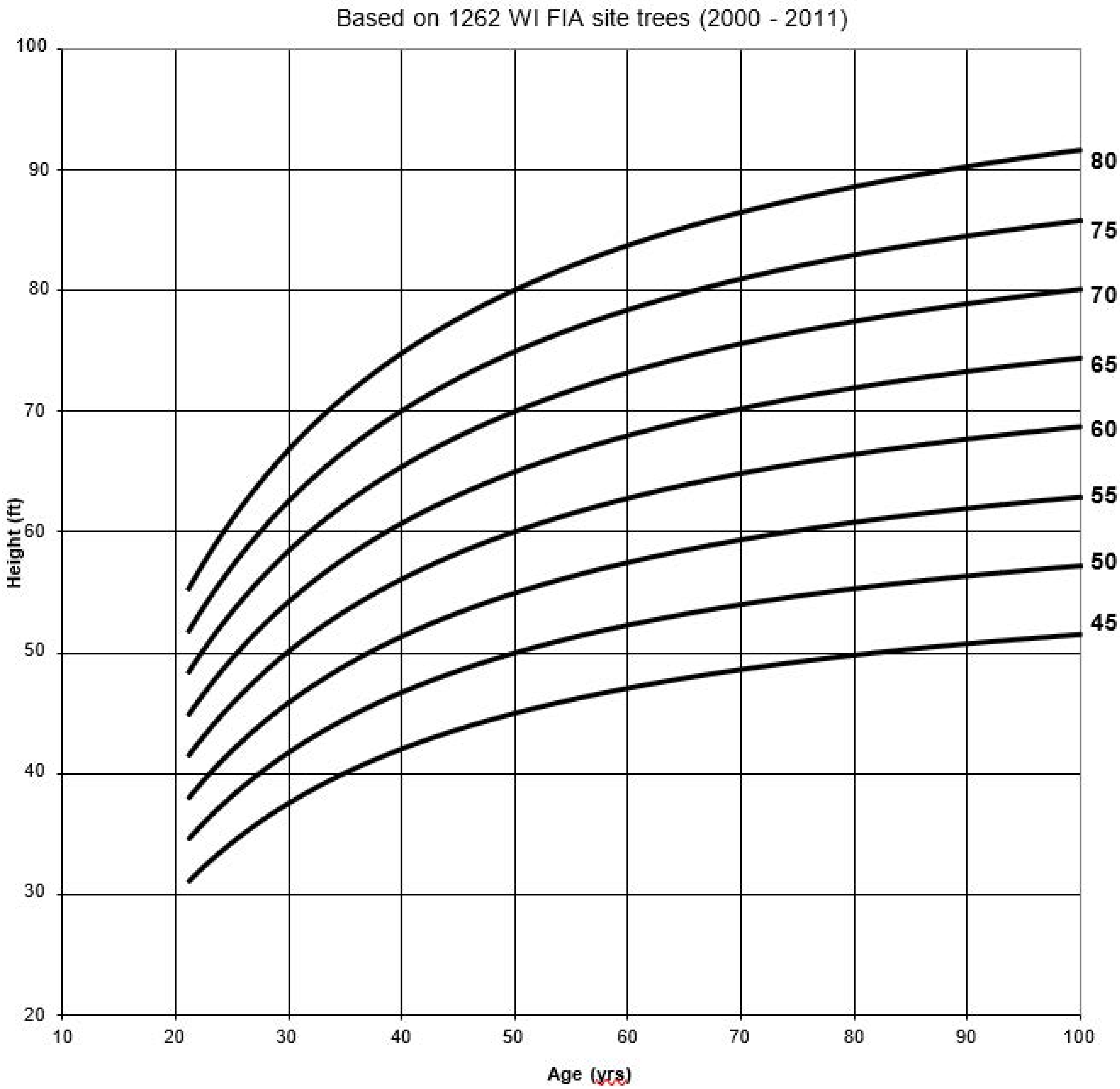


Figure 46.8. Site index curves for green ash in Wisconsin (FIA 2010). Anamorphic curve is based on Wisconsin FIA data.

8.1 Forest Health Guidelines - Forest Health Protection (FHP)

Species included in this table are black ash, green ash, red maple, silver maple, willow, and alder.

For elms spp., refer to the Central Hardwoods Chapter. For swamp white oak, refer to the Oak Chapter. For animal and mechanical issues, please refer to the pest table under the Northern Hardwood Chapter (Ch. 40). For invasive plants, refer to the invasive plant appendix of this handbook.

Disturbance Agent and Expected Loss or Damage	Host(s)	Prevention, Options to Minimize Losses and Control Alternatives	References
DEFOLIATING INSECTS			
Blackheaded ash sawfly – *Tethida barda* **Brownheaded ash sawfly** - *Tomostethus multicinctus* **Spiny ash sawfly** - *Eupareophora parca* Larvae feed gregariously on young ash and ornamentals. Heavily infested trees can be defoliated in 1 – 2 weeks.	ash	☐ Natural enemies play an important role in population control ☐ Insecticides, with conservation of natural enemies, can be considered during severe infestations	
Striped alder sawfly – *Hemichroa croceas* Young larvae feed gregariously. All but the midveins are eaten.	alder and birch	☐ Though an exotic pest, control measures have not been considered necessary	
Willow sawfly – *Nematus ventralis* Can completely defoliate willows, especially young trees	willow		
Woolly ash aphid – *Prociphilus fraxinifolii* Honeydew, sooty mold, and distorted leaves indicate aphid damage. This aphid feeds on the underside of leaves and terminals and produces noticeable white fuzz on leaves and stems.	ash	☐ Natural enemies play an important role in population control	
Woolly alder aphid – *Paraprociphilus tesselatus* Sucks plant juices, but causes little damage. Produces noticeable white fuzz on leaves and stems. This is an aesthetic issue and does not affect tree health greatly.	Silver maple in early summer; alder in late summer	☐ Control not suggested.	
Ash plant bugs – *Tropidosteptes* spp. Discolored, distorted, and stunted expanding leaves and stippled older leaves are indications of ash plant bug feeding. Causes moderate to severe levels of leaf drop.	ash		

Disturbance Agent and Expected Loss or Damage	Host(s)	Prevention, Options to Minimize Losses and Control Alternatives	References
Alder Flea Beetle – *Altica ambiens* Larvae skeletonize alder leaves in late summer.	alder	No known control measures exist.	
Imported Willow Leaf Beetle - *Plagiodera versicolora* Skeletonize and chew holes in leaves. Cause light to severe leaf damage.	Willows and poplars		
Greenstriped mapleworm – *Dryocampa rubicunda rubicunda* Defoliation from this caterpillar is noticed in late July and early August. Late season defoliators do not damage trees as greatly as early season defoliators.	Red maples; sometimes other maples	Natural controls help reduce outbreak populations	
Fall webworm – *Hypantria cunea* Defoliate trees and make tents towards branch ends in later summer. Late season defoliators do not damage trees as greatly as early season defoliators.	hardwoods	Natural enemies are important for controlling populations	
Forest Tent Caterpillar – *Malacosoma disstria* Widespread heavy defoliation occurs periodically at intervals of 5-15 years. An outbreak usually lasts 2-5 years. Stressed trees may die after defoliation. Healthy trees may die after being defoliated for several years in a row.	hardwoods	Maintain healthy forests through proper forest management During an outbreak, insecticide applications can be an option to minimize the damage on highly valuable stands with high proportions of susceptible species.	
Ashleaf gall mites – *Aceria* spp. Induce leaves to grow kidney-shaped galls on their upper surfaces. This is an aesthetic issue and does not negatively affect tree health	ash	Control not suggested.	
Maple gall mites (eriophyid mites) Erineum galls, bladder galls, and spindle galls grow on leaf surfaces. This is an aesthetic issue and does not negatively affect tree health	maples	Control not suggested.	

Disturbance Agent and Expected Loss or Damage	Host(s)	Prevention, Options to Minimize Losses and Control Alternatives	References
FLOWER & SEED INSECTS			
Ash flower gall mite - *Aceria fraxiniflora* Attack male flower clusters, causing them to swell and deform into galls. Old galls turn dark-colored. Little harm is imparted to the tree. This is an aesthetic issue and does not negatively affect tree health	male ash	□ Control not suggested.	
Ash seed weevils – *Lignyodes* species Great proportions of seeds can be destroyed by these weevils. Female adults leave puncture marks on seeds.	ash and lilac seeds	□ Natural controls keep populations in check	
BARK AND WOOD INSECTS			
Scale Insects			
Oystershell scale - *Lepidosaphes ulmi* **European fruit lecanium** - *Parthenolecanium corni* Honeydew, sooty mold, and dieback indicate scale infestation. Scales attach to branches and suck sap and look like small (~3 mm) elongated or round bumps.	Ash		
Woolly alder aphid – *Paraprociphilus tesselatus* Sucks plant juices, but causes little damage. Produces noticeable white fuzz on leaves and stems. This is an aesthetic issue and does not negatively affect tree health.	alder in late summer	□ Control not suggested.	
Flatheaded Borers			
Emerald ash borer – *Agrilus planipennis* An extremely threatening exotic metallic wood borer. Larvae destroy the cambium layer.	ash	□ Refer to the EAB management guidelines	
Flatheaded appletree borer – *Chrysobothris femorata* Larvae destroy the phloem and heartwood of young and weakened trees. Initial damage may result in dieback; trees may die.	ash and other hardwoods	□ Plant trees properly □ Avoid stressing trees	

Disturbance Agent and Expected Loss or Damage	Host(s)	Prevention, Options to Minimize Losses and Control Alternatives	References
Roundheaded Borers			
Redheaded ash borer - *Neoclytus acuminatus* **Banded ash borer** - *Neoclytus caprea* Infest weakened or recently cut ash. The larvae create tunnels in the sapwood and adults leave round exit holes.	Weakened or recently killed ash and other hardwoods	Avoid stressing trees Process recently cut logs promptly	
Clearing Moths			
Ash borer (terminal and trunk borer) - *Podosesia syringae* First feed in early summer on terminals causing forking; then bore into trunks damaging sapwood. Adult leave circular exit holes. Can cause mortality. **Banded ash clearwing** - *Podosesia aureocincta* Causes similar damage to trees as the ash borer.	ash	Natural enemies reduce populations Avoid wounding trees Remove heavily infested trees	
Carpenterworm –*Prionoxystus robiniae* Tunnel into the heartwood of trunks and large branches. Tunnels allow the entry of wood decaying fungi.	Ash, oak, poplar, and other hardwoods	Keep stands well-stocked Avoid wounding trees Remove heavily infested trees	
Bark Beetles			
Eastern, northern, and white-banded ash bark beetles - *Hylesinus* species Typically attack weakened and recently cut ash. Females make egg galleries across the wood grain, and adults leave 1-mm round exit holes. The overwintering stage in the adult.	ash, typically weakened or recently killed	Infested trees can be felled; then debarked or destroyed.	
Ash cambium miner - *Phytobia spp.* Maggots mine cambium in branches, trunks, and roots and are most commonly found near the base of the trunk. The mines often zigzag across the sapwood surface.	ash		

Disturbance Agent and Expected Loss or Damage	Host(s)	Prevention, Options to Minimize Losses and Control Alternatives	References
FOLIAGE DISEASES			
Ash Leaf Spot -*Mycosphaerella effigurata* and *M. fraxinicola* Initially, small flecks and spots form on leaves; later, these dead areas coalesce and form irregular blotches. Expect this disease after prolonged cool, wet weather. These fungal pathogens do no create significant losses in forests.	ash	□ Intraspecies variation in resistance exists – favor resistant ash □ Ensure stands are not overstocked	
Tar Spot – *Rhytisma* This fungus grows black spots on leaves, particularly in the lower canopy. Tar spot does not causes significant losses.	maples		
Ash anthracnose – *Gnomoniella fraxini* (syn. *Discula fraxinea*) Brown leaf blotches form. Expect this disease after prolonged cool, wet weather. Ash anthracnose does not create significant losses in forests but can cause some leaf loss.	ash		
Maple anthracnose – *Discula spp.***,** *Aureobasidium apocryptum***,** and *Colletotrichum gloeosporioides* Causes heavy leaf spotting and blotching. Anthracnose does not cause significant losses.	maples		
Ash rust - *Puccinia sparganioides* Yellow-orange spots on leaf surfaces, yellow spots on petioles and new twig tissue, leaf distortion, and twig galls are symptoms. This disease can cause dieback. Expect this disease in areas that are prone to fog where ash and cordgrass grow in close proximity to each other.	ash and cordgrass (*Spartina spp.)*		
CANKERS / CANKER ROT			
Nectria canker - *Neonectria galligena* This canker is a target-shaped depression on the trunk, killing bark, cambium, and the outer sapwood. Wood decay associated with nectria cankers is rare. If the canker affects >50% of the stem's circumference, there is a high probability of failure.	hardwoods	□ Avoid wounding trees during cool, humid conditions	

Disturbance Agent and Expected Loss or Damage	Host(s)	Prevention, Options to Minimize Losses and Control Alternatives	References
Canker Rots			
Hispidus canker - *Inonotus hispidus* First rots heartwood, but eventually rots sapwood and kills the cambium. It forms an elongate, bark-covered, perennial canker and annual, yellowish to reddish conks.	ash, maple, willow, and other hardwoods	□ Avoid wounding trees □ Remove infected trees during thinning □ Trees infected with canker rots may also provide excellent den trees. Consider leaving an occasional canker-rotted tree as a cavity tree for wildlife.	
Inonotus glomeratus Produces white to light brown spongy heart rot and kills sapwood and cambium. Forms black, sterile conks.	maple, beech, paper birch, balsam poplar, hemlock	□ Avoid wounding trees □ Remove infected trees during thinning □ Trees infected with canker rots may also provide excellent den trees. Consider leaving an occasional canker-rotted tree as a cavity tree for wildlife.	
DECAY			
White Rots			
Perenniporia fraxinophila (=Fomes fraxinophila) Produces white mottled heart rot in trunks and larger limbs. Forms a perennial, bracket-shaped conk.	Ash	□ Avoid wounding trees □ Remove tree if decay in the main stem results in <1" of sound wood around the tree for every 6" in diameter (see FHP Guidelines, Northern Hardwood Chapter)	
Mossy-top conk – *Oxyporus populinus* This fungus forms a spongy, straw-colored white rot in heartwood and sapwood	maple, primarily		
Phellinus igniarius Causes white heart rot. Forms hoof-shaped, perennial conks with cracked, black upper surfaces.	hardwoods		
Ganoderma lucidum Forms a white rot of sapwood in major roots and butt logs. Annual, reddish conks grow from the base of trees or out of major roots.			

Disturbance Agent and Expected Loss or Damage	Host(s)	Prevention, Options to Minimize Losses and Control Alternatives	References
Brown Rot			
Sulfur Shelf – *Laetiporus sulphureus* Leaves brown cubical rot in the roots and trunk. Conks are shelf-like, annual, and yellow to orange.	hardwoods	□ Avoid wounding trees □ Remove tree if decay in the main stem results in <1" of sound wood around the tree for every 6" in diameter (see FHP Guidelines, Northern Hardwood Chapter)	
Ring Shake	Black ash		
WILTS, YELLOWS, AND DECLINES			
Ash Yellows – *phytoplasmas* Light green to yellow foliage, reduced growth, tufted foliage, epicormic branches, dieback, and witches' brooms growing from the root collar are symptoms. Susceptible saplings can die in 1 – 3 years. Expect to see this disease more frequently at stand edges.	ash and lilac	□ Harvest trees with more than 50% crown dieback within five years □ Remove other infected trees during harvests □ Encourage species diversity	How to Identify and Manage Ash Yellows in Forest Stands and Home Landscapes. 1994. USDA FS. NA-FR-03-94.
Black ash decline Growth loss, yellowing, dieback, and mortality are symptoms. Drought is likely responsible for inducing decline. Preliminary research indicates decline is more severe on wetter sites and in trees older than 100 years. Also, winter with little snow cover could induce decline.	ash	□ Avoid regenerating ash on droughty sites	Relating Black Ash (Fraxinus nigra) Decline and Regeneration to tree Age and Site Hydrology. USDA FS. EM Proposal: NC- EM-07-02
ABIOTIC DAMAGE			
Spring frost damage Can cause sparse foliage and leaf drop by damaging developing buds and leaves in the spring.	all species		
Winter frost damage Fine roots can be killed by frost during winters with little snow cover. This results in canopy dieback.			
Drought stress Thin crowns, tufted foliage, and dieback are symptoms of drought stress.			
Flooding Dieback, early fall color development, and mortality are symptoms after flooding.			

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Chapter 47

Bottomland Hardwood Cover Type

WISCONSIN
DEPT. OF NATURAL RESOURCES

Last Full Revision: 7/24/1996
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

1.1.1 Stand Composition

The bottomland hardwood type is associated with flood plains and stream/river bottoms, primarily in the southern two-thirds of Wisconsin. When the bottomland hardwood community is found further north, it can be regionally significant and may provide important habitat for uncommon or rare species.

The major commercial tree species are eastern cottonwood (*Populus deltoides*), green ash (*Fraxinus pennsylvanica*), river birch (*Betula nigra*), swamp white oak (*Quercus bicolor*), and silver maple (*Acer saccharinum*). Unfortunately, Dutch elm disease has precluded management of American elm (*Ulmus americana*).

Cottonwood is commonly found along streams and bottomlands in the southern two-thirds of Wisconsin. An excellent pioneer of recently disturbed sites, cottonwood requires a continuous supply of moisture throughout the growing season. Cottonwood grows best on medium textured soils with good internal drainage; growth is poor on excessively wet sites and areas of impeded drainage.

Green ash is usually confined to bottomland sites. However, it will grow well when planted on moist upland sites. In Wisconsin, it is most commonly found on wet, rich alluvial soils in the southern half of the state.

River birch occurs at the northern edge of its range in southwestern Wisconsin. It extends north along the Wisconsin River to Stevens Point and the Mississippi River to Lake Pepin. It prefers deep rich alluvial soils that are sometimes flooded for weeks at a time.

Swamp white oak commonly occurs on wet sites characterized by hardpan or areas subject to flooding. In Wisconsin, it is most commonly found as a component of bottomland hardwoods.

Silver maple is characteristically a bottomland species, common within alluvial flood plains. It occurs on all major soil types but is more common on medium to fine textured soils.

American elm was an important component of bottomland forests, but Dutch elm disease has killed most large elm. Elm seedlings and saplings may be locally abundant but are not generally favored by foresters due to continuing disease problems.

1.1.2 Associated Species

Other tree species that commonly occur with bottomland hardwoods include: hackberry (*Celtis occidentals*), bur oak (*Quercus macrocarpa*), black willow (*Salix nigra*), basswood (*Tilia americana*), black ash (*Fraxinus nigra*), red maple (*Acer rubrum*), and red oak (*Quercus rubra*).

1.2 Silvical Characteristics

Many bottomland hardwoods share some adaptive characteristics such as seed production at an early age, frequent and abundant seed crops, immediate germination to take advantage of favorable spring moisture conditions.

Table 47.1. Summary of selected silvical characteristics.

Species	Eastern cottonwood	Green ash	River birch	Swamp white oak	Silver maple
Flowers	Dioecious	Dioecious	Monoecious	Monoecious	Monoecious
	April-May	April-May before leaf buds enlarge.	April-May	May-June	Feb.-May; sus-ceptible to frost damage.
Fruit Ripens	May-June	Sept.-Oct. of same year.	May-June	In Sept. and Oct. of the same year.	April-mid June
Seed Dispersal	June to July as seed ripens; seed may be transported miles by wind and water.	In fall and continues through winter. Seed is dispersed by wind. Seed may germinate 1st spring or lie dormant several years.	May-June; Disseminates seed in late spring when water levels recede. Alluvial soil provide excellent seed beds.	Dispersal by gravity, mammals, and moving water.	Seed fall 10-20 days after ripening. Dispersal mainly by wind, occasionally water
Good Seed Years	Annually; poor seed crops rare. Seed production begins at 10 years of age. Optimum seed bearing age is 30 to 40	Annual crops common after trees reach 3 to 4 inches DBH. Seed production begins at an early age.	Almost every year.	Every 3 to 5 years with light crops intervening. Minimum seed bearing age is 20 years; optimum age is 75 to 200 years.	Seed production begins as early as 11 years of age. Prolific seeder with good seed crops almost every year.

Species	Eastern cottonwood	Green ash	River birch	Swamp white oak	Silver maple
	years of age.				
Germination	Short period of viability, 2 to 3 weeks. Moist exposed mineral soil needed for germination.	Seed may germinate the spring after seed fall or lay dormant for several years.	Shortly after dispersal. Moist mineral soil or freshly exposed soil required.	In autumn shortly after seed fall. Root development continues until temperatures are too low for growth.	Most successful on seedbed of moist mineral soil with considerable organic matter.
Seedling Development	Seedlings exceptionally delicate; susceptible to hard rains, high temperature, and damping-off fungi in first three weeks.	Juvenile growth is rapid. Good competitor against weed species. Strong apical dominance.	Juvenile growth may average 6 to 12 inches in the first year. Germination and growth is inhibited by even moderate shade.	Establishment and early growth is favored on better drained lowland soils.	Saturated soil will often stunt growth. Seedlings cannot compete with overtopping weeds and may die after first year.
Vegetative Reproduction	Propagation by cuttings is usual method of artificial regeneration. Will sprout from low cut stumps less than 25 yrs. old.	Sapling and pole size stumps sprout readily. Stump sprouting of larger size classes is not reliable.	Sapling and pole size stumps sprout. Sprouting of larger size classes is not reliable.	Will stump sprout, with best sprouting on stumps less than 10 inches in diameter.	Prolific sprouting from root collars and lower stems. Best sprouts are from stumps up to 12 inches in diameter.
Growth	Grows rapidly. On better sites may grow	Reaches average diameter of 18 to 24 in.	Average diameter of 12 to 24 inches	Relatively long lived, up to 300 years. Average	May live 130 years or more. Have reached

Species	Eastern cottonwood	Green ash	River birch	Swamp white oak	Silver maple
	2/3 to 1 inch in diameter and 4 to 5 ft. in height per year up to 25 to 30 years of age.	and height of 50 to 60 ft. Sawlogs usually of lesser quality than white ash.	and heights of 50 to 80 ft.	diameters 24 to 36 inches; average heights 60 to 70 ft. with occasional trees to 100 ft.	diameters of 36 to 48 inches and heights of 90 to 120 ft. Growth most rapid during first 50 years.
Shade Tolerance	Intolerant; must outgrow its competition to survive.	Intolerant to moderately tolerant. Seedlings can survive for 15 years or more in the understory.	Relatively intolerant pioneer species. Often invades fresh alluvial soils.	Intermediate tolerance. Seedlings can be established under moderate shade.	Moderately tolerant to very intolerant depending on site quality. Intolerant on poor sites.

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

Management objectives should be identified within an ecosystem framework, giving consideration to a variety of objectives within the local and regional landscape. Site index, soils, and vegetation can be used as indicators of site potential. The bottomland hardwood community has important functions and attributes including: flood control, protection of water quality by absorption and filtering of chemical and sediment run-off, timber production, travel corridors for otherwise isolated populations of plants and animals, habitat for a variety of species, including some sensitive, endangered, or rare species, and recreation and aesthetics.

Management alternatives include but are not limited to:

1. Maintaining the forest type. Stand composition and structure may be managed to meet specific objectives within ecological and economic limitations.
2. Allow natural conversion to other species.
3. Reforestation or conversion of severely disturbed stands (e.g., stand that are heavily dominated by reed canary grass or box elder)

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.2 Site and Stand Considerations

3.2.1 Soils

Bottomland hardwood forests are intricate and variable ecosystems due to species richness, flooding, ice movement, internal drainage patterns and the pattern of deposition and development of soils is complex. Being associated with waterways that periodically flood, the soils are stratified. Typical soil profiles have horizons of distinctly different textural classes deposited by the stream. Soil textures are often a mixture of organic material, sands, silts, and clays developing complex microsites. The interaction of these variables precludes the development of any single regeneration prescription which will function adequately on most bottomland sites.

5 SILVICULTURAL SYSTEMS

Uneven-age or even-aged management systems may apply depending upon the species composition of the stand, management objectives of the landowner, and regeneration strategies to be implemented. A brief discussion of uneven-aged and even-aged systems are discussed.

Generally, these silviculture guidelines will require site-specific refinement, but they can help prevent or correct some silvicultural disasters. Following are some precautions:

- If the understory is dominated by reed canary grass, cattails or sedges, regenerating the stand will be difficult if not impossible.
- Wind throw can result from partial cuts in stands growing on wet mineral soils, organic soils and sites exposed to periodic winds.
- Ice flow on river systems can shear or scour established seedlings removing existing reproduction.
- Deer may concentrate in these stands during winter. Advanced reproduction may be severely browsed in deer yarding areas. Other damage may result from rabbits and beaver.
- Changes in the drainage pattern, culverts, ditches, tiles, compacted skid roads, construction of dams, or removal of dams, can alter the amount and rate of water flowing through the system. Mortality and drastic stand conversion may result from a small change in water table or flow.

Given the almost infinite variability of bottomland hardwood site conditions, as well as the species mix and silvicultural characteristics, selection of the most appropriate silvicultural system should be left to the judgement and experience of the local forest manager.

Disturbance and successional patterns are difficult to predict on bottomland sites. Research on bottomland hardwoods is limited. Of the published information, much is based on work done in the south and may be of limited value in Wisconsin. Each site and stand is different, therefore specific recommendations are not possible, but certain generalizations can be made from past studies and observations.

Some bottomland sites are very productive with growth rates of 200-800 bd.ft./ac./yr. Unfortunately past cutting practices have high graded many bottomland hardwood stands leaving an accumulation of poor-quality trees. Dutch elm disease has also greatly impacted many bottomland stands. Stand history should be investigated before concluding that a site has low growth potential.

Shade intolerant trees often form even aged stands. However, many bottomland stands have more than one age class because of past cutting, loss of the elm component, wind damage, and beaver damage.

Cutting trees will temporarily decrease the amount of evapo-transpiration and may raise the water table. One large maple tree will transpire 150 gallons of water/day during the summer. Forested sites have been converted to cattails, reed canary grass, or woody shrubs as a result of the water table rising following heavy cuts or blow downs. Consider this impact when designing the management system.

Due to the proximity of bottomland hardwood sites to waterways and the wetness associated with these sites, consultation of Wisconsin's Forestry Best Management Practices for Water Quality is recommended.

5.1 Seedling / Sapling Stands

Partial overhead shade will reduce the survival and growth rates of shade intolerant seedlings. To maintain the desired intolerant seedlings, established seedlings should be released to full sunlight to stimulate growth and survival.

5.2 Intermediate Treatments

5.2.2 Thinning

<u>Poletimber Stands</u>
Good sites, site index 70 or better for featured tree species, may benefit from intermediate stand treatments. Green ash, swamp white oak and silver maple respond well to thinning. Use even-aged stocking charts (see northern hardwood or red maple stocking charts in Chapters 40 and 51) to determine thinning levels. In general, no more than one-third of the basal area should be removed at any one time. If thinning cannot be done commercially in pole sized stands, crop tree release can be used to increase the growth and vigor of the potential crop trees.

<u>Sawtimber Stands</u>
On good sites, thin stands younger than the desired rotation age or diameter to the B-level or above. Initiate thinning before the A-level is reached. Thinning intervals may vary based on management objectives, site quality, species mix, merchantability and access. Ten to twenty years is common. Stop thinning at approximately three-fourths of the desired rotation age to reduce understory competition at the time of the regeneration harvest.

5.3 Natural Regeneration Methods

There are three sources of reproduction in bottomland forests:

- Advanced reproduction (over 18 inches tall is the most dependable)
- Sprouts from stumps of cut trees under 12-inch DBH (green ash stump sprout origin trees are susceptible to early decay and silver maple sprouts more frequently on wetter sites).
- New seedlings that become established after the harvest.

If adequate desirable advanced reproduction greater than 24 inches tall is present, many different harvest systems could succeed. The goal would be to release the seedlings in one or more cuts. However if advanced reproduction is not present bottomland hardwood stands can prove a challenge to regenerate. Depending on site conditions, species composition, and management objective, select the appropriate silvicultural system.

5.3.1 Even-Age Regeneration Methods

5.3.1.1 Shelterwood

A closed canopy prior to the initial shelterwood cut can benefit the early establishment of intolerant bottomland species, especially silver maple. Under the heavy canopy, the seedbed is maintained relatively free of herbaceous vegetation and 1- to 2-year old silver maple seedlings will often be found. Without additional light these young seedlings do not grow or persist. The goal is to manage the overstory to permit sufficient light, 1/3 - 1/2 full light intensity, for the seedlings to grow without stimulating strong herbaceous competition.

Once established the seedlings should be released before they are 15 feet tall to prevent excessive damage from overstory removal.

5.3.1.2 Clearcut

A common error has been to conclude that since many of the bottomland tree species are shade intolerant, harvesting systems which create large openings will lead to the establishment of the desired intolerant species. Additional light may stimulate an herbaceous ground cover which retards seedling establishment and survival. Without advanced reproduction the composition of the new stand will depend on the sprouting ability of the species harvested, the seeding characteristics of the tree species, and environmental factors.

The following factors should be considered if a clearcut is being prescribed:

- The river system deposits a layer a fresh silt each year. This provides an ideal seed bed for most of the bottomland hardwood species.
- Seedlings are established or enough small diameter stumps are present to produce sprouts (sprout origin trees are not as desirable).
- Cull and non-commercial trees are cut or killed so they do not impede the reproduction.
- Deer population is low or controlled to prevent overbrowsing of the reproduction.
- Water table will not rise after logging and there is little danger the site will convert to cattails, reed canary grass, or woody shrubs.

5.3.2 Uneven-Age Regeneration Methods

5.3.2.1 Group Selection and Irregular Shelterwood

Technically speaking, group selection is an uneven-aged system that regenerates small groups of even aged trees and results in a stand with many groups of different aged trees. An irregular shelterwood is a system that regenerates patches of even-aged trees resulting in a stand of multiple even-aged patches. Removal of the overstory occurs at irregular times depending upon the regeneration and response of the water table. Integrating group selection and irregular shelterwood into a patchwork application, may provide a feasible management approach. These approaches can be applied to a stand depending on the variability of species, age classes, and sensitive sites sometimes found in bottomland hardwoods.

Under both systems the stand is entered every 5 to 20 years. At each entry canopy gaps of various sizes will be created to establish seedlings or increase the light levels to established seedlings. With the irregular shelterwood method the overstory is slowly removed in 2 to 4 cuts. Maintaining a partial canopy of trees to control both light levels and water table are important aspects of these two systems. Green ash and swamp white oak may be favored in this system because they are somewhat shade tolerant and do not require bare mineral soil for seed germination.

5.5 Rotation Lengths and Cutting Cycles

Rotation age will vary by species mix, stand origin, site quality and management objectives. There is some flexibility in rotation age, however many of species are not long lived, the majority being less than 130 years. Use short rotations, 50-60 years, for stump origin and low-quality stands. Green ash can be grown to 18 inches DBH in 80 to 100 years on good sites. Silver maple can be grown to 24 inches DBH or more in 80-110 years on good sites. Swamp white oak is longer lived with trees reaching 300 years on good sites.

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Chapter 51

Red Maple Cover Type

Last Full Revision: 2/12/2019
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand Composition

Red maple comprises 50% or more of the basal area in pole timber and sawtimber stands, or 50% or more of the stems in seedling and sapling stands.

Red maple is most common in New England, Middle Atlantic States, Upper Michigan, and Northern Wisconsin. Recognition of red maple as a separate cover type generally is attributed to disturbances that release red maple advance regeneration and residuals which may respond rapidly. Dramatic increases in current red maple distribution can be attributed to establishment following a variety of disturbances such as land clearing, fire suppression, windthrow, and insect/disease outbreaks (Abrams 1988). The decline of American elm *(Ulmus Americana)* as a result of Dutch elm disease and the selective removal of northern red oak *(Quercus rubra)*, yellow birch *(Betula alleghaniensis),*quaking aspen *(Populus tremuloides),*and sugar maple *(Acer saccharum)* have also contributed to increasing the proportion of red maple stocking in many stands.

Associated Species

Throughout its range, red maple is associated with more than 70 different commercial tree species. It's more common associates include balsam fir *(Abies balsamea),* white pine *(Pinus strobus),* sugar maple, beech *(Fagus grandifolia),* yellow birch, paper birch *(Betula papyrifera),* eastern hemlock *(Tsuga canadensis),* eastern hophornbeam *(Ostrya virginiana),* northern white-cedar *(Thuja occidentalis),* aspen *(Populus grandidentata* and *P. tremuloides),* black ash *(Fraxinus nigra),* pin cherry *(Prunus pensylvanica),* black cherry (P. *serotina),* northern red oak *(Quercus rubra),* American elm, silver maple *(Acer saccharinum),* and swamp white oak *(Quercus bicolor).* (Burns & Honkala 1990)

1.2 Silvical Characteristics

The primary source for the following descriptions and tabular summary is from Silvics of North America (Burns & Honkala 1990).
https://www.srs.fs.usda.gov/pubs/misc/ag_654/volume_2/acer/rubrum.htm

Flowering and Fruiting

Red maple is one of the first trees to flower in the spring, generally several weeks before vegetative bud break. The flowers are small, with slender stalks, red or rarely yellowish, with petals; they appear from March to May depending upon elevation and latitude. Trees can flower and bear seed at an early age; 4-year-old trees have produced seed. Flowering occurs on all branches in the well-lit upper portion of the crown. Characteristically, the non-flowering branches are slow growing and lack vigor.

Red maple flowers are structurally perfect. The species is polygamo-dioecious. Thus, some trees are entirely male, producing no seeds; some are entirely female; and some are monoecious, bearing both male and female flowers. On monoecious trees, functioning male and female flowers usually are separated on different branches. Sex of the flower is not a function of tree vigor. The species shows a tendency toward dioeciousness rather than toward dichogamy

Germination

The fruit, a double samara, ripens from April to June before leaf development is complete. After ripening, seeds are dispersed for a 1- to 2-week period during April through July. The seed does not require pre-germination treatment and can germinate immediately after ripening. The small winged fruits disperse efficiently in the wind. While seed dispersal distance is variable, the height of seed release can impact the actual distance a seed travels. Germination may be 75 to 80 percent in 2 to 6 days. Total germination is often 85 to 91 percent.

Seedling Development

Red maple has few germination requirements. The seed can germinate with very little light, given proper temperature and some moisture. Most seeds generally germinate in the early summer soon after dispersal. Shading by a dense overstory canopy can depress first-year germination; then second-year germination is common. Germination is epigeal.

Vegetative reproduction: Red maple stumps sprout vigorously. Inhibited, dormant buds are present at the base of red maple stems. Within 2-6 weeks after a stem is cut, these inhibited buds are stimulated. Fire can also stimulate these buds. The number of sprouts per stump increases with stump diameter to a maximum of 23-30 cm (9-12 in), and then decreases among larger trees (Solomon 1967). Compared to oak species, stump sprouting with red maple does not decrease in relation to residual basal area and peaks in partial harvest treatments (Atwood 2009). Stumps of younger trees tend to produce taller sprouts. Sprouts grow faster than seedlings, and leaf and internode size is greater. As competition increases, growth rates slow. Many sprouts have poor form and rot present. Also, the attachment of a sprout to the stump is often weak because the base of the sprout grows over the stump bark and the vascular connection between them is constricted. Regeneration by seedling sprout may be especially successful. Generally, the species' great sprouting capacity makes it suitable for coppicing and accounts for its tendency to be found in sprout clumps.

Growth and Development

Red maple height growth starts relatively early in the spring, radial growth starts late in the season. Radial growth then proceeds rapidly, becoming half complete in 50-59 days and fully complete in 70-79 days. Early crop tree release of red maple seedlings and sprouts is feasible in young, even-aged stands. It should be done when the new stand has crown closure and crown dominance is being expressed.

Growth during early life is rapid but slows after trees pass the pole stage. Red maple responds well to thinning. In upper Michigan, thinning was more effective than fertilization for stimulating red maple growth. In the north, the young red maple trees grow faster than sugar maple, beech, or yellow birch, but slower than aspen, paper birch, or white ash

Fire

Red maple is very sensitive to fire injury, and even large trees can be top killed by a fire of moderate intensity. The fire-killed trees sprout vigorously, however, and red maple may become a more important stand component after a fire than before one (Burns & Honkala 1990).

Longevity

Red maple is a short- to medium-lived tree and seldom lives longer than 150 years. It reaches maturity in 70-80 years. Average mature trees are 18-27 m (60-90') in height and 46-76 cm (18-30") in diameter.

Table 51.1. Summary of selected silvical characteristics

Flowers	March-May polygamo-dioecious (i.e. bisexual and male flowers on some plants, and bisexual and female flowers on others)
Seed Ripens	Immediately upon seed fall, late May – early June
No. seeds/lb.	Approx. 23,000
Seed dispersal	Primarily wind dissemination, gravity
Minimum Seed-Bearing Age	4 years
Good Seed Years	Every 2-3 years
Average Seed viability	80%
Cold Stratification	Not required
Seedbed Requirements	Moist mineral soil (wide tolerance of conditions)
Germination	Most germination occurs in early summer soon after dispersal. Dense shade can delay to the second year. The seed can germinate with very little light given proper temperature and some moisture (>36% moisture content).
Seedling development	Fastest root growth on moist soils. Slow shoot growth under closed canopy.
Vegetative reproduction	Pole timber and smaller sized trees sprout readily. Inhibited, dormant buds are always present at the base of red maple stems
Shade Tolerance	Mid-tolerant, can survive with slow growth under closed canopy.
Maximum individual tree longevity	Approximately 150 years

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

Management objectives should be identified in accordance with landowner goals within a sustainable forest management framework, which gives consideration to a variety of goals and objectives within the local and regional landscape. The silvicultural systems described herein are designed to promote the optimum quality and/or quantity of red maple timber products. Modifying these silvicultural systems to satisfy other management objectives could potentially result in reduced vigor, growth and stem quality. The habitat type is the preferred indicator of site potential. Other indicators of site potential include site index, aspect, position on the slope, and soil characteristics.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

The following considerations may be taken into account when making management recommendations.

3.1 Landscape Considerations

3.1.1 Historical Context

When the General Land Office Public Land Surveys (PLS) were conducted in Wisconsin (1832-1866), red maple was a relatively minor component of most forests, representing less than 5% of surveyed trees in the northern hardwood-white pine-hemlock forests (Nowacki et al, 1990). However, since that time, pre-settlement northern hardwood-conifer and pine forests that converted to oak or aspen following cut-over have had a steadily increasing red maple component (Nowacki etal 1990).

Red maple is a generalist species and can probably thrive on a wider range of soil types, textures, moisture, pH, and elevation than any other forest species in North America (Hutnik & Yawney 1961). In northern Wisconsin and Michigan, red maple grows on sites ranging from dry, sandy outwash plains to wet bottomlands and swamp edges. In upper Michigan and New England, red maple grows on ridge tops and dry sandy or rocky upland soils and in almost pure stands on moist soils and swamp borders (Reynolds etal 1979). The distribution of red maple has been described as bimodal, with a primary importance peak on dry-mesic sites and a secondary peak on wet-mesic sites (Curtis 1959). Fast growth rates, regular and abundant seed production, minimal seed-bed requirements, delayed germination, and intermediate shade tolerance have allowed red maple to outcompete other species in mixed hardwood stands, especially where growing space had been vacated by American elms (Ulmus *Americana* L.) (Powell & Erdmann 1980). Red maple is also a prolific sprouter that competes strongly on disturbed sites, and is now considered to be an important resource in the Lake States (Crow & Erdmann, 1983).

Red maple is favored when fire is suppressed and, in many of the forests where it occurs it has increased in dominance dramatically during the past decades. The fire interval for red maple is long (many decades to centuries) and low-intensity surface fires are typical. A thin-barked species, red maple is susceptible to damage, top-kill and mortality from fire. Saplings are more susceptible than larger, older individuals with thicker bark. Fire effects vary according to season of burning; red maple is most susceptible in late spring to early summer. Red maple often responds rapidly to disturbances such as fire. Top killed seedlings and trees sprout vigorously and rapidly from dormant buds on the root crown and seedling establishment readily occurs from surviving trees or from seeds carried by wind. This species may assume increased prominence after a single (unrepeated) fire.

There are several agents which can impact the abundance and quality of red maple on the landscape. In addition to fire injury, red maple is susceptible to defects and/or mortality resulting from leaf diseases, mechanical injury, insect feeding, and attack by sapsuckers. Red maple is also a desirable browse species for white tail deer and reproduction can be suppressed in areas with high deer populations (Burns & Honkala 1990).

3.1.2 Current Context

Today, red maple is one of the most abundant and widespread trees in eastern North America. It grows from southern Newfoundland, Nova Scotia, and southern Quebec to southern and southwestern Ontario, extreme southeastern Manitoba, and northern Minnesota; south to Wisconsin, Illinois, Missouri, eastern Oklahoma, and eastern Texas; and east to Florida. The species is native to most regions of the eastern United States. The most notable exception is the Prairie Peninsula, where red maple is absent from the bottom land forests of the Corn Belt, though it grows abundantly in similar situations and species associations both to the north and south of the peninsula. It is a native species in Wisconsin, distributed throughout the state in a wide range of habitats, but it does best in wet or dry forests. It is not as prominent in mature mesic forests.

Red maple grows in a wide variety of habitats throughout Wisconsin. However, over 90% of red maple growing stock volume is located in northern and central Wisconsin (WDNR 2012). Over 50% of the red maple acreage is found within the Forest Transition and North Central Forest Ecological Landscapes. An additional 11% is found in the Central Sand Plains Ecological Landscape.

The volume of red maple has increased significantly since 1983. This is a result of both natural succession and relatively low mortality as compared to the average for all species. The red maple resource is aging with the volume of large trees increasing over the last two decades (WDNR, 2012) (Figure 51.1). Mortality rates have also increased over that time; however, red maple has a much lower ratio of mortality to growth than the statewide average. Whereas red maple makes up about 12% of all volume of trees in Wisconsin, it accounts for only 4.2% of total mortality (WDNR 2012).

Maintaining a desirable age-class distribution is a landscape-level consideration. A relatively stable age class structure, including all developmental stages, maximizes benefits to wildlife by providing a range of structural conditions. It also contributes to diversified economic interests by supplying different types of materials, including pulp, poles, sawlogs, and veneer.

Table 51.2. Distribution of red maple timberland acreage in Wisconsin.

Ecological Landscape	Approximate Area of red maple timberland - acres
Central Lake Michigan Coastal	15,736
Central Sand Hills	9,099
Central Sand Plains	100,431
Forest Transition	227,818
North Central Forest	249,645
Northeast Sands	59,790
Northern Highland	40,850
Northern Lake Michigan Coastal	36,600
Northwest Lowlands	13,938
Northwest Sands	24,551
Southern Lake Michigan Coastal	1,618
Southgeast Glacial Plains	6,793
Superior Coastal Plain	37,850
Western Coulees and Ridges	60,808
Western Prairie	1,593
Total	887,120

The amount of red maple on the landscape has increased significantly over the last few decades. However, the age class structure has remained fairly steady with a majority of acreage in the middle age classes and fewer acres in the youngest and oldest age classes. The age class distribution of red maple appears to be shifting from the younger middle age classes to the older middle age classes as the red maple resource ages (Figure 51.1). In addition, the number of growing stock trees in the youngest age class is very low, indicating the possibility of future decline of the red maple resource in Wisconsin (Figure 51.2).

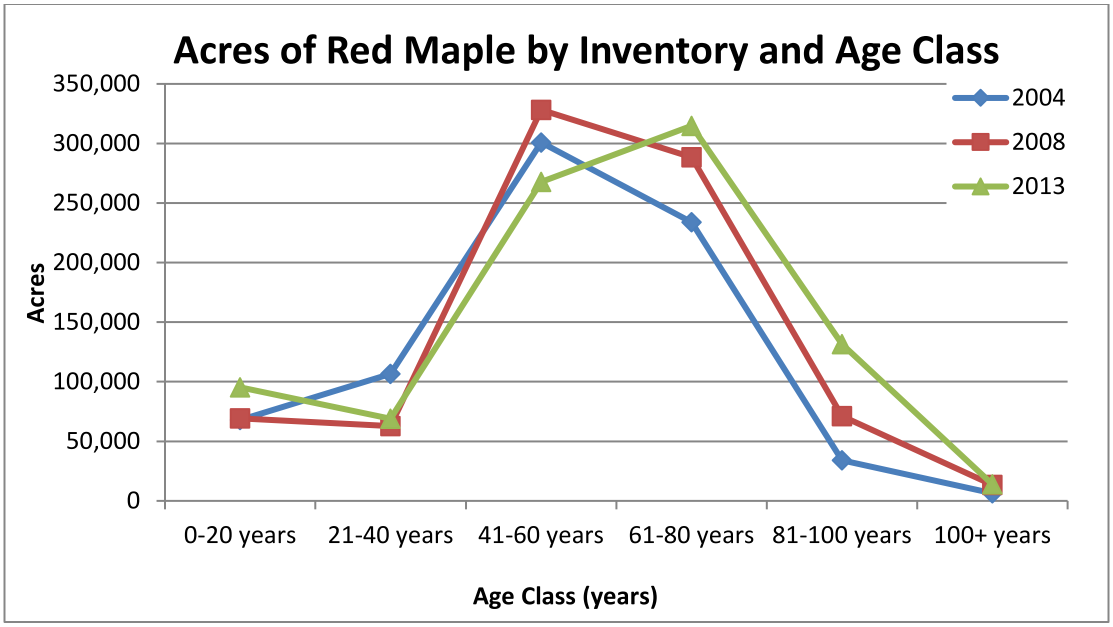


Figure 51.1. Acres of red maple by inventory and age class (FIA).

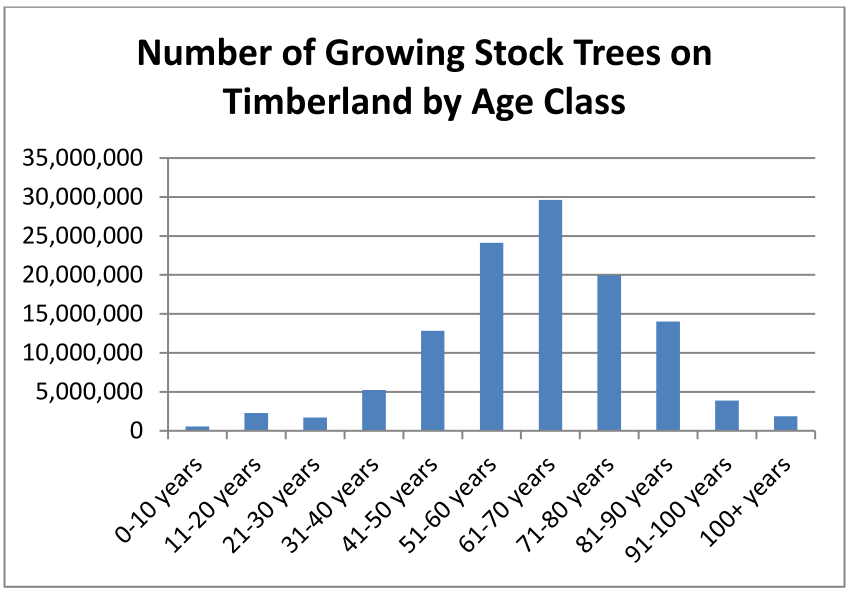


Figure 51.2. Growing stock trees on timberland by age class.

3.1.3 Climate Change

Red maple is one of the most abundant and widespread trees in eastern North America. Current modeling of tree response to climate change under high and low emissions scenarios suggests that the range and extent of red maple will remain largely the same, however, the abundance will decline and the optimum latitude/suitable habitat will move to the south (Iverson & Prasad 2002, Landscape Change Research Group 2014). Red maple shows little change in % area occupied, but a large change in average importance value. It currently occupies much of the eastern US, with higher importance values to the north. After climate change, the estimated importance values would be higher along the more southern Ohio and Mississippi River Valleys relative to its current prominence in northern locations (Iverson & Prasad, 2002; Iverson et al, 2008). Due to a wide tolerance for climatic conditions, red maple is likely to remain as a component of forests in Wisconsin, though importance values may diminish.

3.1.4 Hydrology

Red maple grows on diverse sites, from dry ridges and southwest slopes to peat bogs and swamps. It commonly grows under the more extreme soil-moisture conditions either very wet or quite dry. The species does not show a strong affinity for either a north or a south aspect. It is also common in swampy areas, on slow-draining flats and depressions, and along small sluggish streams.

3.1.5 Forest Simplification

Forest simplification refers to a loss of species diversity and structural diversity, and an increased dominance of fewer species. The increase in maple dominance that is occurring in northern hardwood forests is an example of simplification, as is the lack of features like large woody debris and tip-up mounds. At the landscape level, simplification and homogenization occur when forested patches become similar in size, shape, and composition. Land uses have led to homogenization and reduction of patch sizes, and creation of patch shapes that are less complex (Mladenoff et al. 1993). The cumulative effects of stand-level simplification make composition similar among patches. This is unlike the mosaic of forest patches found in remnant old growth forests. As an opportunistic, shade tolerant species, with the ability to grow slowly for long periods of time awaiting release, red maple may be a resilient component of forests where structural and compositional diversity have declined. Red maple dominance in these simplified stands may be at the expense of other sub-climax, pioneer species that are not as shade tolerant and long lived like aspen and white birch (Burns & Honkala 1990).

3.1.6 Landscape Pattern, Fragmentation and Edge Effects

Fragmentation describes certain kinds of landscape structure. Inherent fragmentation describes landscapes that are naturally heterogeneous due to the physical environment, such as landscapes with numerous small lakes and wetlands dispersed throughout a pitted outwash plain. Permanent fragmentation refers to long-term conversion of forest to urban, residential, or agricultural uses. Habitat fragmentation is defined as a disruption of habitat continuity, caused by forest harvesting or natural disturbance, which creates a mosaic of successional stages within a forested tract. This kind of fragmentation is shorter-term, affecting species while the forest regrows, and is a consideration in red maple management in northern Wisconsin. Red maple regeneration is generally accomplished through the use of even-aged management, and dispersion of clear-cuts throughout the forest creates differences in forest structure that are a type of habitat fragmentation.

In Wisconsin and elsewhere, the loss of forest habitat has a larger impact on species than shorter-term habitat fragmentation. However, area of habitat loss is often correlated with measures of fragmentation (e.g., patch size, distance between patches, cumulative length of patch edges, etc.), making it difficult to quantify their separate effects. Habitat loss may result from second homes, or urban and industrial expansion. A drastic change in land cover, such as that which occurs after a clear-cut harvest, represents a short-term loss of habitat for some species and a gain for others, including red maple which is a pioneer species. Dispersal can be affected if species or their propagules cannot cross or get around the open land, and cannot find suitable habitat within it. The small, winged red maple seeds are dispersed efficiently by wind and can travel some distance. Though seed fall drops off rapidly with distance from stand edge or clear-cut opening. Seed dispersal, shade-tolerance, and relative longevity compared to other early successional species make red maple somewhat tolerant of disturbance and fragmentation, though if habitat is lost due to permanent land use changes red maple could decline locally.

3.1.7 Incorporating Ecological Complexity into Red Maple Management

Forest management generally simplifies forest structure and composition with some negative impacts in terms of biodiversity and resilience. Thus, maintaining structural and ecological complexity is increasingly an objective of sustainable forest management. The integration of complexity into forest management would involve designing harvest operations that maintain or enhance the capacity of forests to adapt to changing conditions, like climate change. Operationally, managing for complexity involves protecting or restoring complex patterns in forest structure. Red maple often grows slowly for long periods of time until it is released by small and large canopy gaps created by disturbance. Management regimes which maintain complexity by mimicking natural disturbance and creating gap habitat within the forested landscape will be beneficial to increasing red maple as a component of the stand and increasing age class diversity within the stand.

3.1.8 Summary of Landscape Considerations

- Red maple is one of the most abundant and widespread trees in eastern North America and thrives on a wider range of soil types, textures, moisture, pH, and elevation than any other forest species in North America.
- Red maple has increased on the landscape since pre-settlement times and it continues to increase as a component of Wisconsin’s forests.
- In northern Wisconsin and Michigan, red maple grows on sites ranging from dry, sandy outwash plains to wet bottomlands and swamp edges. Red maple distribution is bimodal, with a primary importance peak on dry-mesic sites and a secondary peak on wet-mesic sites.
- Red maple is a pioneer species that is more shade tolerant and longer lived than other early successional species such as aspen.
- Red maple is favored when fire is suppressed and, in many of the forests where it occurs it has increased in dominance dramatically during the past decades.
- Red maple is likely to maintain its current range under climate change. However, it’s abundance within that range is expected to decline and the optimal latitude is expected to shift south.
- Red maple is a widely used landscape tree due to brilliant fall coloring. It can also be used for syrup making and it is a highly desirable species for wildlife browse.

3.2 Site and Stand Considerations

3.2.1 Soils

Red maple can probably thrive on a wider range of soil types, textures, moisture, pH, and elevation than any other forest species in North America. The red maple type occurs on a wide range of soil conditions, from sand to clay and from dry to wet. Its range covers soils of the following orders: Entisols, Inceptisols, Ultisols, Alfisols, Spodosols, and Histosols. It grows on both glaciated and nonglaciated soils derived from granite, gneisses, schists, sandstone, shales, slates, conglomerates, quartzites, and limestone.

Best growth is demonstrated on mesic to wet mesic sites with loamy or sandy loam soils but growth potential is good for many sites except for excessively dry or poorly drained. Higher site indices are noted on soils that have an accumulation of fine textured soils (Haag etal. 1989). Red maple trees develop a greater vertical rooting structure (root fan) in this soil type capitalizing on additional water and nutrients.

3.2.2 Site Quality

3.2.2.1 Range of Habitat Types

Red maple has become nearly ubiquitous across sites with varying moisture and nutrient regime being dubbed a “super generalist”. Figure 51.3 displays its wide range in eastern North America, found as far north as Newfoundland and south to Florida. In Wisconsin, it is commonly found across the state in nearly every habitat with varying trends in density. This distribution is in contrast to pre-European settlement where red maple existed mainly in poorly drained areas.

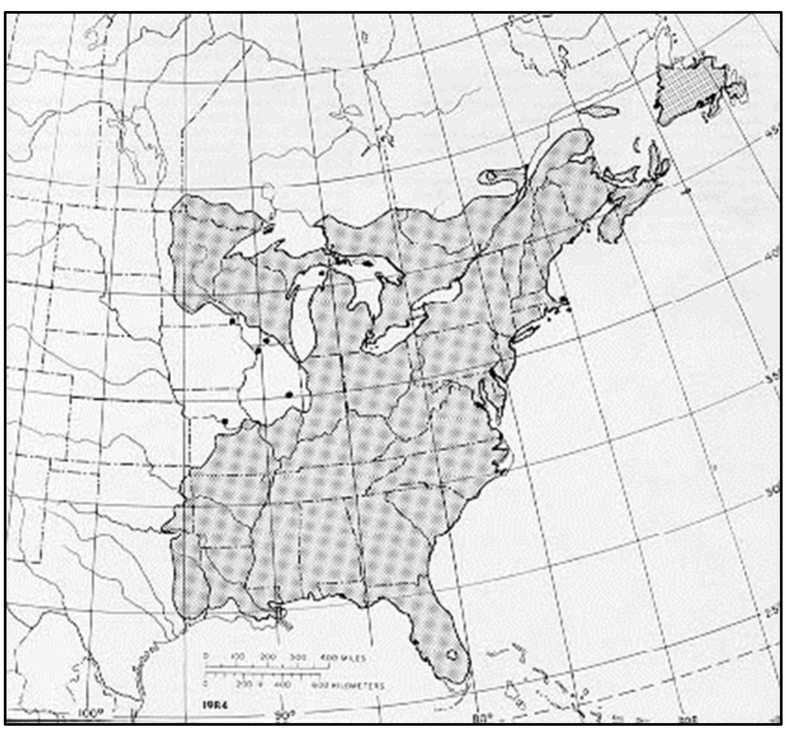


Figure 51.3. Native range of red maple (Burns & Honkala 1990).

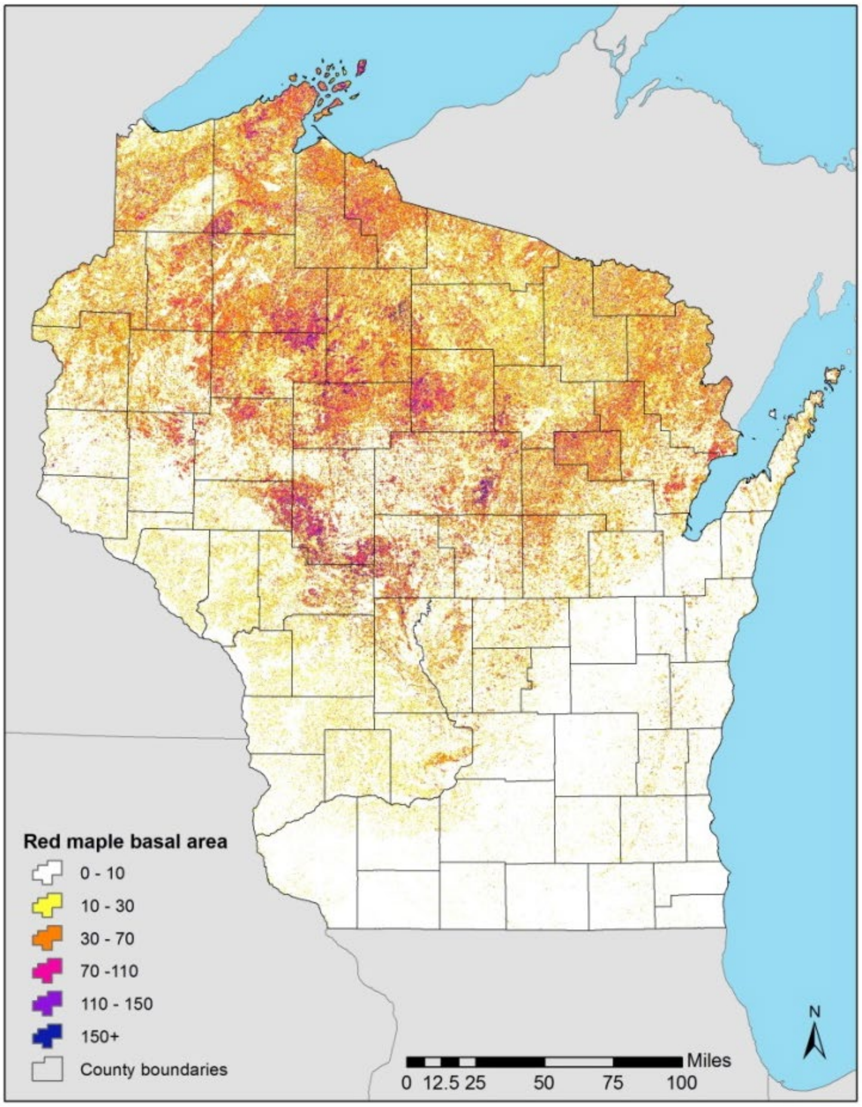


Figure 51.4. Red maple stocking (sq. ft./ac.) in Wisconsin (Wilson et al. 2013).

Red maple is an important component in many cover types, although pure red maple stands represent only a small percentage of forested timberland. Figure 51.4 displays current red maple stocking variation (square feet per acre) throughout Wisconsin (Wilson et al. 2013). It is found to a greater extent in aspen stands (24% of aspen cover type) and as little as 2% in the mixed pines/ hardwood cover types. The pure red maple cover type occupies approximately 2% of Wisconsin’s total forest land acreage (Miles 2009).

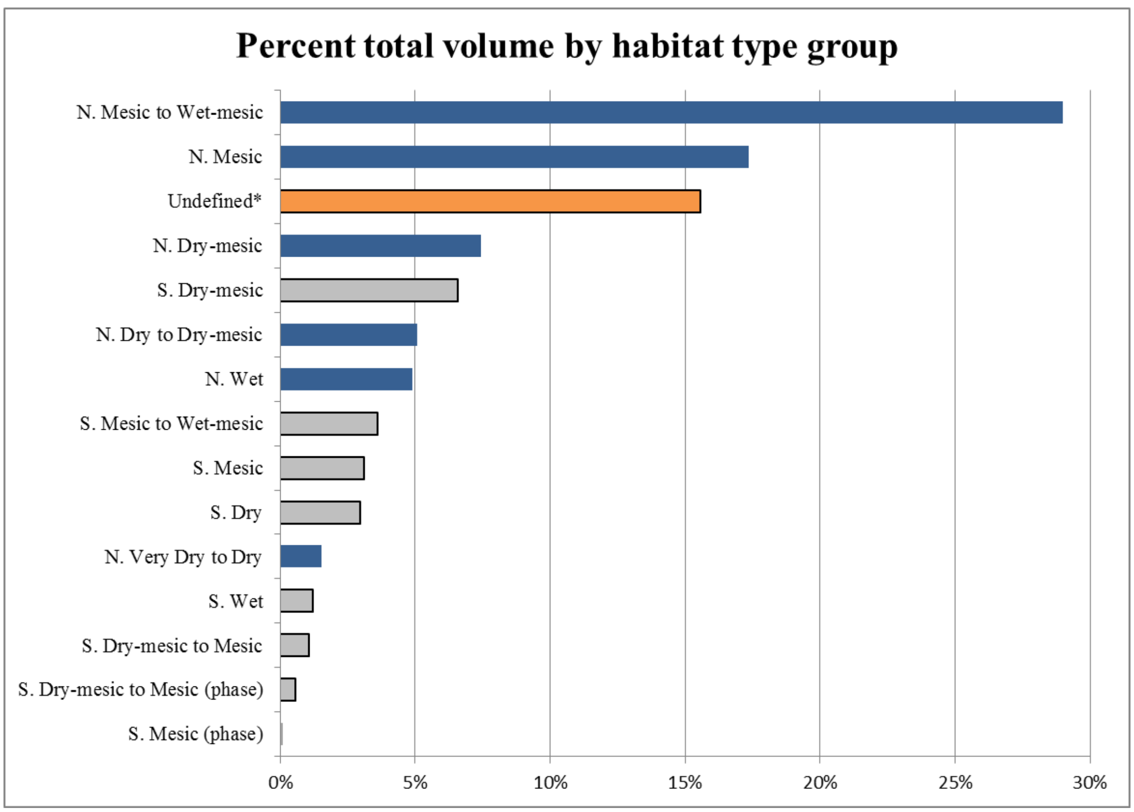
Red maple appears to be a “super-generalist” due to its low resource requirements. It shows characteristics of both early and late successional species (Abrams 1998). Throughout its range, red maple thrives on many landforms, in many different soil conditions, and under widely varying moisture and light regimes. Red maple occurs on lands forms as different as dry ridges and swamps, on soil textures varying from sands to clays, on soils with PH ranging from highly acidic to near neutral, and from high light to deeply shaded sites (Abrams 1998).

The red maple cover type has the potential to develop on all upland habitat type groups and most habitat types in Wisconsin but its actual distribution and productivity across sites vary considerably. Overstory and understory composition of red maple stands vary significantly between southern and northern Wisconsin. Within each region, composition also varies across the range of sites where red maple forests occur, from dry to mesic to wet.

For each of the following habitat type groups, typical red maple forests are described in terms of dominant trees and principal associates. These descriptions of characteristic overstory associations are derived primarily from analysis of Forest Inventory and Analysis (FIA) data and the Forest Habitat Type Classification System (FHTCS) (Kotar & Burger 1996, Kotar etal 2002). Characteristic soil textures are also identified. Northern and southern regions and site types are derived from the FHTCS. Exceptions to these typical conditions should be expected as many red maple sites may still be recovering from recent disturbance. The complete list of habitat types where red maple is a represented can be referenced in the Forest Habitat Type books for both northern and southern Wisconsin (Kotar & Burger 1996, Kotar etal 2002).

Northern Habitat Type Groups

About 77% of red maple volume occurs in northern habitat type groups. This species occurs on all northern groups with the most volume in northern mesic to wet mesic (28%) and northern mesic having slightly less (17%). (Figure 51.5)



*Due to past disturbance, forest habitat type classification on many red maple sites may be problematic

Figure 51.5. Percent volume of red maple from by habitat type groups (Miles 2014).

The northern mesic to wet mesic habitat type is associated with loess plains and moraines (especially ground moraines), poorly drained silt loams and loams but can still be nutrient rich. Red maple can be the dominant species within this habitat type group however sugar maple and aspen are most common. Associated species that exist with red maple in this habitat type group include basswood, black ash, elms, oaks, white ash and yellow birch. Competition from shrubs and grass can be heavy. Some common habitat types include ATAtOn, ArAbCo, TMC, ACaI, ASaI. The first two habitat types are more productive having site index >60.

The northern mesic habitat type group is associated with end/recessional and ground moraines. Occurs on well drained sandy loam and loam soils and the nutrient regime is medium to rich. Associated species in this habitat type group include sugar maple, aspen, red oak, basswood, white ash. This group tends to have a diverse and competitive shrub layer. Management will depend mostly on interpretation of the composition and present condition of the stand. Some common habitat types with red maple present include ATM, ATD and AOCa. These types tend to be more productive having SI > 60.

In the northern dry mesic habitat group, red maple represents about 7% of the volume. This group is associated with end/recessional moraines and outwash and occurs on well drained sandy loam soils. Some habitat types in this group include ParVAaPO, ParVa, AAT, AVVib, and ACl. These stands tend to have lower site index < 60. Associated species includes white and red pine and red oak. Red maple in these stands usually is a result of fire suppression.

Southern Habitat Type Groups

About 23% of red maple volume occurs on southern habitat type groups. This species occurs on all southern habitat type groups with the most volume on southern dry-mesic and smaller volumes on southern dry.

In the southern dry mesic habitat type group, red maple represents about 7% of the volume. The associated soils include silt caps over sandstone, till or loam and typically have a site index of 60 or higher. In the Western Coulees and Ridges landscape, these stands are typically oriented north and east and in shelter coves. These stands often originated from oak stands that were subject to selective cutting, pasturing, or storm damage. Some common habitat types are ArCi-Ph, AARVb.

In the southern dry habitat type group, red maple represents about 3% of the volume. The associated soils include loess over sandstone or outwash. Terrain is generally flat to gently rolling in some areas. In the Western Coulee and Ridge landscape red maple in this habitat type group tends to occur on south and west oriented slopes and the stands are less productive having site index < 60. These stands often developed from oak and pine stands after fire suppression and selective harvests. Some common habitat types are PEu, PVG, and PVCr.

3.2.5 Wildlife

Red maple stands are found throughout the state on both wet and dry sites but this distribution and current stocking levels of red maple are recent phenomena and wildlife species are generally not dependent on red maple. Pure stands are not common. Recommendations for practices that might benefit wildlife can be found in the chapters on Central Hardwood and Swamp Hardwood. To a lesser extent, practices found in the Northern Hardwood and Oak chapters might apply as red maple is a common associate in both of those types.

Wildlife uses red maple as a food source, structural support for nesting, and as cover. Red maple seeds are an important food source for small mammals and some species of song birds. Twigs, bark, and leaves are used by browsing and gnawing mammals and red maple can be an important source of food for deer in Wisconsin. Red maple flowers early in spring and insects attracted to those flowers make up an important food source for birds during migration and prior to the breeding season.

Sapling/seedling stands can be used as early-successional habitat by a wide range of species in even-aged management systems. Regeneration of red maple in gaps and patch clearcuts provide structural diversity to stands and are used by wildlife for food and shelter.

On some sites, generally mesic or wet-mesic, red maple attains large size and may reach a diameter at breast height of up to 30 inches. It is a good cavity tree and can provide this habitat feature for a considerable length of time as both a live tree and as a snag. While cavities in large trees are important regardless of where they occur, red maples in lowland situations may particularly benefit wood ducks, barred owls, and some bat species.

Management of red maple stands incorporating any of the suitable silvicultural systems will benefit wildlife. Even-aged systems utilizing clearcut, coppice, or shelterwood regeneration will create early-successional habitat. Thinnings and regeneration using patch or gap clearcuts or single tree selection will favor wildlife use by species adapted to mature forests or heterogeneous forest landscapes. Regardless of the silvicultural system used, green tree retention provides critical wildlife habitat and should be incorporated into prescriptions both as single trees and aggregates.

Recommendations:

- Maintain diversity of tree species within stands and age classes within a landscape.
- Use best management practices to avoid hydrologic and soil compaction issues during silvicultural treatments in lowland red maple stands. This may be less of a concern on dry sites.
- Monitor stands for invasive species and tailor silvicultural treatments to minimize the possibility of providing competitive advantages for these species particularly in lowland stands. Reed canary grass and buckthorns are major problems in some areas of the state.
- Take advantage of opportunities to protect and provide cavity and snag habitat suitable for a variety of wildlife species.

3.2.6 Endangered, Threatened and Special Concern (ETS) Species

There are no Wisconsin Endangered, Threatened, or Special Concern species (ETS) known to rely, exclusively, on red maple. Further, red maple grows on a wide variety of sites; it can occur in virtually every forested natural community type in Wisconsin, from the driest to the wettest types. Historically, its dominance on any given site would likely have been short-lived since it would either get replaced by more shade-tolerant species or would be set back by disturbance. Combined, these factors make it difficult to generalize about rare species associated with the red maple cover type. Nevertheless, rare species can be found in many stands containing red maple, and it can contribute to stand species diversity and provide cavity trees, snags, and other habitats used by various species.

Dry-mesic forests (northern and southern types) often contain varying amounts of red maple, but it can also play an important role in hardwood swamps and other wetland types such as floodplain forests. In addition, red maple can be abundant in very dry forests of the north along with northern pin oak and/or jack pine. “White Pine-Red Maple Swamp” is a natural community type known from central Wisconsin (e.g., Central Sand Plains Ecological Landscape) where red maple is the co-dominant species, along with white pine. These forests can be important for red-shouldered hawk, northern goshawk, and hooded warbler, along with some uncommon plants that are no longer considered rare enough to be tracked by the department such as long sedge (*Carex folliculata*) and bog fern (*Thelypteris simulata*).

Recent research in Wisconsin has shown that cracks in red maple can provide summer (daytime) roosting habitat for bats, including the northern long-eared bat (*Myotis septentrionalis*), a species proposed for federal listing as of this writing. Individual trees do not have to be large to be used by bats; for example, 33 bats were observed exiting a crack in a 9” red maple in one evening in 2014.

Whether a red maple stand is likely to support rare species will depend on certain stand characteristics, including its location in the state, the composition of the surrounding landscape (i.e., its “ecological context”), stand age, stand species composition, stand structural complexity, and whether certain microhabitats are present. For example, some rare plants are found on rocky ledges or near seeps. Often microhabitats that support rare species in forests can be accommodated without precluding active timber management in the majority of the stand; examples include moist or dry cliffs, ponds and small wetlands, seeps or other aquatic features, and pockets with prairie or barrens vegetation. The prairie remnants can support rare plants and, sometimes, associated rare invertebrates like butterflies or moths, so site preparation considerations are needed to maintain these habitats.

In general, efforts to maintain large forest blocks, a diverse set of tree species including conifers where appropriate, large cavities and other dead wood, and protection of the microhabitats discussed previously can also benefit a number of species in red maple forests.

More information on rare species associated with Wisconsin’s forests can be found on the department’s web site (*dnr.wi.gov* keyword “biodiversity”). Each of Wisconsin’s natural communities is described, as well as rare plants and animals associated with each of them.

Handbook users are encouraged to submit sightings for species on the NHI Working List (*dnr.wi.gov* keyword “NHI”). Electronic forms are available for this purpose, and documenting these observations helps improve our collective knowledge regarding these species.

3.2.7 Economic Issues

Red maple is utilized by primary wood-producing industries as a pulpwood, biomass, or sawn product and is considered a soft maple. The wood is close grained and as such it is similar to that of sugar maple, but its texture is softer, less dense, and has a poorer figure. High grades of red maple wood can be substituted for sugar maple. In Wisconsin, production of red maple veneer logs is limited with predominantly curly red maple sorted and sold to veneer mills.

Due to the wide range of site conditions on which red maple can occur, quality and economic value are important management considerations. In application, foresters will need to regularly review stands in the field and exercise professional judgment concerning quality, vigor, and mortality. This applies both to the highest product possible and the point in time at which a stand reaches production of that product. While ultimately a rotation age will fall within the generally accepted red maple rotation age range, other factors should also be considered in determining whether the stand has achieved its maximum economic value.

One consideration is landowner objectives. With many products possible, objectives must adapt to site capability as informed by site productivity. For some landowners a wildlife objective may promote a shorter rotation and focus on fiber management rather than saw log potential. Other landowners may have an objective focused on aesthetics which may result in a longer rotation and a focus on saw log production. Desired rate of return on timber investment can also play a role (Grisez & Mendel 1972). If the site is not capable of quality saw log production, objectives would need to be reexamined.

Another important consideration is past management and its effect on current stand origin and the resulting stem quality. As a historically non preferred species, many current red maple stands were not regenerated with red maple as the target cover type. As a result, some red maple stands are the result of poor management and can be stocked with formerly suppressed and/or intermediate trees as well as poor quality dominants and codominants, released with full or partial overstory removal. Other factors which can impact current stand potential based on past management include:

- Seed origin vs. stump sprout: Seed origin tend to have less internal defect than that of coppice/stump sprout origin.
- Harvest history: When was the first entry? What were residual stocking levels after the first entry, second, third, etc.? Was tree retention planned? Are current trees vigorous? Past mismanagement or lack of management may limit current options based on stem quality.

A further consideration is the optimal stem size to capture the most value. In general as the size of the stem increases past its optimum product, log grade and quality have the potential to diminish. Based on conversations with many Wisconsin mills (2014), there is a consensus that due to stand history (i.e. conversion from aspen, high grading, woodlot grazing, etc.) defect is more prevalent in red maple trees with an average 18” – 24” DBH. The primary defects found as a tree increases in diameter are an increase in heart size, color, staining, and ring shake, all of which are major issues in lumber grade.

Given current markets, another consideration is diameter. Based on conversations with many Wisconsin pulp and chipper mills (2014), many are unable to accept wood over 24” dia. due to mechanical limitations in the debarking and chipping process.

4 STAND MANAGEMENT DECISION SUPPORT

4.1 Stand Inventory

In addition to clearly identifying landowner goals and objectives, in-depth and accurate stand assessment will facilitate discussion of management options and objectives in relation to realistic and sustainable management goals. Red maple stand assessment should include quantifying variables such as:

- Present species composition
  - Canopy, shrub, and ground layers
  - Sources of regeneration
  - Potential growth and competition
  - Potential non-red maple sources of regeneration
- Stand structure
  - Size class distribution and density
  - Age class distribution
- Stand and tree quality
- Site quality - The habitat type is the preferred indicator of site potential. Other indicators of site productivity include site index (should not be the only factor), soil characteristics, cubic ft./acre/year growth rate, and topographical characteristics. Site has a strong influence on volume growth and potential yield. Site index for red maple provided in the appendix.
- Site history
  - Stand origin (seedling, sprout)
  - Management history
- Hydrology
- Topography
- Stand and site variability
- Damaging insects and diseases, herbivory
- Special considerations: watershed, BMPs, rare species, archaeology, landscape

4.3 Cover Type Decision Model

The red maple decision models below outline initial considerations in the planning process for a management plan and integrate the use of silvics, site capabilities (soil, habitat type, competition, regeneration, successional pathways), methods (timing/sequence), and timeline at growth stages under ideal conditions. Sustainable forestry practices must be based on compatible landowner objectives, the capability of each site and generally accepted silvicultural practices. Each of these factors should be considered when approaching these models.

The primary focus for red maple stands are timber production and maintenance of the type, or conversion to other species appropriate to various sites where red maple stands are found. Habitat type and site index are the two primary factors recommended to evaluate red maple stands. Many other site factors may influence red maple growth and stand quality. To further evaluate sites for potential management, it is recommended to consider the characteristics or site conditions defined for dry, dry-mesic, mesic, and wet-mesic. Stand/site conditions are defined in the following text which includes site index, soils, habitat type, and past disturbance.

Dry Stands

Stand/site conditions of dry red maple stands (SI < 60) may include: shallow bedrock, ridge tops, glacial outwash, outwash terraces, and valley alluvium, and dry habitat types. Fiber management is recommended on dry sites.

Dry –Mesic Stands

Stand/site conditions on dry-mesic sites (SI > 60) may include: sandstone residuum soils, north and east slopes, and dry-mesic habitat types. Dry-mesic sites may have sawlog potential however fiber management is an option. Both are viable alternatives based on stand objectives and site capability.

Mesic Stands

On mesic sites red maple is not the climax species and is often managed as a component of another cover type. If a red maple stand is present in this habitat type range, consider transitioning to another cover type, especially northern hardwood. Sawlog potential is optimal on mesic habitat types.

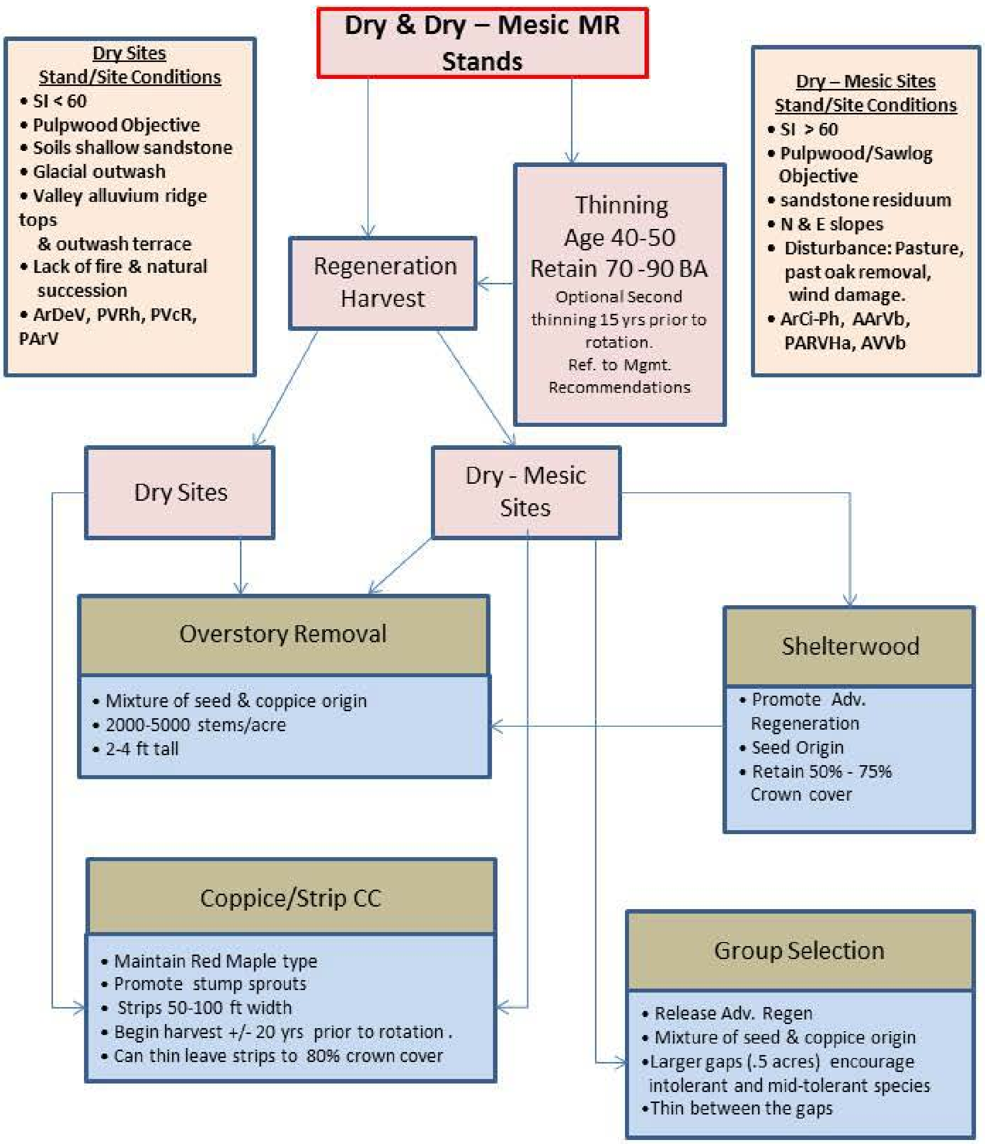
Wet- Mesic

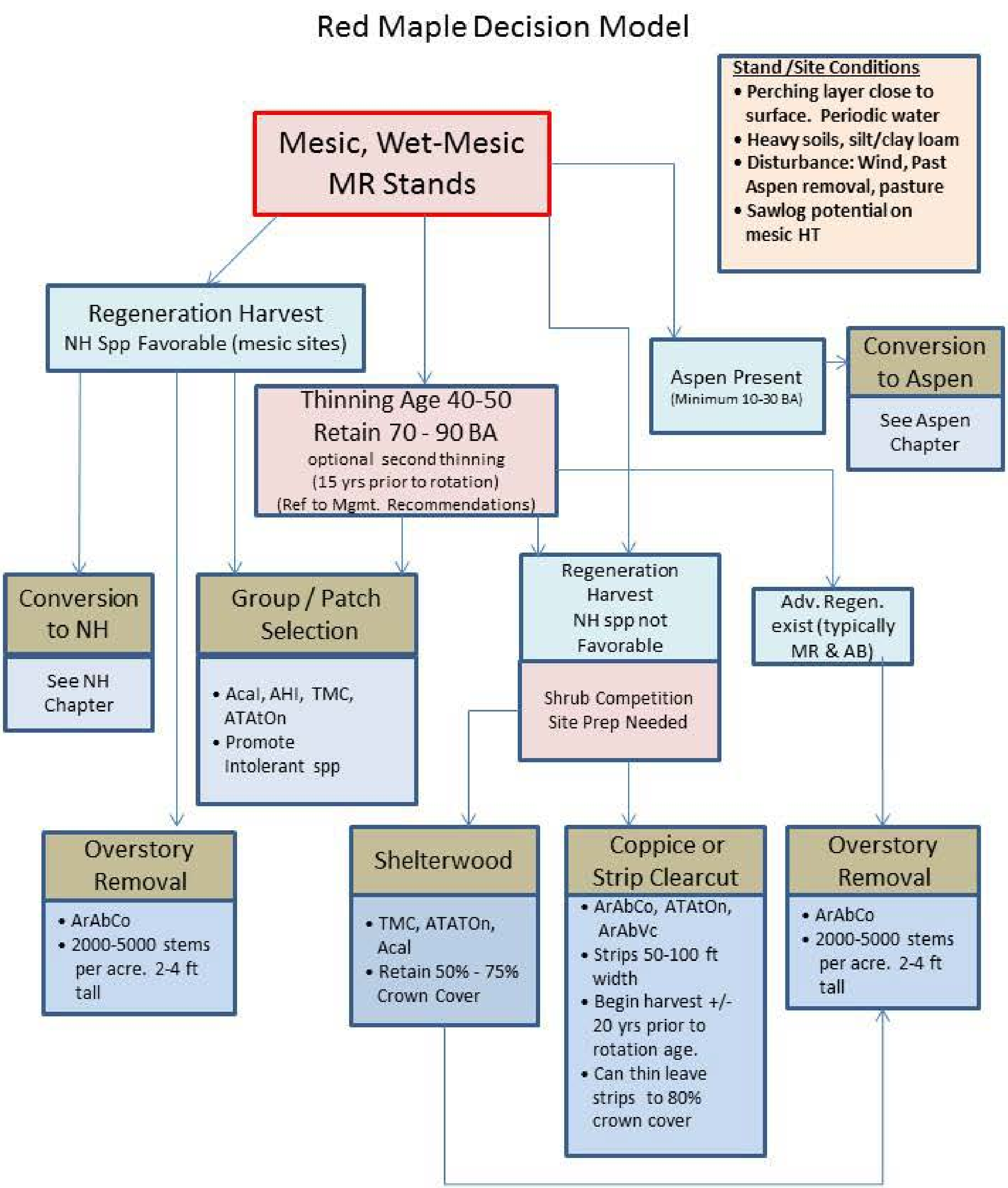
Stand/site conditions on wet-mesic sites may include heavy (silt/clay) soils, perched water close to surface, and periodic surface water. Competition (grass, hazel, musclewood) may be a factor on these sites. On wet-mesic sites, fiber management is recommended however many sites may have sawlog potential.

Even-aged silvicultural systems are commonly recommended for the management of red maple on dry, dry-mesic, and wet-mesic stands to emphasize fiber management. Sawlog potential may exist on dry-mesic and wet-mesic but is optimal on mesic sites.

Past disturbance has shaped many of today's red maple stands. Red maple stands on dry sites are commonly the result of fire suppression and natural succession. On dry-mesic sites fire suppression, oak removal, storm damage and grazing have played a role in shaping these stands. On wet-mesic sites aspen removal, Dutch elm disease, storm damage (wind), and grazing have favored red maple.

Red Maple Decision Model




Red Maple Decision Model
Stand /Site Conditions
• Perching layer close to surface. Periodic water
• Heavy soils, silt/clay loam
• Disturbance: Wind, Past Aspen removal, pasture
• Sawlog potential on mesic HT
Mesic, Wet-Mesic MR Stands
Regeneration Harvest
NH Spp Favorable (mesic sites)
Thinning Age 40-50
Retain 70 - 90 BA
optional second thinning
(15 yrs prior to rotation)
(Ref to Mgmt. Recommendations)
Aspen Present
(Minimum 10-30 BA)
Conversion to Aspen
See Aspen Chapter
Conversion to NH
See NH Chapter
Group / Patch Selection
• Acal, AHI, TMC, ATAtOn
• Promote Intolerant spp
Regeneration Harvest
NH spp not Favorable
Shrub Competition
Site Prep Needed
Adv. Regen. exist (typically MR & AB)
Overstory Removal
• ArAbCo
• 2000-5000 stems per acre. 2-4 ft tall
Shelterwood
• TMC, ATATOn, Acal
• Retain 50% - 75% Crown Cover
Coppice or Strip Clearcut
• ArAbCo, ATAtOn, ArAbVc
• Strips 50-100 ft width
• Begin harvest +/- 20 yrs prior to rotation age.
• Can thin leave strips to 80% crown cover
Overstory Removal
• ArAbCo
• 2000-5000 stems per acre. 2-4 ft tall

5 SILVICULTURAL SYSTEMS

A silvicultural system is a planned program of vegetation treatment during the entire life of a stand. Silvicultural systems typically include three basic components: intermediate treatments (tending), harvesting, and regeneration. Relatively little information is available regarding silvicultural systems for the red maple type. Most of the information in this section is adapted from northern hardwood silviculture as well as red maple trials and field experience in Wisconsin. Previously, the red maple cover type was not considered independent of the northern hardwood cover type. With the red maple type, silvicultural systems are frequently adapted to meet site-specific and species-specific conditions.

With the goal of regenerating red maple as well as shade intolerant to mid-tolerant species, even-aged management is the preferred method. The even-aged regeneration methods generally accepted and supported by literature are:

- Overstory Removal
- Strip Clearcut/Coppice
- Shelterwood

With the goal of regenerating red maple as well as shade tolerant species, uneven-aged management may be suitable. The uneven-aged regeneration method generally accepted and supported by literature is:

- Group and/or Patch Selection

5.1 Seedling/Sapling Stands

Once established, red maple seedlings and saplings exhibit optimal vigor (growth and health) when exposed to (near) full sunlight. Seedlings and saplings in free-to-grow conditions have the greatest potential to survive and to maximize growth and productivity. To ensure full stocking while developing stem quality, the stocking of desirable species should be more than 5,000 per acre of well distributed seedlings >3’ tall (Erdmann 1986).

5.2 Intermediate Treatments

5.2.1 Non-Commercial Intermediate Treatments

Where sawlog production is a management objective, the development of individual tree quality is a principal concern. Stand and tree quality depends on many factors. In many situations it may be necessary to enhance stand development with non-commercial intermediate treatments or timber stand improvement practices (TSI). For details on these methods refer to Chapter 23, Intermediate Treatments. Within the red maple cover type, TSI is often a combination of some or all of the following practices:

5.2.1.1 Weeding

This practice eliminates or suppresses competing plants (trees, shrubs, vines, and herbaceous vegetation) within a stand. Most often these plants are aggressive shrubs and herbaceous species that retard advance regeneration or prevent the establishment of desirable regeneration. Intensive management techniques may be required to control competition and establish regeneration. Within the red maple cover type, trees and shrubs which are commonly weeded include:

- Ironwood (*Ostrya virginiana*)
- Hazelnut (*Corylus americana*, *C. cornuta*)
- Witchhazel (*Hamamelis virginiana*)
- Musclewood (*Carpinus caroliniana*)
- Prickly ash (*Zanthoxylum americanum*)
- Common buckthorn (*Rhamnus cathartica*)
- Glossy buckthorn *(Rhamnus frangula*)
- Bush honeysuckles (*Lonicera tatarica, L. morrowii, L. x bella*)

5.2.1.2 Liberation

This practice releases a young crop of desirable seedlings and/or saplings by removing less desirable, older, overtopping trees. With red maple, this often entails the removal of poor quality trees to favor the advancement and quality of young, vigorous and potentially valuable trees. Retention of some wildlife trees may be desirable for non-timber goals.

5.2.1.3 Cleaning

This practice releases desirable seedlings and saplings from undesirable tree species in the same age class. It is used to control a stand's species composition and to improve growth and quality of crop trees.

5.2.3 Thinning

5.2.3.1 Non-Commercial Thinning and Improvement

Crown thinning in non-commercial pole timber stands favor crop trees by removing adjacent crown competitors. This allows crop trees to develop full, vigorous crowns necessary for improving growth and quality. This is often referred to as "crop tree release." With young red maples, release may not affect height growth and can delay natural pruning. It can however help these trees retain their dominant or codominant crown position (Trimble 1974).

5.2.3.2 Commercial Thinning and Improvement

Intermediate thinning is used in red maple stands to control stand density, structure, and composition between stand regeneration and final harvest. , The primary objectives of intermediate thinning in red maple stands are:

1. To increase the rate of growth of residual trees
2. To concentrate growth on the most desirable trees
3. To improve species composition
4. To salvage losses that would occur as a result of competition and suppression.
5. To generate income during the stand rotation
6. To enhance forest and tree health

As is true for other species and cover types, thinning does not significantly alter the gross production of stand volume but does concentrate growth on desirable trees. With red maple, both survival and crown class ascension of codominant, intermediate, and suppressed trees are improved by thinning (Rentch 2009). Being sensitive to crown position, the amount of red maple which can be expected in future stands depends not only on number of stems, but also on the distribution of stems among crown classes (Ward 1993). Unlike uneven-aged selection harvesting, reproduction is not a management concern.

Thinning can be difficult, especially on wetter sites, due to operability concerns. When thinning is considered, implement when stocking is above 100% crown cover. Reduce stocking to a density near 80% crown cover, choosing a residual basal area that will accommodate landowner objectives. A general rule of thumb is do not remove >35% of the basal area in any one thinning operation. Refer to the stocking chart (Figure 51.6) to help determine timing and level of thinning.

When or whether to thin a stand depends on site capability, management objectives, stand conditions, and operability. Intermediate thinning should be implemented at least 20 years prior to rotation. Reduce stand residual basal area to the prescribed stocking level (80 percent crown cover for first entry) using the even-aged stocking guide for red maple (Figure 51.6). Thinning should free crop trees from poor quality main canopy competition with crown thinning or thinning from above. Red maple stands should be thinned to 70-90 sq. ft. residual basal area.

Since red maple stands can differ widely in species composition, estimates of stocking based on stocking charts may be inaccurate and should be used with caution (Stout & Nyland 1986). Relative stand density (stocking), may be more accurately calculated directly from stand data using a species-specific tree-area ratio than with stocking charts (Table 51.5). If the relative density of a stand is calculated this way, a ratio can be developed for determining the desired residual basal area.

> *Example*: A red maple stand is inventoried with the aid of software that calculates relative density. Per this calculation the stand basal area is 130 sq. ft. and the relative density is 90%. The target residual relative density for this stand is 60% after an intermediate thinning. To estimate the residual basal area when marking the stand, a ratio is developed:
>
> Current RD/Current BA = Residual RD/Residual BA
> 90/130 = 60/X
> X=86.7

For ease of use in the field and assuming a negligible increase in mean diameter (quadratic) if thinned from above, 85 sq. ft. would be a useful guide for 60% relative density in this stand.

5.3 Natural Regeneration Methods

Table 51.3. Summary of natural regeneration methods.

FOREST COVER TYPES[1]	NATURAL REGENERATION METHODS							
	Coppice	Clearcut	Seed Tree	Overstory Removal	Shelterwood	Patch Selection (0.5-2.0)	Group Selection (0.1-0.5)	Single-tree Selection (<0.1 acre)
Red Maple	R	CR*	NR	R	R	R	R	CR

Note: **R** **Recommended practice**
CR **Conditionally recommended practice ()**
NR Not recommended practice
* See Regeneration Systems for more detail

5.3.1 Even-Age Regeneration Methods

When the goal of stand management is regenerating red maple as well as shade intolerant to mid-tolerant species, even-aged management is the preferred method.

5.3.1.1 Shelterwood

Even-aged management, using the shelterwood method, is typically implemented in dry mesic and wet mesic red maple stands to establish seed origin red maple and promote advanced reproduction (Erdmann 1986). In both situations, site preparation (chemical and/or mechanical) may be required for successful seedling establishment. While stands are maturing, intermediate even-aged thinning guidelines should be followed. Stand rotation is based on landowner objectives, species present, site quality, tree vigor and stand condition, and requires the presence of adequate established regeneration (see Rotation Length).

Regeneration is usually accomplished using a two-step shelterwood. Initial harvesting (seed cut) is designed to provide proper crown closure and tree spacing depending on the preferred species composition, leaving a high, and uniform crown cover of 50 - 75 % in the residual shelterwood overstory. Retain vigorous, high quality (best phenotypes) dominant and codominant trees to serve as seed sources.

If possible, consider timing the shelterwood cut and site preparation operations relative to the production of good seed crops. Site preparation on these sites can be difficult due to accessibility, rutting potential and further development of swamp grass and other competitive species. Site preparation can be accomplished via mechanical or chemical methods, prescribed burning, or a combination of these techniques. The intent is to provide a moist, mixed seedbed of mineral soil and humus in addition to reducing competition. Complete the final harvest and release established regeneration using the overstory removal methodology described below.

5.3.1.2 Overstory Removal

This method removes all or a portion of the canopy placing established, advanced regeneration in a free to grow position. Gradual or patch overstory removal may be necessary on wet sites to reduce the chance of raising the water table, causing damage or mortality to regeneration. Red maple regeneration is considered established when it reaches sufficient height, usually 2 to 4 feet tall, however, taller established regeneration may be needed to address deer browse and competition concerns. To ensure full stocking while developing stem quality, the stocking of desirable species should be more than 5,000 per acre of well distributed seedlings >3' tall (Erdmann 1986). Overstory removal operations should be conducted during dry or frozen ground conditions in order to minimize the damage to advance regeneration. Careful skid trail design prior to harvesting activities will help protect seedlings from equipment damage. Overstory removal is typically conducted when the canopy is at or near rotation age or in degraded stands with adequate advanced regeneration.

General considerations in the application of the overstory removal method are: overstory health, condition and composition; potential risk of raising the water table on wet sites; adequate stocking, distribution, vigor; site capability; existing and potential competition including invasive species. Gradual or patch overstory removal may be necessary on wet-mesic sites where competition is an issue and patch of advanced regeneration exist. This variation can also be used to slowly convert a stand to a different composition.

5.3.1.3 Progressive Strip Clearcut/Coppice

Clearcutting is a method used to regenerate a standby the removal of most or all woody vegetation creating a (nearly) completely open area for seedling establishment. Progressive strip clearcut is a variation of the clearcut method. The stand is removed using a series of strips harvested over two or three entries, usually covering an equal area on each occasion. The entire stand level strip removal process is completed within a period of time not exceeding 20% of the intended rotation (creating an even-aged stand). This method is recommended when hydrology, regeneration and less frequent entries are a consideration. Red maple stands that contain an aspen component may be managed using coppice/strip clearcut. Coppice/strip clearcut has been utilized with favorable results in many areas of Wisconsin. Most WDNR strip clearcut/coppice trials have shown that adequate regeneration establishes within 2 years. Typically, the uncut area serves as the primary seed source for regenerating the cut strip (and to maintain the water table). The clearcut strips are often oriented so that they are at right angles to the direction of seed-dispersing winds. Additional regeneration can come from seed previously dispersed, trees cut during each strip harvest operation, natural seeding from nearby stands, and stump sprouting (coppice). Regeneration is established during or following stand removal. There is the option of having the uncut strip harvested up to 80% crown closure so long as damage does not occur to the residual trees.

Recommended process:

1. Cut first ½ or 1/3 of stand in strips approximately 50 (to 200) feet wide. Strip orientation and width is dependent on road layout, stand shape, windthrow concerns, and hydrology. Wait until well established regeneration is 2 to 4 ft. tall and 2,000 – 5,000 stems per acre.

2. Cut next adjacent strip 50-200 feet wide. Cut strips should be located adjoining the previously cut strips.
3. Wait until well established regeneration is 2 to 4 ft. tall (unless there are browse or hydrology concerns) and at 2,000 – 5,000 stems per acre.
4. Cut final strips, retaining seed trees and reserve trees.

Strip management recommendations:
- 1st and 2nd strip cuts: Remove all trees >1 inch dbh and retain only exceptional reserve trees for green tree retention purposes.
- 2nd and later strip cuts: Care should be taken to protect the regeneration in the previously cut strips.
- Last strip cut: Remove all trees >1 inch dbh but consider retaining seed trees and reserve trees.
- Consider the timing of the strip cuts relative to the production of good seed crops, seed dispersal and germination, and site preparation operations.

5.3.2 Uneven-Age Regeneration Methods

Even-aged management is the preferred silvicultural system to manage and maintain the red maple cover type. Potential alternatives to even-age red maple management should be identified and evaluated in relation to sustainable land management goals, site quality/capability and stem quality. Higher quality sites with an adequate stocking of potential crop trees could theoretically be managed using modified uneven-aged management techniques such as single tree selection harvests.

Uneven-aged silvicultural systems, group selection and/or patch selection may be utilized for the management of red maple stands on the mesic and wet-mesic sites which have the potential for sawlog production. Though group and/or patch selection may be implemented based on stand volume regulation, it is easier to implement based on area regulation.

5.3.2.1 Group and/or Patch Selection

Group and/or patch selection may also be utilized to produce regeneration in small cohorts throughout a stand. Spatial distribution of groups and/or patches may be irregular and dictated by variations in stand conditions, such as the vigor, health, and size of individual and small groups of trees. Site quality will determine the potential for high quality products. Other considerations in selecting this method may include economic feasibility and operability.

The group and/or patch selection regeneration method in red maple stands is appropriate for promoting a higher preponderance of mid-tolerant shade species including Northern red oak, yellow birch, black ash or white pine. In addition, because red maple sprouting is consistent under partial cutting systems, is it likely that red maple will increase in abundance in future stands managed under these systems (Atwood 2009). Groups of trees are selectively or systematically removed to create holes the canopy ranging from 0.1 acres up to approximately 2.0 acres in size. Factors affecting the size of the opening include stand management objective, structure, quality, vigor, and shade tolerance of desired regeneration species.

Groups and/or patches often require site preparation and release of preferred species of regeneration from competition. Site preparation on these sites can be difficult due to operational considerations (swamping, rutting potential and further development of grass and other competitive species). Site preparation can be accomplished via mechanical or chemical methods or a combination of these techniques. The intent is to provide a moist, mixed seedbed of mineral soil and humus in addition to reducing competition. In application, openings are cleaned of all non-crop tree stems down to one inch in diameter. Create openings by removing groups of trees with poor stem form, vigor or quality, releasing desirable advance regeneration, or removing mature trees. The number of openings is dependent upon the landowner objectives and the size of the area being managed as well as the maturity of the overstory. During opening creation, thinning and crop tree release should occur throughout the remainder of the stand.

5.3.2.2 Single-Tree Selection[1]

Single tree selection may be a viable option on mesic to wet-mesic red maple sites where northern hardwood species are favorable. On these sites red maple is only a phase and northern hardwood management is a viable goal. With single tree selection, regeneration is established by creating canopy gaps with each entry. Gaps (25-75' diameter) may be created by cutting large crowned trees or groups of low vigor/poor quality trees. All poor-quality residual stems larger than 2 inches DBH must be cut in these gaps so that vigorous regeneration can develop. Residual stand structure recommendations can be found in Table 40.15 and Table 40.16. For more information about application of single tree selection, see Chapter 40 Northern Hardwood Cover Type.

5.3.2.3 Even-aged to Uneven-Aged Conversion Process

Stands that are even-aged or two-aged may be converted to uneven-aged management (single tree selection) by combining crop tree release, thinning and gap /group /patch formation techniques. Though there is no research on this conversion technique in red maple stands, this method could be applied in stands capable of sawlog production. Due to the lack of information about this management method in red maple, the currently recommended procedure to convert even-aged stands to uneven-aged structure is adapted from northern hardwood Argonne Experimental Forest studies. See page 40-17 for a discussion of conversion as applied to the northern hardwood cover type.

5.5 Rotation Lengths and Cutting Cycles

In even-aged silvicultural systems the rotation is defined as the period between regeneration establishment and final cutting. The length of rotation may be based on many criteria including culmination of mean annual increment, mean size, age, attainment of particular minimum physical or value growth rate, stand history, and biological condition.

[1] Management practice that may have potential for application in managing red maple but has not been widely utilized and tested.

Commonly the lower end of the rotation length range is defined by the age at which maximization or culmination of mean annual increment (MAI) growth occurs. The upper end of the rotation length range would be defined by the average stand life expectancy. However, very little objective data exists identifying these endpoints in general and even less by site type. In addition, growth and mortality rates vary among stands and can be affected by many variables, including site characteristics, silvics, stocking, silvicultural methods, and units of measure.

Stands can be grown as long as vigor and net volume growth are maintained. Documenting the site and stand conditions are important when determining a rotation age for a stand. In application, foresters use crown class, dbh, and tree condition to evaluate vigor. Vigorous stands are generally stands that have been well-managed and consist of trees with well-developed crowns that hold a good position in the main canopy and exhibit smooth bark without epicormic branches. Stands with red maple trees that have had a good competitive position for extended periods of time are often capable of growing longer and maintaining productivity.

Different rotation lengths can result in increased production of some benefits and reduced production of others. Landowner goals and objectives will also inform rotation age determination. See the discussions under management considerations in the following sections to evaluate some benefits and costs (ecological, economic, social, and cultural) associated with different forest management strategies.

Table 51.4. Red maple recommended and extended rotation ages by habitat type group (1st and 2nd number represent the timber rotation age, and the 2nd and 3rd numbers represent the potential extended rotation age).

Habitat Type Group	Rotation*	Principal Product
Dry	50-80-*95*	Fiber
Dry-Mesic	50-90-*110*	Fiber, Sawlog
Mesic	50-90-*110*	Sawlog
Wet-Mesic	50-90-*110*	Fiber

* On all sites, individual trees and stands may maintain vigor longer or decline earlier than these rotation length guidelines. In application, foresters will need to regularly review stands in the field and exercise professional judgment concerning quality, vigor, and mortality. The numbers provided are based on general data, empirical evidence, and the best estimations of the authors and other contributors. Rotation ages may be shortened or extended (i.e. extended rotations may exceed 110 years) based on the considerations above.

5.6 Other Silvicultural Considerations

5.6.2 Cover Type Conversion

When considering natural conversion evaluating site condition is important. Knowledge of site factors such as soils, habitat type, existing vegetation and site potential will aid in decision making. Of high importance is the presence of a desired seed source. Some of the dominant species that may be considered in conversion include aspen and sugar maple. Other species that may be a component of these stands include black ash, white pine, oaks, and yellow birch. These species respond well to large gaps in the canopy for regenerating. Group selection, variations of shelterwood harvests, coppice with standards, and wide strip clearcuts (50-200 feet wide) are all viable options for natural conversion. Conversion of this type to conifers, aspen, or northern hardwood can be successful if regeneration criteria are met:

- Aspen conversion: 1-2 healthy aspen per acre required for coppice sprouting
- Northern hardwood conversion: Northern hardwood seedlings/saplings present (1,000 or more stems per acre is desirable) and habitat type and soils support good quality northern hardwood growth.
- Conifer conversion: Conifer component present in understory or in numbers that would support conversion in overstory.

Other species to consider for conversion include more shade tolerant species such as balsam fir, sugar maple, and hemlock. Small gaps in the canopy can be used to recruit regeneration. Regeneration systems that may work well for these species include shelterwood harvests, narrow strip clearcuts (30-60 feet wide), coppice with standards and single tree selection. Regenerating some of these recommended species can be difficult but refer to each species cover type chapter when considering natural conversion.

8 APPENDICES

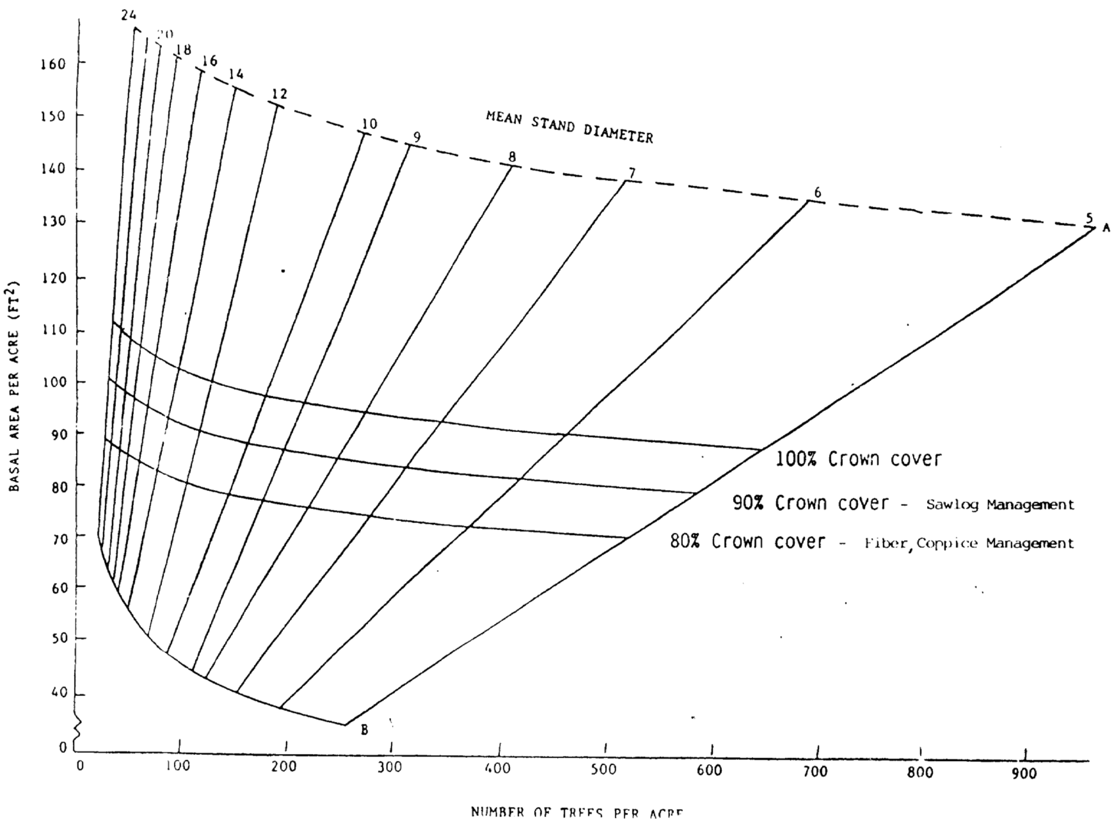


Figure 51.6. Red maple stocking chart.

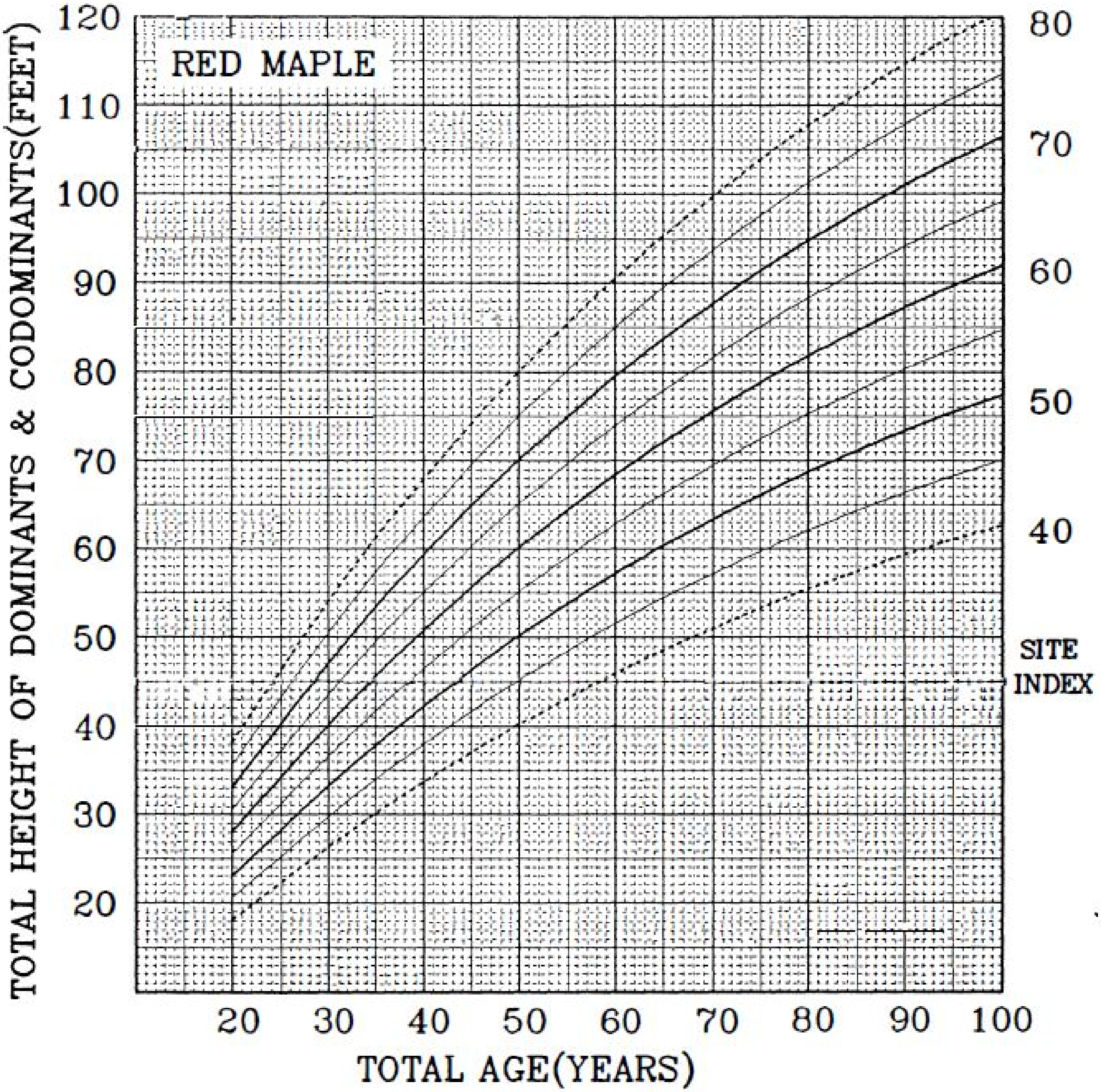
Table 51.5. Even-age stocking levels for red maple stands by mean stand diameter, basal area, and number of trees per acre for specified crown covers after thinning.

Mean stand diameter[a] (In)	Crown area per tree[b] (Ft^2)	Basal area per tree[c] (Ft^2)	Crown cover (Percent of 43,560 ft^2/acre)					
			80 percent		90 percent		100 percent	
			Trees/Ac (No.)	BA/AC (Ft^2)	Trees/Ac (No.)	BA/AC (Ft^2)	Trees/Ac (No.)	BA/AC (Ft^2)
5	68	0.1364	512	69.9	577	78.6	641	87.4
6	95	0.1963	367	72.0	413	81.0	459	90.0
7	126	0.2673	277	73.9	311	83.2	346	92.4
8	161	0.3491	216	75.6	244	85.0	271	94.4
9	200	0.4418	174	77.0	196	86.6	218	96.2
10	243	0.5454	143	78.2	161	88.0	179	97.8
11	290	0.6600	120	79.3	135	89.2	150	99.1
12	340	0.7854	102	80.5	115	90.6	128	100.6
13	394	0.9218	88	81.5	100	91.7	111	101.9
14	452	1.0690	77	82.4	87	92.7	96	103.0
15	513	1.2272	68	83.4	76	93.8	85	104.2
16	578	1.3963	60	84.2	68	94.7	75	105.2
17	646	1.5763	54	85.0	61	95.7	67	106.3
18	718	1.7671	49	85.8	55	96.5	61	107.2
19	793	1.9689	44	86.5	49	97.3	55	108.2
20	872	2.1817	40	87.2	45	98.1	50	109.0
21	954	2.4053	36	87.9	41	98.8	46	109.8
22	1,039	2.6398	34	88.5	38	99.6	42	110.7
23	1,128	2.8852	31	89.1	35	100.3	39	111.4
24	1,220	3.1416	29	89.7	32	101.0	36	112.2

[a] For tree of average basal area

[b] Dominant and codominant high-quality forest grown red maple trees (Crown area = $3.478\ DBH^{1.844}$)

[c] BA/tree = $D^2 \times 0.00545415$



Red maple (Carmean 1978)

Northern Wisconsin and Upper Michigan
114 plots having 438 dominant and codominant trees
Stem analysis, nonlinear regression, polymorphic
Add 4 years to d.b.h. age to obtain total age (BH = 0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	2.9435	0.9132	-0.0141	1.6580	-0.1095	0.99	0.49	2.0
SI	0.3263	1.0634	-0.0106	-1.2573	-0.0646	0.99	0.51	2.2

Figure 51.7. Site index curves for red maple in northern Wisconsin and upper Michigan (Carmean et al. 1989).

8.1 Forest Health Guidelines - Forest Health Protection (FHP)

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
DEFOLIATING INSECTS	
MOTHS Baltimore bomolocha – *Bomolocha baltimoralis* Caterpillars from May to November	Usually, controls are not needed and not realistic Natural enemies play an important role in population control Maintain stand vigor by thinning when appropriate and encouraging species and structural diversity Avoid thinning one year prior or one year after defoliation Insecticides, with conservation of natural enemies, can be considered during severe and prolonged infestations. Use biorational insecticides if possible. Note: Late season defoliators do not damage trees as much as early season defoliators.
Definite-marked tussock moth – *Orgyia definite* Caterpillars from April to September	
Elm spanworm – *Ennomos subsignaria* Caterpillars from late May to early July	
Maple leaftier moth - *Epismus tyrius* Caterpillars in early summer	
Green-striped mapleworm – *Dryocampa rubicunda* Caterpillars from July to September	
Spongy moth – *Lymantria dispar* Caterpillars in May and June	
Lesser maple spanworm – *Itame pustularia* Caterpillars from late May to July	
Linden looper – *Erannis tillaria* Caterpillars from late May to early July	
Maple looper – *Parallelia bistriaris* Caterpillars from late May to September	
Maple spanworm – *Ennomos magnaria* Caterpillars from late June to August	
Maple trumpet skeletonizer – *Catastega aceriella* Caterpillars from early July to early October. Feed inside a trumpet-shaped tube formed by folding a leaf.	
Orange-humped mapleworm – *Symmerista leucitys* Caterpillars from late July to September	

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
The half-wing - *Phigalia titea* Caterpillars from May to July	
Ruby quaker – *Orthosia rubescens* Caterpillars from late April to early July	
Maple leafblotch miner – *Cameraria aceriella* Caterpillars from July to September	
Maple leafcutter moth – *Paraclemensia acerifoliella* Caterpillars from June to September. Older larvae cut two circular portions of a leaf and sew them together as a portable case.	
GALL FORMERS	
FLIES Ocellate gall midge - *Acericecis ocellaris* Eyespot galls formed by a midge larva in the spring. The red and yellow coloration is most intense in June.	Usually, controls are not needed and not realistic Maintain stand vigor
Gouty vein midge - *Dasineura communis* Cause greenish or reddish pouch galls on leaf veins in June.	
MITES Maple bladdergall mite – *Vasates quadripedes* Forms spindle and bladder galls on leaves that may lead to leaf distortion during outbreaks. Galls are noticeable in May when leaves have fully expanded. Galls change from green to pink to red and eventually black. Leaves may become deformed or drop when galls are numerous.	
TWIG BORERS	
Boxelder twig borer – *Proteoterus willingana* Caterpillar attacks dormant buds in fall and early spring, kills new shoots in May and June, and skeletonizes leaves in July.	Usually, controls are not needed and not realistic Maintain stand vigor

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
Maple twig borer moth – *Proteoterus aesculana* Caterpillars feed in the buds and terminal shoots in May and early June.	
SUCKING INSECTS	
Scale insects and aphids Heavy infestations cause leaf yellowing, premature foliage drop, and dieback of twigs and branches. These insects also produce honeydew which can lead to growth of sooty mold.	Usually, controls are not needed and not realistic Maintain stand vigor
BARK AND WOOD INSECTS	
METALLIC WOOD-BORING BEETLES *Actenodes acornis* Breeds in dry heartwood	Plant trees properly Avoid wounding trees Maintain stand vigor – do not operate in stands the year before, during, or year after stressful environmental (e.g. drought, flooding) or biological events (e.g. defoliation) Infested trees can be felled; then debarked or destroyed. Harvest during the fall and winter Promptly ship logs off landings during summer (within 2 weeks) Promptly process logs during summer or by spring (mid-April) if cut during winter
Chrysobothris sexsignata	
BARK BEETLES Columbian timber beetle – *Corthylus columbianus* Native ambrosia beetle that attacks the xylem of vigorously growing trees.	
LONGHORNED BEETLES Gall-making maple borer - *Xylotrechus aceris* Larvae bore into the sapwood and later the heartwood which weaken trees	
CLEARWING MOTHS Maple callus borer – *Sylvora acerni* Larvae bore into the sapwood	
FOLIAGE DISEASES	
Anthracnose – *Aureobasidium apocryptum* and *Discula campestris* Causes heavy leaf spotting and blotching. Anthracnose does not cause significant losses.	Favor resistant trees Ensure stands are not overstocked

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
Tar Spot – *Rhytisma acerinum* This fungus grows black spots on leaves, particularly in the lower canopy. Tar spot does not causes significant losses.	
Venturia Leaf Blotch – *Fusicladosporium humile* Causes round reddish-brown to dark brown lesions on leaves. Lesions combine to kill large areas of leaves.	
WILT	
Verticillium Wilt – *Verticillium dahlia* and *V. albo-atrum* Causes wilt, leaf curling and drying, yellowing, defoliation and green-gray streaking in sapwood.	Generally not a problem in a forested setting Favor immune or resistant hosts like conifers, oaks, hickories, birches, etc.
CANKERS/ CANKER ROT	
Cerrena unicolor Causes discrete or diffuse cankers, white rot of sapwood and dieback in trees weakened by wounds or environmental stress. Small, white to greenish gray, hairy, bracket shaped mushrooms on bark.	Avoid wounding trees Harvest during the winter or dry part of summer Remove trees infected with canker-rotting fungi Trees infected with canker rots may provide excellent den trees. Consider leaving an occasional canker-rotted tree as a cavity tree for wildlife. Shorten rotation age
Eutypella canker – *Eutypella parasitica* Target shaped cankers that may have the margins greatly expanded to resemble to head of a cobra. Fungal reproductive structures may cause bark on the canker to be black. Cause wood decay.	
Hispidus canker - *Inonotus glomeratus* First rots heartwood, but eventually rots sapwood and kills the cambium. Fungus forms an elongate, bark-covered, perennial canker. Annual conks are yellowish to reddish. Heart rot is spongy and white to light brown.	
Hypoxylon canker – *Kretzschmaria deusta* Causes basal cankers associated with butt rot. Internal rot appears as reddish brown wood	

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
discoloration and light-colored decay. Conks are large, lumpy groups of grayish white (early), or copper brown to brown or black (advanced) fungal structures.	
Nectria canker - *Neonectria galligena* Causes a target-shaped depression on the trunk and kills bark, cambium, and the outer sapwood. Wood decay associated with nectria cankers is rare.	
Valsa canker – *Valsa ambiens* Causes elongate, shallow cankers on stems and branches. Bark in the center of cankers usually contains many small, gray to white reproductive bodies. Does not typically kill trees and only affects branches < 10cm diameter typically.	
DECAY	
White Rots Mossy-top conk – *Oxyporus populinus* This fungus forms a spongy, straw-colored white rot in heartwood and sapwood	Avoid wounding trees Remove tree if decay in the main stem results in < 1” of sound wood around the tree for every 6” in diameter (see Northern Hardwoods Chapter 40 Section 8.1 for FHP Guidelines) Trees with decay may provide excellent den trees. Consider leaving an occasional decayed tree as a cavity tree for wildlife.
Phellinus igniarius Causes white heart rot. Forms hoof-shaped, perennial conks with cracked, black upper surfaces.	
Lacquered polypore - Ganoderma lucidum Causes white rot of sapwood in major roots and butt logs. Annual, reddish conks grow from the base of trees or out of major roots.	
ABIOTIC DAMAGE	
Spring frost damage Can cause sparse foliage and leaf drop by damaging developing buds and leaves in the spring.	
Winter frost damage	

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
Fine roots can be killed by frost during winters with little snow cover. This results in canopy dieback.	
Drought stress Thin crowns, tufted foliage, and dieback are symptoms of drought stress.	
Flooding Dieback, early fall color development, and mortality are symptoms after flooding.	

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Chapter 52

Central Hardwood Cover Type

WISCONSIN
DEPT. OF NATURAL RESOURCES

Last Full Revision: 1/16/2009
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand Composition
The central hardwood cover type consists of variable associations of upland hardwood species, predominantly oaks (*Quercus spp*.), shagbark hickory (*Carya ovata*), bitternut hickory (*Carya cordiformis*), elms (*Ulmus spp*.), black cherry (*Prunus serotina*), red maple (*Acer rubrum*), white ash (*Fraxinus americana*), green ash (*Fraxinus pensylvanica*), basswood (*Tilia americana*), hackberry (*Celtis occidentalis*), and sugar maple (*Acer saccharum*). This association does not satisfy the defining criteria for:

Oak (Chapter 41) – at least 50% of the basal area is oak
Red maple (Chapter 51) – at least 50% of the basal area is red maple
Northern Hardwood (Chapter 40) – at least 50% of the basal area is any combination of sugar maple, beech, basswood, white ash, yellow birch.

Tree size, age, and condition in addition to stand composition, reflect physical site factors, natural history, and human impacts (e.g. fire, grazing, harvesting, and clearing for agriculture). The present composition of many stands depends more upon the past history of the stand than on site quality. Poor harvesting practices (e.g. high grading, diameter limit cutting, and commercial clear cutting) and grazing have resulted in many low density, low quality stands with high density shrub layers.

Associated Species
Aspen (*Populus grandidentata, P. tremuloides*), black walnut (*Juglans nigra*), butternut (*J. cinerea*), honey locust (*Gleditsia triacanthos*), black locust (*Robinia pseudoacacia*), box elder (*Acer negundo*), white birch (*Betula papyrifera*), ironwood (*Ostrya virginana*), white pine (*Pinus strobis*).

1.2 Silvical Characteristics[1]

Shagbark Hickory
Shagbark hickory represents 10% of the total net growing-stock volume within Ecological Province 222 which encompasses most of southern Wisconsin (Vissage *et al.* 2005). Although shagbark hickory grows best in humid climates, it is adapted to a wide range of climatic conditions and occupies a variety of sites.

Shagbark hickory is a medium-sized slow growing tree that ranges in height from 70 to 80 feet. Shagbark hickory is a long lived, mid to late successional species classed as intermediate in shade tolerance. Saplings and small reproduction can persist for many years under a dense canopy overstory and respond rapidly when released.

Shagbark hickory reaches seed bearing age at 40 years, and produces abundant seed crops every 1 to 3 years. The heavy seeds are dispersed from September through December, primarily by gravity and small mammals. The seed is encapsulated within a husk that becomes

[1] Burns, R.M., and B.H. Honkala (tech. coords.). 1990. Silvics of North America: 2. Hardwoods Agric. Hndbk 654. USDA For. Serv., Wash. D.C.

dry at maturity and splits freely into four valves along grooved sutures. Germination of fresh seed ranges between 50 - 75%. Once established, hickory seedlings typically develop a large deep taproot that can extend down 2 feet or more. Successful germination of seed requires cold stratification either naturally through over-wintering within forest litter or artificially for a period of 90 - 120 days. Shagbark is rated as windfirm on most sites.

Shagbark hickories less than 8 inches in diameter can produce vigorous stump sprouts. However, as stump diameters increase in size, stump sprouting declines, and the proportion of root suckers increases. Young sprouts generally compete well in newly regenerated stands, but after 10 to 20 years, the rate of sprout growth declines and shagbark hickory may be outcompeted by faster growing associates.

Although they do develop clear straight boles, shagbark hickories also have a propensity to fork at one-half to two-thirds the height of the tree. Due to its relatively slow growth, shagbark hickory can be at a distinct disadvantage under even-aged management systems where rotation lengths are less than 100 years. Growing more slowly than oaks and other associated species, shagbark hickories can be found in subdominant crown positions by mid-rotation thus making them likely candidates for removal during periodic thinnings. Since shagbark hickory is considered a long-lived tree that can withstand shading and crowding and responds well to release, it appears to be well suited (along with white oak) for longer rotations up to 200 years or more.

Shagbark hickory is an excellent source of food for wildlife.

<u>Bitternut Hickory</u>
Bitternut hickory represents 4% of the total net growing-stock volume within Ecological Province 222 which encompasses most of southern Wisconsin (Vissage *et al.* 2005). Bitternut hickory grows on a wide range of sites from dry, gravelly uplands to moist flats. In Wisconsin, it grows well on mesic, nutrient rich sites.

Bitternut hickory produces good seed crops every 3 to 5 years, with optimum seed production occurring between 50 and 125 years of age. Seed dissemination is almost exclusively by gravity, and seed viability is estimated to range between 70% and 85%. Establishment of bitternut hickory trees from seedlings can be difficult primarily due to seed predators (e.g. squirrels, chipmunks, rabbits and wild turkey). Seeds remaining on the ground for more than 1 year seldom germinate. Germination time is usually 90 to 120 days. In addition, hickory seed requires a period of cold stratification for approximately 30 to 150 days in temperatures that range between 33 to 40 degrees.

Bitternut hickory is considered to be intermediate in shade tolerance. Seedling survival is poor under low light conditions which occur underneath dense forest canopies. Once established, bitternut hickory quickly develops a dense root system with a large taproot. Within the first year of growth, a seedling’s taproot reaches to a depth of 12-36 inches, and by the second year it can reach to a depth of 48 inches.

Bitternut hickory sprouts from roots and stumps. Saplings and pole-sized trees produce sprouts from the root collar whereas sawtimber-sized trees produce only root suckers. The copious production of sprouts allows bitternut to withstand damage from a variety of sources such as intensive browsing, breakage, drought and fire. Repeated top dieback and eventual re-sprouting allow each new shoot to become larger in size and develop a stronger root system. This process allows hickory reproduction to gradually increase under moderately dense canopies, especially on drier sites that limit the establishment of more tolerant species. In areas where advanced regeneration of bitternut hickory is adequate, overstory removal results in a fast-growing stand of saplings.

Bitternut hickory typically reaches a height of approximately 100 feet with a maximum life span of about 200 years, making it the shortest lived of all the hickories. When grown in partial light to full sunlight, bitternut hickory rarely experiences significant epicormic branching, and is considered a good self-pruner. In comparison with other true hickories, bitternut hickory is not equal in its wood grain strength, hardness and toughness.

Bitternut hickory is considered a valuable food source for wildlife.

<u>Black Cherry</u>
Black cherry represents 8% of the total net growing-stock volume within Ecological Province 222 which encompasses most of southern Wisconsin (Vissage *et al.* 2005). Although black cherry has a large natural range, its best growth and reproduction occurs on well drained, mesic sites.

Black cherry is a fast growing, shade intolerant tree that can quickly outgrow and overtop any tolerant competitors in stands when initiated simultaneously. In partial shade the reverse is true and height growth of black cherry is considerably less than that of its shade tolerant associates.

Black cherry produces seed most years with abundant crops every 1 to 5 years. Seeds are dispersed primarily by gravity, birds and mammals. The majority of seed falls to the ground in the vicinity of the parent tree. Consequently the number of seedlings is directly proportional to the number and distribution of seed trees in the overstory; birds and mammals are successful in distributing seeds to stands where seed-producing cherry trees are lacking. Black cherry seeds require a period of cold stratification, and utilize a delayed germination process whereby seeds from one crop can germinate over a period of three years. This process allows black cherry to bank large amounts of seed in the forest floor. Mineral soil is not a requisite for successful germination of black cherry. Few seeds germinate in areas lacking organic horizons or compacted by logging machinery. Germination occurs best on undisturbed humus or leaf litter and beneath a canopy that represents 60% canopy coverage or more. In addition to natural seeding, black cherry can regenerate itself vegetatively through stump sprouts.

Below 60% canopy cover, germination decreases and is poorest in full sunlight. However, newly germinated seedlings under these conditions grow rapidly and can reach heights of 2 to 4 inches within 30 days. In contrast, black cherry seedlings established under dense shade can survive 3 to 4 years, but few will grow to be more than 5 or 6 inches tall or survive more than 5 years. Seedlings that die are soon replaced because of the abundance of buried seed. When seedlings are released, growth is rapid and quickly fills an existing gap, overtopping any shade tolerant associates present. Black cherry has a shallow and spreading root system (within 24 inches of the soil surface) making it highly susceptible to wind damage.

Black cherry can attain heights ranging from 60 to 125 feet, with a maximum life span of 150 to 200 years depending on site. On well drained mesic sites, black cherry saplings and poletimber are outcompeted by more shade tolerant species when under a dense canopy cover. In contrast, sites that are either dry-mesic or dry, and generally dominated by oaks and pine, tend to provide more favorable light conditions for black cherry seedlings and sapling. However, on these sites, black cherry has measurable limitations in growth, size, and quality.

American Elm

Collectively the elm species (American and slippery elm) represent 11% of the total net growing-stock volume within Ecological Province 222 which encompasses most of southern Wisconsin (Vissage *et al.* 2005). American elm commonly occurs on poorly drained flats and bottomlands sites, but grows best on rich, well-drained loams. Within the Lake States and Central States, it is common on the plains, moraine hills, bottomlands and swamp margins. It seldom grows in pure stands and is usually found in mixture with other species. American elm is considered a soil-improving species due to a relatively high content of potassium and calcium in its rapidly decomposing leaf litter.

American elm is a prolific spring seed producer, sometimes beginning as early as age 15; however abundant crops seldom occur before age 40. Seeds are light and disseminated primarily by wind and water with the majority of seed falling within 300 feet of the parent tree. Within river-bottom stands seeds may be carried for miles. Seed crop reduction may occur due to predation by many species (e.g. mice, squirrels, opossum, ruffed grouse). Elm seeds germinate in the spring and usually within 6 to 12 days of seed drop. Mineral soil is the best substrate for germination of elm seeds, but alternate seed beds include moss, moist litter, and decayed stumps and logs.

American elm is classified as intermediate in shade tolerance; responding well to release even at advanced ages. First and second year seedlings grow best in about 60% canopy cover. After two years, elm seedlings perform best in full sunlight. Although elm is considered intermediately tolerant when exposed to dormant season flooding, mortality will result in seedlings and saplings when prolonged flooding occurs into the growing season. In addition to natural seeding, small American elms are capable of producing vigorous stump sprouts. Where seeds are available, American elm is a prominent early invader of abandoned fields.

American elm is a fast growing, large-sized tree attaining heights ranging from 80 to 125 feet, and a lifespan of 175 to 200 years, with some older than 300. Its' shallow wide-spreading roots penetrate to depths of 3 - 4 feet on wet, heavy soils, and 5 - 10 feet on drier, medium textured soils. On bottomland sites, the growth rate of elm is considered moderate.

Dutch elm disease arrived in the United States from Europe in 1930. The disease and removal efforts to reduce the disease have since limited elm commercially across much of its landscape. The disease is caused by the fungus *Ceratocystis ulmi*. Spores of this fungus are carried by the American (*Hylurgopinus rufipes*) and European bark beetles (*Scolytus multistria*) from diseased trees to healthy trees. Once a tree is infected, spores of the fungus plug the xylem and a toxin is produced killing the tree.

<u>Slippery Elm</u>
Slippery elm, also called red elm, shares many of the same silvical characteristics as that of American elm; therefore only their primary differences will be described in detail below.

The seeds of slippery elm are larger than those of American elm and produced most years with good crops occurring every 2 to 4 years. Seeds are primarily dispersed by both gravity and wind, and once established elm seedlings are often susceptible to damping off. Slippery elm seedlings can become established in a variety of conditions including grasses and herbaceous plants but is best suited on mineral soil. Slippery elm is classified as a shade-tolerant species, however under fully-stocked stands, reproduction is unpredictable and erratic.

Like American elm, slippery elm produces vigorous sprouts from both the stump and root crown. During its seedling stage it produces sprouts from rhizomes that sometimes form reproduction less than 2 feet tall and in patches 30 feet or more in diameter. Slippery elm can also reproduce by layering.

Slippery elm is fast growing, medium-sized tree reaching heights of 60 to 70 feet on average sites, and 135 feet on the best sites with a maximum lifespan of 200 to 300 years. It grows best on moist, rich soils of lower slopes, stream banks, river terraces, and bottomland, but it can often be found on much drier sites, especially those of limestone substrate.

Like American elm, slippery elm is subject to infection from Dutch elm disease. In contrast, the wood of slippery elm is considered inferior to that of American elm.

<u>Hackberry</u>
In Wisconsin, hackberry is a minor species, representing less than 1% of both the total wood volume and hardwood volume (Vissage *et al.* 2005).

Hackberry is considered intermediate to tolerant of shade, and survival of hackberry seedlings varies significantly under various light conditions and on various sites. Trees suppressed for extended periods of time often become poorly formed.

Hackberry is found in a wide variety of forest types ranging from early-successional to subclimax. It can be propagated by stem cuttings and layering. Sprouts develop from stumps of small trees but rarely from large ones.

Hackberry produces abundant seed crops most years with light seeded crops occurring on intervening years. The seed (a spherical drupe) ripens in September and October and is principally disseminated by birds and small mammals.

Hackberry is a small to medium sized tree ranging in height from 50 to 80 feet, with a maximum life span of 150 to 200 years. It is deep-rooted, reaching depths of 10-20 feet on most sites. It commonly occurs on moist bottomland soils but will grow rapidly in a variety of soil types from moist, fertile valley soils to hot, dry, rocky locations such as limestone or sandstone ridges in full sun. Hackberry is classified as moderately tolerant of flooding, but growth is poor on sites which have high water tables.

Table 52.1. Summary of selected silvical characteristics.

Species	Shagbark Hickory	Bitternut Hickory	Black Cherry	American Elm	Slippery Elm	Hackberry
Flowers	April-May Monoecious wind pollinated	April-May Monoecious wind pollinated	May-June Monoecious, Perfect	April-May Perfect flower	April-May Inconspicuous perfect flowers	May-June population both polygamous and monoecious
Fruit Ripens	Sept.-Oct.	Sept.-Oct.	Aug.-Sept.	May-June	April-June	Sept.-Oct.
# seeds/lb.	100/lb.	125-185/lb.	3,100 - 8,100/lb.	70,900/lb.	35,000 - 54,000/lb	1,600/lb.
Seed Dispersal	Sept.-Jan. Principally gravity rodents extend seeding range	Sept.-Dec. Principally gravity rodents extend seeding range	Autumn. Principally gravity also dispersed by birds and mammals.	May-June, wind dispersed up to .25 miles, waterborne farther.	April to June Principally gravity, wind, and water	Autumn. Principally gravity also dispersed by birds, mammals, and water.
Good Seed Years	Every 1-3 years	Every 3-5 years	Every 1-5 years	Most years unless flower/ fruit frozen.	Every 2-4 years	Most years unless flower/ fruit frozen.
Seeding, yrs (begins/optimal/ declines)	40/60/200	30/50/175	10/25/100	15/40/125	15/40/150	15/30/70
Seed Viability	Prolific seeder. High viability, 50-75%.	Prolific seeder. High viability, 70-85%. Seldom viable >one year in seed bank	Prolific seeder. High viability, avg. 80%. Can remain viable on forest floor >5 years.	Very prolific seeder. High viability, 63% average.Viable on forest floor up to 1 year.	Prolific seeder. With a low viability, 23% average. Stored seed can exhibit lower germination rates.	Prolific seeder. High viability, avg. 47%. Viable on forest floor up to 2 years.
Germination	Spring with pronounced dormancy, requires cold stratification; hypogeal.	Spring with pronounced dormancy, requires cold stratification; hypogeal.	Spring with pronounced dormancy, requires cold stratification; hypogeal.	Spring with no dormancy. Usually within 6-12 days of seed drop, increases in light; epigeal	Spring. Occasionally shows dormancy. Germination soon after sowing in cold conditions: epigeal.	Spring; epigeal

Seedbed Requirements	Moist leaf litter, humus, or mineral soil.	Moist leaf litter, humus, or mineral soil; tolerates moister seedbed than shagbark, less susceptible to frost	Variable. Mineral soil not required. Burial of seed (1-2") and moist seedbed are beneficial.	Variable. Moist litter, moss, and decayed logs & stumps but best on mineral soil.	Variable, but mineral soil seedbeds are best.	Variable. Moist leaf litter, humus, or mineral soil.
Vegetative Reproduction	Sprouts readily up to 10" stump dia. As stump diameters increase, stump sprouting declines and proportion of root suckers increases	Sprouts very readily from stump, root collar and roots. As stump diameters increase, stump sprouting declines and proportion of root suckers increases	Sprouts readily and rapidly in all sizes, especially in full sun. Root collar sprouts are an important and highly desirable.	Small trees produce vigorous stump sprouts.	Sprouts readily from stump and root collar.	Small stumps sprout readily, as stump diameter increases, stump sprouting declines
Seedling development	Produces a long taproot and very little top growth during early development.	Produces long taproot. Top dieback and resprouting occur frequently, successive shoots progressively larger.	Only produces taproot as seedling. High light levels improve seedling survival and height growth.	Depth of rooting varies with soil texture and soil moisture, grow best in full sunlight.	Root system shallow but wide spreading. Juvenile growth is rapid in the open or under light shade.	Deep rooted but taproot rarely develops. Seedlings less flood tolerant than saplings, mature trees.
Shade Tolerance	Intermediate. Saplings/seedlings can survive under dense canopy then recover rapidly when released.	Intermediate, can persist under low light condition on dry-mesic to mesic sites.	Intolerant of both shade and competition	Intermediate, responds well to release	Tolerant, reproduction is erratic under fully stocked stands.	Intermediate – tolerant, successional position is difficult to determine.
Maximum Longevity	Approx. 300 years	Approx. 200 years	Approx. 150-200 years	Approx. 175-300 years	Approx. 200 years	Approx. 100-150 years

Note: For information on central hardwood associate species not listed in this summary, refer to the appropriate cover chapter within this handbook.

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

Management objectives should be identified in accordance with landowner goals within a sustainable forest management framework, which gives consideration to a variety of goals and objectives within the local and regional landscape. The silvicultural systems described herein are designed to promote the optimum quality and quantity of central hardwood sawtimber. High quality sawlog and veneer production is the objective for most sites of average to better quality. These silvicultural systems may be modified to satisfy other management objectives, but vigor, growth and stem quality could potentially be reduced. The habitat type is the preferred indicator of site potential. Other indicators of site potential include site index, slope, slope position, aspect, and soil characteristics.

Prior to development and implementation of silvicultural prescriptions, landowner goals need to be clearly defined and articulated, management units (stands) must be accurately assessed, and landowner stand management objectives should be detailed. In-depth and accurate stand assessment will facilitate discussion of management options and objectives in relation to realistic and sustainable management goals.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.1 Landscape Considerations

Central hardwood forests occur south of the Tension Zone in Wisconsin, occupying areas that were formerly oak forest or savanna and which are now undergoing succession to maple-dominated forest. Past management has altered species composition and affected timber quality in these forests. Landscape considerations for managing central hardwoods are intended to mitigate some of the anticipated negative effects of the transition of oak forests to central hardwoods, including considerations for forest composition and structure, and the cumulative effects of management practices.

3.1.1 Historical Context

Historically, central hardwood forests as we currently define them appear to have been of very limited extent in Wisconsin (Finley 1976). When Euro-American settlement began in the 1830’s, the areas that are now central hardwoods were dominated by oak forest and savanna. Land clearing for agriculture led to the loss of many oak-dominated forests. Oaks and other hardwoods were used for fences, building materials, and fuels, and many were piled and burned to clear the land. As marginal agricultural areas reverted to forest, the combined effects of burning and pasturing created ideal conditions for the re-establishment of oak forests. As oaks re-grew, fire suppression allowed the new forests to achieve a greater density than was typical of the savannas and forests that existed prior to Euro-American settlement.

Figure 52.1. Central hardwood range (USA) (Clark and Hutchinson 1989).

During the past several decades, FIA data have indicated a steady decline in the oak component of mesic forests in southern Wisconsin. Lack of fire, competition from native and non-native species, as well as herbivory by white-tailed deer, has impacted oak regeneration and caused a gradual shift to shade-tolerant species characteristic of later-successional central hardwood forests, including red and sugar maple, basswood, hickories, elms, green and white ash, black cherry, and ironwood. The selective removal of commercially valuable red and white oaks has contributed to the loss of an oak component (see Oak Cover Type chapter). In locations where sugar maple seed sources are present, central hardwoods appear to be succeeding to northern hardwoods, and this trend is expected to continue. Improper forest management practices have genetically and structurally degraded many central hardwood stands, often resulting in low-density stands with thick understory shrub layers, and low economic value.

FIA data indicate that central hardwoods increased between 1996 and 2005 in poletimber and sawtimber size classes, but not in seedling/sapling classes (Figure 52.2). Overall acreage occupied remained about the same. This analysis used FIA plots that closely matched WDNR's criteria for the central hardwood cover type within Province 222 excluding the Central Sand Plains.

Figure 52.2 shows trends in central hardwoods as well as "non-central hardwoods", which generally represent northern hardwoods, red maple, and oak cover types on dry-mesic to mesic sites in southern Wisconsin, excluding the Central Sand Plains.

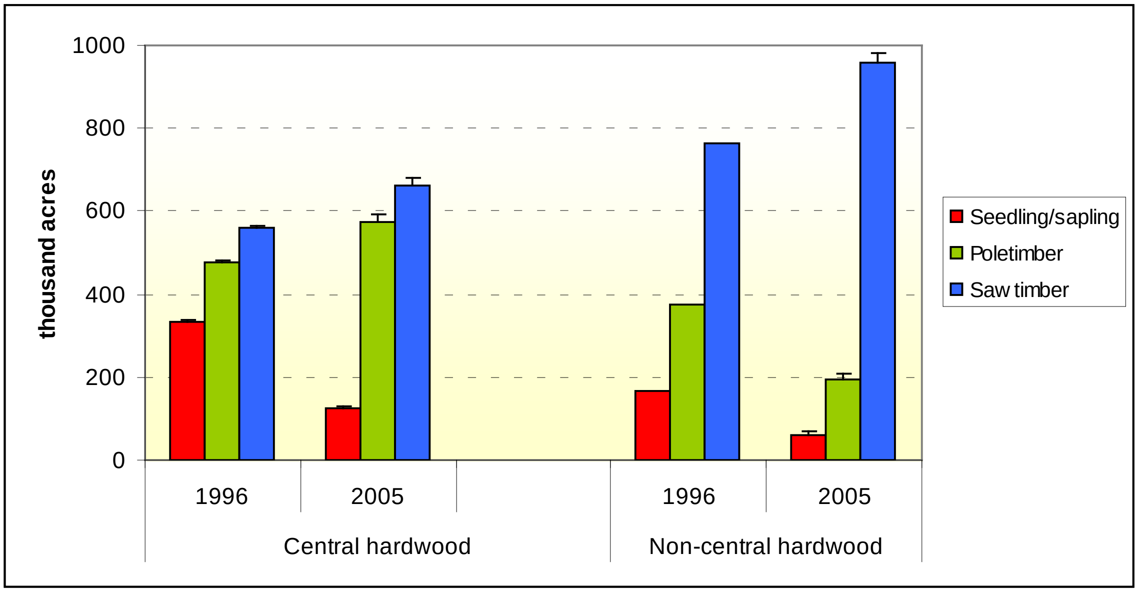

Figure 52.2. Acreage trends by stand-size class in central hardwoods and non-central hardwoods in Province 222, excluding the Central Sand Plains (FIA data, 1996-2005).

3.1.4 Landscape Composition

Central hardwoods are a forest type that until recently was uncommon in Wisconsin, and we have very little information on how its increasing dominance will affect wildlife, understory plant species, and other ecosystem properties. Central hardwoods are gradually replacing oak-dominated forests on mesic and dry-mesic sites, and the decrease of oak, a valuable wildlife species, is of concern. Many structural characteristics of oak species are not duplicated in the central hardwoods. Also, leaf litter from central hardwood stands is a poor carrier of fire, and the loss of fire disturbance will lead to further changes in soil and microbial properties. We anticipate that the increase in Central Hardwoods will have net negative effects on wildlife and ecosystem components that have been associated with oak forests during the past century. Generally, when an environment changes, some wildlife species lose their habitat while others benefit. In this case we do not know which species might benefit, because central hardwoods were not previously common. We do not know of any species that prefer central hardwoods to oak forest.

3.1.5 Landscape Structure

The central hardwood forests of southern Wisconsin are primarily distributed as small, isolated patches, or as linear features with little interior forest, with a few exceptions. Forests are mostly separated by agricultural and suburban areas, which differ starkly in habitat quality, making it difficult for certain wildlife and plant species to move from one forest patch to another. This landscape is characterized by a high level of “permanent fragmentation” – a term that refers to the long-term conversion of native habitat to urban, residential or agricultural uses.

Fragmentation and edge effects are particularly prominent in the central hardwood forest type. Southern Wisconsin’s rich prairie soils were developed for agriculture early in the process of

Euromerican settlement, and rural areas have been further impacted in recent decades by extensive residential development. Consequently, there are few remaining large blocks of forested land. The average size of private non-industrial forest land parcels declined from 36 to 30 acres between 1984 and 1997 in southern Wisconsin. By comparison, in northern Wisconsin parcel size declined only slightly, from 44 to 43 acres, during the same time period (Roberts *et al*. 1986, Leatherberry 1997).

The fragmented patch structure of central hardwood forests leads to excessive amounts of edge habitat, which is beneficial to some species, but is associated with declines in populations of neotropical migratory songbirds (NTMB's). Edge effects on other wildlife species are not as well documented. NTMB's are considered "indicators of ecosystem health" (Robbins 1995). During the 1980's, research studies identified increases in predation and nest parasitism along forest edges (Brittingham and Temple 1983, Wilcove 1985). These effects are more harmful to songbirds in areas where agricultural and urban land uses predominate (Small and Hunter 1988). The less-fragmented forests of northern Wisconsin are "centers of abundance" for breeding populations of some species of NTMBs (Howe et al. 1995), and may be population "sources" (net productivity is positive and population increases). Parts of southern Wisconsin may be 'sinks' (excess population from source areas occupies inferior habitat where net productivity is negative, but populations persist over time because of proximity to the source area). In this fragmented landscape, cowbird parasitism is of large concern for NTMB's, as is nest predation from small mammals, crows, jays, raccoons, skunks, opossums, coyotes, foxes, domestic pets, and feral cats and dogs.

Some species are "area-sensitive", requiring large patches of relatively contiguous forest cover. Mossman and Hoffman (1989) summarized a number of breeding bird surveys, noting that isolated forest patches of 40 to 80 acres in size were dominated by generalist species, while interior forest specialists such as Cerulean Warbler and Acadian Flycatcher occurred in patches of 100 acres or larger. Among the interior forest species, the Worm-eating Warbler, Kentucky Warbler, and Hooded Warbler only bred consistently in forest patches larger than 500 acres. As larger forest patches become increasingly scarce in southern Wisconsin, smaller patches of mature central hardwoods, especially those with an oak component, may be important if they are located near large, forested tracts, especially if there is potential for restoring connectivity or increasing patch size in the future. These smaller tracts may also be important as migratory stopovers, and as habitat for amphibians.

3.1.6 Cumulative Effects

The cumulative effects of stand-level characteristics can alter the function of a landscape. Declines in components of oak, large old trees, dead woody material, or supercanopy stand structure are a consequence of natural as well as human-induced disturbance. Historically, disturbances would have impacted only a portion of the landscape at each event, so that most of the area was largely undisturbed. In today's environment, disturbance has accelerated and become more pervasive, and is now a constant influence throughout the landscape. These changes affect wildlife habitat and ecosystem function.

Oak has been shown to be a species utilized by many species of wildlife, for mast as well as foraging sites and shelter (Rodewald 2003, Mossman and Hoffman 1989). Maintaining an oak component in central hardwood stands may be necessary to continue to provide for viable populations of some species that utilize southern Wisconsin forests. Often, a component of oak can be regenerated or planted within a central hardwood stands, if competition and herbivory can be controlled. Given the diminishing oak component on mesic and dry-mesic sites in southern Wisconsin, some older central hardwood forests that contain mature oaks could be deferred or managed on extended rotation. The longer that forests with a significant oak component can be retained, the better the chance of maintaining wildlife habitat while developing oak regeneration techniques that will be more successful in the future.

Within-stand structure of the central hardwood forest is often characterized by low density, relatively short stature, and small diameter trees. Understories, particularly in southeast and south central Wisconsin, are frequently choked with non-native or undesirable brush species. Management of these degraded stands should encourage development of a taller canopy including supercanopy trees, larger diameter trees, and dead woody material.

3.1.7 Summary of Landscape Considerations

When deciding whether to regenerate a central hardwood stand or convert another forest type to central hardwoods, assuming the habitat type is suitable, consider the following factors:

- Consider landscape composition and structure, including species composition; successional and developmental stage; age structure; stand/patch size; type, intensity, and pattern of fragmentation; habitat diversity; NTMB populations and habitat needs; and common/uncommon management techniques.
- Maintain or increase the representation of oak species wherever possible.
- Promote diversity of species within a stand.
- Increase structural diversity within stands (i.e. supercanopy trees, large trees, large cavity trees, large snags, large downed woody debris, and variable gap and patch sizes).
- Encourage connectivity of forest patches where it is possible to coalesce adjacent central hardwood or oak stands, to create larger blocks of forest over time.
- Increase the representation of older trees and stands.
- Apply a variety of management techniques, including old-growth reserves, managed old forests, extended rotations, uneven-aged management, even-aged management, and the maintenance of reserve trees.
- Control deer and limit herbivory.
- Limit the area devoted to infrastructure (e.g. roads and landings).

3.2 Site and Stand Considerations

3.2.2 Site Quality

3.2.2.1 Range of Habitat Types

The central hardwood forest region is one of the largest hardwood forest areas in the nation (Figure 52.1). Four distinct tree associations defined within this type are oak-hickory, oak-pine, mixed hardwoods, and elm-ash-cottonwood. In Wisconsin, the central hardwood type is located within Province 222 which lies south of the Tension Zone (Figure 52.4). All Ecological Landscape units within this Province except the Central Sand Plains contain a significant component of the central hardwood type.

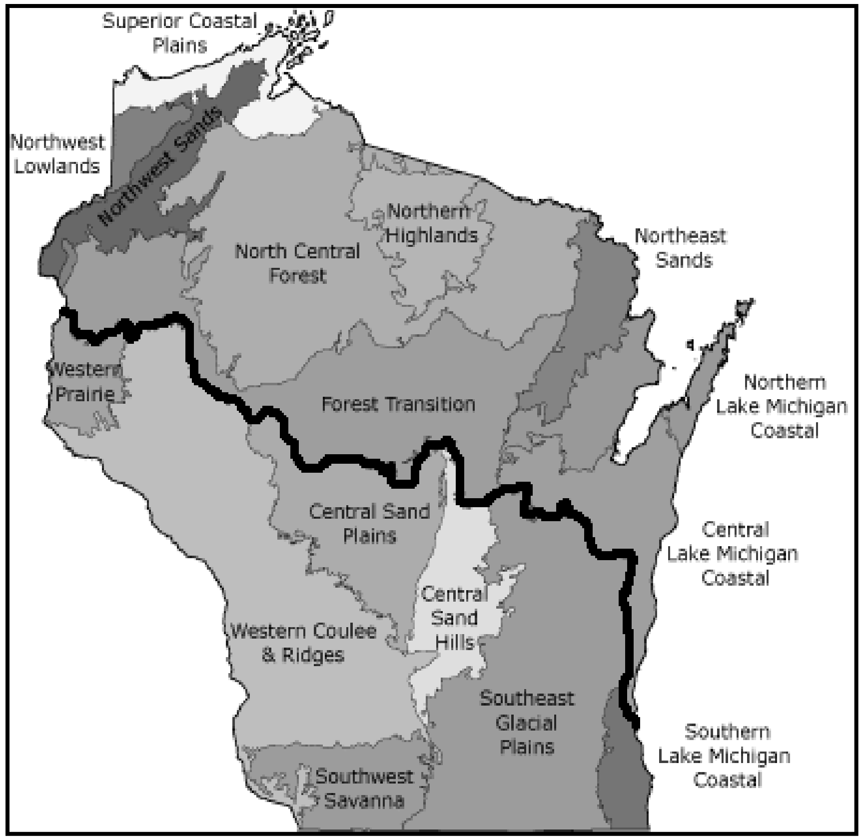

Figure 52.3. Central hardwood cover type area of application (WI). CH occurs south of the dark line which represents the approximate location of the tension zone and separates province 222 in the south from 212 in northern WI.

Compositional variation occurs within the central hardwood type across ecological units (Table 52.2). These variations are normally associated with a significant oak canopy component (Figure 52.5).

The central hardwood association is a mid-successional community type characterized by a variety of tree species occurring in a variety of combinations. Oaks are the most common overstory dominants. Successional directions tend toward northern hardwoods dominated by sugar maple with basswood, white ash, and ironwood. Northern hardwoods are most prominent on mesic sites. In areas where northern hardwood seed sources have not become well established (e.g. habitat type phases), and on sites that are marginal for the vigorous growth of sugar maple (e.g. dry-mesic), species that may increasingly dominate central hardwood stands include red maple, elms, shagbark hickory, and ironwood. In some stands, aggressive shrub and herb layers may out-compete tree seedlings; intensive management techniques may be required to control competition and establish regeneration.

Table 52.2. Variation in abundance and composition of the central hardwood cover type by ecological regions in Southern Wisconsin (Province 222 except the Central Sand Plains). The Western Coulee and Ridges Unit is divided into north and south subunits based on FIA interpretation. That division extends east/west across the unit near La Crosse.

Ecological Landscape Unit (ELU)	Central Hardwood Acres Within ELU	Compositional Variation Within Central Hardwood Type (% of acreage)		
Western Prairie	12,370	77% Elm-oak	23% Hickory-oak	0% Cherry-oak
Western Coulee and Ridges-North	115,616	31% Elm-oak	41% Hickory-oak	29% Cherry-oak
Western Coulee and Ridges-South	361,864	36% Elm-oak	50% Hickory-oak	14% Cherry-oak
Central Sand Hills	28,889	36% Elm-oak	10% Hickory-oak	53% Cherry-oak
Southwest Savanna	65,543	69% Elm-oak	13% Hickory-oak	18% Cherry-oak
Southeast Glacial Plains	97,994	49% Elm-oak	27% Hickory-oak	24% Cherry-oak
Southern Lake Michigan Coastal	9,128	0% Elm-oak	65% Hickory-oak	35% Cherry-oak

The two habitat type group phases are characterized by the lack or poor representation of northern hardwoods and red maple. Following oak, central hardwood is the next most common cover type. Hickories, elms, and black cherry often are comparatively abundant on these sites. In contrast these three species tend to be poorly represented and less productive on the poorer dry-mesic sites. They also tend to be less abundant on mesic sites, where they are out-competed by vigorous northern hardwoods.

See Chapter 12 – Forest Habitat Type Classification System for information summarizing the system and the habitat type groups. Information about specific habitat types associated with central hardwoods can be found in: *A Guide to Forest Communities and Habitat Types of Central and Southern Wisconsin* (Kotar & Burger 1996). The central hardwood cover type commonly occurs on the following habitat type groups (site types):

- dry-mesic
- dry-mesic to mesic
- dry-mesic to mesic (phase)
- mesic (phase)
- mesic

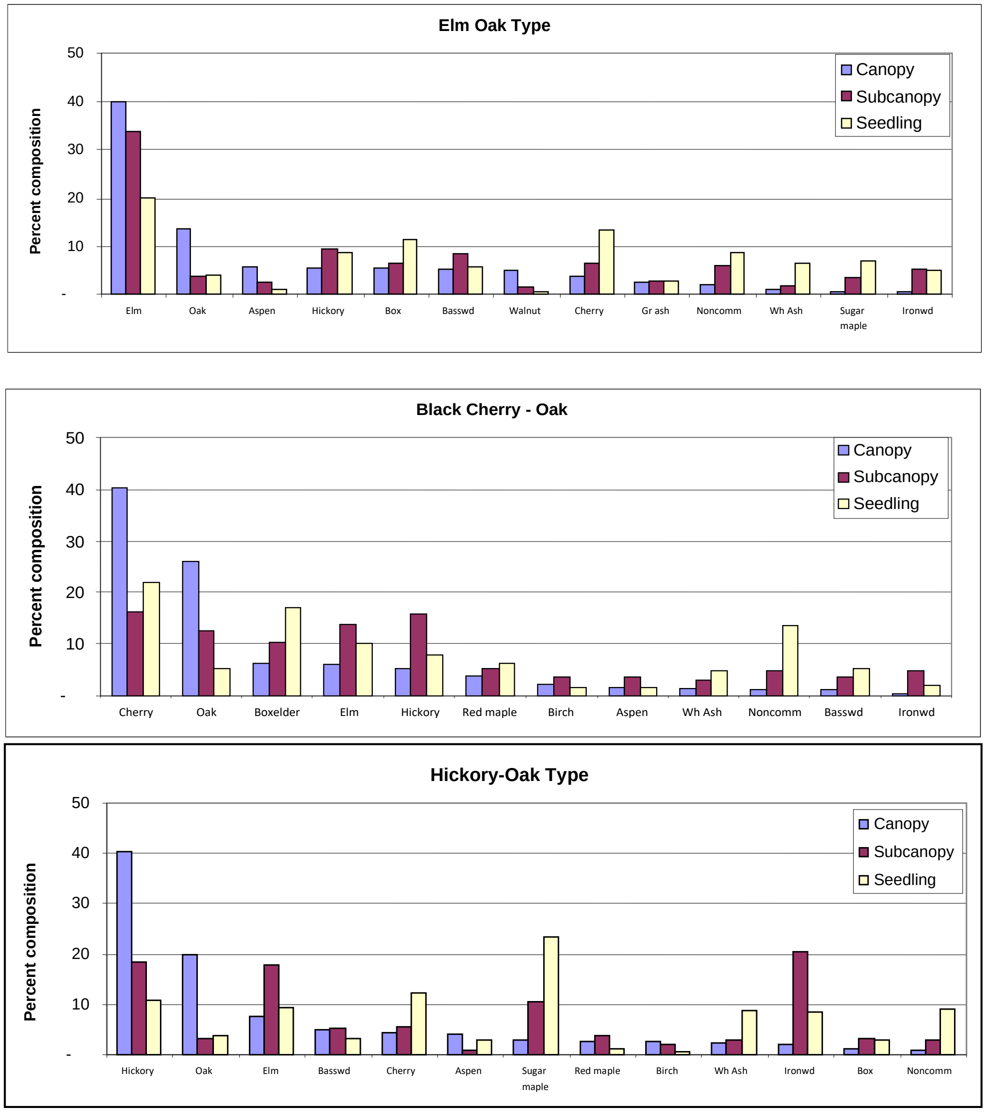

Figure 52.4. Compositional variations within the central hardwood cover type in Southern Wisconsin. The three bar charts demonstrate compositional differences among the three major subgroups of the type.

Table 52.3. Occurrence of central hardwood compositional variations in regards to habitat type, aspect and position on slope. Text bolding within the table characterize a general tendency of occurrence of the central hardwood variations.

Central Hardwood Type Variations	Percent of Acres by Habitat Type	Percent of Acres by Aspect	Percent of Acres by Position on Slope
Hickory-Oak	**38% DM-M** **36% M** 22%DM	35% N/NE/NW **58% S/SE/SW** 2% Flat	5% Flat 13% Lower **50% Mid** **31% Upper**
Cherry-Oak	**42% DM** **35%DM-M** 20% M	**71% N/NE/NW** 28% S/SE/SW	6% Flat 19% Lower **46% Mid** **29% Upper**
Elm-Oak	**34% DM-M** **33% M** 15%DM	**30% N/NE/NW** **38% SE/SW** 3% Flat	9% Flat **24% Lower** **49% Mid** 18% Upper

Chapters 40 (Northern Hardwood), 41 (Oak), 45 (Black Walnut), and 51 (Red Maple) provide specific information about variability in the occurrence and relative growth potential across habitat types of these important components of the central hardwood cover type. This information can provide a base for evaluating growth potentials, successional potentials, and potential impacts of alternative silvicultural practices in central hardwoods.

3.2.5 Wildlife

The variety of plant species and structural attributes found in the central hardwood cover type create a wide spectrum of food and cover for wildlife species. As in other forest cover types, one species' niche may appear and then disappear rather quickly while another species' preferred niche is still developing.

In the central hardwood cover type some developmental stages have a higher value for a larger variety of species than others. Early regeneration (stand initiation and early stem exclusion) stages offer exceptional cover, abundant forage, and soft mast from shrubs while the transitional and multi-aged developmental stages offer a good selection of hard and soft mast and also provide cavities and snags that are used by wildlife species that den, cavity nesters, and birds that forage by probing and searching tree trunks. A tree that may be problematic when overabundant in transitional and multi-aged stands but is also a valuable wildlife food source is ironwood. In areas that lack aspen, ironwood buds and male catkins and are often the primary ruffed grouse winter food.

Even-aged, pole-size stands of central hardwoods provide habitat for relatively few wildlife species. While these young stands produce little or no mast, their closed canopies result in a sparse understory. As a central hardwood stand matures from the sapling stage to the pole timber stage, it will likely go through an extended period of poor forage and low mast production. Consequently, a principal wildlife concern is to mitigate this condition in stands. A management practice that can lessen this condition is the designation of reserve trees and patches. Reserve trees and patches may be retained to develop into large, old trees and to complete their natural lifespan. In doing so, these trees may satisfy cavity and mast tree recommendations and later become large snags and coarse woody debris

Another technique used to improve habitat in dense, even-aged early successional central hardwood stands is the creation of living brush piles. Living brush piles are established to improve or maintain cover and forage in depauperate stands. Trees 2 to 6 inch in diameter can be cut part way through and pushed over, leaving as much bark uncut as possible. Falling 5 or 6 of these onto each other creates an area of dense cover that will last several years. A more aggressive approach would be to cut more trees in this manner, creating a larger tangle. On larger piles, the trees are not be shaded out as quickly and survive longer. The resulting dense cover protects nesting and foraging birds from predation while promoting soft mast production. Grapevines, while problematic when overabundant, are an excellent source of late season soft mast and contribute substantial cover value. When possible, incorporate them into living brush piles and at least selectively leave other grapevines where the threat of killing or deforming neighboring trees is minimal.

3.2.6 Endangered, Threatened and Special Concern (ETS) Species

Rare species are continuously under threat due to shrinking habitat. These species are usually rare because they rely on small niches, rare seral stages, or use specific microhabitats, although some rare species occupy a large home range. They are often best addressed during the early planning stages of timber management. Consideration of various landscape elements can alleviate many potentially negative effects of management activities. Numerous species can be accommodated in central hardwoods by identifying and protecting special habitats such as cliffs, caves, rockslides, thermal features, prairie/savanna openings, and vernal features, as well as managing for patches of late-developmental forest, often lacking in the local landscape. Managing for a single species may be necessary in some cases; however, considering a broad set of ecological characteristics can enrich the overall forest for many rare species and improve their chances for survival.

Structural Retention at the Time of Regeneration Harvest

Retaining structure from the original central hardwood stand such as large decadent trees, snags, and logs can enhance structural complexity. Structural retention is modeled on the biological legacies that remained after natural forest disturbances. Even under the most intense fires many individual trees and groves would survive. Consider reserving scattered decadent trees and snags in even-aged silvicultural systems (see Chapter 24).

Little data exists on how much structure to retain. Some of the decisions would require more analysis and consideration of species-specific requirements. In general, retention of old trees can provide benefits such as cavities both present and future, distinctive architecture with large branches that are used as movement corridors or the foundation for large nests, and diverse habitats for insects and spiders, which provides the prey base for vertebrates and maintenance of diverse fine root and fungi systems in the soil.

Remnant patches of late developmental forest and maintenance of long-rotation forest with high canopy closure can greatly affect the persistence of species like cerulean warbler (*Dendroica cerulea*). Planning for species, such as cerulean warbler, requires looking into the species life history to develop a management strategy. This species prefers old mixed hardwood forest, especially with large oaks, that occurs in large patches (>250 acres) with at least 70% crown closure; therefore, a forest management plan may need to consider forest size, age, and crown closure.

Identify Special Habitats

Many rare species are limited in their distribution to small or microhabitats within larger blocks of forest. Habitats such as cliffs, vernal or ephemeral pools, seeps or springs, rock outcrops, or prairie/savanna remnants may harbor rare species. Even if no records of rare species exist, management of these areas can provide habitat for existing or future rare species populations. Often special habitats can be protected while achieving other goals such as retention of biological legacies (see Chapter 24 for more information).

Cliffs may require two different approaches, depending on their physical characteristics and the species present. The first is retention of shading on the cliff face and searching for sources of seepage flow. If the species of concern has shading and moisture requirements, a modification of harvest near the feature is recommended. If the species requires more open conditions, then removal of shade, especially by removing trees from the base of the cliff could great improve the conditions for these species.

Vernal features can have a similar approach. For those species found in areas rarely affected by disturbance (both past and present) retention of shade on pools can be very beneficial. For those species found in vernal areas affected regularly by fire, such as northwest barrens or former prairie areas, consideration should include greatly reducing shade.

Riparian Habitats: The well-known and widely used Best Management Practices for Water Quality has greatly improved our knowledge and appreciation of riparian areas. However, additional considerations may be needed for some rare species. Wider corridors may be necessary for species whose optimum habitat is riparian features. A good rule is to look at the stream order. For species using small streams (1 or 2) riparian areas the existing BMP’s are most likely adequate. Mid-order Streams (3 and 4) may require looking at topographic relief to assess the extent of the floodplain. These streams can have very narrow riparian or broad meanders. Large high order streams have extremely complex disturbance regimes which may necessitate gathering information on flood pulses, wind events and fire intervals to address the effects on rare species populations.

Biological Hotspots: Bird rookeries, bat hibernacula, herp hibernacula, migratory bird concentration areas, and cave/sinkhole systems can harbor many rare species. These hotspots can be permanent, as with caves, or ephemeral as in the case of bird rookeries. Different strategies may apply. When these hotspots are encountered, seek consultation and advice from wildlife or endangered resources specialists.

Artificial Habitats: In some instances, a critical habitat requirement for a species is missing or is much reduced on the landscape. For some species, competition for the few spaces remaining prevents them from being successful. An example is the Eastern Bluebird (*Sialia sialis*), which most often loses competition battles with other larger more aggressive birds; therefore, erecting and monitoring nest boxes with dimensions that exclude competition can increase the chances of survival for this species.

Risk Spreading: Many aspects of endangered and threatened species management are not well known. Applying the best available information for species life history or ecological disturbance patterns can help address habitat needs. However, in cases of uncertainty, it will be important to employ more than a single method. To improve our knowledge and guide future management, the best approach would involve monitoring and documentation of the various management techniques in use by foresters throughout the state while making every effort to protect existing known species populations.

Table 52.4. Rare species associated with central hardwood stands, their general habitat preferences, and sample management considerations that for which they may benefit. These are meant as broad considerations for planning purposes, rather than avoidance measures, and neither the species, habitat information, nor the management considerations are meant to be exhaustive.

Species	Habitat	Mgmt Considerations
	Plant Species	
Bluestem goldenrod- *Solidago caesia* – E	Central Hardwood forest and rich maple forest in southeast Wisconsin	Extended rotation or old-growth management.
Three birds orchid – *Triphora trianthophora* -SC	Rich oak and central hardwood forests.	Extended rotation or old-growth management
Prairie trillium – *Trillium recurvatum* – SC	Rich oak and central hardwoods in the southern two tiers of counties	Extended rotation or old-growth management.
Hairy-jointed meadow parsnip – *Thaspium barbinode – E*	Oak woodlands near loess capped crests or in ravines.	Manage near minimum stocking levels or convert to oak savanna native community management and prescribed fire.
Heart-leaved skullcap – *Scutellaria ovata – SC*	Scattered locations in central hardwoods.	Responds well to group selection and prescribed fire. Avoid clear cuts, shelterwood harvests and landings on populations.
October ladies-tresses – *Spiranthes ovalis – SC*	Found in oak and central hardwood forests.	Extended rotation or old-growth management.
Hooker orchid – *Platanthera hookeri* – SC	Found primarily in pine stands but also in central hardwood stands contain scattered white pine in the Driftless Area.	Management should consider retaining the white pine in mixed forests.
Large roundleaf orchid – *Platanthera orbiculata* – SC	Found primarily in pine stands but also in central hardwood stands contain scattered white pine in the Driftless Area.	Management should consider retaining the white pine in mixed forests.
Upland boneset – *Eupatorium sessilifolium* – SC	Rich oak woodlands	Manage near minimum stocking levels or convert to oak savanna native community management and prescribed fire
Hoary tick-trefoil – *Desmodium canescens* – SC	Rich oak woodlands	Manage near minimum stocking levels or convert to oak savanna native community management and prescribed fire
Mullein foxglove – *Dasistoma macrophylla* – SC	Found in rich oak and hardwood forest mostly southwest.	Extended rotation or old-growth management, esp. near shaded rocks.
Rocky Mountain sedge – *Carex backii – SC*	A species of grass found mostly on sandy soils and rocks.	Open bedrock management.
Yellow-billed cuckoo - *Coccyzus americanus* – SC	Prefers floodplains and mature hardwoods	Riparian BMP’s and extended rotation.
Cerulean warbler - *Dendroica cerulea* – T	Mature to old oak and central hardwoods and floodplains	Extended rotation and landscape planning
	Animal Species	
Great blue heron - Ardea herodias – SC	Forages along nearly every watercourse. Nests in rookeries, often in woodlots far from water.	Rookery management

Species	Habitat	Mgmt Considerations
Worm-eating warbler - Helmitheros vermivorus – T	Prefers wooded slopes within mature to old blocks of hardwoods	Extended rotation and landscape planning
Red-shouldered hawk - Buteo lineatus – T	Floodplain forest and mature to old-growth hardwoods are preferred habitats	Riparian BMP's and extended rotation.
Acadian flycatcher – Epidonax virescens – T	Moist mature hardwoods in southern Wisconsin	Extended rotation and landscape planning
Kentucky warbler – Oporonis formosus – T	Large blocks of mature hardwood forest usually near streams or in ravines	Extended rotation and landscape planning
Louisiana waterthrush - Seirus motacilia – SC	Large blocks of mature hardwood forest usually near streams or in ravines	Riparian BMP's on small streams and extended rotation.
Hooded warbler – Wilsonia citrine- T	Brushy gaps in large blocks of oak and hardwoods forest	Group selection management and Landscape planning
Timber rattlesnake – Crotalus horridus – SC	Steep rocky prairies and adjacent oak woodlands	Manage near minimum stocking levels and prescribed fire
Black rat snake - Elaphe obsoleta – SC	Large blocks of mature forest in southwest Wisconsin	Extended rotation
Hickory hairstreak – Satryium caryaevorum- SC	Host plant is hickory	Retention of hickory
Cherrystone drop – Hendersonia occulta – T	Moist cliffs or under woody debris on moist slopes in central hardwoods	Extended rotation and keep shade in the cliffs

Other rare species may occur in central hardwoods considered for harvest. Many of these species will be found in specialized habitats such as rock outcrops, cliffs, ephemeral ponds, and seeps. If a rare species is known to be present, including Element Occurrences documented in the NHI database, refer to department screening guidance for avoidance, and contact the appropriate staff, as needed. Information on NHI Working List species and their habitats can be found through the Bureau of Endangered Resources Web pages (dnr.wi.gov/org/land/er/).

3.2.8 Operational Considerations and Maintaining Soil Productivity

The central hardwoods cover type presents some unique operational considerations for implementing silvicultural prescriptions while maintaining soil productivity and stand quality. Poor skidding technique and timing can reduce both residual stem quality and soil productivity. Harvesting during spring when trees are actively growing can result in increased defects on residual stems as the bark is more easily damaged at this time of year. Silvicultural practices need to be properly implemented.

Central hardwoods occur on loamy soils where vehicle traffic can cause detrimental soil compaction. Soil compaction and rutting have been shown to decrease forest productivity in aspen stands and probably have the same consequences in central hardwoods. While soil compaction cannot be avoided entirely during a harvest, it should be minimized. Utilize a system of pre-planned skidding routes and landing areas designed to meet the needs of the harvest while impacting as little of the stand area as possible. As a general rule, less than 15 percent of a harvest area should be devoted to haul roads, skid trails, and landings (WDNR 2003). Soils are most susceptible to compaction and rutting when they are saturated, so harvesting when the soil is frozen or dry can reduce compaction. Increasing the interval for re-entry into stands may partially mitigate and reduce the amount of compaction and rutting.

Many central hardwood stands are located in southwest Wisconsin's "Driftless Area", which is characterized by steep, easily eroded hillsides and shallow bedrock. In these areas, soil compaction, displacement, and erosion are a particular concern. Roads should be designed with a consideration for slopes, and operations during periods of rainfall should be carefully monitored to ensure that compaction, rutting, and erosion do not exceed guidelines. See "Wisconsin Forest Management Guidelines" (WDNR 2003).

The cumulative effects of infrastructure development and soil compaction in forests have been studied in other parts of the country and found to be correlated with changes in hydrologic regimes, surface drainage patterns and soil moisture. The negative ecological effects of soil compaction and rutting and of forest roads are well known at fine scales but the issues have not been studied in an integrated fashion on larger landscapes in our area. Roads and utility corridor have been implicated in the spread of non-native invasive plants. They also act as barriers to the movement of some species, create fragmentation and edge and can attract human disturbances.

Central hardwood stands sometimes contain small, seasonally flooded ponds called "vernal pools". Vernal pools are in confined basins, lack established fish populations, and dry up annually or every few years. Their size depends on landscape characteristics, but most are smaller than a quarter acre (Colburn 2004). They support tree species, other flora, and fauna that are typically not found in the remainder of a stand of central hardwoods and are especially important for the production of amphibians. Harvesting should avoid felling trees into or skidding through vernal pools. These areas, along with a suitable buffer, should be delineated in some manner prior to beginning harvesting. Vernal pools may not always be readily apparent due to the lack of standing water at dry times of the year, or when they are under snow cover.

4 STAND MANAGEMENT DECISION SUPPORT

4.1 Stand Inventory

Central hardwood stand assessment should include quantifying variables such as:

- present species composition
    - canopy, shrub, and ground layer
    - sources of regeneration
    - potential growth and competition
    - invasive and/or exotic species

- stand structure
    - size class distribution and density
    - age class distribution

- stand and tree quality (present and potential crop trees)
- site quality
- stand and site variability.

4.2 Key/ Checklist for Evaluating Cover Type Stand Management Options

Note: The following recommendations assume the management objective is to maximize quality and quantity of central hardwood sawlogs and the site has the potential for fair to excellent central hardwood growth as identified by habitat type(s) and/or site index.

Poletimber and Sawtimber Stands

1. Management objective best achieved by even-aged management	2
1. Management objective best achieved by continuous forest cover, uneven-aged management	7
2. Stand quality and stocking levels sufficient for continued management (meets one of the following): >40 crop trees per acre >40% stand relative density or C-line stocking	3
2. Stand quality and stocking levels insufficient for continued management (meets one of the following): <40 crop trees per acre <40% stand relative density or C-line stocking	6
3. Stand relative density > B-line or 60%	4
3. Stand relative density < B-line or 60%	Apply crop tree release if needed. Cut only the trees in direct competition with the crop trees, all non-competing trees remain in the stand. Otherwise, do nothing, let stand develop; periodically monitor stocking and crop tree development.

4. <75% of desired rotation age	When stand relative density is 80-100%, apply a commercial intermediate treatment and thin to B-line or 60-70%. Never remove more than 1/3 of stand relative density. Thinning should follow appropriate central hardwood stocking guides and the recommended order of removal. Wait 10-15 years. Thinning interval will vary based on intensity of previous thinnings, site quality, species present, and landowner objectives.
4. >75% of desired rotation age	5
5. Within 75-100% of desired rotation age	Let grow until rotation age as thinning is generally not recommended. Thinning will only remove a few trees per acre and relatively few remaining trees will benefit directly.
5. Attained rotation age	6
6. Stocking of desired advance regeneration established adequate for stand objective	Apply overstory removal regeneration method.
6. Stocking of desired advance regeneration established inadequate for stand objective	Apply shelterwood regeneration method.
7. Stand currently even-aged	8
7. Stand currently uneven-aged	Apply group and patch selection regeneration method with area regulation. Rotate groups or patches as they attain rotation age. Apply intermediate treatments to majority of stand not at rotation.
8. Stand quality and stocking levels sufficient for continued management (meets one of the following):	Apply group and patch selection regeneration method with area regulation. Rotate groups or patches that are:

>40 crop trees per acre >40% stand relative density or C-line stocking	poorest quality understocked stocked with desirable advance regeneration.
8. Stand quality and stocking levels insufficient for continued management (meets one of the following): <40 crop trees per acre <40% stand relative density or C-line stocking	Apply even-aged regeneration method and work toward uneven-aged management with new stand.

5 SILVICULTURAL SYSTEMS

As defined in Chapter 21, Natural Regeneration, a silvicultural system is a planned program of vegetation treatment during the entire life of a stand. All silvicultural systems include three basic components: intermediate treatments (tending), harvesting, and regeneration. With central hardwoods, silvicultural systems can be adapted to meet multiple land management considerations. Regeneration of central hardwoods can be accomplished with either even-aged or uneven-aged regeneration methods though even-aged silvicultural systems are most commonly recommended.

For land managers with the goal of maintaining shade intolerant to mid-tolerant species, even-aged management is the preferred method. The even-aged regeneration methods generally accepted and supported by literature are:

- Overstory removal
- Shelterwood

Where maintenance of mid-tolerant central hardwood species is a goal, uneven-aged management may be suitable. The uneven-aged regeneration method generally accepted and supported by literature is:

- Group or patch selection

5.1 Seedling / Sapling Stands

Although little research has been done on the silviculture of central hardwood stands dominated by non-oak species, principles of sound management can be gleaned from similar oak dominated stands. The first 10-15 years of stand development are a dynamic period. During this “brushy” stage, there may be as many as 10,000 stems per acre, in a wide variety of species. Management at this stage should focus on improving stand composition (Smith & Lamson 1983). When desired species are present in sufficient numbers, their growth is often slow and mortality high due to intense competition from herbaceous vegetation and less preferred species. Early, intensive release can be used to improve stand species composition and growth by reducing competition (Della-Bianca 1969). Individual release of selected stems can facilitate adequate stocking of preferred species as the stand matures. Select 50 – 100 trees per acre, approximately 20 – 30 feet apart, and remove all trees whose crown touches the crown of the selected tree. This should occur when a stand is 5-20 years old or when tree height averages 25 feet. Apply the release cut before selected crop trees fall below the codominant size class.

In many situations, existing seedling/sapling stands do not contain sufficient numbers or adequate size of preferred species. One option is to consider altering stand objectives to accept a less desirable species composition. Changing markets (e.g. aspen, red maple) and landscape species dynamics (e.g. emerald ash borer) often alter our understanding of how desirable species are defined. Another option is to interplant the stand with desirable species. Interplanting is often used to establish or increase the number of desirable species within degraded stands. This approach may also be used to introduce genetically superior hardwoods (Clatterbuck 2006). Mechanical or chemical competition control will improve the long-term survival and viability of planted trees.

A serious threat to forest regeneration throughout Wisconsin is locally high populations of white-tailed deer. It is important for foresters prescribing intermediate treatments in these stands to anticipate and plan for this additional constraint on seedlings and saplings. In areas of extremely high deer populations, regeneration should be protected against browsing (Marquis *et al.* 1992).

5.2 Intermediate Treatments

For most central hardwood management objectives, the development of individual tree quality is a principal concern. Tree quality depends on stand history, species composition, stand density, site quality, tree age, and damage due to factors such as grazing, insects, disease, ice, wind, and poor harvesting techniques (e.g. logging damage, high grading, diameter limit cutting, and commercial clear cutting). It may be necessary to enhance stand development with non-commercial intermediate treatments or timber stand improvement practices (TSI). To reduce the risk of resprouting, it may be necessary to treat many undesirable species with an appropriate herbicide according to label rates. For details on these methods refer to Chapter 23, Intermediate Treatments.

Within the central hardwood cover type, TSI is often a combination of some or all of the following practices:

5.2.1 Weeding

This practice eliminates or suppresses undesirable plants (trees, shrubs, vines, and herbaceous vegetation) within a stand. Most often these plants are aggressive shrubs and herbaceous species that retard advance regeneration or prevent the establishment of desirable regeneration. Intensive management techniques may be required to control competition and establish regeneration. Within the central hardwood cover type, undesirable plants which are commonly weeded include:

Native Species:

a. Ironwood (*Ostrya virginiana*): Ironwood is a tolerant, slow-growing small to medium-size tree that often forms a subcanopy which can suppress the recruitment and development of desirable tree species. High populations of ironwood are often associated with a history of livestock grazing.
b. Grapevine (*Vitis spp*.): Grapevines often grow through and over the tops of trees, and can kill or deform them. Note lianas or perennial vines that develop rootlets (hairs) which fasten to tree trunks are not grape and do not need to be removed because they do not grow over the top of tree leaves and branches.
c. Prickly ash (*Zanthoxylum americanum*): Prickly ash is a native shrub of deciduous woods that grows to 10-15 ft. It is common at the woods edge or in the interior when land has a history of disturbance such as grazing. It spreads by suckers from shallow roots, a very large patch may be a single plant or clone.

Invasive / Exotic Species:

a. Garlic mustard (*Alliaria petiolata*): A shade tolerant rapidly spreading biennial herb capable of establishment on a wide range of forest habitats except acidic soils. First year plants (rosettes) are 2-4-inches tall with round, scalloped leaves. Second year plants are 12-48-inches tall with 2-4 stems and white flowers in May. Crushed leaves have an onion/garlic odor. A single plant can produce hundreds of seeds in 1-3-inch capsules that easily disseminate in late summer/fall by wildlife, streams, people and equipment.
b. Common buckthorn (*Rhamnus cathartica*), Glossy buckthorn *(Rhamnus frangula)*: Shade tolerant shrubs that can reach 20-25 feet in height and 12-inches diameter. Both species grow rapidly and resprout vigorously after cutting. Prolific black, pea-size fruits are eaten and dispersed widely by birds.
c. Bush honeysuckles (*Lonicera tatarica, L. morrowii, L. x bella*): Shade tolerant shrubs 3-10 feet in height, shaggy bark, begin leaf development 1-2 weeks before native shrubs and hold leaves later into fall than native species. Occupies broad range of habitats and favors disturbed sites. Small red to orange fruits are dispersed widely by birds. Young shrubs are shallow rooted and easily pulled.
d. Japanese barberry *(Berberis thunbergii):* Shade tolerant compact, spiny shrub, 2-3 feet in height. Prefers well-drained soils. Survives well under oak/central hardwood canopy. Branches root freely when they touch the ground. Bright red fruit is dispersed widely by birds.
e. Multiflora rose *(Rosa multiflora):* Often established in pastures and pastured woodlands this shrub will persist and spread in woodlands after cattle are excluded. Mature shrubs are dense and can obtain 15-feet in height and an 8-feet spread with arching canes and stiff curved thorns. Branches are capable of rooting when they touch the ground. Red, ¼-inch fruits persist in winter which are readily eaten and spread by birds. A mature shrub can produce 500,000 seeds per year.

When abundant, invasive plants alter forest composition and structure, and can ultimately affect successional patterns and future forest conditions over large landscapes (WDNR 1997). A website useful for additional identification, information and methods of control of invasive species is:

http://www.ipaw.org/

5.2.2 Liberation

This practice releases a young crop of desirable seedlings and/or saplings by removing less desirable, older, overtopping trees. With central hardwoods, this often entails the removal of poor-quality trees to favor the advancement and quality of young, vigorous and potentially valuable trees. Retention of some wildlife trees may be desirable for non-timber goals.

5.2.3 Cleaning

This practice releases desirable seedlings and saplings from undesirable tree species in the same age class. It is used to control a stand's species composition and to improve growth and quality of crop trees.

5.2.4 Non-Commercial Thinning and Improvement

Crown thinning in non-commercial poletimber stands favor crop trees by removing adjacent crown competitors. This allows crop trees to develop full, vigorous crowns necessary for improving growth and quality. This is often referred to as "crop tree release."

5.2.5 Commercial Thinning and Improvement

Intermediate thinning is used in central hardwood stands to control stand density and structure. Unlike uneven-aged selection harvesting, reproduction is not a management concern. The primary objectives of intermediate thinnings in central hardwood stands are:

1. To increase the rate of growth of residual trees
2. To concentrate growth on the most desirable trees
3. To improve species composition
4. To salvage losses that would occur as a result of competition and suppression.
5. To generate income during the stand rotation
6. To enhance forest and tree health

To determine how much to remove and retain with an intermediate thinning, stocking charts have been developed for many forest types (Figure 52.7 and Figure 52.8). These charts identify a stand's relative density when stand basal area and the number of trees per acre are known (see Chapter 23 – Intermediate Treatments). Relative density is a measure of tree crowding that accounts for both the size of the tree and the amount of space typically occupied by a tree of that size and species, so it is an especially useful measure in mixed species stands (Stout & Nyland 1986). A relative density of 100 percent implies that the growing space is fully occupied and trees must either slow their growth to survive and some trees will be crowded out and die. On most stocking charts, 100% relative density is represented as the A-line. If relative density is between 60% and 100%, trees can fully occupy the growing site. The optimum relative density to retain after a thinning is a compromise between an individual tree's rate of growth, quality, and the number of trees needed to fully utilize available growing space (Gingrich 1967). The lower limit of stocking necessary to reach 60% (B-line) stocking in ten years on average sites is centrally represented as the C-line and corresponds roughly to 40-

50% relative density. Typically, thinnings are implemented at 80-100% stocking (usually economically operable), and density is reduced to 60-70% stocking to optimize sawtimber growth and quality.

To use stocking charts as a guide for thinning, the current stand relative density, the desired stand residual density, stand (quadratic) mean diameter, and the probable (quadratic) mean diameter of the residual stand must be estimated (Roach 1977). This allows the conversion of stand relative density to basal area. This is important, since inventory procedures and marking controls are applied using basal area (Marquis *et al.* 1992).

Since central hardwood stands can differ widely in species composition, estimates of relative density based on stocking charts may be inaccurate and should be used with caution (Stout & Nyland 1986).

Relative stand density (stocking), may be more accurately calculated directly from stand data using a species-specific tree-area ratio than with stocking charts (Table 52.11). If the relative density of a stand is calculated this way, a ratio can be developed for determining the desired residual basal area.

> *Example*: A central hardwood stand is inventoried with the aid of software that calculates relative density. Per this calculation the stand basal area is 124 sq. ft. and the relative density is 90%. The target residual relative density for this stand is 60% after an intermediate thinning. To estimate the residual basal area when marking the stand, a ratio is developed:
>
> Current RD/Current BA = Residual RD/Residual BA
> 90/124 = 60/X
> X=82.6
>
> For ease of use in the field and assuming a slight increase in mean diameter (quadratic) with thinning from below, 85 sq ft. would be a useful guide for 60% relative density in this stand.

5.2.6 Tree Selection for Thinning and Improvement Cutting

When thinning central hardwood stands, determine which crop trees to favor by first identifying desirable crop tree characteristics. The following characteristics are identified for selecting the ideal timber crop tree (see Chapter 24 – Marking Guidelines):

- Low risk of mortality or failure (expected longevity of 20+ years)
- Good crown vigor
    - Dominant or codominant trees
    - Full concentric crown with good silhouette and healthy leaves
- Good timber quality
    - 16’ butt-log potential of tree grade 1 or 2
    - No indicators of high probability of degrade due to defect on trunk (see FHP defects table at end of this chapter)
- Desirable species
    - Valuable commercial species

- Species well adapted to the site

Trees may also be selected for retention to achieve other objectives such as aesthetics or wildlife management (see Chapter 24 – Marking Guidelines).

When thinning central hardwood stands, determine which trees to cut by following the recommended order of removal (also see chapters 23 and 24):

1. High risk of mortality or failure – cut high risk trees that are likely to die between cutting cycles, unless retained for wildlife
2. Release crop trees – cut poorer quality competitors to provide crown growing space around crop trees to promote growth and quality development
3. Low crown vigor – cut low vigor trees, based on crown class, size and condition
4. Poor stem form and quality - cut based on usable log length and potential degrade due to defect
5. Less desirable species (determined by landowner objectives, site, and silvics)
6. Improve spacing

Intermediate thinning should control both stand density and structure to maximize both stand growth and quality. As a rule of thumb when thinning central hardwoods, approximately 75% of the cut relative stand density should be removed from below the average stand diameter (low thinning) and 25% from above (crown thinning) (Nowak & Marquis 1997). This avoids many of the pitfalls of diameter limit harvesting and high grading.

As a general guideline, thinning is most effective as a management tool in young stands but can be implemented in stands up to 75% of the desired stand rotation age. Thinning young stands offers the best opportunity to influence stand species composition and increases the growth rate of residual trees. Past 75% of the rotation age, thinning large trees will remove and benefit relatively few trees per acre while often encouraging a brushy understory that may interfere with desirable regeneration at stand rotation. Thinning later than 75% of a stand's rotation age may even remove the periodic growth of the stand and defeat the purpose of thinning (Marquis *et al.* 1992).

In central hardwood stands that have been grazed, high graded, or contain a wide variety of stand conditions, prescriptions for first thinnings will tend to be imprecise and will combine thinning and improvement cutting (Roach & Gingrich 1968). Free thinning is the removal of trees to control stand spacing (density) and favor desired crop trees, using a combination of thinning criteria without strict regard to crown position. In central hardwood application, this method is likely a combination of low and high thinning with improvement cutting while applying the order of removal. Often, free thinning is conducted in previously untreated natural stands in preparation for a more systematic future thinning method.

5.3 Natural Regeneration Methods

5.3.1 Even-Age Regeneration Methods

5.3.1.1 Shelterwood

This even-aged management system is appropriate for the establishment and advancement of most central hardwood species. It involves two or three cutting treatments that can be extended over a 5 to 20 year period and includes:

1. **Preparatory cutting** designed to remove poor quality trees, leave good phenotypes, and increase vigor and seed production among the residuals. This treatment often is not applied, especially in well managed stands that have been thinned previously.
2. **Seeding cut** to open the stand sufficiently to encourage the development of regeneration.
3. **Overstory removal** is conducted after regeneration is established to release the new stand to grow vigorously. Retention of some reserve trees (5-15% canopy cover) is recommended to achieve sustainable forest management benefits (see Chapter 21).

Regeneration is usually accomplished using a two-step shelterwood (seed cutting and removal cutting) implemented over a 5 to 10 year period. Initial harvesting will provide for proper crown closure and tree spacing depending on the preferred regeneration species composition. Leave a high uniform crown cover of 40-60% in the residual shelterwood overstory. Consider timing of the shelterwood cut and site preparation operations relative to the production of good seed crops. Site preparation is generally recommended when hickories, walnut and oaks are the preferred species to be regenerated and when there is an unacceptable presence of undesirable species such as ironwood, prickly ash and non-native invasive species. Site preparation can be accomplished via mechanical or chemical methods, prescribed burning or a combination of these techniques (see Chapters 21 & 22). Complete the final removal of the shelterwood overstory once acceptable advanced regeneration has been achieved. Acceptable regeneration can generally be defined as a minimum of 1,000 well distributed desirable seedlings per acre (Loftis 1998) that are at least 2-feet tall. During the removal cutting, care should be taken to preserve as much of the desirable advance regeneration as possible. Release may be needed in 1-10 years.

5.3.1.2 Overstory Removal

This even-aged regeneration method removes all trees in one cut to fully release sufficient numbers of desirable, advanced regeneration. Acceptable regeneration can generally be defined as a minimum of 1,000 well distributed desirable seedlings per acre that are 2’ – 4’ tall. Retention of some reserve trees (5-15% canopy cover) is recommended to achieve sustainable forest management benefits (see Chapters 21 & 24). When considering overstory removal, contemplate methods to protect advance regeneration. Ideally, overstory removal operations should be conducted during the winter or fall to limit damage to the regeneration. Overstory removal is conducted typically when the canopy is mature (at rotation age/size), or has such poor quality that management for sawlog production is not a viable option. Release may be needed in 1-10 years.

Previous View

5.3.1.3 Clearcut[2]

Clearcutting involves the felling of all trees in a stand in one operation for harvest and for regeneration of a new stand; regeneration from seed is established during or following stand removal. To some degree, this system mimics natural disturbances such as windstorms, fire, and insect and disease outbreaks which promote regeneration of fast growing, shade intolerant species that exploit these conditions. Risks to success of new stand establishment include seed sources and annual productivity, variability in the type and amount of regeneration, the potential proliferation of unwanted competing vegetation, and the potential impact of deer browsing. Clearcutting can result in stand conversion to another forest type. It is important to assess the potential for such competitive interactions before clearcutting. A clearcut needs to be least 1-2 acres in size to create the characteristics of a clearcut (Sander 1992, Dale *et al.* 1994), and at least 2 acres to conform to DNR protocols. To favor tree regeneration, soil compaction needs to be minimized during logging by confining equipment to skid trails and landings. Additional release of regeneration may be needed within the initial 10 years of establishment. Intermediate thinnings would be conducted as described in the Commercial Intermediate Treatments section of this chapter.

5.3.2 Uneven-Age Regeneration Methods

5.3.2.1 Group and Patch Selection

This method is appropriate for promoting an uneven-aged forest structure in the central hardwood type. A goal of group and patch selection is to produce a balanced uneven-aged stand by creating cohorts of regeneration. Spatial distribution and size of groups and patches may be systematic or irregular and dictated by the presence of desirable and adequate regeneration, the silvical characteristics of the species to be regenerated, and small variations in stand conditions such as vigor, health and size of individual and small groups of trees. Retention of scattered groups of reserve trees is recommended to achieve sustainable forest management benefits (see Chapters 21 & 24).

Group and patch selection should be viewed as a relatively intense stand management practice with several different cultural practices applied at the same time in different parts of the stand. Groups of trees are selectively removed on 5-15% of the area per entry to create “small openings “(Smith 1986). Group selection openings range from 0.1 to 0.5 acres while patches range from 0.5 to 2 acres. Smaller openings often encourage increased representation of tolerant to mid-tolerant species, whereas larger openings can facilitate increased representation of intolerant to mid-tolerant species. For shade intolerant and mid-tolerant species regeneration and development, an opening should be 150-feet in diameter or more (at least 0.5 acres).; a general rule of thumb is to make opening diameters twice the total height of mature codominant trees expected for the forest type (Miller *et al.* 1995). Within the openings, all undesirable trees of one-inch and greater stem diameter are cut. Herbicide control of unwanted competition may be utilized as seed bed site preparation. Release may be needed in 1-10 years. Beyond openings within the stand, thinning and crop tree release within different aged groups occurs following a standard order of removal. As stands undergo

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[2] Management practice that may have potential for application in managing central hardwoods but has not been widely utilized and tested.

multiple entries with group and patch selection, tracking locations of group and patch openings in the field becomes difficult. Placement of new groups and patches without overlapping prior openings becomes increasingly difficult over time and failure to do so effectively decreases the rotation length and/or reduces harvest volume by removing groups and patches earlier than prescribed (Shifley *et al.* 2006).

5.5 Rotation Lengths and Cutting Cycles

In even-aged silvicultural systems the rotation is defined as the period between regeneration establishment and final cutting. The length of rotation may be based on many criteria including culmination of mean annual increment, mean size, age, attainment of particular minimum physical or value growth rate, and biological condition. Ideally, the lower end of the rotation length range would be defined by the age at which maximization of mean annual increment (MAI) growth occurs. The upper end of the rotation length range would be defined by the average stand life expectancy. However, very little objective data exists identifying these endpoints in general and even less by site type.

Central hardwoods are usually managed to produce sawtimber on sites where relative potential productivity is good to excellent (red oak SI>60). The recommended even-aged rotation to balance high quality development and high growth rates (vigor) is species specific. Table 52.9 and chapters 40 (Northern Hardwood), 41 (Oak) and 51 (Red Maple) provide rotation age guidelines for central hardwood associates.

Table 52.5. Recommended and extended rotations for selected central hardwood species.

Species	Recommended Rotation	Extended Rotations
Ash, green	70-110	-
Cherry, black	70-110	120-150
Elm, American	80-120	-
Elm, slippery	80-110	-
Hackberry	70-100	110-130
Hickory, bitternut	70-110	120-150
Hickory, shagbark	80-120	140-200

For some species, rotations up to 200 years can be considered (on excellent sites), but volume growth rates will decline and economic risk will increase. On poorer sites, recommended rotation ages may be on the lower end of the range because of reduced quality and slower growth rates. Actual rotation ages may vary based on stand conditions and landowner objectives. In application, foresters will need to regularly review stands in the field and exercise professional judgment concerning quality, vigor, mortality, and merchantability. The numbers provided are based on general data and the best estimations of the authors and other contributors.

5.5.1 Uneven-Aged Management

Group and patch selection rotates groups or patches of trees rather than stands of trees. Group or patch rotations depend on the same criteria used to determine an even-aged rotation. Groups range in size from 0.1 to 0.5 acres whereas patches range in size from 0.5 to 2.0 acres. In either version of uneven-aged management, groups or patches should be established on approximately 5% - 15% of the stand area at each entry. Groups and patches will require both site preparation and follow up treatment.

In stands managed under uneven-aged management, the cutting cycle re-entry interval generally ranges from 10 to 20 years based on landowner objectives, site quality, and growth. Shorter cutting cycles can maintain higher tree growth rates but operability (costs and benefits) must be considered. Shorter, more frequent re-entries may increase the potential for degrading stand quality through stem damage and soil compaction. Conversely, shorter cutting cycles will allow for capture of more high risk and low vigor trees succumbing to mortality. Longer cutting cycles can maximize tree quality and reduce negative impacts, such as damage to residual trees, soil compaction, aesthetic impacts (e.g. reduced slash), and ecological impacts (e.g. habitat disruption).

5.5.2 Extended Rotation

Management goals for extended rotations attempt to balance economic, social, and ecological management goals. While timber production is still an important value, increased emphasis is placed on other values, such as aesthetics, wildlife habitat, and biodiversity. In central hardwoods, extended rotations are compatible with even-aged or uneven-aged management. Additional ecological management techniques will be applied, such as the retention of reserve trees and management of coarse woody debris (e.g. large snags and downed rotting logs).

5.6 Other Silvicultural Considerations

5.6.1 Managing “Degraded” Stands

Many central hardwood stands throughout southern and central Wisconsin are “degraded”. These stands, many of which started as oak dominated stands, have been reduced in quality due to a number of factors including:

- woodland grazing
- poor harvesting techniques
    - residual logging damage
    - diameter limit cutting
    - incomplete clear-cuts
    - high-grading
- intense fire
- abiotic agents
    - wind
    - ice storms
- biotic agents
    - insects
    - disease

Many of these stands have an abundance of poor quality stems, poor species composition, poor quality larger diameter stems overtopping a younger stand (poles, saplings, or seedlings), or a combination of these conditions.

To assess the management potential of each degraded stand, a thorough stand assessment is required to determine:

- site quality (site index, habitat type, soil, topographic position)
- species composition
  - canopy, understory, and ground layer
  - sources of regeneration
  - potential growth and competition
  - invasive and/or exotic species

- stand structure (size and density)
- stand and tree health and vigor
- stand and tree quality - number or percentage of acceptable growing stock (AGS) trees and potential crop trees.
- variability across the stand.

Poletimber and sawtimber stands with less than 40 crop trees per acre or less than 40% stand relative density are generally considered degraded and should be regenerated (Clatterbuck 2006). Acceptable growing stock is defined as trees capable of producing sawtimber products. If stand quality and stocking levels are sufficient for management, the stand should be thinned to improve residual stand quality. If stand quality and stocking levels are insufficient for management, the stand should be regenerated using an even-aged regeneration technique.

The adequacy of advance regeneration will help determine which even-aged regeneration technique is applicable. For stands with adequate desirable regeneration (>1000 well distributed seedlings / acre, >2' tall), an overstory removal harvest is appropriate. This may be done in one or more harvests depending upon the volume to be harvested, the silvical needs of the advance reproduction, and other management goals.

For stands with inadequate desirable regeneration (<1000 well distributed seedlings / acre, >2' tall), a shelterwood harvest and/or supplemental seedling planting is appropriate. Site and species selection criteria for supplemental seedling planting should follow the guidelines established in chapter 22*, artificial regeneration*. A high percentage of degraded central hardwood stands will also have dense shrub layers that limit light availability and inhibit regeneration. This layer often should be controlled or killed as part of site preparation for supplemental planting.

APPENDICES

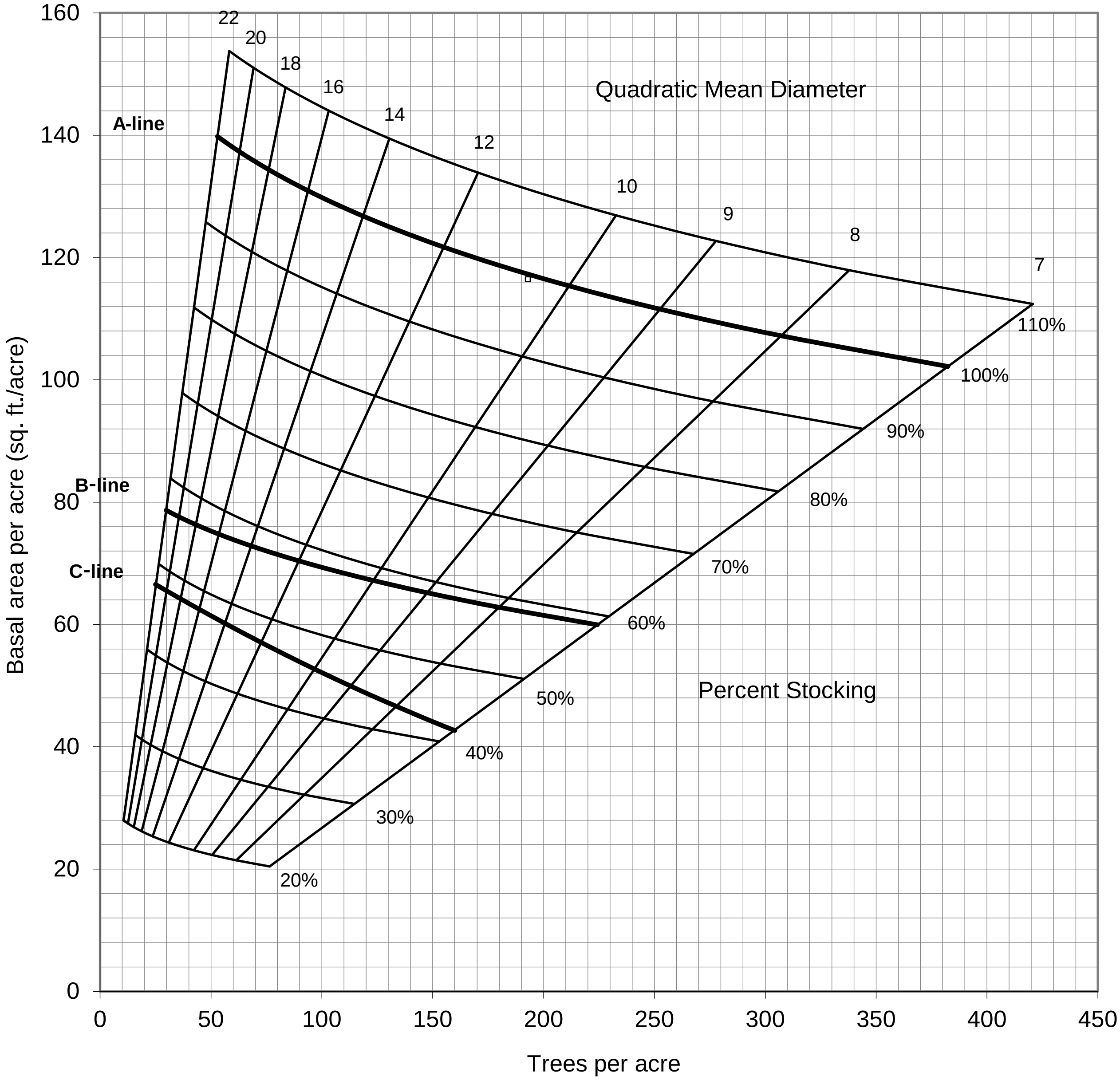

Figure 52.5. Upland central hardwood stocking guide, average diameter 7-22 in (Larsen 2002).

The Upland Central Hardwood Stocking Guide displays the relationship between basal area, number of trees, and mean stand diameter and provides a statistical approach to guide stand density management (see Chapter 23).

- To utilize the stocking guide, statistically accurate estimates of at least two stand variables must be obtained, including basal area per acre, number of trees per acre, and/or mean stand diameter. For the applicable central hardwood stocking guides, these variables are measured only for canopy trees.

- The area between the A-line and B-line indicates the range of stocking where optimum stand growth and volume yield can be maintained.
  - The A-line represents maximum stocking. Maintaining stocking levels near (but below) the A-line will produce comparatively more trees, but of smaller diameter.
  - The B-line represents minimum stocking. Maintaining stocking levels near (but above) the B-line will produce larger diameter trees faster, but comparatively fewer trees.
  - The C-line shows the limit of stocking necessary to reach the B-line level in 10 years on average sites.
- When designing and implementing a thinning regime for a stand, do not reduce stand density to below the B-line or allow it to surpass the A-line.
- Thinning can occur at any time as long as stand density is maintained between the A-line and B-line. The A-line is not a thinning “trigger.” When to thin depends on management objectives, stand conditions, and feasibility.

Typically, thinning is implemented when average stand stocking is halfway or more between the B-line and A-line. Stocking is reduced to slightly above the B-line. Crop tree concepts are applied to retain and focus growth on desirable trees, and order of removal concepts are applied to select which trees will be cut to achieve stand management objectives.

In overstocked stands, thin lightly and frequently, with increasing intensity, for the first several thinnings, to safely develop tree crown vigor and stem strength, and until target residual densities (near the B-line) are achieved. A general rule of thumb is do not remove >33% of the basal area in any one thinning operation.

Since central hardwood stands can differ widely in species composition, estimates of relative density based on stocking charts may be inaccurate and should be used with caution (Stout & Nyland 1986).

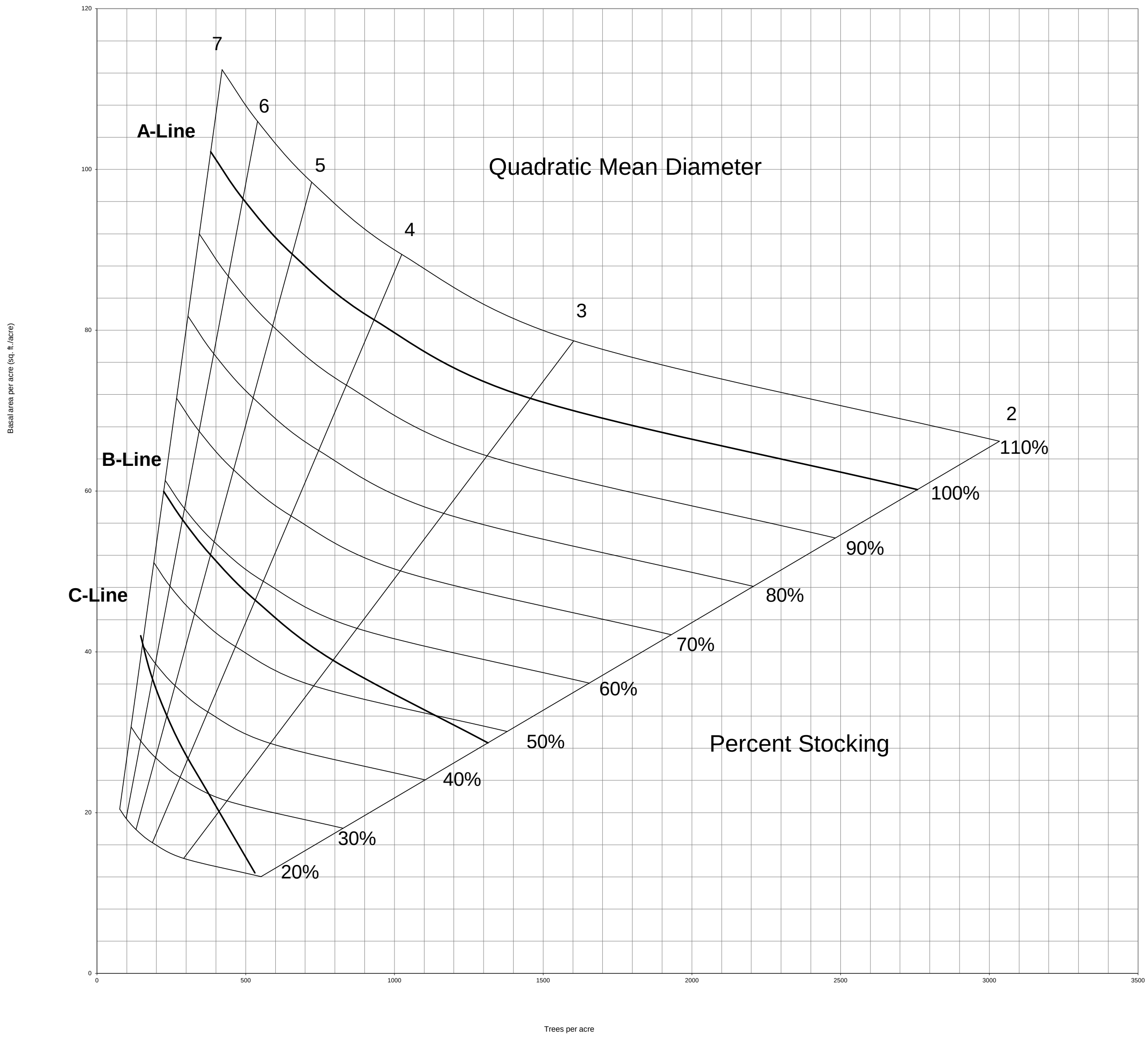

Figure 52.6. Upland central hardwood stocking guide, average diameter 2-7 in (Larsen 2002).

Table 52.6. Tree area ratio coefficients for Wisconsin tree species (NED-2).

Species	WDNR Species Code	K_1	K_2	K_3
Ash, Black	AB	-0.01797900	0.02142500	0.00171100
Ash, Green	AG	0.03258900	0.00743860	0.00383380
Ash, White	AW	0.02793700	0.01545200	0.00087100
Aspen	A, AQ, AY	0.00418710	0.01255100	0.00237960
Basswood, American	BA	-0.00815040	0.00081670	0.00280480
Beech	BE	0.00770410	0.00626130	0.00384800
Birch, River	BR	-0.01797900	0.02142500	0.00171100
Birch, Yellow	BY	0.00770410	0.00626130	0.00384800
Black Walnut	W	0.03087800	0.01805800	0.00423210
Box Elder	BS	-0.01797900	0.02142500	0.00171100
Butternut	WC	0.03087800	0.01805800	0.00423210
Cedar, White	C	-0.00240550	0.00494220	0.00226670
Cherry, Black	CH	0.02793700	0.01545200	0.00087100
Cottonwood	CW	0.03258900	0.00743860	0.00383380
Elm, American	EA	0.03258900	0.00743860	0.00383380
Elm, Slippery	ES	-0.01797900	0.02142500	0.00171100
Fir, Balsam	FB	-0.01970100	0.02164000	0.00031039
Hackberry	HB	-0.01797900	0.02142500	0.00171100
Hemlock	H	-0.01152800	-0.00085458	0.00264390
Hickory, Bitternut	HI	0.00280200	0.01188100	0.00354600
Hickory, Shagbark	HS	0.00280200	0.01188100	0.00354600
Locust, Black	LB	-0.01797900	0.02142500	0.00171100
Locust, Honey	LH	-0.01797900	0.02142500	0.00171100
Maple, Red	MR	-0.01797900	0.02142500	0.00171100
Maple, Silver	MS	-0.01797900	0.02142500	0.00171100
Maple, Sugar & Black	MH, MB	0.00770410	0.00626130	0.00384800
Miscellaneous Hardwoods	MX	-0.01797900	0.02142500	0.00171100
Oak, Northern Red	OR	-0.00534020	0.00737650	0.00432100
Oak, not Northern Red Oak	OW, OS, OM, OB, OO	0.00280200	0.01188100	0.00354600
Pine, Jack	PJ	-0.07219700	0.03416300	0.00102220
Pine, Red	PR	-0.02541800	0.01475300	0.00162290
Pine, White	PW	0.02798000	0.00783220	0.00174670
Spruce	SW, SB, SN	-0.01970100	0.02164000	0.00031039

Tree Area Ratios

Relative stand density (stocking), may be more accurately calculated directly from stand data using a species-specific tree-area ratio than with stocking guides. Stocking based on a tree-area ratio is determined by calculating the area occupied by individual trees within a stand based on species and diameter (Chisman & Schumacher 1940). When summed across the stand, this ratio reflects relative stand density.

$$(K_1 + (K_2 \times dbh) + (K_3 \times dbh^2)) \times \text{stems per unit area} = \text{Relative Density}$$

In this equation K_1, K_2, and K_3 depend on the individual tree species coefficients (see above).

Estimates derived from the tree area ratios will be nearly identical to estimates from a stocking chart when the stand species composition is appropriate to the chart (Stout *et al.* 1987). If the stand composition is not appropriate to the chart, the latter technique will be more accurate. The main advantage of this technique is its flexibility for use in stands with a variety of cover types and species compositions. This technique is greatly simplified when using spreadsheets or computer programs that summarize and calculate stand data.

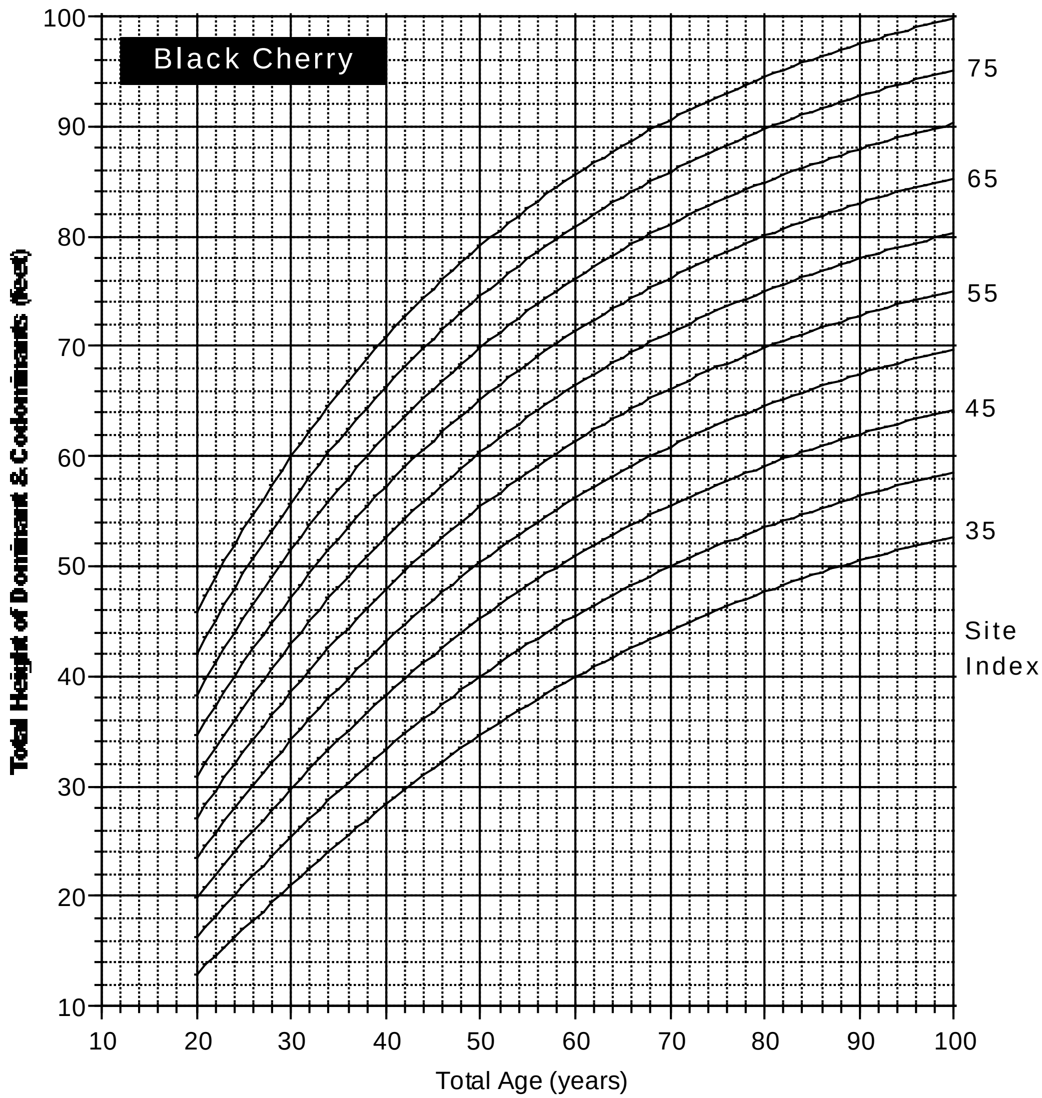

Figure 52.7. Site index curve for black cherry in northern Wisconsin and upper Michigan (Carmean et al. 1987).

Black cherry (Carmean 1978)

- Northern Wisconsin and Upper Michigan
- 42 plots having 126 dominant and codominant trees
- Stem analysis, nonlinear regression, polymorphic
- Add 4 years to dbh. age to obtain total age (BH=0.0)

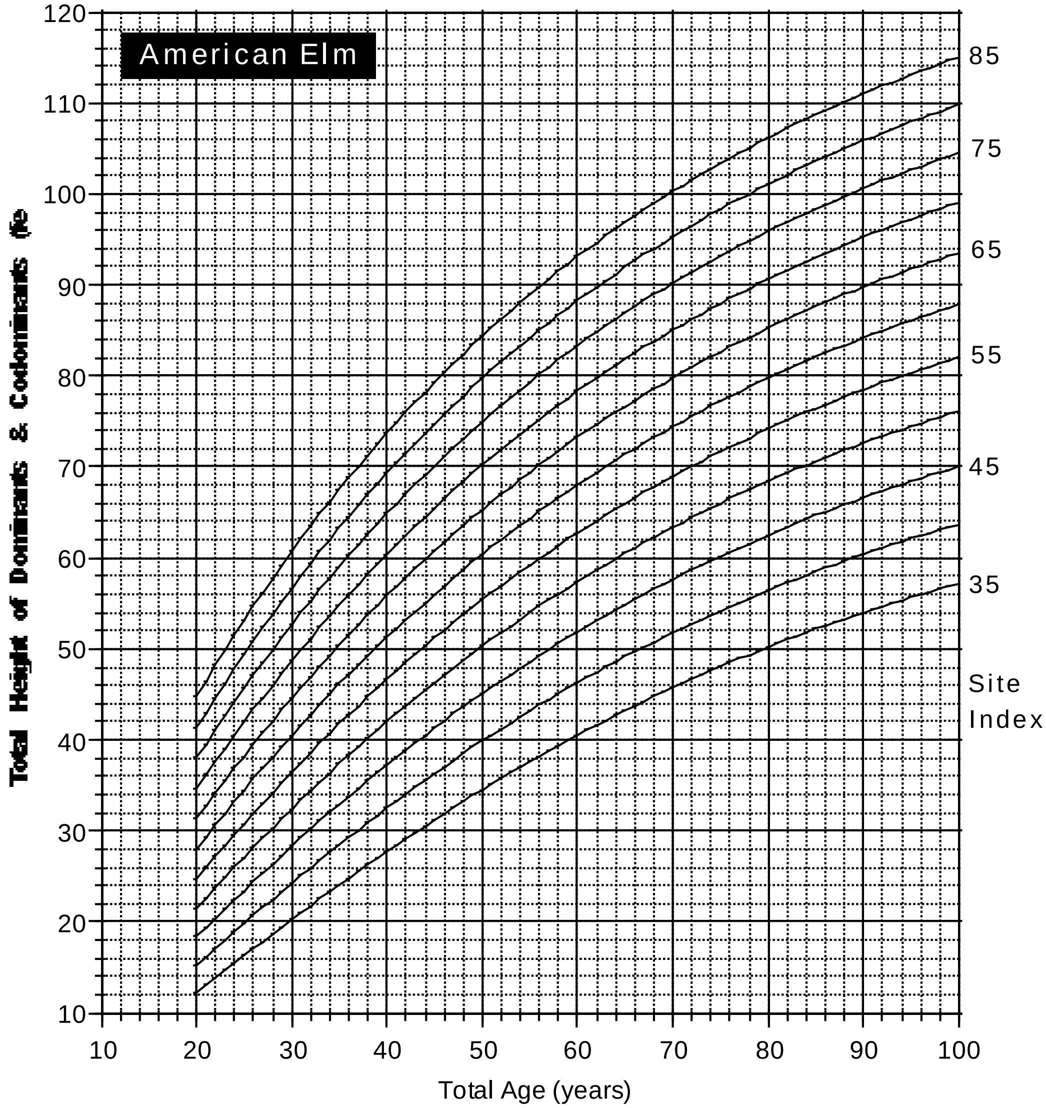

Figure 52.8. Site index for American elm in northern Wisconsin and upper Michigan (Carmean et al. 1989).

American elm (Carmean 1978)

- Northern Wisconsin and Upper Michigan
- 109 plots having 416 dominant and codominant trees
- Stem analysis, nonlinear regression, polymorphic
- Add 4 years to dbh. age to obtain total age (BH=0.0)

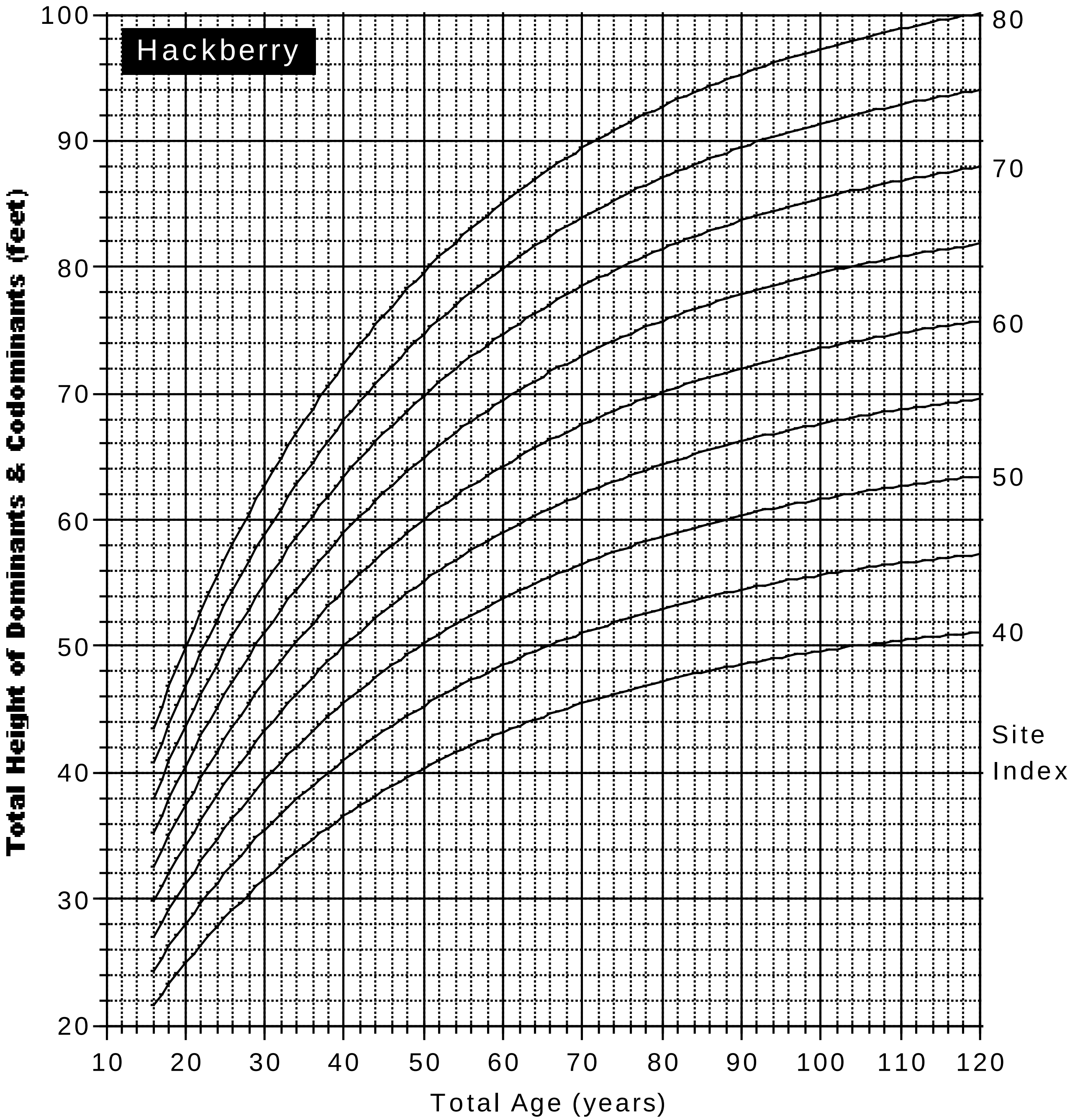

Figure 52.9. Site index for hackberry (Carmean et al. 1989).

Hackberry (Lynch, KD and Geyer, WA) Kansas

- General equation based on 130 dominant and codominant trees, number of plots not given

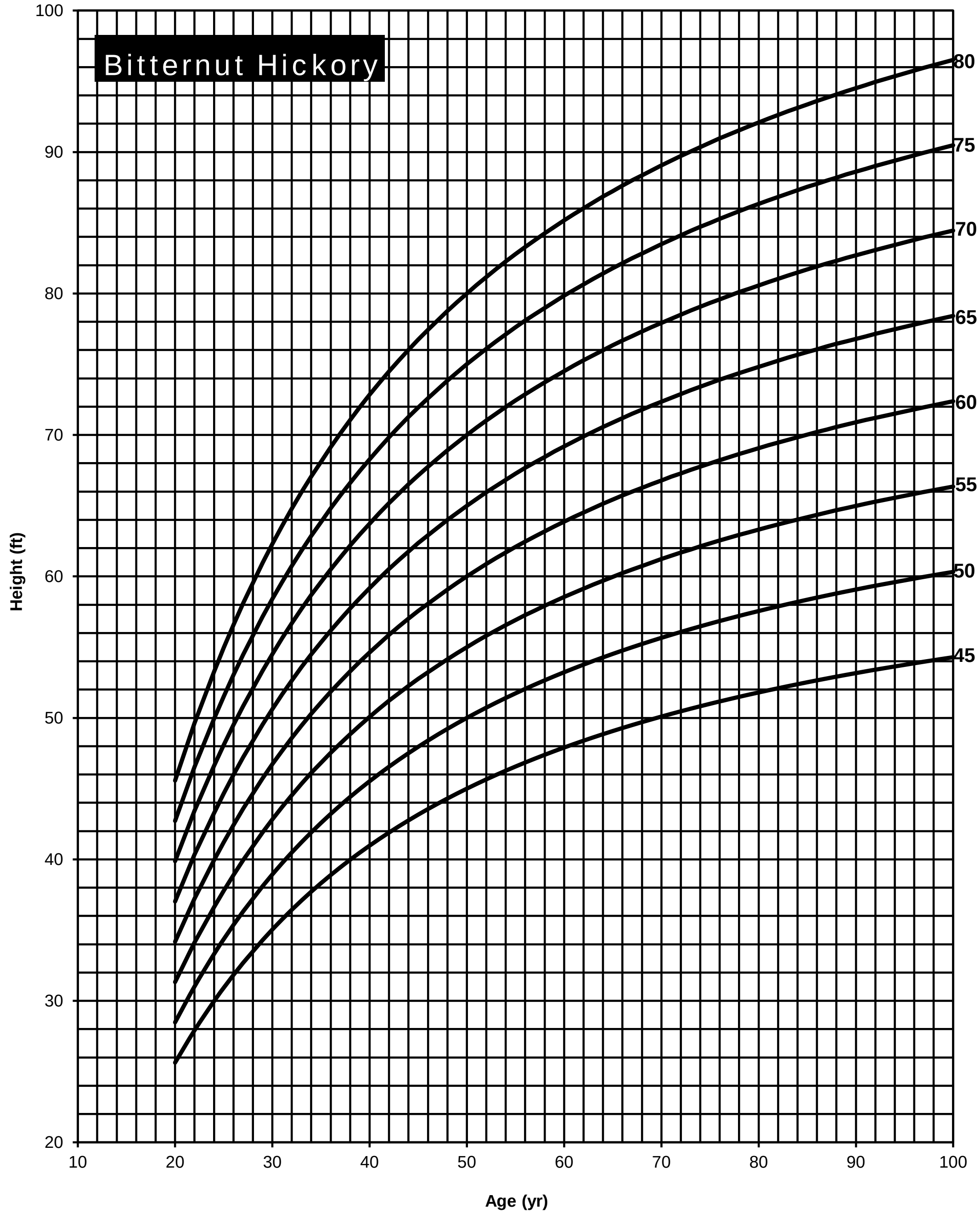

Figure 52.10. Site index for bitternut hickory in Wisconsin.

Bitternut hickory

- Chart based on 264 trees from 1983, 1996, 2003 FIA Site Tree Data
- Total height and age, anamorphic
- Convert dbh age to total age by adding 4 years
- Created by Brad Hutnik and Rick Livingston

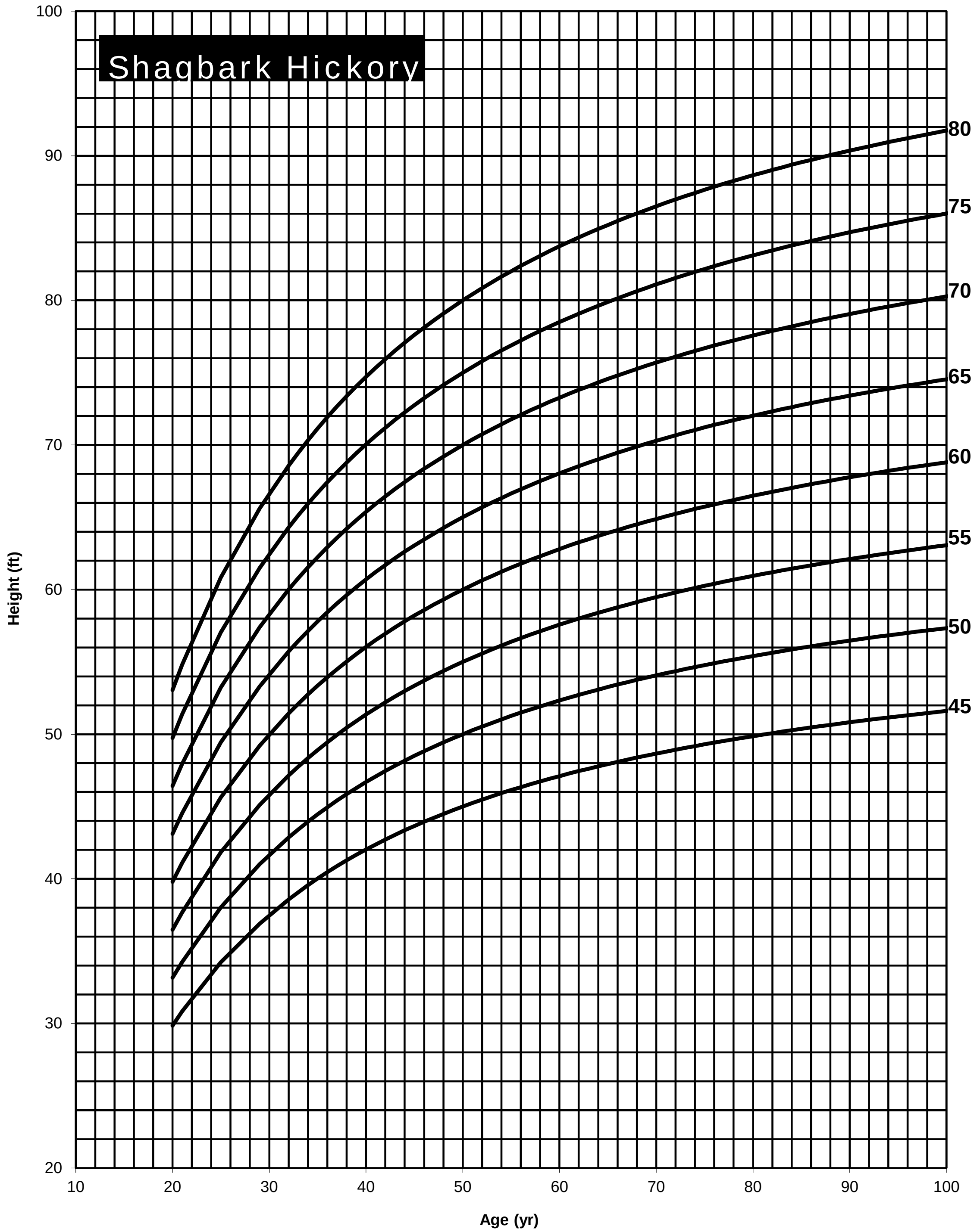

Figure 52.11. Site index for shagbark hickory in Wisconsin.

Shagbark hickory

- Chart based on 318 trees from 1983, 1996, 2003 FIA Site Tree Data
- Total height and age, anamorphic
- Convert dbh age to total age by adding 4 years
- Created by Brad Hutnik and Rick Livingston

7.1 Forest Health Guidelines - Forest Health Protection (FHP)

Species included in this table are butternut, cherry, elm, hackberry, and hickory.
For other species found in central hardwoods, please refer to appropriate chapters.

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
DEFOLIATING INSECTS			
Cherry scallop shell moth - *Hydria prunivorata* Larvae tie margins of the leaves and form an elongated tube-like nest. Feeding occurs on the upper tissues of the leaves inside the nest. Severe defoliation may be seen.	Cherry	Maintain stand vigor through proper forest management	Pest Alert: Cherry Scallop Shell Moth. USDA Forest Service. NA-PR-01-96 https://www.forestpests.org/acrobat/cherry_scallop_shell_moth.pdf
Eastern tent caterpillar – *Malacosoma americanum* Defoliation in spring by larvae. Larvae construct a silken tent on a fork of branches.	Many hardwood species. Cherry is one of the preferred hosts	Maintain stand vigor through proper forest management Insecticides may be applied to control this pest in urban setting	Eastern tent caterpillar. 1999. UW Extension A2933.
Elm flea beetle - *Altica ulmi* Elm leaf beetle – Xanthogaleruca luteola Grub-like larvae skeletonize the undersides of the leaves, leaving the veins and upper leaf surface. Infested leaves later turn brown, dry and may fall off.	Elm	Maintain stand vigor through proper forest management Insecticides may be applied to control this pest in urban setting	Elm Leaf Beetle. Ohio State University Extension Factsheet. HYG-2036-94.
Elm leafminer – *Fenusa ulmi* Larvae mine leaves and cause blister-like blotches on leaves. Mined areas are initially white, and then later turn brown. Adult is a sawfly.	Elm	Maintain stand vigor through proper forest management	Insects of Eastern Hardwood Trees. 1997. Natural Resources Canada
Elm sawfly – *Cimbex americana*	Elm and other hardwood species	Maintain stand vigor through proper forest management	Insects of Eastern Hardwood Trees. 1997. Natural Resources Canada

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
Defoliation in summer to early fall by larvae. Largest species of sawfly in North America.			
Elm spanworm – *Ennomos subsignarius* Defoliation in late spring by larvae.	Elm, Hickory and other hardwood species	Maintain stand vigor through proper forest management	Insects of Eastern Hardwood Trees. 1997. Natural Resources Canada
Fall webworm – *Hyphantria cunea* Defoliation in mid- to late summer by larvae. Larvae construct a silken web, covering the ends of branches, and feed within the web. Webs as large as a few feet across may be formed.	Many hardwood species	Control is usually not necessary as defoliation occurs toward the end of growing season. Maintain stand vigor through proper forest management	Fall webworm. 2004. UW Extension Garden Facts XHT1066. https://hort.extension.wisc.edu/files/2014/11/Webworms.pdf
Lace bugs – *Corythucha* spp. Lace bugs feed on the undersides of leaves by inserting their needle-like sucking mouthparts and extracting sap. Infested leaves have white or yellow spots. Heavily infested leaves may turn yellow or brown in summer.	Many hardwood species, including butternut, cherry, elm, and hackberries	Control is usually not necessary as the damage does not affect the health of the trees significantly Maintain stand vigor through proper forest management	Lace bugs on deciduous trees and shrubs. 2002. Univ. of Minnesota. Yard & Garden Brief.
Ugly nest caterpillar – *Archips cerasivorana* Defoliation by larvae in late spring to summer. Larvae tie leaves with silk and construct a dense web filled with excrement and bits of leaves.	Cherry and other hardwood species	Maintain stand vigor through proper forest management Chemical control is usually not necessary as the damage does not affect the health of the trees significantly.	Insects of Eastern Hardwood Trees. 1997. Natural Resources Canada

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
FOLIAGE DISEASES			
Anthracnose – Multiple Anthracnose causing fungi (see reference) Irregular dead blotches on foliage. Growth loss.	Many hardwood species including elm and hickory	Maintain stand vigor through proper forest management Direct control is impractical and usually unnecessary. Silvicultural measures to encourage air circulation may reduce infection.	Anthracnose Diseases of Eastern Hardwoods. 1985. Forest Insect & Disease Leaflet 133 https://www.fs.usda.gov/foresthealth/docs/fidls/FIDL-133-AnthracnoseHardwoods.pdf
GALL MAKING INSECTS			
Elm cockscombgall aphid – *Colopha ulmicola* The insect causes a gall that resembles a comb on leaves. Galls are irregularly toothed, reddish brown, and later turn brown and hard. Woolly elm aphid - *Erisoma americanum* The insect is covered with white waxy threads. Infested leaves are twisted and curled.	Elm	Maintain stand vigor through proper forest management Chemical control is not necessary as the damage does not affect the health of the trees significantly.	Insects of Eastern Hardwood Trees. 1997. Natural Resources Canada
Hackberry nipple gall - Pachypsylla celtidismamma Round nipple-like galls on leaves are caused by psyllids or jumping plant lice.	Hackberry	Maintain stand vigor through proper forest management Chemical control is not necessary as the damage does not affect the health of the trees significantly.	Deciduous Tree Galls. 2000. UW Extension Garden Facts. X1064. https://hort.extension.wisc.edu/files/2014/11/Deciduous-Tree-Galls.pdf Insect and Mite Galls. 2005. Univ. Minn. Ext. DG1009 http://cues.cfans.umn.edu/old/extpubs/1009galls/DG1009.html

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
Phylloxera galls - Phyllloxera spp. Galls are caused by aphid-like insects called phylloxera. Gall growths vary in size and shape. Hickory pouch gall The insects cause pouch-like growths on the twigs and leaves.	Hickory	Maintain stand vigor through proper forest management Chemical control is not necessary as the damage does not affect the health of the trees significantly.	Deciduous Tree Galls. 2000. UW Extension Garden Facts. X1064. Insect and Mite Galls. 2005. Univ. Minn. Ext. DG1009
GALL DISEASES			
Black knot - Apiosporina morbosa The fungus causes black, corky swelling, primarily on twigs and branches, but also on main stems. Severe infections girdle branches and trunks and cause branch dieback and could lead to tree mortality.	Cherry and other Prunus spp.	Trees with galls on main stem have a high probability of degrade in value during the next cutting cycle and may be selected against during the normal thinning practice1. Pruning of branches at least six to eight inches below each swelling is effective to control this disease in urban situations.	Black Knot. 2000. UW Extension Garden Facts. X1056. https://hort.extension.wisc.edu/files/2014/11/Black-Knot.pdf
Phomopsis gall - Phomopsis spp. The fungus causes round tumor-like growths on twigs, branches, and trunks. Galls occur singly or in clusters. Severe infections girdle branches and trunks and cause branch dieback and could lead to tree mortality.	Hickory	Trees with galls on main stem have a high probability of degrade during the next cutting cycle and may be selected against during the normal thinning practice1.	Phomopsis Canker & Gall. 2000. Univ. Minn. Ext. Yard & Garden Brief.
SCALE INSECTS			

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
Lecanium scale – Parthenolecanium spp. This insect sucks plant juice, causing twig and branch dieback, and growth loss.	Many hardwood species	Maintain stand vigor through proper forest management Chemical control is impractical, and usually unnecessary.	Scale Insects of Trees and Shrubs. 1999. Univ. Minn. Ext. FO-01019.
CANKERS			
Butternut canker - Sirococcus clavigignenti-juglandacearum The fungus causes perennial cankers on twigs, branches, stems and exposed roots. Multiple stem cankers eventually girdle and kill infected trees. A statewide survey conducted in Wisconsin in 1992 found that 27% of the surveyed trees were dead and 91% of live trees were cankered.	Butternut	Tree Retention Guidelines (the 70-20-50 Rule) Retain all trees with more than 70% live crown and less than 20% of the combined circumference of the bole and root flares affected by cankers. Retain all trees with at least 50% live crown and no cankers on the bole or root flares. Harvest dead or declining trees based on landowner objectives	How to Identify Butternut Canker and Manage Butternut Trees. 1996. USDA FS Butternut-Strategies for Managing a Threatened Tree. 1994. USDA FS General Technical Report NC-165.
Nectria canker – Nectria cinnabarina Trunk deformity and growth loss (all ages). Although it rarely causes mortality, a tree may break off at the point of canker.	Many hardwood species	Silvicultural control measures are based on percent of infected trees in stand (see reference). Most infections occur when trees are 12-20 years old. Conduct improvement cut after age 20. A canker that affects >50% of the stem's circumference or >40% of the stem's cross	How to Identify and Control Nectria Canker of Hardwoods. R. Anderson. 1978. USDA FS

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
		section has a high risk of failure during the next cutting cycle. 1	
WOOD BORERS			
Hickory bark beetle – Scolytus quadrispinosus Larval mining radiates from egg galleries, creating etching that resembles a centipede. Foliage of infested trees turns yellow and later brown. Larval tunneling girdles branches and stems, causing branch dieback and mortality.	Hickory is the primary host. Butternut is listed as a host; however infestations have not been reported in Wisconsin yet.	Maintain stand vigor through proper forest management. Destroy trees harboring overwintering larvae during winter and spring.	Hickory Bark Beetle:Biology and Control. 1964. WI Conservation Dept. Forest Pest Leaflet No.6 Guide to insect borers of North American broadleaf trees and shrubs. 1995. USDA Forest Service. p504-506
Hickory borer – Goes pulcher Larvae are round-headed wood borers. Larval feeding causes serious damage to young trees. Attacks in large trees are usually restricted to branches and upper stem.	Hickory	Maintain stand vigor through proper forest management. Destroy trees harboring overwintering larvae during winter and spring.	Guide to insect borers of North American broadleaf trees and shrubs. 1995. USDA Forest Service. p308-311
Peach bark beetle – Phloeotribus liminaris First confirmed case of infestation in Wisconsin was found on a mature black cherry stand in 2000. The insect is known to attack individual trees repeatedly until the trees die.	Black cherry	Caution is urged when making partial cuts in black cherry. Utilization of the logging slash as much as possible would be a wise practice until more information about this insect becomes available.	Black Cherry Pest Alert! Peach Bark Beetle. 2001. WI DNR FHP.
ROOT DISEASE			

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
Armillaria root disease (shoestring root rot) – Armillaria spp. Stringy white rot. Dieback and mortality, especially during drought years or following 2 or more years of defoliation (all ages).	Many tree and shrub species	Maintain stand in healthy condition. Harvest declining trees before mortality and decay take place.	Armillaria Root Disease. R. Williams, et al. 1986 USDA Forest Service, Forest Insect and Disease Leaflet 78
WILT DISEASE			
Dutch elm disease – Ophiostoma ulmi/O. novo-ulmi Infection by the fungus results in clogging of the vascular system of a tree. Foliage of the infected tree becomes wilted, turns yellow and later brown. First, wilting symptoms appear at the end of an individual branch (flagging), and then progress to the entire crown. Infected tree eventually dies.	Elm	Remove and destroy infected trees. If infected wood is stored as firewood it needs to be debarked or covered with thick plastic tarp during growing season. Disruption of root grafts prevents the movement of the fungus from diseased to nearby healthy elms. Fungicides can be applied to protect individual valuable trees in urban setting.	How to Identify and Manage Dutch Elm Disease. 1998. USDA Forest Service. NA-PR-07-98.
MORTALITY			
Hickory mortality Dieback and mortality on hickory have been observed in central and southern Wisconsin. Recent research found that the mortality is associated with the hickory bark beetle and two fungal species of the genus Ceratocystis (C. carya and C. smalleyi). The fungus has been isolated from sunken bark cankers and discolored	Hickory	Since this problem is currently under investigation, no known control is available, though practices to reduce hickory bark beetle attacks may be considered (see hickory bark beetle under wood borers).	Pest Alert: Hickory Mortality. 1994. USDA Forest Service. NA-FR-02-94.

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
wood associated with beetle attacks. At this point, little is known about the relative role of the fungus and its distribution in Wisconsin.			
ANIMAL DAMAGE			
Sapsuckers (Sphyrapicus varius) Value loss through wood decay and discoloration. Occasional tree mortality.	Central Hardwood	Leave attacked tree in place. It will concentrate most of the attacks on one tree.	How to Identify Sapsucker Injury to Trees. M. Ostry. 1976. USDA FS. NSEFES.
Voles/mice (Microtus spp.) Mortality of reproduction through stem girdling in grassy plantations.	Central Hardwood	Control grass first five years	Animal Damage to Hardwood Regeneration and Its Prevention in Southern Ontario. F.W. Von Althen. 1983. Information Report 0-X-351.
Rabbits/hares (Sylvilagus spp./Lepus americanus) Mortality of reproduction through stem girdling.	Central Hardwood	Control usually unnecessary	Animal Damage to Hardwood Regeneration and Its Prevention in Southern Ontario. F.W. Von Althen. 1983. Information Report 0-X-351
Squirrels (Sciurus spp., Tamiasciurus hudsonicus, Glaucomys spp.) Gnawing on bark of maple saplings occasionally causes tree mortality. Squirrels also tend to feed on the edges of fungal cankers.	Central Hardwood	Control usually unnecessary	Animal Damage to Hardwood Regeneration and Its Prevention in Southern Ontario. F.W. Von Althen. 1983. Information Report 0-X-351

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
White-tailed deer (Odocoileus virginianus) Browsing can cause mortality, deformity, or reduced growth rates of seedlings. Preferential browsing can alter forest composition. Antler polishing can shred bark and can cause deformity or mortality of small trees.	Forests, including Central Hardwood	Population management by hunting Fencing (exclusion) Tree shelters, bud caps, and repellents	Controlling Deer Damage in Wisconsin. S. Craven et al. 2001. UW Extension G3083. Animal Damage Management Handbook. 1994. USDA FS PNW-GTR-332.
Livestock Potential impacts include soil compaction, root and stem wounding, reduced tree vigor and sap production, mortality and deformity of seedlings, and altered forest composition. Damage can be severe when soil is saturated or grazing is heavy (large populations or extended time periods).	Forests, including Central Hardwood	Eliminate or limit livestock from forests.	Sugarbush Management: A Guide to Maintaining Tree Health. 1990. D. Houston et al. USDA FS GTR-NE-129. Wisconsin Forest Management Guidelines. 2003. WDNR PUB-FR-226.
European earthworms (Lumbricus, Dendrobaena, Octolasion, and Aporreclodea spp.) Declines in native understory plant species and tree seedlings follow the invasion of non-native earthworms. They rapidly decompose the leaf litter that makes up the duff layer, leaving a bare soil surface inhospitable to tree seedlings and other plants that germinate in the duff or require it for protection. Partial recovery occurs after the invading front has passed and the earthworms become naturalized.	Forests and open lands, including Central Hardwood.	Prevent new earthworm introductions. Don't transplant plants and trees into areas where earthworms are not present. Dispose of extra fishing bait in the trash. Experts recommend limiting deer populations in areas with new invasions to avoid stacking stresses on flora.	

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
ABIOTIC and MECHANICAL DAMAGE			
Storm damage Limb and trunk breakage. Decay and discoloration through wounds.	Central Hardwood	See FHP Signs of Defect table for specific recommendations related to impact.	Caring for ice-damaged woodlots and plantations. 1999. Ontario Extension Notes
Cold injury Cold injury occurs when the winter temperature falls to approximately -35° F or colder. Species' sensitivity varies. Injury is typically manifested by patches of dead (brown and black) cambium. In spring, affected trees will have reduced bud break and may have epicormic sprouts.	Central Hardwood	Monitor for dieback in upper and outer crown. If more than 50% of the crown dies, expect decline to continue to mortality.	
Late spring frost damage This phenomenon is unpredictable and occurs when temperatures dip below freezing during bud expansion, break and when foliage is just emerging. Foliage turns black and wilts. Twig dieback can occur. New lateral buds can break within 4 weeks after damage.	Central Hardwood	In frost pockets, expect injury to new expanding growth during years with late spring frost. Monitor for dieback in upper and outer crown. If more than 50% of crown dies, expect decline to continue to mortality.	
Drought Symptoms of drought include premature defoliation, thin crowns, subnormal leaf size and in severe cases, wilting foliage. If drought persists for more than one year, dieback of the upper and outer crown may occur.	Central Hardwood	Monitor for dieback in upper and outer crown. If more than 50% of crown dies, expect decline to continue to mortality. Hardwoods take longer to recover from drought than	

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
		conifers. Improvement in crown may not be noticeable for a year after normal precipitation returns.	
Logging damage Wounds. Limb and trunk breakage. Decay and discoloration through wounds.	Central Hardwood	Careful felling and skidding, directional felling techniques, careful harvest plan layout. Limit harvest activities to times when soil is frozen or dry enough as to minimize soil compaction. See FHP Signs of Defect table for specific recommendations related to impact.	
INVASIVE PLANT SPECIES			
Black-bindweed, False buckwheat - Polygonum convolvulus Black-bindweed can outcompete and displace other flora.	Forests, including Central Hardwood.	Little is known about control in forests. Herbicide or hand-pulling may be used where control is needed.	
Field bindweed - Convulvulus arvensis A Wisconsin state-listed “noxious weed” that can outcompete and displace other flora.	Forests, including Central Hardwood.	Little is known about control in forests. Herbicide or hand-pulling on a regular basis (perhaps only once per year), may be used where control is needed.	

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
Garlic mustard - Alliaria petiolata A major invasive plant that outcompetes herbaceous flora and tree seedlings. There is some evidence of allelopathy to beneficial mycorrhizae. Small seeds spread easily on equipment and clothing.	Forests, including Central Hardwood. One of the few invasive understory plants to thrive in full shade.	Use preventative measures; clean equipment and clothing before entering the forest. Monitor to ensure early detection. Small infestations can be eradicated by hand pulling, or by repeatedly cutting the flower stalk close to the soil surface before flowering begins. Spray with glyphosate in spring or fall to kill basal rosette; avoid non-target species.	
Japanese knotweed - Polygonum cuspidatum Outcompetes and displaces other flora. Early emergence, height, and density allow it to shade out other vegetation and limit tree regeneration. Not yet widespread in Wisconsin. Difficult to eradicate once established.	Central Hardwood forests, riparian forests, open lands with mesic or wet-mesic conditions.	Repeated cutting (3x per growing season) provides control but may not eradicate a stand. The herbicide glyphosate can be effective, especially applied in fall. Continued monitoring and follow-up are needed after treatment.	
Japanese barberry - Berberis thunbergii Has potential to limit forest regeneration as it becomes more abundant. With a concerted effort, potential remains to suppress this species. It can outcompete and displace other flora. Its thorns make it	Forests and semi-open areas, including Central Hardwood.	Mechanical removal in early spring is recommended for small infestations. Wear thick gloves. Glyphosate or triclopyr herbicides can be effective.	

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
difficult to work or recreate in an infested area.	Tolerates full shade.	Avoid impacts to non-target vegetation.	
Common buckthorn and smooth (glossy) buckthorn (Rhamnus cathartica and R. frangula) Tall shrubs form dense thickets that outcompete and displace other flora. There is some evidence that they are also allelopathic. Seeds are spread by birds, and in mud on equipment.	Forests, including Central Hardwood, and open lands. Smooth buckthorn is more restricted to wet and wet-mesic areas.	Monitor to ensure early detection. Clean equipment before entering the forest. Small plants can be eradicated by hand pulling. Large shrubs can be mechanically removed, cut and stump-treated, or controlled with a basal bark application. Foliar sprays should be restricted to fall months when buckthorn is still actively growing but other species are dormant, to avoid impacts to non-target vegetation. Trichlopyr may be more selective than glyphosate. In areas with high water tables, use herbicides labeled for use over water. Continued monitoring and follow-up are needed after treatment.	

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
Bush honeysuckles (Lonicera spp.) Forms dense shrub thickets that outcompete and displace other flora. Seeds are spread by birds, and in mud on equipment.	Forests, including Central Hardwood, and open lands.	Monitor to ensure early detection. Clean equipment before entering the forest. Small plants can be eradicated by hand pulling. Large shrubs can be mechanically removed or cut and stem-treated. Foliar spray using glyphosate in spring, prior to emergence of native plants. In areas with high water tables, use herbicides labeled for use over water.	
Norway maple - Acer platanoides A tree species that can outcompete and displace other flora, including sugar maple seedlings. The sap is not suitable for maple syrup. Identification is difficult, as morphology is ambiguous with sugar maple. Flattened seed cavity is distinctive. Norway maples may or may not have milky sap.	Central Hardwood and other upland forests. Tolerates shade. Prolific stump sprout reproduction and viable seeds.	Pull seedlings. Cut stump and treat with glyphosate or basal bark spray stem with triclopyr.	https://www.dnr.state.mn.us/invasives/terrestrialplants/woody/norwaymaple.html

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
Amur maple - Acer ginnala A tall shrub or small tree that can outcompete and displace other flora. Foliage turns bright red in fall.	Central Hardwood and other upland forests. Tolerates shade. Prolific stump sprout reproduction and viable seeds.	Mechanical removal of small infestations Cut stump and treat with glyphosate or basal bark spray stem with triclopyr.	https://www.dnr.state.mn.us/invasives/terrestrialplants/woody/amurmaple.html

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Signs of defect, and evaluation of potential impacts on risk, vigor and value
For the complete defect table of northern hardwood species, please refer to Chapter 40, Northern Hardwood Cover Type.

DEFECT	High Probability of Mortality or Failure (high risk)	High Probability[1] of Degrade due to Defect
Canker Localized area of dead bark and cambium; wood behind canker may or may not be decayed. Commonly caused by fungi. Fungal cankers are a source of spores that may infect healthy trees.	Canker affects >50% of the stem's circumference or >40% of the stem's cross section. Horizontal crack on a canker face. >20% of combined circumference of the stem and root collar are affected by butternut canker.	Decay associated with large canker (affects >50% of stem's circumference). Fruit body visible in the canker's face. Extent of decay and discoloration will vary depending on organisms involved.
Wounds Any injury to tree that exposes the cambium or wood beneath cambium.		1 or more wounds ≥50 in^2 or ≥30% of tree's circumference. >2 large (>5") branches broken close to the stem. Codominant ripped from stem. Fire scars affecting ≥ 20% of tree's circumference
Decay Wood that is missing or structurally compromised. Canker rot fungi are not compartmentalized and will cause significant decay.	Decay in main stem results in <1" of sound wood for every 6" in diameter; must have 2"of sound wood for every 6" dbh if there is also a cavity present. Decay or cavity affects >40% of the stem's cross-section. Tree infected with a canker-rot fungus	Tree infected with a canker-rot fungus including but not limited to: Cerrena unicolor (maple & oak) Phellinus everhartii (oak) Inonotus hispidus (oak) Spongipellis pachyodon (Irpex mollis) (oak)
Cracks (open, can see into the tree at least an inch) A split through the bark, extending into the wood. Wood fibers are not fused. Cracked stems or branches cause wood to act as 2 separate	Crack goes completely through a stem or is open for >4-6' (length). Two open cracks occur on the same stem segment. The stem has an open crack in contact with another defect such as decay, a canker, or weak union.	>1 face with open crack or seam or any spiral crack. Open cracks are more likely to be associated with decay and discoloration.

DEFECT	High Probability of Mortality or Failure (high risk)	High Probability[1] of Degrade due to Defect
beams, weakening mechanical support.		
Galls Abnormal growths on stems and branches. Galls are typically sound but may cause degrade in a localized area around the gall.		Galls on main stem Black knot of cherry (cherry) Phomopsis galls (hickory&oak) Unknown growth (aspen&cherry)
Weak union Union with ingrown bark between stems; wood fibers are not fused. Weak unions are characterized by an acute angle between stems.	Stump sprouts joined above ground in V-shaped union and associated with a crack, showing failure has already begun.	Large (>8" diameter stems) tight union that is either cracked or decayed or associated with another defect. Could result in failure; stain and decay will vary.
Structural compromise Unusual form typically initiated by storm damage.	Leaning tree with recent root lifting. Leaning tree with a horizontal crack, long vertical crack, or buckling wood on the underside of the tree. New leader formed in response to a dead or broken top. Risk increases as top gets larger and stem decays at break point.	
Root defects Loss of structural support due to root rot, wounding, severing or any other factors that cause root mortality.	More than 33% of roots severed, decayed or otherwise compromised. Stump sprouts with a tight union where root structure is not sufficient to support stems.	>3 root wounds within 4' of the main stem; each wound encompasses >30% of root diameter.
Crown density/dieback/ leaf condition Crown symptoms are often showing a response to poor root health, stress such as defoliation or	50% of the crown dead, unless loss of crown is due to stem breakage. 75% of leaves subnormal in size or abnormal in color. (excluding iron chlorosis.) Signs of cambium miners	Multiple large (>5" diameter) dead branches, dead top or codominant (>10" diameter).

DEFECT	High Probability of Mortality or Failure (high risk)	High Probability[1] of Degrade due to Defect
drought or infestation by cambium-mining beetles.		

[1] There is a high probability that the defect will cause a significant reduction in value over a 15-year period; rate of decay/stain development varies by species. Defect may be limited to localized area.

NOTE:

Fire scars are common entries for decay fungi in central hardwood species. Ten years after fire injury, decay may extend .5 – 1 foot above the top of the fire scar. Avg. rate of decay development = 1.25'/ decade. Fire scar wound size may be calculated:

Wound height: multiply bark scorch height x 0.9

Wound width: multiply bark scorch width at 1' above ground x 0.6

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Previous View

Chapter 61

Big Tree Silviculture

Last Full Revision: 11/21/2007
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

1 INTRODUCTION

Big tree silviculture (BTS) currently is a silvicultural guideline identifying practices that can be applied to accomplish specified forest management goals and objectives in selected stands. Big tree silviculture refers to the cultivation of long-lived, large diameter trees, either as entire even-aged stands or as reserve trees within stands of smaller sized trees. Big trees are retained until they approach senescence (biological maturity). The management of large trees can provide a variety of benefits but can also incur costs.

1.1 Potential benefits of BTS:

1.1.1 Aesthetics

a. Provide visually unique stands and trees (big old trees)
b. Provide diversity in current and future stands
c. Reduce unobstructed line of vision
d. Break-up clearcut look

1.1.2 Wildlife and plant populations, habitat, and biodiversity

e. Altered populations. Some desired species may be more abundant.
f. Protect areas of special concern (special habitat)
g. Habitat diversity
h. Buffer adjacent stands (habitat)
i. Travel corridors
j. Future coarse woody debris
k. Cover
l. Den and nest trees
m. Food (foraging, hunting)
n. Display locations

1.1.3 Timber Production

o. Produce large diameter sawtimber
p. Reserve high quality trees for future harvest

1.1.4 Water and Soil Quality

q. Reduce run-off
r. Reduce erosion
s. Maintain water and nutrient cycles

1.1.5 Miscellaneous

t. Protect cultural resources
u. Preserve landmarks, such as marker trees and witness trees

1.2 Potential costs of BTS:

1.2.1 Aesthetics

a. Cluttered forests – less order – more mortality and decay.

1.2.2 Wildlife and plant populations and habitat

b. Altered populations. Some desired species may be less abundant, with less habitat.
c. Potential for increased predation of some wildlife

1.2.3 Timber Production

d. Reduced timber volume growth and productivity rates (MAI)
e. Susceptible to stem and crown damage during stand harvests
f. Reserve trees susceptible to epicormic branching following stand rotation
g. Reserve trees susceptible to crown dieback and mortality following stand rotation
h. Reserve trees susceptible to wind throw on wet or shallow soils, or for shallow rooted species
i. Reserve trees can shade and reduce vigor of nearby regeneration
j. Damage to younger stand if reserves are harvested during mid-rotation

1.2.4 Miscellaneous

k. Provide potential sites for pathogen breeding and maintenance

2 HISTORY

The initial formal recommendation advocating for the application of big tree silviculture on State Forest lands is presented in the *Final Report – Governor's Committee To Review Timber Management Policies On State-Owned Lands – March, 1974*.

The recommended policy stated:
- "Because of the unique recreational values of old growth and big trees, as well as the need for large timber by some industries, 'big tree silviculture' and longer rotations than at present should be used in State Forests."
- "High intensity forest management for maximum timber production … would be limited."

Some comments included:
- "Therefore, State Forests should generally be managed for recreation and long rotation species, except for those sites unusually adapted to shorter rotation species."
- "Sites not suitable for such production naturally would not be managed in this fashion."
- "A policy for larger basal tree size and for stands of greater maturity in State Forests will have an important effect upon local wildlife management."
- "The implementation of this policy would significantly change the character of the State Forests."

This report recommends that, on State Forests, management should encourage the dominance of long-lived species, and stands should be managed on extended rotations.

These policy recommendations were interpreted by DNR Forestry and used to develop the Big Tree Silviculture policy and guidelines detailed in the Silviculture Handbook in 1977. In summary:

- "Big tree silviculture … is to govern the management of selected types on state forests … to achieve the objective of old growth timber and aesthetic desirability … will take precedent over maximizing timber yields."
- The application is limited to five cover types (red pine, white pine, red oak, northern hardwood, hemlock-hardwood), where rotation ages "will be extended to approach biological maturity."
- In addition, the concept should be applied to three species (red pine, white pine, hemlock) as individual trees or clumps in stands of other non-BTS cover types (e.g. white pine standards in aspen stands).

The big tree silviculture policy and guidelines in the Silviculture Handbook were updated in 1990. There were two major changes:

- The role of old-growth was reduced, because "old growth has important ecological implications that are not yet fully understood … These guidelines may be modified in the future as we improve our understanding of the structure and function of old growth forests." Therefore, the objective of big tree silviculture was revised "to achieve the objective of aesthetic desirability."
- Forest habitat types were integrated to identify site types where large, vigorous, long-lived trees could be expected to develop. Big tree silviculture was then limited to specific species on specific site types.

From 1990 until 2006, big tree silviculture stated that, on State Forests, when specific cover types or tree species occur on specific sites, they will be managed to an age approaching biological maturity before harvesting. Every acre that meets the species and site requirements will be managed on an extended rotation.

In 2006, DNR Division of Forestry leadership reviewed and rescinded the big tree silviculture policy. Section 28.04, Wis. Stats., identifies the purpose of the State Forests. Chapter NR 44, Wis. Adm. Code, Rules for Master Planning, details the master planning process, and guides the allocation of land to different management goals and strategies. Big tree silviculture is now maintained as a silvicultural guideline to accomplish predetermined management goals and objectives in selected stands.

3 STANDS OF TREES

In extended rotations, mature stands are dominated by relatively large trees, older than their traditional rotation age, yet younger than their pathological rotation age (average life expectancy). They are managed for both commodity production and the development of some social and ecological benefits associated with older forests dominated by big trees. These stands can be even-aged or uneven-aged. Most trees eventually will be harvested for timber production, although some trees can be reserved to live out their natural lifespan.

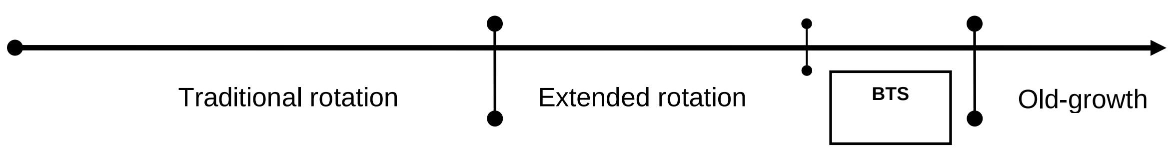
Big tree silviculture is applied to develop specific stand characteristics which are a subset of potential conditions developed through extended rotations.

- BTS only applies to the management of **even-aged stands**.
- BTS is restricted to species and sites where stands of large diameter trees can be grown

Big Tree Silviculture Potential Forest Cover Types and Corresponding Site Types	
Forest Cover Types	Habitat Type Groups (site types)
Red Pine	Dry, Dry-mesic
White Pine	Dry, Dry-mesic, Mesic, Wet-mesic
Oak (red, white, bur)	Dry-mesic, Mesic
Oak (swamp white)	Wet-mesic, Wet
Central Hardwood	Dry-mesic, Mesic

- BTS only covers the period near the end of an extended rotation. Stands managed under BTS will be carried to the later stages of an extended rotation, nearing senescence (approaching biological maturity).

Stand development over time:



Big tree silviculture potentially can be applied to even-aged stands comprised of relatively long-lived tree species growing on sites that can support vigorous growth and the development of large trees. Stand and tree health should be monitored and managed. Although expected rotation ages should be identified, actual rotation ages will depend on stand vigor.

Big tree silviculture only applies to even-aged cover types. For **uneven-aged stands**, BTS would be analogous to extended rotations. Where similar management objectives are delineated for uneven-aged types (e.g., northern hardwood, hemlock, white cedar), apply extended rotation concepts and guidelines to develop large, long-lived trees. Designate and retain some reserve trees to live out their natural lifespan. These uneven-aged stands will contain trees of many different ages and sizes, including some old, senescent individuals.

The forest cover type chapters within this handbook provide management guidelines applicable to extended rotations. The DNR Old-growth and Old Forests Handbook (2480.5) provides definitions, considerations, and management guidelines by major forest type for extended rotations, as well as for managed and reserved old forest and old-growth.

4 RESERVE TREES

*(standards, leave trees, legacy trees, green tree retention)

Reserve trees are scattered individuals, groups, or patches retained to reach greater ages and larger sizes than the stand matrix. They may be the same species that dominate the main stand, but often are longer lived associated species. Reserves can be retained in even-aged and uneven-aged stands. In even-aged management, reserve trees function as stand legacies, providing an ecological connection between stands (developmental stages). Depending on management objectives, reserve trees may be harvested or retained to live out their natural lifespan.

Reserves can be uniformly or irregularly distributed individual trees, small groups, larger patches (usually <2 acres, based on DNR Recon protocol), or any mixture thereof. Reserve trees should not significantly inhibit the vigor of the younger stand. In general, the canopy cover of reserve trees should be maintained below 20% to limit excessive shading.

Big tree silviculture is applied to develop specific reserve tree characteristics which are a subset of potential conditions developed through standard reserve tree management.

- BTS applies to reserve tree management in even-aged or two-aged stands; it does not apply to reserves in uneven-aged management.
- BTS is restricted to species and sites where relatively long-lived, large diameter trees can be grown
- BTS reserve trees will be retained until they near senescence (approach biological maturity) or longer. Some trees will be retained to live out their natural lifespan and to produce large diameter snags and coarse woody debris.

For big tree silviculture, reserve trees are expected to continue to grow and to survive, so they should be vigorous trees, relatively long-lived species, and growing on sites that can support continued growth and the development of large trees.

Big Tree Silviculture – Potential Reserve Tree Species by Site Types	
Habitat Type Groups (site types)	Reserve Tree Species
Dry	Red pine, White pine
Dry-mesic	Red pine, White pine, White spruce, Oaks (red, white, bur)
Mesic	White pine, White spruce, Oaks (red, white, bur), Shagbark hickory, Basswood, Sugar maple, Beech, Yellow birch, Hemlock
Wet-mesic	White pine, White spruce, Swamp white oak, Yellow birch, Hemlock, Cedar

Wet	White pine, Swamp white oak, Hemlock, Cedar

Within this guide, see Chapter 21, Natural Regeneration, and Chapter 24, Marking Guidelines, for additional discussion of reserve tree management. In addition, the forest cover type chapters provide species specific information applicable to reserve tree management.

Previous View

Chapter 62

Economic Considerations

WISCONSIN
DEPT. OF NATURAL RESOURCES

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1. INTRODUCTION

1.1 Goal of chapter

The goal of this chapter is to review economic aspects of forest management in order to more fully integrate them with ecological and social aspects of management in Wisconsin. The considerations presented will assist foresters in understanding economic aspects of management when writing and implementing forest plans and designing and implementing harvests. These economic considerations are intended to be used in combination with WDNR silviculture and forest management guidelines to address integrated resource management objectives. This chapter does not attempt to explain all aspects of forest economics or recommend specific management actions but is limited to defining general forest economics subjects that are relevant to silviculture in Wisconsin. Not all management that is financially attractive is sustainable. The Wisconsin Forest Management Guidelines (WDNR, 2011) provide a more comprehensive overview of additional forest economics topics to assist in private land management.

1.2 Overview

Forest management practices are prescribed to satisfy sustainable landowner goals and achieve stand or property level objectives. In forest management, individual trees, stands, and forests each have different kinds of benefits and values. The most easily recognized is the revenue generated when timber is harvested. Activities designed to achieve many management objectives can be costly and may not be undertaken by the landowner unless there is an offsetting revenue stream. Timber revenue creates an opportunity to achieve objectives. The economic benefits extend to the landowner, the logger, the mills, the local communities that receive tax revenue and the indirect benefits of forest industry employees spending their wages in the community. Protecting both short-term and long-term values and economic benefits ensures the sustainability of the forest industry in Wisconsin. This chapter will discuss factors that affect forest management including economic rotation age, economic considerations of even versus uneven aged management, product considerations, access to markets, non-timber forest resources, and the forestry value chain. The chapter is designed as an introduction to basic forest economic concepts, with additional resources listed in the reference section.

A fundamental question in forest management is when to harvest trees. With even-aged management, this question becomes “what is the optimal rotation age?” The economic rotation age maximizes the net present value of the stand and forest type being considered. The economic rotation age may consider only financial returns but could also include non-timber benefits. Adding non-timber benefits may more accurately reflect landowner objectives, especially when the objectives are not easily quantified. The components of an economic rotation are discussed in section 2.

Forestry textbooks that discuss even versus uneven aged management often assume that even aged management leads to higher timber volumes and net present values based on financial returns. This is not always the case and depending on the species uneven aged stands managed in a steady state can provide better long run returns and higher quality trees. Section 3 will explain the importance of several key economic differences between even and uneven aged stands.

Quality forest products have historically demanded higher prices in the market. It is important to understand what markets are available and to plan harvests that utilize current markets and consider future markets when considering long term management. Log grade is one measure to determine the quality and value of a tree. Section 4 will discuss the basics of log grading and market considerations.

There are many things that affect the financial returns on a timber sale. Access to markets, including the distance to the nearest mill and the marketability of the species, are two of many factors affecting timber prices. Forest landowners must have access to markets for their wood products if these lands are to remain financially productive. Section 5 will discuss the basics of market access and the importance of considering potential markets for trees.

The final section will look at valuing non-timber resources. Most discussions on forest economics focus on timber resources. But non-timber forest resources such as wildlife habitat or recreation may provide value to landowners. Section 6 will briefly discuss the economics of valuing non-timber forest resources.

The final section will look at the role of forest economics in the value chain. Forest economics is a consideration by landowners, loggers, log buyers, truckers, primary and secondary processors and communities.

2. ECONOMIC ROTATION

2.1 What is economic rotation

The economic rotation age is that which maximizes the net present value (NPV) or willingness to pay for bare land, of a stand managed with an even aged regeneration system. The economic rotation age must compare the annual growth in timber value against the cost of holding the timber for an extra year. It must consider the marginal benefits and marginal costs of growing the forest one additional year.

2.2 Components of economic rotation

The economic rotation is the rotation age that maximizes the net present value. Calculating the economic rotation age requires knowledge of the various cash flows associated with a single or multiple rotations of a stand. One complication in determining economic rotation age is that the timing of a cost or revenue can have a large effect on the value of the cost or revenue. To determine the net present value, all the costs and revenues of owning the forest are discounted back to the present year. The formulas used to discount costs and revenues to the present are presented in Appendix B. This section will look at seven types of costs and revenues that influence the economic rotation age:

- establishment costs (e.g., site preparation, tree planting, etc.)
- annual costs of ownership and management
- annual stand growth and log grade changes
- current and future timber prices
- revenue from commercial thinning
- revenue from harvest
- discount rate

2.2.1 Establishment costs

Site preparation and reforestation costs vary by location, current stand conditions, prior stand history, landowner preferences, desired future stand objectives and budget. For a reforestation investment to be financially viable, the present value of the estimated future returns must exceed the cost of reforestation. High reforestation costs generally do not change the economic rotation age of a forest but may decrease the overall returns if there is not a subsequent increase in revenue when the trees are harvested. The cost of regeneration and site preparation methods needs to be compared to the future yield and quality of the forest. For example if it costs $300 per acre to seed or plant a jack pine stand versus natural regeneration, assuming a 50 year rotation and a 4% discount rate (Section 2.2.7) you need to earn $2100 more per acre at harvest to pay for the establishment costs. A present value is a value that is expressed in terms of dollars received immediately. A future value is a value that is expressed in terms of dollars received at some future time. In this case, it is a future value being calculated ($2100 additional future dollars) and the additional amount of income needed per acre to offset the planting costs, assuming all other factors (annual costs, growth rates, timber prices, etc.) are the same.

The additional income needed to offset various planting costs is shown in Table 62.1. A recent study by the Michigan DNR found that successful natural regeneration on a red pine stand costs about $60/acre while planting averaged $230/acre. However, a failed natural regeneration costs $400/acre. This is due to the cost of regeneration surveys, additional administration expenses and additional roller chopping and/or herbicide site preparation.

Table 62.1 The future value of establishment costs for a Michigan jack pine stand.

	Additional income needed at harvest to offset planting costs		
Establishment cost (per acre)	Rotation age 50	Rotation age 60	Rotation age 70
$100	$711	$1,052	$1,557
$200	$1,421	$2,104	$3,114
$300	$2,132	$3,156	$4,671
$400	$2,843	$4,208	$6,229
$500	$3,553	$5,260	$7,786

2.2.2 Annual costs

Annual costs may include property taxes, certification, fertilization, management services (i.e. management planning, value estimation, etc.), fire protection, stand maintenance or other activities. Annual revenues may include money received from selling non-timber forest products or payments for ecosystem services, which may include incentives provided to landowners. The revenues can be actual or anticipated. Due to compounding of money, minimizing annual costs or maximizing annual revenues is often the best way to increase returns to a forest stand. High annual costs shorten the economic rotation age, decrease the total returns on the stand, and may cause the landowner to choose a less costly and less productive silvicultural alternative.

Example: Lands enrolled in MFL incur lower property taxes than lands not enrolled in MFL. A red pine plantation that is enrolled in MFL and pays $11/acre in taxes has an economic rotation age of 57 years and a NPV of $755/acre. The same plantation that is not enrolled in MFL and pays $35/acre in taxes has an economic rotation of 51 years and a NPV of $277/acre. High annual costs shorten the economic rotation age and decrease the total returns on the stand.

2.2.3 Current and future timber prices

Future log and pulpwood prices can be calculated by inflating current prices and modified if there is an expectation of a price increase or decrease for a tree species or a management practice. For instance, a landowner may think certified wood will receive a price premium or a specific species will be in higher demand. Log prices are determined by wood availability, consumer preferences and other market fluctuations outside the control of foresters. Higher expected timber prices generally lengthen the economic rotation age. Timber Mart North is a popular document for tracking current timber prices.

Example 1: Since 1996, prices for red pine have fluctuated from $29-$80/ cord and $90-$200/mbf (Prentiss and Carlisle, 2014). If we assume the property is enrolled in MFL, a 4% rate of return and that the stand will receive 4 thinnings beginning in year 27, the economic rotation age ranges from 57 to 75 years. If we receive the lowest prices at the final harvest and the intermediate thinnings, the rotation age is 57 years and the NPV is $804/acre. If we assume we will receive the highest prices at the final rotation and the intermediate thinnings, the rotation age is 75 years and the NPV is $2,543/acre.

2.2.4 Annual growth and log grade changes

As trees age, they grow both in height and diameter. As such, their total volume increases, usually making them more valuable. Trees may be worth more per unit volume as they increase from lower value to higher value products. Foresters can help maximize growth through forest management actions such as timber stand improvement practices and intermediate thinnings. Well managed stands that maximize their annual growth are often higher in value than unmanaged stands. Annual growth is used to calculate the mean annual increment (MAI), periodic annual increment (PAI), and biological rotation ages.

As trees increase in size, some logs may be moved into a higher grade. If a tree is close to the next grade it may be economical to postpone harvesting it until the next stand entry. Table 62.2 demonstrates the relationship between grade change and value increase for a red oak tree. Where a grade change occurs, the rate of return for postponing harvest is relatively large. But unless a grade change occurs in the most valuable portion of the tree, the rate of return for postponing harvest can be quite low. Table 62.2 demonstrates the change in rates of return as a tree moves up in grade. In Table 62.1, the rate of return on the entire tree is 4.5%, demonstrating the importance of the value change for the butt log. In a situation like this, where (a) the rate of return in the butt log is low, (b) the grade change for upper portions is uncertain and (c) holding the tree another 10 years increases risk to the valuable butt log, the economic forester may very well decide that postponing harvest is not the most rational course of action.

Table 62.2 Relationship between grade change, value increase, and rates of return in a red oak tree

Year 1	Year 10	Internal Rate of Return	Value Increase
6” pulp stick, .024 cord, $0.12	8” sawbolt, 10 board feet, $1.00	23.5%	$0.88
8” sawbolt	10” grade 2 log, 30 board feet, $8.82	24%	$7.82
10” grade 2 log	12” grade 1 log, 40 board feet, $19.00	8.0%	$10.18
12” grade 1 log	14”veneer log, 60 board feet, $46.20	9.5%	$27.20
14” veneer log	16” prime veneer log, 80 board feet, $97.44	8.0%	$51.24
16” prime veneer log	18” prime veneer log, 110 board feet, $133.98	3.0%	$36.54
18” prime veneer log	20” prime veneer log, 140 board feet, $170.52	2.5%	$36.54
Change in entire tree		4.5%	$124.40

Source: WDNR, 2011

Each wood using industry has preferences and specifications. At some point trees can lose value if they decrease in quality or exceed the mills maximum size requirements. Most mills will accept large diameter logs but there may be quality challenges due to site conditions or past stand management. Managing a forest to improve growth, vigor, quality and diversity usually maximizes financial returns. It is also important to consider the impact of harvesting an individual tree on the stand-level management objectives. While individual tree rates of return may be a consideration, this information needs to evaluated in the context of stand-level management objectives.

2.2.5 Revenue from commercial thinning

When modelling a stand, the revenues from thinning are discounted back to the present time from the year they occur and the revenues are assumed to be reinvested (back in forestry or in an alternative investment) at the assumed discount rate. Thinnings generally do not change the economic rotation age but will increase the NPV of the stand by providing intermediate income, higher quality trees and higher merchantable stand volume. Table 62.3 demonstrates the difference in NPV (assuming a 4% discount rate) for thinned and un-thinned conifer and mixed wood stands in Maine.

Table 62.3 Net present value of thinned and unthinned stands in Maine

Site Index	Stand Type	Thinning	NPV
60	Pure Conifer	No	$834-$1116
		Yes	$1022-$1457
	Mixed Forest	No	$825-$1093
		Yes	$928-$1463
80	Pure Conifer	No	$1531-$1821
		Yes	$1846-$2679
	Mixed Forest	No	$1470-$1771
		Yes	$1754-$2665

Source: Saunders, et al, 2008

2.2.6 Revenue from harvest

The revenue from harvest is determined by tree, stand and market characteristics. Tree characteristics include the species, quality, and size (diameter and height). Stand characteristics include the type of silviculture system and type of harvest (Ex. clear cutting versus shelterwood or single-tree selection), harvest volume, site accessibility, and distance to market. Market characteristics include current demand for the products, what mills are currently accepting, currency exchange rates and other factors. Demand changes may be due to change in consumer preferences or the general strength of the economy and these can be difficult to predict when trying to determine economic rotation age. Most forestry costs increase along with the inflation rate but stumpage prices may increase or decrease at other rates as supply and demand change. For example, a red maple stand with a 20% lower stumpage price than expected lowers the NPV by 15% and the economic rotation age by 9 years. This assumes a landowner is enrolled in MFL, a discount rate of 4% and all other costs and benefits being equal under both stumpage prices.

2.2.7 Discount rate

The discount rate is the most critical component in understanding forest economics, economic rotation ages and net present values. Most individuals feel a dollar received today is worth more than a dollar to be received in the future. The discount rate is the rate at which future values are discounted to the present. The higher the discount rate, the lower the present value of the forest.

Discount rates can be expressed in either real or nominal terms. A real discount rate has been adjusted for inflation while a nominal discount rate includes inflation. For example, if the nominal rate is 8 percent and the inflation rate is 2 percent, the correct way to convert the nominal rate is $(1.08/1.02)-1 = .0588$ = a real discount rate of 5.88%. Most forestry analyses are conducted using real discount rates, but use of nominal rates is acceptable. The key is to match the type of cash flow with the type of discount rate, i.e. if a real rate is used, cash flows should be inflation-adjusted.

Landowners decide on a discount rate by considering their alternative rate of return. That is, if they did not invest in forestry, what rate of return could they earn in an alternative investment? The rate of return is higher or lower depending on the riskiness of the investment. Investors require higher rates of return to take on greater risk. Landowners must decide on a forestry discount rate by considering the rate of return they could achieve in alternative investments, but adjusting for the riskiness of forestry compared to the riskiness of the alternative investments. If forestry is judged to be less risky than the alternative investment, then the forestry discount rate might be set lower than the alternative rate of return, and of course vice versa.

Risk can be divided into two components: market or unique. Market risk is the degree of sensitivity of the investment to the market as a whole and influenced by interest rate changes, general price swings, and demand for the product. Unique risk is the portion of risk specific to the product and includes fire and wind damage, changes in intrinsic values of the forest, poor silviculture, or changes to preferences for certified wood.

Companies and individuals have a discount rate they apply to revenue and expense decisions but these change as the economy changes. Today real discount rates for forestry are generally between 3-7%. At the WDNR we generally use a real discount rate of 4%. In a red pine stand with four thinnings the economic rotation age varies from 51-100 years based on a real discount rate of 3-5% as shown in Table 62.4. The table below is based on a single red pine stand and individual stands would produce different rotation ages.

Table 62.4 Net present value per acre of a red pine stand at various discount rates*

		Discount rate		
		3%	4%	5%
Rotation age	50	$1,370	$895	$588
	70	$1,523	$913	$561
	100	$1,614	$877	$510
Economic rotation age		100 years	74 years	51 years

*This assumes a price of $36/cord and $144/mbf, annual costs of $4, and thinnings at 27, 37, 47 and 62 years and 1/3 of the timber cut at each thinning.

As a stand ages the timber value growth declines. A rational investor chooses to harvest when the timber value growth is equal to the chosen discount rate. Harvesting when timber is growing faster than the discount rate is not maximizing returns because you are still earning more than alternative investments. Harvesting timber when the timber value growth is lower than the discount rate means you are not maximizing returns as you are better off to cut the trees and invest them in an alternative investment. Figure 62.1 demonstrates the relationship between timber value growth, age of the stand and the discount rate.

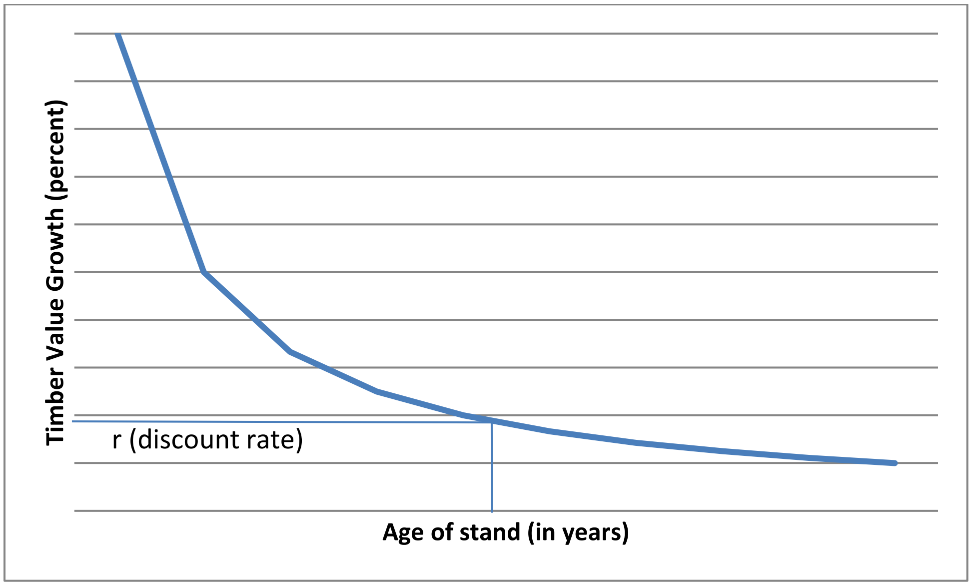

Figure 62.1 Economic rotation

3. BIOLOGICAL VERSUS ECONOMIC ROTATION

The rotation age that maximizes the mean annual increment (MAI) is defined as the biological rotation. The biological rotation age seeks to maximize the long-term sustained yield (i.e., volume yield over multiple rotations) from a forest. In general, biological rotations do not consider financial costs and benefits of harvesting and are unlikely to maximize economic returns on the forest investment while economic rotations may not yield the highest ecological or social benefits. Stands may also be managed on an extended rotation which does not maximize the financial rotation but may provide other ecological benefits. Each rotation has various costs and benefits. The rotation age should be based on landowner objectives. If a tree has reached financial maturity, carrying it until the next entry causes a loss in value due to discount rates and risk of it losing value. In most cases the maximum NPV and MAI are not sharp peaks with steep declines on either side of the maximum but usually a gradual plateau. The gradual plateau allows for flexibility in interpreting the most efficient rotation. Figure 62.2 illustrates the biological rotation that maximizes MAI and the economic rotation that maximizes NPV. An extended rotation generally does not maximize financial benefits but may reflect other landowner objectives.

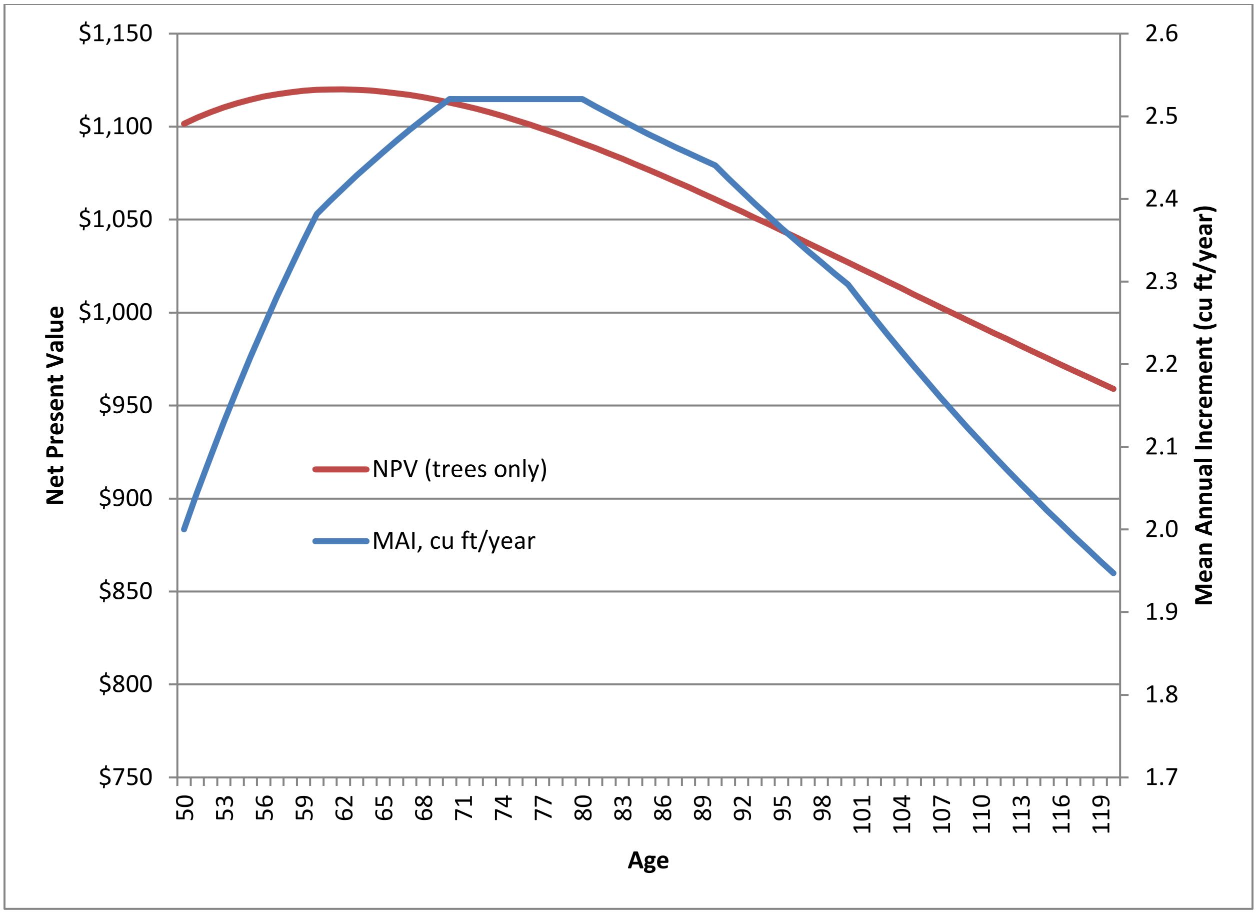

Figure 62.2 Biological versus economic rotation age

4. ECONOMICS OF UNEVEN AGED MANAGEMENT

The economic goal of uneven aged management is a steady state which can provide stable returns indefinitely. In a steady state, the present value of the harvest is directly proportional to the periodic value of the harvest. The most important economic consideration is to leave desirable species and grades in each cut, specifically trees with the highest potential to increase in value. Ideally the rate of increase for each tree in the stand should be greater than the alternative rate of return. Steady economic returns are important in even aged management as well and it is important to consider both the NPV and the long run steady returns from a stand.

Existing studies provide evidence that uneven aged management can provide economics returns that are similar to even aged management. Studies have shown that partial cutting can provide steady, long-term rates of return between 4 and 6 percent (Buongiorno et al, 1994; McCauley and Trimble 1972; Miller, 1991; and Reed et al, 1986). The key economic considerations in uneven aged management are the distribution of trees by size (or age) and the frequency of harvests. Uneven aged management is characterized by periodic harvesting and any economic analysis should consider the frequency of harvests and how much of the stand should be harvested at each entry.

5. PRODUCT CONSIDERATIONS

Higher quality products usually command higher prices in the market. Log and lumber grades are as important as volume in the economics of producing sawlogs. There is a relationship between log and lumber grades. Log grades for softwood and hardwood lumber start with the same general steps:

1) Establish four grading faces
2) Determine number and length of clear cuttings on each face
3) Determine grade based on second worst face

Most log grading focuses on identifying veneer and the rest is identified as sawlog although in reality there are three USFS hardwood log grades (F1, F2, F3) and two softwood grades. Veneer is not an official USFS grade but is important. For more information on log grading the USFS offers several publications (Rast, et al, 1973, Hanks et al, 1980). USFS log grades are not commonly used throughout Wisconsin and often the Northern Hardwood Log Grading Rules published by Great Lakes Timber Professionals Association are more common.

The hardwood and softwood log grades have sometimes been applied to logs in standing trees. Problems often are encountered when estimating bark diameters and other factors. These difficulties are compounded when trying to grade the upper logs. An alternative to grading logs in standing trees is available in several publications (Miller and Hanks, 1986; and Brisbin and Sonderman, 1971). It presents a system of tree grades that only require consideration of the butt log.

USFS log grades are used to predict the yield of lumber by grade. The National Hardwood Lumber Association (NHLA) established yield tables that predict the volume of lumber by USFS grade, species and diameter class. NHLA lumber grades are based on the minimum size of the board, the size cutting permitted, the maximum number of cuttings permitted and the area of the board required in clear face cuttings. There are five NHLA hardwood lumber grades: FAS, selects, 1, 2 and 3. Softwoods lumber grades were established by the American Softwood Lumber Standard. Softwood lumber grades can be classified into three major categories of use: yard lumber, structural lumber, and factory and shop lumber. More information on lumber grades is available from the USFS (McDonald and Krestchmann, 1999) and UW-Extension (Govett, 2008).

It is important to consider log and tree grades when evaluating the economics of a stand. If you are unsure, it is important to find a training session in your area to learn more about the factors involved in determining log and tree grades.

It is important to manage for short and long term markets. It is also important to manage for quality and quantity but to achieve this goal it helps to understand what the local markets are currently accepting. Preferences for certain species change over time and impact the price mills are willing to pay. Researching local markets will help to maximize economic returns for landowners.

6. ACCESS TO MARKETS

There are many things that affect the bid price on a forest. Access to markets, including distance to the nearest mill, access within the property, seasonality and the marketability of the species all influence bid prices. Access to markets varies depending on location in the state. Currently, landowners in Northeast Wisconsin are closer to a variety of local mills than landowners in Southwestern Wisconsin. Mills buy a diversity of tree species and size classes and being closer to a variety of mills provides more opportunities and often higher returns for landowners. Bid prices are also influenced by fuel prices as they affect the cost of running equipment in the woods and the cost to transport the logs to the mill. Landowners that are further from mills will be impacted by an increase in transportation costs.

Optimizing efficiencies in the woods will lower costs and increases the returns on the forestry investment. Access within the property helps increase the timber sale marketability. Having established roads or trails reduces logging costs. The distance from the landing to the logging site is important, generally distances over ½ mile lower stumpage prices. An established landing saves the logger time and leads to more competitive bids. The topography of the site affects the overall returns on the forest. Sites with well-drained soils on level terrain are easier to operate compared to wet, steep or rocky sites which lead to slower machine operation and higher machine maintenance costs.

Access issues are not limited to terrain or distance from mills. Access can also be a seasonal issue. When considering the seasonality of a sale, factors such as seasonal hunting restrictions, frozen ground restrictions, the presence of threatened, rare or endangered species, archeological sites, oak wilt restrictions or other constraints can limit the opportunity to harvest and may result in lower bids.

Often a timber sale prospectus will include details that may lead to lower bids for the landowner. A prospectus or contract may include seasonal hunting limitations or language that limits harvesting to “frozen ground only”. Removing broad seasonal restrictions and allowing harvests on “frozen or dry” ground may garner higher bids.

7. VALUING NON-TIMBER FOREST RESOURCES

Forests are often valued for their non-timber resources such as wildlife habitat or recreation. Valuing non-timber resources is generally expressed as an annual dollar benefit. The WDNR forest management guidelines state that “There are many benefits from owning and managing forests. Stocks and bonds are usually purchased for the sole purpose of making money, and their financial performance is judged on that basis alone. But forests are more than mere collections of trees, and landowners benefit from a wide array of non-timber goods and services like berries and mushrooms, recreational enjoyment, aesthetics, water quality, and wildlife. Some of these are traded in the marketplace, for example income from leasing hunting rights, but most are not, and there is no easy way to determine their value to the landowner. These non-market benefits can have significant value though, as evidenced by the prices paid for forestland. Even land that is a long distance from a population center and has no unusual attractions, such as lakes or streams, will typically be bought and sold for much more than its value for timber production alone. Investment analysis that focuses only on costs and returns from timber production will ignore important non-market benefits, and will provide an incomplete measure of total investment performance” (WDNR, 2011).

Non-timber values are generally defined as direct, indirect and existence values. Direct use values are things that involve direct human interaction. For example, non-timber forest products, recreation and hunting are all direct use values. Indirect use refers to values that do not require human involvement. Existence values are the values that people have for non-timber resources existing. Existence values are often cultural uses or the importance of places. Most non-timber forest valuation focuses on direct and indirect use values. Not considering the non-timber values can create problems with inefficient allocation of resources or uninformed management decisions.

8. FOREST ECONOMICS IN VALUE CHAIN

The forest industry has an extensive history in Wisconsin and to continue forestry in the future we need to maintain economically-viable and ecologically sustainable returns. Forest economics can help make fully informed management decisions for landowners, loggers, log buyers, truckers, primary and secondary processors and communities.

8.1 Landowners

Forest landowners are the base of the economic chain. Private forest land owners may work with foresters to develop forest management plans and conduct timber sales. The timber sales can be purchased by loggers, timber haulers, primary processors, and even secondary processors. After the sale is purchased a logger harvests the selected trees, a timber hauler delivers them to a mill, which processes the logs into any of several possible products. At all stages of the value-chain the owner of the timber or logs tries to steer the products into their highest value use. This optimization is unique for everyone as costs and benefits are different and units may be difficult to define. Foresters can help by looking for ways to remain flexible in writing and interpreting management plans, lay out of harvests and working with members of the forest industry.

Landowners usually consider long and short term costs and benefits. Landowners, even those that derive other benefits from the forests, may hope to receive a financial return. Small landowners may not have maximizing financial returns as their primary goal but they often cannot afford to own forest land and practice sound management without a modest return for their effort. By understanding forest economics, landowners may be able to meet other ownership and management objectives (for example, invest financial returns into habitat management). For industrial owners, maximizing returns is usually the primary management objective. The returns on the forest are influenced by the landowner objectives and may vary due to the size of the forest, access, available capital, silvicultural methods, and expected services. Managing forests as cost-effectively as possible requires an understanding of the financial aspects of decisions.

8.2 Loggers

A significant cost in the forestry value chain is the costs associated with harvesting and transporting the wood. A forester is a key part of helping minimize costs associated with harvesting and transporting. Inaccurate cruises, inappropriate harvesting restrictions, poor harvest layouts or access issues all lead to higher costs to the logger and lower returns to the logger and landowner. A recent study found that harvesting in the Lake States was 34-37% of the total supply chain costs (Gibeault and Coutu, 2014). The study also found transportation costs averaged $0.19 per ton per mile in the Lake States and account for 27% of the supply chain costs. Haul distances in the Lake States averaged 106 miles for conifer, 114 miles for hardwood and 72 miles for aspen (Gibeault and Coutu, 2014 and Baker et. al., 2013).

A 2013 study of felling productivity in Minnesota found that for every 1% increase in volume of merchantable timber, productivity increased 0.3% (Goychuk, et. al., 2011). The study also found that skidding productivity was improved by increases in the number and size of skid trails and landings and the shape of the tract.

Loggers have money tied up in capital expenses and they need the equipment running all year in order to afford to continue operating and have money available for other investments such as purchasing stumpage. A study of Wisconsin loggers found the median capital investment was $223,000 and the most productive operations (more than 15,000 cords per year) had median capital investments of $2 million (Rickenbach, et. al. , 2015).

8.3 Mills

Wisconsin has almost 1,300 forest products companies and 92% of the wood harvested in Wisconsin is used by Wisconsin manufacturers. Capital investment in sawmills and paper mills continues to increase. Mills need a steady sustainable source of wood to continue operations by maintaining equipment and investing in upgrades. The cost of an average paper mill is $1 billion. The annual capital investment in the US paper industry averages $10 billion/year (Glass, 2014). In 2013, the US paper industry spent $6.2 billion on capital investments and the wood products industry spent $3.6 billion. The paper industry is the most capital intensive industry in the nation. Understanding what mills will accept and ensuring that they have a year round supply of wood helps protect the jobs of the 55,000 people employed in paper and wood products mills in Wisconsin.

8.4 Communities

Forestry is important to rural communities. It provides jobs, forest industry employees spend money in local businesses and communities rely on tax revenue. The forest industry employs almost 60,000 people in Wisconsin. They earn $3.6 billion in wages and the money they spend in their communities supports schools, hospitals, retail, restaurants, and other services. County forest timber sale revenues are used to offset local tax levies. Lands enrolled in MFL receive a reduced property tax and in return they pay a yield tax when they harvest. The yield tax is returned to counties and municipalities. The yield tax brings in approximately $1.5 million a year in Wisconsin and the municipality where the timber was harvested receives 80% while the county receives the remaining 20%. The rates for the yield tax are based on the species and products harvested. In addition, local communities rely on a sustained yield of products from the local forests. Healthy, well managed forests provide more economic benefits to a community than degraded, unmanaged forests.

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10. APPENDIX A- GLOSSARY

Ad Valorem Tax-a tax levied as a percentage of asset value

Allowable cut-volume of timber that may be harvested during a given period to maintain sustained production

Allowable-cut effect-allocation of anticipated future forest timber yields to the present allowable cut; this is employed to increase current harvest levels (especially when constrained by evenflow) by spreading anticipated future growth over all the years in the rotation

Alternative rate of return-the percent rate of return on capital in an investor's best alternative.

Amortization-the process of gradually reducing some monetary amount over time, can referrer to income tax calculations where some cost is gradually deducted over time.

Annualized cost (or revenue)-an equal annual payment with the same present value as payments that are not annual. May be calculated for a fixed or infinite time horizon

Annuity-equal payments at regular intervals (for example monthly or yearly)

Appraisal-the procedure for finding market value of an asset

Benefit-cost ratio- ratio obtained by dividing the anticipated benefits of a project by its anticipated costs. Either gross or net benefits may be used as the numerator

Bequest value-our willingness to pay for the opportunity to transfer resources to future generations

Biological rotation-a rotation age based on a biological, not economical, criterion and is usually based on maximum mean annual increment

Board foot-unit of measurement represented by a 12- by 12- by 1-inch unfinished board

Capital-Plant, equipment, and related facilities used to produce goods and services

Capital budgeting-deciding how to invest money, the capital budget sot that its value to the investor is maximized

Capital gain-difference between the sale prices and the purchase cost of an asset.

Capitalization rate-see discount rate

Capitalize-to find the present value or to discount. In income tax calculations it means to carry forward ta capital expense and deduct it form sale proceeds of an asset to find taxable income

Commercial thinning-partial harvesting of a stand of trees for economic gains from the harvested trees and to accelerate the growth of the trees left standing

Commercial timber-standing timber that can be sold for wood products and is available for harvest

Compound interest-earnings accruing as a percentage of capital value such that earnings occur on the original capital and on all previous earnings

Compounding-refers to the process whereby a current capital investment (present value) grows over time to a larger future value

Constant dollars-values expressed in real dollars of some base year, excluding inflation

Consumer price index (CPI)-an index of average prices for a typical market basket of consumer goods. The index is set at 100 for a specified base year. The annual rate of change in the CPI is the inflation rate for consumer goods.

Contingent valuation-a way to value nonmarket good and services by asking users the maximum amount they would be willing to pay for them (willingness to pay_ or the minimum compensation they'd require to willingly give them up (willingness to sell).

Cost of capital-the interest rate firms pay on capital raised for investment

Current dollars-values in dollars of the year in which they actually occur, including inflation. Also known as nominal dollars

Cutting cycle-In uneven aged management, the number of years between partial cuts

Deflate-to deflate a current dollar value means to express it in constant dollars of a base year n, removing inflation

Depletion-in income tax calculation, the deduction made for original purchase cost when assets are sold

Depreciation-an account charge for the wearing out of assets

Direct effects-income and employment resulting directly from constructing and operating a project

Discount rate-The interest rate at which future values are discounted to present values

Discounted cash flow-In evaluating investment opportunities, the various costs and benefits anticipated in future years discounted to the present. These values are expressed by either (a) their difference, giving a net present value, b) the benefit-cost ratio, or (c) calculating the discount rate that equates them, giving the internal rate of return

Discounting-the process whereby a future value is reduced to arrive at the present value

Economics-the study of how best to allocate or distribute resources to maximize human well-being

Equity-the portion of a firm's assets on which no debt is owed to creditors

Even aged-refers to forest in which trees have been established at about the same time and are thus roughly the same age

Existence value-consumers' willingness to pay for the assurance that something remains in existence, even if they may never use it

Expected value-the sum of the possible values multiplied by their probabilities of occurrence (usually used to refer to an expected cost or expected revenue)

Expensing-In income tax calculation, the practice of deducting or subtracting allowable costs from income to arrive at the taxable income

Fee timber-timber that a firm owns outright on its lands, derived from the legal term, "ownership in fee simple"

Financial maturity- the age beyond which an assets' growth rate is unacceptable or less than the owner's minimum acceptable rate of return. Can refer to a forest or individual trees

Financial rotation-rotation of tree crops determined solely by financial considerations (which are related to biological production potential) in order to obtain the highest monetary values over time, in terms of optimum net present value

Fixed costs-costs that remain fixed as a firm's output increases

Forest value growth percent-annual percent rate of change in the liquidation value of trees and land

Future value-the value of any income or wealth accumulated with compound interest to a specified future date

Gross domestic product (GDP)-the market value of all goods and services produced by residents of a nation in a year, excludes income of residents

Holding value-the owner's net present value of future cash flows from an asset

Hurdle rate-a minimum acceptable rate of return or hurdle that new investments must clear before they are acceptable to an investor

Indirect effects- The impact of local industries buying goods and services from other local industries.

Induced effects-The effect of income spent by employees

Impacts-total changes to the economy as a result of an event. Impacts=direct effects+ indirect effects+ induced effects

Inflation-a general increase in prices of all goods and services in an economy, usually expressed as an inflation rate.

Input output analysis-a technique for measuring interdependencies between different sectors of an economy and making economic forecasts

Interest- the payment made to lenders of money, often expressed as an interest rate

Internal rate of return-for a given project, the interest rate at which the present value of revenues equals the present value of costs

Machine rate-cost per unit of time for owning and operating a logging machine or other piece of equipment

Managed forest law- a landowner incentive program that encourages sustainable forestry on private woodlands in Wisconsin

Marginal-in economics, added or extra, as opposed to total

Mean annual increment-average annual timber volume growth per unit area

Minimum acceptable rate of return-the lowest rate of return that will induce an investor to willingly invest

Model-a simplified representation of an actual process, situation or object

Multiplier effect-the multiplied amounts of income, employment or sales beyond the initial amounts. For example a 1.5 multiplier on employment means that for every 100 employees another 50 people are employed due to indirect or induced effects

Net income-total revenue minus total cost (usually synonymous with profit)

Net present value-present value of future revenues minus present value of future costs

Nominal-with respect to values or rates of return, in current dollars, including inflation

Nonmarket-not traded in the market for a price

Pareto optimum-a resource allocation where no change can make anyone better off without making someone else worse off

Payback period-the number of years it takes to recover the final capital invested in a project

Periodic-occurring at regular intervals of more than one year (in this chapter)

Present value-any future value discount to a present value. Discounting is the reverse of compounding

Producer price index (PPI)- an index of average prices for a mix of industrial outputs, excluding services for each year. The index is set to 100 for a base year.

Property tax-an annual tax levied as a percentage of property value.

Public good-a good or service not easily parceled out and sold. You can't exclude those who don't pay for the good from receiving its benefits.

Rate of return-earnings on capital

Real-with respect to monetary values, excluding inflation

Regeneration-process by which trees are reestablished

Reinvestment rate-the rate of return at which you assume future income from a project could be reinvested

Reservation price-the minimum stumpage price that will induce a forest owner to sell or plant forest

Risk-the variation in expected cash flow. The possibility of loss

Risk adjusted discount rate-the interest rate for discounting risky cash flows

Rotation-age, in years, at which timber is harvested

Roundwood-harvested wood in round or log form

Sawtimber-live trees capable of yielding sawlogs

Short run-in economics, the period of time for which some inputs are fixed

Stumpage value-the estimated or actual amount that buyers would pay for standing timber

Sunk costs-costs that have already been incurred

Supply-in economics, supply refers to the quantities of a good or service that a producer or group of producers will supply per unit of time at different prices

Sustained yield-a commitment to continued long-term wood output through an even flow of timber

Trade-off-in a system of interrelated inputs and outputs, a trade-off refers to the process whereby changing one output can change other outputs

Utility-in economics, human satisfaction or well-being

Valuation-the procedure for finding an individual investor's value of an asset

Value added-the difference between the sale price of goods sold and cost of materials and supplies used in production

Variable costs-costs that change as a firms output changes

Willingness to pay-a maximum monetary amount an individual is willing to pay for good or service

Willingness to pay for land-starting with bare land, WPL is the net present value of all future expected cash flows discounted at some rate of return.

Yield tax-a tax levied as a percentage of harvested stumpage value

Source: Klemperer, 1996

11. APPENDIX B- FORMULAS

Table 62.5 Decision Tree for Present Value and Future Value Formulas

Number of Payments	Time Between Payments	Evaluation Period		Time of Value	Formula	Formula Name
One		Terminating		Future	$Vn = Vo(1+r)^n$	Future value of an amount
				Present	$Vo = \frac{Vn}{(1+r)^n}$	Present value of an amount
Series	Annual	Terminating		Future	$Vn = p\left[\frac{(1+r)^n - 1}{r}\right]$	Future value of a terminating annual series
				Present	$Vo = p\left[\frac{1-(1+r)^{-n}}{r}\right]$	Present Value of a terminating annual series
		Perpetual		Future	$Vn = infinity$	
				Present	$Vo = \frac{p}{r}$	Present value of a perpetual annual series
	Periodic	Terminating		Future	$Vn = p\left[\frac{(1+r)^n - 1}{(1+r)^t - 1}\right]$	Future Value of a terminating periodic series
				Present	$Vo = p\left[\frac{1-(1+r)^{-n}}{(1+r)^t - 1}\right]$	Present value of a terminating periodic series
		Perpetual		Future	$Vn = infinity$	
				Present	$Vo = \frac{p}{r(1+r)^t - 1}$	Present value of a perpetual periodic series (Faustmann Formula)

r		Annual interest rate/100
Vo		Present value (or initial value)
Vn		Future value after n years (including interest)
n		Number of years of compounding or discounting
P		Amount of fixed payment each time in a series (occurring annually or every t years)
t		Number of years between periodic occurrences of p

Source: Klemperer, 1996

APPENDIX A

GLOSSARY OF TERMS

Advance Regeneration (Reproduction): Seedlings or saplings that develop or are present in the understory in advance of rotation.

Afforestation: The practice of planting trees with the intent of creating a forest on presently non-forested land.

Artificial Regeneration: The establishment of young trees through planting seedlings or seed.

Basal Area: 1) The cross-sectional area of a single stem, including the bark, measured at breast height. 2) The cross-sectional area of all stems in a stand expressed per unit of land area.

Biological Diversity (Biodiversity): The spectrum of life forms and ecological processes that support and sustain them. Biological diversity occurs at four interacting levels: genetic, species, community, and ecosystem.

Biological Legacy: An organism, a reproductive portion of an organism, or a biologically derived structure or pattern inherited from a previous ecosystem. Biological legacies often include large trees, snags, and down logs left after harvesting to provide refugia and to structurally enrich the new stand.

Board Foot: The amount of wood contained in an unfinished board 1 in thick, 12 in long, and 12 in wide.

Canopy (Crown) Closure: The point at which the crown perimeters within a canopy touch.

Canopy (Crown) Cover: The ground area covered by the crowns of trees or woody vegetation as delimited by the vertical projection of crown perimeters and commonly expressed as a percent of total ground area.

Cavity (Den) Tree: A (partially) hollow tree potentially used by wildlife (e.g. shelter).

Cleaning: A release treatment made in an age class not past the sapling stage to free the favored trees from less desirable individuals of the same age class that overtop them or are likely to do so.

Clearcut: The removal in one operation of essentially all the trees in a stand.

Clearcut Regeneration Method: A silvicultural method designed to naturally regenerate a stand by the removal of most or all woody vegetation during harvest creating a completely open area leading to the establishment of an even-aged stand. Regeneration can be from natural seeding from adjacent stands or from trees cut in the harvest operation. Regeneration is established during or following stand removal.

Climax Forest: 1) An ecological community that represents the culminating stage of a natural forest succession for its environment. 2) Any forest capable of reproducing its own composition in the absence of severe disturbance. 3) A relatively stable and long-lived community that develops late in the course of vegetational development, in the absence of major exogenous disturbance, and on a specific site. It is a position of relative compositional stability, although change continues at a relatively slower pace.

Coarse Woody Debris (CWD): 1) Any piece(s) of dead woody material on the ground in forest stands or in streams. 2) Dead woody material, ≥ 4 inches diameter inside bark at the small end, on the ground in forest stands or in water.

Codominant Crown Class: A tree whose crown helps to form the general level of the main canopy, receiving full light from above and comparatively little from the sides.

Cohort: 1) An age group of individuals. 2) A group of individuals or vital statistics about them having a statistical factor in common, such as age class. 3) A group of trees developing after a single disturbance, or a cluster of disturbances occurring over a relatively short time period, commonly consisting of trees of similar age.

Community: 1) An assemblage of plants and animals living together and occupying a given area. 2) A group of human families.

Compartment: A portion of a forest under one ownership, usually contiguous and composed of a variety of forest stand types, defined for purposes of locational reference and as a basis for forest management.

Composition: 1) The constituent elements of an entity (e.g. the species that constitute a plant community). 2) The proportion of each tree species in a stand expressed as a percentage of the total number, basal area, or volume of all tree species in the stand.

Coppice Regeneration Method: A silvicultural method designed to naturally regenerate a stand using vegetative reproduction.

Cord: A stack of wood that measures 4 x 4 x 8 feet (128 ft^3).

Crop Tree: 1) Timber crop trees are trees selected to become a component of a future commercial harvest. 2) Sawtimber crop trees are the best quality, high vigor trees of desirable species that are targeted for (near) final harvest; they will be grown to rotation age or maximum desired size class.

Crown Class: A category of tree based on its crown position relative to those of adjacent trees.

Crown Thinning (High Thinning, Thinning From Above): The removal of trees from the dominant and codominant crown classes in order to favor the best trees of those same crown classes.

Cubic Foot: A unit of true volume that measures 1 x 1 x 1 ft.

Cull: Any item of production (e.g. trees, logs, lumber, seedlings) rejected because it does not meet certain specifications of usability or grade.

Cutting: 1) The felling of trees or stands. 2) A shoot, twig, or other plant part removed from a plant.

Cutting System: A method of cutting logs that determines the grade and size of lumber.

Cut-to-length Harvesting: A system in which felled trees are processed into log lengths at the stump before they are carried to the road or landing.

Deforestation: The removal of a forest stand where the land is put to a nonforest use.

Demographic Transition: A stage of stand structural development, following stem exclusion and preceding old multi-aged. The crowns of the trees are now large enough so that when one dies the surrounding trees cannot fill the gap. As a result, a new cohort of trees has space to enter the canopy. Trees from the original cohort become senescent. This stage lasts from the time the first trees younger than the disturbance cohort are able to grow into the canopy until the disturbance cohort no longer has a significant presence in the stand.

Diameter (at) Breast Height (DBH, dbh): The diameter of the stem of a tree measured at 4.5 ft. (1.37 m) from the ground (on the uphill side).

Diameter Limit Selective Cut: A selective cut of all merchantable trees greater than a specified diameter.

Dioecious: Pertaining to a species having male and female flowers (or strobili) produced on separate plants.

Disturbance: Any relatively discreet event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment.

Dominant Crown Class: A tree whose crown extends above the general level of the main canopy, receiving full light from above and partial light from the sides.

Dormancy: A condition in the life of an organism or its parts when a tissue predisposed to proliferate does not do so and visible growth and development are temporarily suspended.

Economic Clearcut: A clearcut that does not include a plan for regeneration.

Ecoregion: A contiguous geographic area having a relatively uniform macroclimate and used as an ecological basis for management or planning.

Ecosystem: A spatially explicit, relatively homogeneous unit of the earth that includes all interacting organisms and components of the abiotic environment within its boundaries.

Ecosystem Management: 1) WDNR: A system to assess, conserve, protect, and restore the composition, structure, and function of ecosystems, to ensure their sustainability across a range of temporal and spatial scales, and to provide desired ecological conditions, economic products, and social benefits. 2) Management guided by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on the best understanding of ecological interactions and processes necessary to sustain ecosystem composition, structure, and function over the long term.

Element Occurrence (EO): An area of land or water in which an element (a natural community, a rare plant population, a rare animal population, or other feature tracked by the Natural Heritage Inventory program) is, or was, present. For natural community elements, the EO may represent a stand or patch of a natural community, or a cluster of stands or patches of a natural community.

Endangered Species: 1) A species threatened with extinction throughout all or a significant portion of its range. 2) A species whose continued existence as a viable component of Wisconsin's wild animals or plants is determined to be in jeopardy on the basis of scientific evidence.

Endogenous: 1) Intrinsic, caused by internal factors. 2) Growing from or on the inside.

Epicormic Branch: A shoot arising spontaneously from an adventitious or dormant bud on the stem or branch of a woody plant often following exposure to increased light levels or fire.

Environment: The sum of all external conditions affecting the life, development, and survival of an organism.

Even-aged Stand: A stand where the trees have only small differences in their ages (a single age class). By convention, the spread of ages does not differ by more than 20% of the intended rotation.

Exogenous: 1) Extrinsic, originating from or due to external causes. 2) Growing from or on the outside.

Exotic (Nonnative): A species introduced from another country or geographic region outside its natural range (an exotic can become naturalized, i.e. establish, grow, reproduce, and maintain itself).

Extended Rotation Forest: Old forests which are dominated by trees older than their traditional rotation age yet younger than their pathological rotation age (average life expectancy), and are managed by objective for both commodity production and the development of some ecological and social benefits associated with older forests.

Fine Woody Debris (FWD): Dead woody material, <4 inches diameter inside bark at the large end, on the ground in forest stands or in water.

Fine Woody Material (FWM): Woody material, living or dead, <4 inches diameter inside bark at the large end; including fine woody debris and portions of standing living and dead shrubs and trees.

Forest: 1) An ecosystem characterized by a more or less dense and extensive tree cover, often consisting of stands varying in characteristics such as species composition, structure, age class, and associated processes, and commonly including meadows, streams, fish, and wildlife. 2) An organized assemblage of trees, other plants, and animals in complex association with each other and their physical environment.

Forest Cover Type: 1) A category of forest usually defined by its vegetation, particularly its dominant vegetation as based on percentage cover of trees. 2) The plant species forming a plurality of composition across a given area.

Forest Ecology: The science concerned with the forest as a biological community dominated by trees and other woody vegetation, the interrelationships between the various trees and other organisms constituting the community, and the interrelationships between the organisms and the physical environment in which they exist.

Forest Health: The perceived condition of a forest derived from concerns about such factors as its age, structure, composition, function, vigor, presence of unusual levels of insects or disease, and resilience to disturbance.

Forest Management: The practical application of biological, physical, quantitative, managerial, economic, social, and policy principles to the regeneration, management, utilization, and conservation of forests to meet specified goals and objectives while maintaining the productivity of the forest.

Forest Regulation: 1) The technical aspects of controlling stocking, harvests, growth, and yields to meet management objectives, including sustained yield. 2) The control of private forest management by exercise of public authority. 3) A legal enactment or ordinance affecting forests.

Free Thinning: The removal of trees to control stand spacing and favor desired crop trees, using a combination of thinning criteria without strict regard to crown position.

Free-To-Grow: A seedling or small tree free from direct competition from other trees, shrubs, grasses, or herbaceous plants.

Gap: The space occurring in forest stands due to individual or group tree mortality or blowdown.

Gap Dynamics: The change in space and time in the pattern, frequency, size, and successional processes of forest canopy gaps caused by the fall or death of one or more canopy trees.

Germination: The beginning of growth of a mature, generally dormant seed, spore, or pollen grain (for seed, generally characterized by rupture of the seed coat and the emergence of a radicle or plumule).

Germinative Capacity: The percent of seeds, spores, or pollen grains in a given sample that actually germinate irrespective of time.

Grading: The classification of logs, stems, lumber, or seedlings according to quality, value, potential use, or function.

Group Selection (see selection regeneration method): A regeneration method where regeneration is managed in group openings 0.1-0.5 acres in size (comprising part of a larger uneven-aged stand).

Growing Stock: All the trees growing in a forest or in a specific part of it, usually commercial species, meeting specified standards of size, quality, and vigor, and generally expressed in terms of number or volume.

Habitat: The place (environment) where an animal, plant, or population naturally or normally lives and develops.

Habitat Type: 1) A land or aquatic unit consisting of an aggregation of habitats having equivalent structure, function, and responses to disturbance. 2) An aggregation of units of land capable of producing similar plant communities at climax.

Habitat Type Classification System: A site classification system based on the floristic composition of plant communities. The system depends on the identification of potential climax associations, repeatable patterns in the composition of the understory vegetation, and differential understory species. It groups land units with similar capacity to produce vegetation. The floristic composition of the plant community is used as an integrated indicator of those environmental factors that affect species reproduction, growth, competition, and community development. A system to classify forest plant communities and the sites on which they develop.

Hardening Off: 1) The natural process of adaptation by plants to cold, drought, etc. 2) Preparing seedlings or rooted cuttings in a nursury for transplanting or planting out, by gradually reducing watering, shade, or shelter and thus inducing changes in the leading shoot that render it more tolerant of cold, dessication, etc.

Harvest Cutting: An intermediate or final cutting that extracts salable trees.

Harvesting (Logging): The process of gathering a timber crop. It includes felling, skidding/forwarding, on-site processing, and removal of products from the site.

Harvesting Method: A procedure by which a stand is logged, where emphasis is on meeting logging requirements while concurrently attaining silvicultural objectives.

Harvest Scheduling: A process for allocating cutting and other silvicultural treatments over a forest with emphasis on which treatments to apply and where and when to apply them.

Herb: 1) A nonwoody, vascular plant such as a grass, a fern, or a forb. 2) A seed-producing annual, biennial, or perennial that does not develop persistent woody tissue but dies down at the end of a growing season.

Herbivory: The consumption of plants by animals.

High-grade Selective Cut: A selective cut of the most valuable and highest quality trees, that leaves low value and poor quality trees to predominate.

Improvement Cutting: The removal of less desirable trees of any species in a stand of poles or larger trees, primarily to improve composition and quality.

Increment Borer: An auger-like instrument with a hollow bit and an extractor used to extract thin radial cylinders of wood (increment cores) from trees having annual growth rings, to determine increment or age.

Ingrowth: The volume, basal area, or number of those trees in a stand that were smaller than a prescribed minimum diameter or height limit at the beginning of any growth-determining period and that, during that period, attained the prescribed size.

Intermediate Crown Class: A tree whose crown extends into the lower portion of the main canopy, but shorter in height than the codominants and receiving little direct light from above and none from the sides.

Intermediate Treatment: Any treatment or tending designed to enhance growth, quality, vigor, and composition of the stand after establishment of regeneration and prior to final harvest.

Landscape: A spatial mosaic of several ecosystems, landforms, and plant communities across a defined area irrespective of ownership or other artificial boundaries and repeated in similar form throughout.

Layering: A form of vegetative reproduction in which any intact branch develops roots as the result of contact with soil or other media.

Liberation: A release treatment made in a stand not past the sapling stage to free the favored trees from competition with older, overtopping trees.

Litter Layer (Forest): A layer that lies above the mineral soil, made up of organic debris, including leaves, needles, bark, and wood, in different stages of decomposition, with a variety of insects, microbes, and fungi that feed on the litter.

Logging Residue (see slash): The unused portions of trees cut or killed during logging and left in the woods.

Low Thinning (Thinning From Below): The removal of trees from the lower crown classes to favor those in the upper crown classes.

Management Goal: A broad, general statement, usually not quantifiable, that expresses a desired state or process to be achieved.

Management Objective: A concise, time-specific statement of measurable planned results that correspond to preestablished goals in achieving a desired outcome.

Management Plan: A predetermined course of action and direction to achieve a set of results, usually specified as goals, objectives, and policies.

Management Policy: A definite course or method of action to guide present and future decisions or to specify in detail the ways and means to achieve goals and objectives.

Management Prescription: A set of management practices and intensities scheduled for application on a specific area to satisfy multiple goals and objectives.

Mast: Fruit and nuts consumed as food by livestock and certain kinds of wildlife.

Matrix: 1) The most extensive and connected landscape element that plays the dominant role in landscape functioning. 2) A landscape element surrounding a patch. 3) The non-reserved portion of the forest land base. 4) A rectangular array of mathematical elements consisting of m rows and n columns.

Mature: Pertaining to a tree or even-aged stand that is capable of sexual reproduction, has attained most of its potential height growth, or has reached merchantability standards.

Mean (Arithmetic): The average value of a series or set of observations, obtained by dividing the algebraic sum of all observations in the set by the number of observations; often referred to as a measure of central location or central tendency.

Mean Annual Increment (MAI): The total increment of a tree or stand (standing crop plus thinnings) up to a given age divided by that age. The culmination of mean annual increment (CMAI) is the age in the growth cycle of a tree or stand at which the MAI for volume, basal area, diameter, or height is at a maximum.

Mean Diameter (of a stand or group of trees): 1) Quadratic mean diameter, the diameter corresponding to their mean basal area. 2) Arithmetical mean diameter, the arithmetical mean of the diameters.

Mechanical Thinning: The removal of trees in rows, strips, or by using fixed spacing intervals.

Milacre: An area of 1/1000 (0.001) acres.

Milacre Stocking: Proportion of milacres (sample plots) occupied by a plant of interest (species and/or size), expressed as a percentage of the total number of milacres sampled. A measure frequently applied to sample stocking of seedling and sapling regeneration. For example, at least 60% milacre stocking for established oak regeneration reflects that ≥60% of milacre plots sampled contained at least one oak seedling greater than a specified minimum size.

Monoecious: A population or species having functional male and female flowers (or strobili) in separate places on the same plant.

Mycorrihizal Association: The usually symbiotic association between higher plant roots (host) and mycelia of specific fungi that aid plants in the uptake of water and certain nutrients and may offer protection against other soil-borne organisms.

Natural Regeneration: The establishment of young trees through natural seeding, sprouting, suckering, or layering.

Nonnative (Exotic) Invasive Plants: Plant species accidentally or intentionally introduced from another country or geographic region, having the ability to significantly displace desirable vegetation or reduce crop yields.

Nurse Tree(s): A tree, or group of trees, used to improve survival or improve the form of a more desirable tree, or group of trees.

Old Forest: Forests which are older than the typical managed forest (beyond traditional rotation age) but are not biologically old. They are beyond economic maturity but are not senescent.

Old-growth Forest: Forests which are relatively old and relatively undisturbed by humans. The forest is biologically old, containing some trees which are nearing or beyond their average expected lifespan. The original even-aged overstory, established following a catastrophic disturbance, is becoming senescent, is senescing, or has senesced.

Old Multi-aged: The final stage of stand structural development. An uneven-aged forest with few or no remnants left from the original cohort. This stage will last until another stand-replacing disturbance occurs.

Overmature: 1) A tree or even-aged stand that has reached that stage of development when it is declining in vigor and health and reaching the end of its natural life span. 2) A tree or even-aged stand that has begun to lessen in commercial value because of size, age, decay, or other factors.

Overstory: That portion of the trees in a forest forming the uppermost canopy layer.

Overstory Removal Regeneration Method: A silvicultural method in which the entire stand overstory is removed in one cut to provide release of established seedlings and saplings. Also referred to as a natural shelterwood and a one-cut shelterwood.

Passive Management: A deliberate decision to not manipulate forest vegetation.

Patch: 1) A small area distinct from that about it. 2) A small part of a stand or forest. 3) An ecosystem element (e.g. an area of vegetation, that is relatively homogeneous internally and differs from surrounding elements).

Patch Selection (see selection regeneration method): A regeneration method where regeneration is managed in patches >0.5 acres in size (comprising part of a larger uneven-aged stand).

Perfect Flower: Having both functional pistils and stamens.

Pioneer: A plant capable of invading bare sites and persisting there or colonizing them until supplanted by successional species.

Pistillate Flower: Having female organs only.

Poletimber: A tree of a size between a sapling and a sawtimber tree. Hardwood trees ranging in size from 5 to 11 inches dbh, and conifers ranging in size from 5 to 9 inches dbh.

Polygamous: With bisexual and unisexual flowers on the same or different individuals of the species.

Precommercial thinning: The removal of trees not for immediate financial return but to reduce stocking to concentrate growth on the more desirable trees.

Prescribed Burning: The application of fire in order to attain management objectives.

Pruning: The removal, close to the branch collar or flush with the stem, of side branches and multiple leaders from a standing tree.

Radicle: The root of a seed embryo from which the primary root develops.

Reforestation: The practice of regenerating and growing healthy trees on previously forested sites.

Regeneration (Reproduction): 1) The seedlings or saplings existing in a stand. 2) The act of renewing tree cover by establishing young trees naturally or artificially.

Regeneration Cutting: Any removal of trees intended to assist regeneration already present or to make regeneration possible.

Regeneration Method: A procedure by which a stand is established or renewed by means of natural or artificial reproduction. The various methods include the removal of the old stand (usually involving a harvest), the establishment of a new one, and any supplementary treatments of vegetation, slash, or soil that are applied to create conditions favorable to the establishment of reproduction.

Regeneration Period: The time between the initial regeneration cutting and the successful reestablishment of a new age class by natural means, planting, or direct seeding.

Release: 1) A treatment designed to free young trees (not past the sapling stage) from undesirable, usually overtopping, competing vegetation. 2) To relieve (set free) from restraint, confinement, oppression, or burden.

Relict Forest: Forests which appear never to have been manipulated, exploited, or severely disturbed by humans of European origin; in Wisconsin the stand and site should show no evidence of significant human disturbance since about 1800 AD.

Reserve Trees: Living trees, ≥5 inches dbh, retained after the regeneration period under even-aged or two-aged silvicultural systems. They can be dispersed uniformly or irregularly, as single trees or aggregated groups or patches, or any mixture thereof. They are retained well beyond stand rotation, and for purposes other than regeneration. Reserve trees may be harvested eventually or retained to complete their natural lifespan. Synonyms may include leave trees, green tree retention, and standards.

Rhizome: A modified stem that grows below ground, commonly stores food materials, and produces roots, scale leaves, and suckers irregularly along its length and not just at nodes.

Risk: 1) The probability that a tree will die or fail (main stem will break) within a specified time period. 2) The probability that an insect population or outbreak will occur in a particular stand or forest, or that a particular tree will be severely damaged under a given set of conditions. 3)

Fire risk. 4) The relative probability of any of several alternative outcomes as determined or estimated by a decision maker when the actual outcome of an event or series of events is not known. 5) The product of the probability of the event taking place, the probability of being exposed to the event, and the probability of certain outcomes if exposure to the event occurs.

Root Collar: The location on a plant where the primary vascular anatomy changes from that of a stem to that of a root.

Rotation: In even-aged silvicultural systems, the period between regeneration establishment and final cutting. Rotation may be based on many criteria including culmination of mean annual increment, mean size, age, attainment of particular minimum physical or value growth rate, and biological condition.

Salvage Cutting: The removal of dead trees or trees damaged or dying because of injurious agents other than competition, to recover economic value that would otherwise be lost.

Sanitation Cutting: The removal of trees to improve stand health by stopping or reducing the actual or anticipated spread of insects or disease.

Sapling: A usually young tree larger than a seedling but smaller than a poletimber tree. Trees ranging from 1 to 5 inches dbh.

Sawtimber: Trees with minimum diameter and length and with stem quality suitable for conversion to lumber. Hardwood trees larger than 11 inches dbh, and conifers larger than 9 inches dbh.

Scaling: The measurement or estimation of the quantity or quality of felled timber.

Scarification: Mechanical removal of competing vegetation and/or interfering debris, or disturbance of the soil surface, designed to enhance regeneration for species that require mineral soil seed beds.

Seedling: 1) A usually young tree smaller than a sapling. Trees less than 1 inch dbh. 2) A plant grown from seed.

Seed Tree Regeneration Method: A silvicultural method designed to bring about reproduction on what are essentially clearcut harvest areas by leaving enough trees singly or in groups to naturally seed the area with adequate stocking of desired species in a reasonable period of time before the site is captured by undesirable vegetation. Only a few trees of the original stand are left, and this residual stocking is not sufficient to protect, modify, or shelter the site in any significant way.

Seed Year: A year in which trees or other plants produce abundant seed as individuals or as a stand.

Selection Regeneration Method: A silvicultural method designed to regenerate and maintain uneven-aged stands by removing some trees at regular intervals. Trees are removed in various size classes, either singly or in small patches. An uneven-aged stand is maintained by periodically regenerating new age classes while manipulating the overstory structure to facilitate continual development of quality growing stock. Regeneration cuts, thinning, and harvesting usually occur simultaneously.

- Single-tree selection: Regeneration managed in gaps <0.1 acres.
- Group selection: Regeneration managed in group openings 0.1 – 0.5 acres.
- Patch selection: Regeneration managed in patches >0.5 acres.

Selective (Partial) Cutting: The removal of only a portion of the trees in a stand.

Senescence: 1) The life phase of an organism, or a part of the organism, that precedes natural death, usually involving a decreased ability to repair damage and degradation. 2) The state of being old: the process of becoming old.

Serotinous: Pertaining to cones or fruit that remain on a tree without opening for one or more years. In some species cones open and seeds are shed when heat is provided by fires or hot and dry conditions.

Shelterwood Regeneration Method: A silvicultural method designed to regenerate a stand by manipulating the overstory and understory to create conditions favorable for the establishment and survival of desirable tree species. Regenerates an even-aged stand and normally involves removal of all or most of the overstory once the new stand is established. The overstory serves to modify understory conditions, create a favorable environment for reproduction, and provide a seed source. The system is characterized by a preparatory cut (optional), seeding cut(s), and overstory removal.

Silvics: The study of the life history, ecology, and general characteristics of forest trees and stands, with particular reference to environmental factors, as a basis for the practice of silviculture.

Silvicultural Prescription: A planned series of treatments designed to change current stand structure to one that meets management goals and objectives. The prescription normally considers ecological, economic, and societal constraints.

Silvicultural System: A planned program of vegetation treatment during the entire life of a stand. The three basic components are tending, harvesting, and regeneration. Named after the stand age class structure and the regeneration method employed.

Silviculture: 1) WDNR: The practice of controlling forest composition, structure, and growth to maintain and enhance the forest’s utility for any purpose. 2) The art and science of controlling the establishment, growth, composition, health, and quality of forests to meet the diverse needs and values of landowners and society on a sustainable basis.

Single-tree Selection (see selection regeneration method): A regeneration method where regeneration is managed in gaps <0.1 acres in size (comprising part of a larger uneven-aged stand).

Site: 1) The sum total of environmental conditions surrounding and available to the plant. The physical (climate, topograhy, soil) and biotic (plants, animals) factors interact to yield the light, heat, water, and chemicals that are directly available and used by the plant, as well as other chemical and mechanical disturbance factors. 2) The area in which a plant or stand grows, considered in terms of its environment, particularly as this determines the type and quality of the vegetation the area can carry. 3) A spatially explicit, relatively homogeneous portion of land characterized by specific physical and chemical properties that affect ecosystem functions, and where a more or less homogeneous forest type may be expected to develop.

Site Class: A classification of site quality based on actual measured forest productivity, generally measured in terms of the gross volume of bole wood per unit area per year over the normal rotation (mean annual increment at culmination). Some definitions include site index as a direct measure of site quality.

Site Index: A species-specific measure of actual or potential forest productivity (usually for even-aged stands), expressed in terms of the average height of trees included in a specified stand component (dominants, codominants, or the largest and tallest trees) at a specified index or base age.

Site Index Curve: A curve showing the expected height growth pattern for trees of the specified stand component in even-aged stands of a given site index.

Site Preparation: Hand or mechanized manipulation of a site, designed to enhance the success of regeneration. Treatments may include bedding, burning, chemical spraying, chopping, disking, raking, and scarifying and are designed to modify the soil, litter, or vegetation and to create microclimate conditions conducive to the establishment and growth of desired species.

Site Potential (Site Capability): The sum total of all the factors affecting the capacity to produce forests or other vegetation. Collective physical resources (e.g. moisture, nutrients, heat, light) available for plant growth. Different potentials facilitate growth of some species and limit growth of others. Consequently, site potential has a strong effect on plant community development

Site Quality (Site Productivity): The productive capacity of a site, usually expressed as volume production of a given species.

Site Type: A classification of site quality or potential based on indirect measures utilizing site factors (individually or in combination) such as climate, topography, geology, soil, and vegetation. Some definitions include site index as an indirect measure of site quality.

Slash: The residue left on the ground after logging, or accumulating as a result of storm, fire, girdling, or delimbing.

Snag: A standing dead tree.

Special Concern Species: A species with some problem of abundance or distribution suspected but not proved.

Species of Greatest Conservation Need (SGCN Wisconsin): Animal species identified as at risk or declining in the Wisconsin Wildlife Action Plan. They include threatened and endangered species, as well as many other species whose populations are of concern.

Staminate Flower: Having pollen-bearing organs (stamens) only.

Stand: 1) A contiguous group of trees sufficiently uniform in species composition, structure, and age-class distribution, and growing on a site of sufficiently uniform quality, to be considered a relatively homogeneous and distinguishable unit. 2) A contiguous group of similar plants.

Stand Density: 1) A quantitative measure of stocking expressed either absolutely in terms of number of trees, basal area, or volume per unit area or relative to some standard condition. 2) A measure of the degree of crowding of trees within stocked areas commonly expressed by various growing space ratios.

Stand Density Index (SDI): 1) A widely used measure developed by Reineke (1933) that expresses relative stand density in terms of the relationship of a number of trees to stand quadratic mean diameter. 2) Any index that expresses relative stand density based on a comparison of measured stand values with some standard condition.

Stand Initiation: The initial stage of stand structural development, lasting from the time of stand-replacing disturbance until the new cohort forms a continuous canopy and trees begin competing with each other for light and canopy space.

Stand Structural Development: Changes in forest stand structure over time.

Stand Structure: 1) The physical and temporal distribution of plants in a stand. 2) The horizontal and vertical distribution of components of a forest stand including the age, height, diameter, crown layers, and stems of trees, shrubs, herbaceous understory, snags, and down woody debris.

Stem Analysis: The analysis of a complete tree stem by counting and measuring the annual growth rings on a series of cross sections taken at different heights to determine its past rates of growth and changes in stem form, and to develop taper and volume equations.

Stem Exclusion: A stage of stand structural development, following stand initiation and preceding demographic transition. The canopy continues to have only one dominant cohort, and competition among trees is intense. Crowns are small enough so that when one tree dies, the other trees are able to fill the vacated space in the canopy by expanding their branches horizontally. The canopy is dense enough to prevent new saplings from growing into the canopy – there is no space available for new trees.

Strobili: Conifer cones.

Stocking: 1) An indication of growing-space occupancy relative to a preestablished standard. Common indices of stocking are based on percent occupancy, basal area, relative density, stand density index, and crown competition factor. 2) The amount of anything on a given area, particularly in relation to what is considered optimum.

Stratification: 1) The exposure of seed to a cold, moist treatment to overcome dormancy and promote germination. 2) The subdivision of a population into strata (blocks) before sampling, each of which is more homogeneous for the variable being measured than the population as a whole.

Stump Sprout: Regeneration of shoot growth from either adventitious or dormant buds from a cut tree stump.

Succession: The gradual supplanting of one community of plants by another (compositional change).

Sucker (Root Sprout): Shoots arising from below ground level either from a rhizome or from a root.

Sunscald: Localized injury to bark and cambium caused by a sudden increase in exposure of a stem or branch to intense sunlight and high temperatures.

Suppressed (Overtopped) Crown Class: A tree whose crown is completely overtopped by the crowns of one or more neighboring trees.

Sustainability: The capacity of forests, ranging from stands to ecoregions, to maintain their health, productivity, diversity, and overall integrity, in the long run, in the context of human activity and use.

Sustainable Forest Management (Sustainable Forestry): 1) WDNR: The practice of managing dynamic forest ecosystems to provide ecological, economic, social, and cultural benefits for present and future generations. 2) The practice of meeting the forest resource needs and values of the present without compromising the similar capability of future generations. 3) The stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality, and potential to fulfill, now and in the future, relevant ecological, economic, and social functions at local, national, and global levels, and that does not cause damage to other ecosystems.

Sustained Yield: 1) The yield that a forest can produce continuously at a given intensity of management. Sustained-yield management implies continuous production so planned as to achieve a balance between increment and cutting. 2) The achievement and maintenance in perpetuity of a high-level regular periodic output of the various renewable resources without impairment of the productivity of the land.

Tending: Treatment of the stand during the time period between stand origin and final harvest.

Thinning: 1) A cultural treatment made to reduce stand density of trees primarily to improve growth, enhance forest health, or recover potential mortality. 2) To reduce in number or bulk, thickness or depth, density or viscosity, or to dilute or weaken.

Threatened Species: A species likely to become endangered within the foreseeable future, based on scientific evidence.

Timber Quality (Tree): Tree stem form, soundness, and potential timber value.

(Timber) Stand Improvement (TSI): 1) An intermediate treatment made to improve stand composition, structure, condition, health, and growth. 2) Non-commercial intermediate treatments.

Tolerance: 1) The capacity of an organism or biological process to subsist under a given set of environmental conditions. 2) The capacity of trees to grow satisfactorily in the shade of, and in competition with, other trees. 3) The ability of animals to adjust to different or disturbed habitats.

Two-aged Stand: A stand with trees of two distinct age classes, separated in age by more than 20% of rotation.

Understory: All forest vegetation growing under an overstory.

Uneven-aged Stand: A stand where the trees differ markedly in their ages, with trees of three or more distinct age classes either mixed or in small groups.

Variable Retention Harvest System: An approach to harvesting based on the retention of structural elements or biological legacies (trees, snags, logs, etc.) from the harvested stand for integration into the new stand to achieve various ecological objectives.

Viability: 1) The capacity of a seed, spore, or pollen grain to germinate and develop under given conditions. Actual viability is determined by measuring germinative capacity. 2) The ability of a wildlife or plant population to maintain sufficient size to persist over time in spite of normal fluctuations in numbers.

Vigor: Active healthy well-balanced growth.

Weeding: A release treatment in stands not past the sapling stage that eliminates or suppresses undesirable vegetation (including shrubs and herbs) regardless of crown position.

Whole-tree Harvesting: Cutting and removing an entire upper portion of a tree consisting of trunk, branches, and leaves or needles.

Wildlife: All nondomesticated animal life.

Winter Injury: The dessication and sometimes mortality of foliage or twigs by strong dry winds at times when water conduction is restricted by cold or frozen soil or by frozen plant tissues.

Winter Sunscald: Localized injury to bark and cambium caused by freezing following warming by the sun in late winter or early spring. Winter sunscald is localized on the side of the stem exposed to midday and afternoon sun, and often results in wounds or cankers, particularly on smooth-barked trees.

Wolf Tree: A generally predominant or dominant tree with a broad, spreading crown that occupies more growing space than its more desirable neighbors.

Yield: 1) The amount of wood that may be harvested from a particular type of forest stand by species, site, stocking, and management regime at various ages. 2) The amount of product output recovered from a quantity of raw material input. 3) The harvest, actual or estimated, of mammals, birds, or fish expressed by numbers or weight, or as a proportion of the standing crop, over a given period.

Yield Determination: The calculation, by volume regulation or, less directly, by area regulation, of the amount of timber that may be harvested annually or periodically from a specified area over a stated period in accordance with the management objectives.

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APPENDIX B

SCIENTIFIC AND COMMON NAMES OF NATIVE TREES

Abies balsamea - Balsam Fir
Acer negundo - Box Elder
Acer nigrum – Black Maple
Acer rubrum - Red Maple
Acer saccharinum - Silver Maple
Acer saccharum – Sugar Maple
Acer spicatum – Mountain Maple
Alnus rugosa – Speckled Alder
Amelanchier spp. – Serviceberry, Juneberry
Betula alleghaniensis - Yellow Birch
Betula nigra - River Birch
Betula papyrifera - Paper Birch
Carpinus caroliniana - Hornbeam, Bluebeech, Musclewood
Carya cordiformis - Bitternut Hickory
Carya ovata - Shagbark Hickory
Celtis occidentalis - Hackberry
Crataegus spp. - Hawthorn
Fagus grandifolia - Beech
Fraxinus americana - White Ash
Fraxinus nigra - Black Ash
Fraxinus pennsylvanica - Green Ash
Fraxinus quadrangulata - Blue Ash
Gleditsia triancanthos - Honey Locust
Gymnocladus dioicus - Coffee Tree
Juglans cinerea - Butternut
Juglans nigra - Black Walnut
Juniperus virginiana - Eastern Red Cedar
Larix laricina – Tamarack, Eastern Larch
Morus rubra - Red Mulberry
Ostrya virginiana- Hophornbeam, Ironwood
Picea glauca - White Spruce
Picea mariana - Black Spruce
Pinus banksiana- Jack Pine
Pinus resinosa - Red Pine
Pinus strobus - Eastern White Pine
Platanus occidentalis - Sycamore
Populus balsamifera - Balsam poplar
Populus deltoides - Eastern Cottonwood
Populus grandidentata - Bigtooth Aspen
Populus tremuloides - Trembling Aspen, Quaking Aspen, Popple
Prunus pennsylvanica - Pin Cherry
Prunus serotina - Black Cherry

Prunus virginiana – Choke Cherry
Quercus alba - White Oak
Quercus bicolor - Swamp White Oak
Quercus ellipsoidalis - Northern Pin Oak
Quercus macrocarpa - Bur Oak
Quercus muehlenbergii - Chinkapin Oak
Quercus rubra - Northern Red Oak
Quercus velutina - Black Oak
Salix nigra - Black Willow
Sorbus americana - Mountain Ash
Sorbus decora - Showy Mountain Ash
Thuja occidentalis - Northern White Cedar
Tilia americana – Basswood, Linden
Toxicodendron vernix - Poison Sumac
Tsuga canadensis - Eastern Hemlock
Ulmus americana - American Elm
Ulmus rubra - Red Elm, Slippery Elm
Ulmus thomasii - Rock Elm, Cork Elm

APPENDIX C

FORESTCOVER TYPE DEFINITIONS AND ABBREVIATIONS

Forest Cover Types	Symbol	Definition
Jack Pine	PJ	Jack pine comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands. In mixed pine stands, jack pine is predominant.
Red Pine	PR	Red pine comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands. In mixed pine stands, red pine is predominant.
White Pine	PW	White pine comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands. In mixed pine stands, white pine is predominant.
White Spruce	SW	White spruce comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands.
Balsam Fir	FB	Balsam fir comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands. In mixed swamp conifer stands, balsam fir is predominant.
Black Spruce	SB	Black spruce comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands. In mixed swamp conifer stands, black spruce is predominant.
Tamarack	T	Tamarack comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands. In mixed swamp conifer stands, tamarack is predominant.
White Cedar	C	White cedar comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands. In mixed swamp conifer stands, white cedar is predominant.

Hemlock	H	Hemlock comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands.
Northern Hardwood	NH	Any combination of sugar maple, beech, basswood, white ash, and yellow birch comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands.
Central Hardwood	CH	Any combination of oaks, hickories, elms, black cherry, hackberry, red maple, white ash, green ash, basswood, and sugar maple, which does not satisfy the defining criteria for NH, MR, or O cover types. The CH type occurs only on uplands within and south of the Tension Zone (southern Wisconsin).
Black Walnut	W	Black walnut comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands.
Oak	O	Oak comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands.
White Birch	BW	White Birch comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands.
Aspen	A	Aspen comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands.
Red Maple	MR	Red Maple comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands. If soil is poorly drained, then swamp hardwood.
Swamp Hardwood	SH	Any combination of black ash, green ash, red maple, silver maple, swamp white oak, and American elm comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands. This type occurs on wetlands characterized by periodic inundation (fluctuating water table near or above the soil surface) and nearly permanent subsurface water flow.

Bottomland Hardwood	BH Any combination of silver maple, green ash, swamp white oak, American elm, river birch, and cottonwood comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands. Hardwood dominated forests occurring on floodplains and some terraces.
Miscellaneous Deciduous	MD Hardwood forests dominated by uncommon or exotic species; e.g. box elder, honey locust, black locust, Norway maple.
Miscellaneous Coniferous	MC Conifer forests dominated by uncommon or exotic species; e.g. Eastern red cedar, Scotch pine, Norway spruce, European Larch.

APPENDIX D

SITE INDEX CURVES FOR TREE SPECIES IN WISCONSIN

Species	Source
Balsam fir (*Abies balsamea*)	Lake States (Gevorkiantz 1956; Carmean et al., 1989)
Red maple (*Acer rubrum*)	Minnesota (Gevorkiantz, 1957; Carmean et al., 1989)
Sugar maple (*Acer saccharum*)	Northern Wisconsin and Upper Michigan (Carmean et al., 1989)
Yellow birch (*Betula alleghaniensis*)	Northern Wisconsin and Upper Michigan (Carmean et al., 1989)
White birch (*Betula papyrifera*)	Northern Wisconsin and Upper Michigan (Carmean et al., 1989)
Bitternut hickory (*Carya cordiformis*)	Wisconsin (anamorphic curve based on FIA)
Shagbark hickory (*Carya ovata*)	Wisconsin (anamorphic curve based on FIA)
Hackberry (*Celtis occidentalis*)	Northern Wisconsin and Upper Michigan (Carmean et al., 1989)
White ash (*Fraxinus americana*)	Northern Wisconsin and Upper Michigan (Carmean et al., 1989)
Black ash (*Fraxinus nigra*)	Northern Wisconsin and Upper Michigan (Carmean et al., 1989)

Species	Source
Green ash (*Fraxinus pennsylvanica*)	Wisconsin (anamorphic curve based on FIA)
Black walnut (*Juglans nigra*)	(Schlesinger and Funk, 1977)
Tamarack *(Larix laricina)*	Minnesota (Gevorkiantz, 1957; Carmean et al., 1989)
White spruce *(Picea glauca)*	Minnesota (Gevorkiantz, 1957; Carmean et al., 1989)
Black spruce *(Picea mariana)*	Lake States (Technical Note no 473)
Jack pine *(Pinus banksiana)*	Minnesota (Gevorkiantz, 1957; Carmean et al., 1989)
Red pin *(Pinus resinosa)*	Minnesota (Gevorkiantz, 1957; Carmean et al., 1989)
Eastern white pine *(Pinus strobus)*	Northern Wisconsin (Carmean et al., 1989)
Bigtooth aspen *(Populus grandidentata)*	Northern Wisconsin and Upper Michigan (Carmean et al., 1989)
Trembling aspen *(Populus tremuloides)*	Northern Wisconsin and Upper Michigan (Carmean et al., 1989)
Black cherry *(Prunus serotina)*	Northern Wisconsin and Upper Michigan (Carmean et al., 1989)
White oak *(Quercus alba)*	Central States (Carmean 1971, 1972)

Species	Source
Northern red oak *(Quercus rubra)*	Northern Wisconsin and Upper Michigan (Carmean 1978)
Black oak *(Quercus velutina)*	Central States (Carmean 1971, 1972)
Northern white cedar *(Thuja occidentalis)*	Lake States (Gevorkiantz 1956; Carmean et al., 1989)
Basswood *(Tilia americana)*	Northern Wisconsin and Upper Michigan (Carmean et al., 1989)
American elm *(Ulmus americana)*	Northern Wisconsin and Upper Michigan (Carmean et al., 1989)