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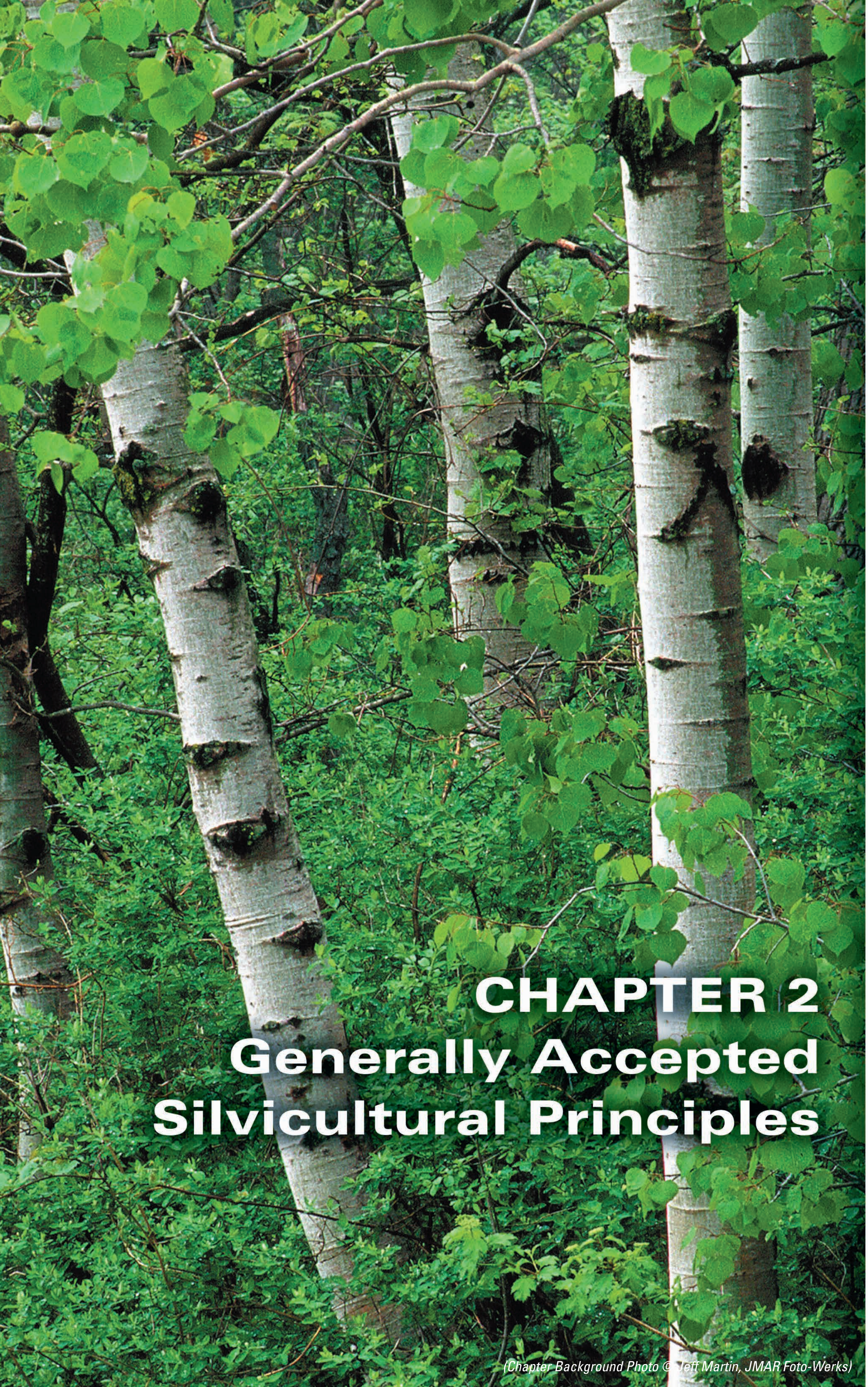
CHAPTER 2
Generally Accepted Silvicultural Principles



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CHAPTER 2
GENERALLY ACCEPTED SILVICULTURAL PRINCIPLES

Figure 2-1: Integrated guidelines recognize the forest as a community of related resources, rather than a collection of separate resources, as shown in this photo of the Baraboo Bluffs and Devil's Lake in Sauk County.

The purpose of this chapter is to focus on growing stands of trees and the generally accepted silvicultural practices used in Wisconsin.

This chapter will:

- Provide an overview on the interdependence of compatible landowner objectives, a careful evaluation of site capability, and the selection of an appropriate **silvicultural system** – the three essential elements of sustainable forestry practices.
- Expand upon each of the preceding three essential elements of sustainable forestry practices.
- Identify, define and explain various silvicultural systems and their application to the common forest cover types in Wisconsin.
- Address other types of harvesting, unsustainable cutting methods, and passive management strategies.
- Provide examples of how to distill all the sustainable forestry considerations into an effective management prescription at the stand level.

For more detailed silvicultural information related to a specific forest cover type, forest management treatment readers are referred to the Wisconsin DNR *Silviculture Handbook, 2431.5*. The handbook can be found at: ***dnr.wi.gov – keyword "silviculture."***

SUSTAINABLE FORESTRY

FOREST ECOLOGY

The science concerned with 1) the forest as a biological community dominated by trees and other woody vegetation; 2) the interrelationships between various trees and other organisms constituting the community; and 3) the interrelationships between organisms and the physical environment in which they exist.

SUSTAINABLE FORESTRY

The practice of managing dynamic forest ecosystems to provide ecological, economic, social, and cultural benefits for present and future generations (from Ch.28.04(1)e, Wisconsin Statutes).

SILVICS

The study of the life history, characteristics and ecology of forest trees. It involves understanding how trees grow, reproduce and respond to environmental variations. The silvics of a particular tree species would describe the climatic range, temperature and light requirements, moisture needs, thermoperiodicity, soil conditions and topography, life history and development, commonly associated trees and shrubs, and any environmental, insect and/or disease factors that affect its growth and survival.

SILVICULTURE

The practice of controlling forest composition, structure and growth to maintain and enhance the forest's utility for any purpose.

Sustainable forestry practices must be based on compatible landowner objectives, the capabilities of each particular site and sound silviculture. Each of these factors is equally important.

Landowners' goals and objectives might encompass a wide range of values and benefits such as commercial products, recreation, aesthetics, wildlife habitat, endangered and threatened resources, and clean water. Understanding landowners' goals and objectives is essential to ensure that prescribed forestry practices are relevant and will endure over time. Landowners' goals and objectives must also be compatible with sustainable forestry defined as the management of dynamic forest ecosystems to provide ecological, economic, social, and cultural benefits for present and future generations. The silvicultural principles discussed in this guide assume that landowners are committed to sustainable forestry.

Site capabilities help define sustainable forestry practices. Each particular growing space has its own set of environmental conditions affecting tree growth. Factors like soil type, aspect and climate influence the moisture and nutrients available to individual trees, and must be considered to ensure long-term tree health and vigor (see "Site Evaluation and Stand Delineation," page 2-5).

Silviculture is based on both forest ecology (relations between organisms) and the silvics (behavior or response) of individual tree species. Silvicultural systems are applied to stands of trees (rather than to individual trees) composed of species that commonly grow together. By definition, silviculture is the practice of controlling forest composition, structure and growth to maintain and enhance the forest's utility for any purpose. Silviculture is applied to accomplish specific landowner objectives.

The following sections of this guide will cover a number of silvicultural systems and harvest methods. The ability to adapt silvicultural systems to address multiple objectives is limited only by one's imagination and creativity, making the practice of sustainable forestry both an art and a science. Table 2-1 (see page 2-32) summarizes the array of regeneration methods generally considered acceptable for the forest cover types in Wisconsin.

LANDOWNER GOALS AND OBJECTIVES

Silviculture and forestry practices are not ends within themselves, but rather a means of achieving specific objectives in a landowner's overall goal to manage a forest on a sustainable basis. The test of a silvicultural prescription or recommended forestry practice is how well it meets the landowner's sustainable forestry goals and objectives.

As noted previously, landowner goals may be varied, reflecting a variety of forest values and benefits. Some goals may have a higher priority than others, but it is important to remember they are often interrelated, and generally depend on sound forestry practices to be realized.

Figure 2-2: Landowners and resource managers should meet on-site prior to preparing a plan or conducting operations. Such meetings can help assure common understanding of landowner objectives, forestry prescriptions and site.

Goals can be achieved by accomplishing specific objectives. For example, a goal of periodic income or maintenance of wild turkey habitat might be achieved through an objective to regenerate an oak timber type through small shelterwood harvests spread over time. Think of a silvicultural prescription as a site-specific "action plan" to accomplish objectives.

In developing goals, landowners should realize that although specific site characteristics of their land could make some objectives unsustainable, there might be other viable courses of action to choose from. It is up to the forester and other resource professionals to identify all options open to the landowner, and to use as much flexibility as possible in designing a silvicultural prescription that best addresses the full range of landowner goals (see Chapter 10: Forest Management Planning for more information).

GOAL
A concise statement that describes a future desired condition normally expressed in broad, general terms that are timeless with no specific date by which the goal is to be achieved.

OBJECTIVE
Concise, time-specific statements of measurable, planned results that relate to overall goals.

NOTE: Generally, "goals" apply to an entire property and "objectives" to individual stands.

SITE EVALUATION AND STAND DELINEATION

Site capability determines what types of forestry practices are sustainable. A **site** is defined by the sum total of environmental conditions surrounding and available to the plants. A site is also a portion of land characterized by specific physical properties that affect ecosystem functions and differ from other portions of the land (Kotar, 1997).

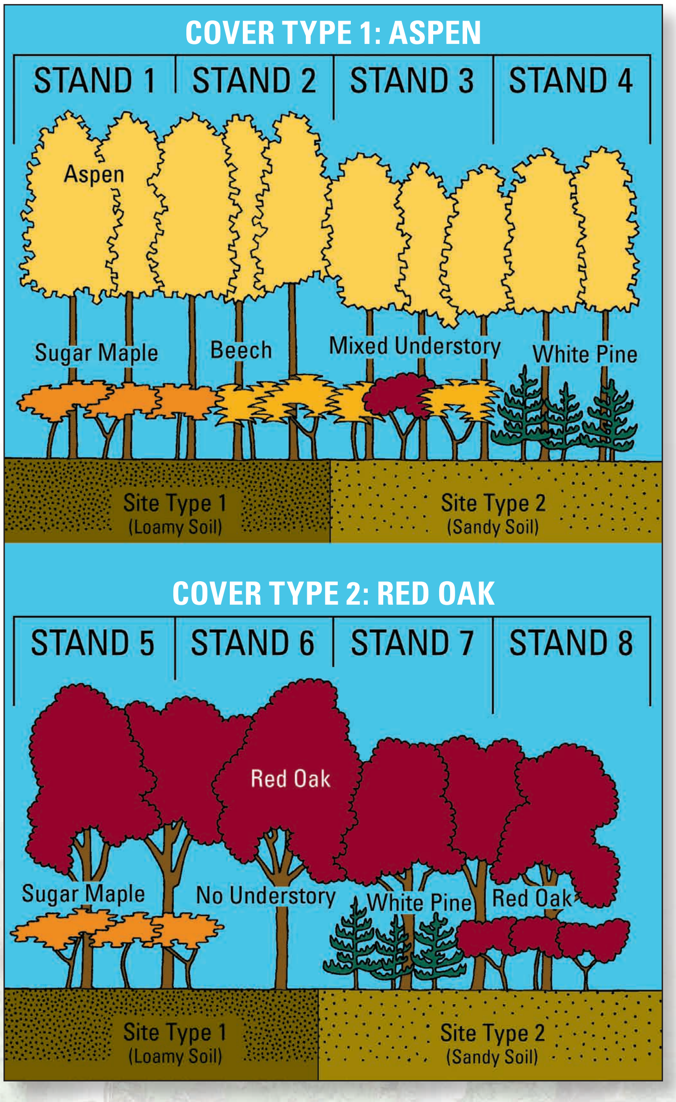


Figure 2-3: A schematic representation of two site types (loamy soil and sandy soil), two forest cover types (aspen and red oak), and eight stands. Each stand has unique composition and is defined by a specific combination of overstory and understory species. Each stand also can be considered as a unique ecological or silvicultural opportunity unit. (Figure Credit: Kotar, page 10)

Forestry practices are carried out on a stand basis which determines where practices will occur. A **stand** may loosely be defined as a contiguous group of trees sufficiently uniform in species composition, arrangement of age classes, and general condition to be considered a homogeneous and distinguishable unit.

A stand is usually treated as a basic silvicultural unit. Stands are normally identified by the forest cover type involved (e.g., an "aspen stand," a "northern hardwood stand," or a "jack pine stand"). Cover types are discussed in more detail later in this chapter.

Forest stands are delineated through the use of aerial photographs, forest reconnaissance, inventory, and cruising. Sites are generally delineated based on soils, topography, landforms, geology, vegetation associations, and site index.

It is important to note that forest stands and sites often overlap each other. As illustrated in Figure 2-3, a single stand may occupy more than one site and a single site may support more than one stand.

Since a stand is the basic unit of silvicultural planning, care should be taken to ensure that it represents a uniform ecological opportunity unit. In other words, each specific site and stand combination has a unique set of silvicultural opportunities and constraints, which can be used to increase the number of outcomes available to the landowner. As shown in Figure 2-4 and Figure 2-5, defining stands by cover type and site type will facilitate the determination of management objectives.

Forest **site quality** is the sum total of all factors affecting the capacity to produce forests or other vegetation. Biotic and abiotic factors impact moisture, nutrient and energy (light and heat) gradients, which determine vegetation growth and dynamics. Site quality affects tree growth, species composition and succession (plant community development). As site quality varies, so do forest management potentials and alternatives.

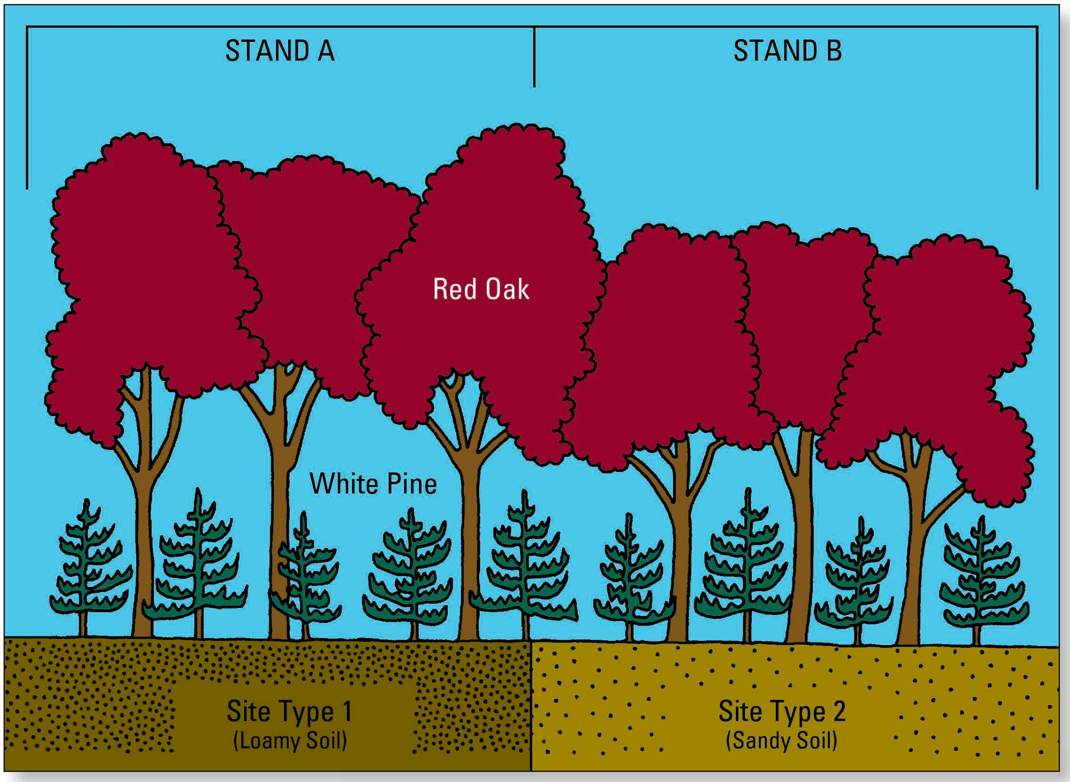


Figure 2-4: A single stand (red oak overstory with white pine regeneration) "straddles" two significantly different site types. Because ecological and silvicultural potentials differ for the two site types, the stand was split (A and B) to identify two ecological and silvicultural opportunity units. (Figure Credit: Kotar, page 12)

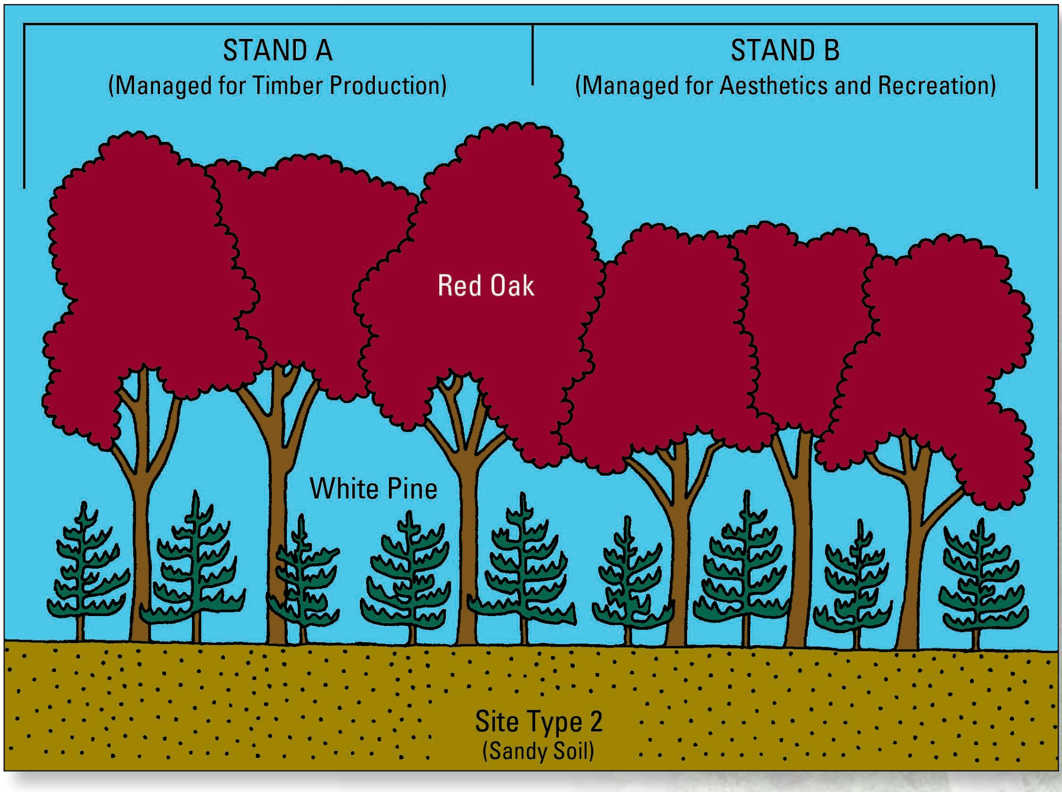


Figure 2-5: This stand is divided into two management units on the basis of different management objectives. E.g., in Stand A, oak will be harvested and white pine released to form a new crop, while in Stand B, oak overstory will be retained to provide a food source for wildlife and conditions for future old growth. (Figure Credit: Kotar, page 13)

Forest site productivity is a measure of the rate of tree growth and overall wood volumes that can be expected on a given site. Productivity for a given species will generally vary between different sites as will productivity for different species on the same site.

There are direct and indirect ways to evaluate forest site quality and productivity:

- **Direct measures** of forest productivity such as historical yields and mean annual increment. These measurements are influenced by stand characteristics and may not be available.

- **Indirect measures** that relate environmental characteristics to tree growth and productivity are more commonly used. Indirect measures can be applied individually or in combination.
  - **Site Index:** Growth rates are measured and compared to tables that predict the height a particular species will attain at a given age.
  - **Vegetation Associations:** The number and relative density of key characteristic ground plants are measured, and a vegetative habitat type is identified. A great deal of inventory and other productivity data are available for each habitat type in Wisconsin.
  - **Physical Site Characteristics:** Examples include geology, landform, aspect, topography, and soil. These characteristics can be used to differentiate among types of sites that are significantly different with respect to their capabilities to support or produce different cover types or rate of tree growth. It is important to remember, however, that different combinations of individual site factors can result in functionally similar sites.

Regional site classification systems can provide tools to understand local site variability, impacts on site quality and productivity, and potential management alternatives.

Forest Cover Types and Silvicultural Alternatives

In a forested situation, tree species tend to occur in associations known as forest cover types. They range from a single tree species to several different species that commonly grow together on a specific site. The Department of Natural Resources recognizes 18 forest cover types statewide. It is important to understand that only a subset of these cover types will naturally occur on any given site, and as a result, the range of sustainable management alternatives available are usually limited.

The forest cover type existing at a given point in time on a particular site will tend to change over time through the natural process of forest succession. Succession refers to a gradual change in plant community composition, and eventual replacement of one community of species by another. Following a major disturbance, such as fire or windstorm (or a silvicultural treatment designed to create similar conditions), an **early successional community** may invade a site. These communities (or forest cover types) are made up of sun-loving species able to rapidly establish themselves on an open, highly-disturbed site. Over time, the canopy begins to close and limit available sunlight, which results in other more shade-tolerant species eventually becoming established.

As the original early successional species are no longer able to compete, other **mid-to-late successional communities** better adapted to the changing microenvironment gradually replace them. A gradual transition to a number of different successional communities may occur as each gains a reproductive edge on the continually changing site conditions. At some point, after a long period free of disturbance, sites will transition to a potential climax community that is self-regenerating. This **climax community** will occupy the site until another disturbance creates conditions favoring re-establishment of an early successional community (a major disturbance) or a mid-to-late successional community (a lesser disturbance).

COMMON FOREST COVER TYPES FOUND IN WISCONSIN

Oak	White Birch	Northern Hardwood
Aspen	White Pine	Hemlock
Red Pine	Red Maple	Central Hardwood
Jack Pine	Black Spruce	Swamp Hardwood
Cedar	White Spruce	Bottomland Hardwood
Walnut	Balsam Fir	Tamarack

In Wisconsin, these successional trends are fairly well understood for each ecological habitat type (site type). The pathways on some sites involve only a few stages; on others there may be several. Figure 2-6 is an example of the successional stages and trends on one particular site type.

An understanding of forest succession on a particular site can provide a great deal of useful information to a landowner evaluating potential management goals and objectives, and a forester developing the silvicultural prescriptions needed to achieve those goals. Referring to Figure 2-6, for example, one might reason:

- Only seven generalized successional stages occur naturally on this site. Long-term management for quality northern hardwood or black walnut sawtimber, for example, would not be practical.
- Of the naturally occurring successional stages, some are currently more common at a landscape scale (as identified by the circles).
- Since a climax association is normally self-sustaining, maintaining an existing red maple, red oak, white pine, white spruce, and balsam fir type on this site would minimize regeneration costs.
- Based on the successional paths identified for this habitat type, the changes resulting from various levels of disturbance can be predicted. A partial removal of red pine overstory trees to release invading white pine, for example, would hasten the conversion from a red pine to a white pine timber type. On the other hand, a severe windstorm in a red oak-red maple stand might re-establish an aspen-white birch association for a period of time.
- Maintaining an early or mid-successional stage would require a disturbance, such as active management, to overcome the natural tendency to convert to the next stage. Increasing light levels by maintaining a lower canopy density is needed to allow reseeding of the more light-demanding, earlier successional stages. Marking criteria would have to focus on releasing preferred species from more shade-tolerant species to ensure survival.
- Reversing the trend and going back to a previous successional stage would generally require a significant disturbance. Even-aged management would normally be needed to create conditions favorable for re-invasion by early successional stages like aspen and white birch. Prescribed fire or mechanical scarification may be required to favor jack pine. Site preparation and planting would probably be needed to re-establish red pine. In general, the further succession is set back, the more disturbance and effort will be required.

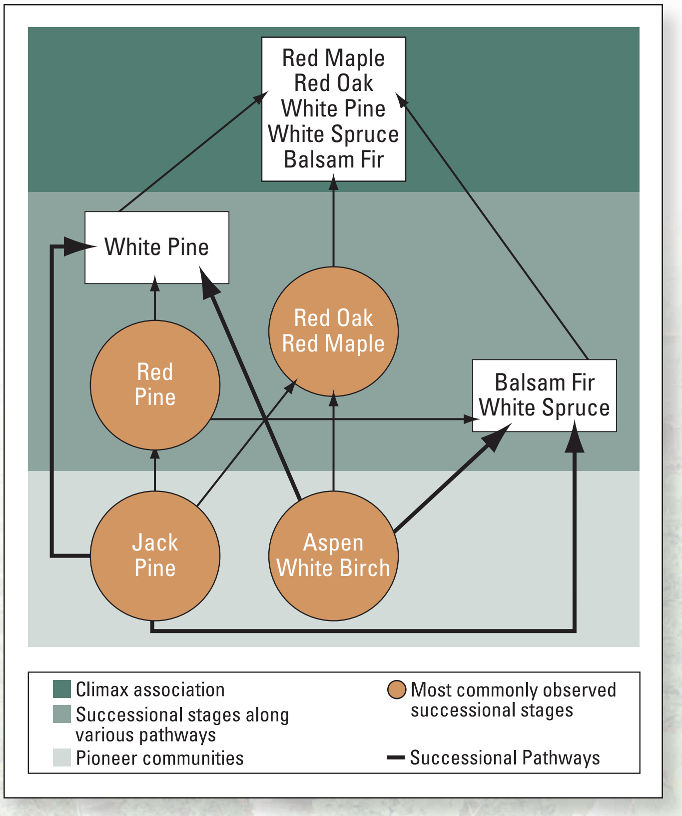


Figure 2-6: A generic example of the information available relative to the most commonly observed successional stages and probability of succession for a particular site type.

SILVICULTURAL SYSTEMS OVERVIEW

A **silvicultural system** is a planned program of vegetative manipulation carried out over the entire life of a stand. All silvicultural systems include three basic components: **harvest**, **regeneration** and **tending**. These components are designed based on understanding and partially simulating natural processes and conditions fostering healthy, vigorous stands of trees. Typically, silvicultural systems are named after the regeneration method employed to create the conditions favorable for the establishment of a new stand.

A **harvest method** differs from a simple harvest cut in that it is specifically designed to accomplish two objectives – removal of trees from the existing stand, and the creation of conditions necessary to favor regeneration and establishment of a new stand. The method selected depends on the species to be regenerated or established in the new stand. Harvest methods vary from the complete removal of a stand in a single cut or in stages over several years, to the selection of individual trees or groups of trees on a periodic basis.

A **regeneration method** is a process by which a stand is established or renewed. The various methods include: 1) removal of the old stand; 2) establishment of a new one; and 3) any supplementary treatments of vegetation, logging residue, or soil applied to create conditions favorable for the establishment of reproduction. Two general regeneration techniques are:

- **Natural regeneration systems** rely on natural seeding or root/stump sprouts and are generally carried on concurrently with the harvest process. In some cases, additional follow-up activities (e.g., scarification, understory competition control, slash treatment, or prescribed fire) may be necessary.

- **Artificial regeneration systems** depend on the planting of tree seedlings or seeds. Generally, planting occurs on non-forested land or following complete removal and harvest of a forest overstory, and results in an even-aged stand. Examples of artificial regeneration systems are:
  - **Afforestation:** Establishing a new forest on non-forested land.
  - **Reforestation and Conversion:** Forest type conversion when the desired species is not present or is inadequately represented to provide sufficient seed or vegetative reproduction.
  - **Reforestation and Re-establishment:** Forest type re-establishment when the desired species are difficult to regenerate, and it appears to be more efficient to utilize artificial regeneration than to depend on natural regeneration.

Table 2-1 (see page 2-32) shows the regeneration harvest methods described in this chapter as generally accepted for application to Wisconsin forest cover types.

Tending includes a variety of intermediate treatments that begin after regeneration is established and are implemented as prescribed throughout the rotation of a forest stand. These treatments include pruning, release, thinning/improvement, and salvage/sanitation. They are done to improve stand composition, structure, growth, quality and health, and to produce specific benefits desired by the landowner. Some tending operations are non-commercial (e.g., pruning, early release of crop trees, precommercial thinning) requiring outright investment by the landowner, and can be collectively referred to as timber stand improvement (TSI). Other tending operations, such as commercial thinning, can generate revenue for a landowner. Intermediate silvicultural treatments are discussed in detail in Chapter 16: Intermediate Silvicultural Treatments.

Several different silvicultural systems are discussed in detail in the next section of this chapter, emphasizing the particular rationale and goals of each. The systems can be adapted based on stand and site conditions, and stand management objectives. Flexibility and imagination are key in tailoring silvicultural systems to address the host of values inherent in sustainable forest management.

SILVICS, THE BASIC BUILDING BLOCKS OF A SILVICULTURAL SYSTEM

Examples of Selected Silvical Characteristics for Three Common Wisconsin Tree Species

	Aspen	Northern Red Oak	Sugar Maple
Pollination	March to April	April to May	March to May
Seeds Mature	May to June	September to October of the next year	Fall
Seed Dispersal	Immediately after ripening. Wind and water long-distance dissemination.	September to December Gravity and animal dissemination.	Fall Wind dissemination up to 330 feet.
Good Seed Years	Every 4 to 5 years	Every 2 to 5 years	Every 1 to 5 years
Germination	Immediately after dissemination. No dormancy. 32ºF to 95ºF. Bare soil required.	Spring, two years after pollination. Mixed mineral/ humus soil preferred.	Spring, one year after pollination. Best at 34ºF. Bare soil not required.
Seedling Development	Six to 24" height and 8" to 10" taproot development in the first year in full sunlight.	Moderate height growth. Dieback common. Rapid taproot development.	Best growth in 30 to 90 percent full sunlight. Sensitive to moisture stress.
Vegetative Reproduction	Vigorous root suckers after fire or cutting. 4' to 6' height growth in first year.	Stumps sprout readily and can average 24" of height growth per year.	Stumps sprouting decreases with increasing tree size.
Shade Tolerance	Intolerant. Pioneer species.	Mid-tolerant. Maximum photosynthesis occurs at 70 percent shade.	Very tolerant.
Typical Rotation Age	45 to 70 years	80 to 200 years	80 to 175 years
Max. Life Expectancy	100 to 150 years	300 to 400 years	300 to 400 years

For a complete listing of all Silvical Characteristics for all Wisconsin trees, see the following website:
na.fs.fed.us/spfo/pubs/silvics_manual/table_of_contents.htm

Another key factor to keep in mind is that all harvests are not necessarily part of a regeneration system. In some cases, a harvest is specifically designed to capture the value of trees that might otherwise be lost. An example would be a situation where past cutting practices or natural events have left many mature trees scattered over an otherwise immature stand. Waiting for the scheduled regeneration harvest of the younger stand would likely result in loss of valuable forest products. As a result, a harvest might be carried out as part of an intermediate or salvage operation specifically to remove all or a portion of the older trees. Even though such harvests are not part of the overall regeneration system being applied to the primary stand, they should be compatible with overall long-term silvicultural objectives.

Remember, too, that silvicultural systems are developed based on the characteristics of forest cover types and a consideration of site factors. Specific treatments within a system should be modified to accommodate any special requirements.

GENERAL SHADE TOLERANCE OF WISCONSIN TREE SPECIES

Shade-tolerant

Able to reproduce and grow under a dense canopy.
Balsam Fir[1], Basswood, Beech[1], Black Spruce, Boxelder, Hemlock[1], Ironwood, Musclewood, Red Maple, Sugar Maple[1], White Cedar, White Spruce

Mid-tolerant

Reproduce best under a partial canopy which admits limited sunlight.
Ashes, Black Oak, Bur Oak, Elms, Hackberry, Hickories, Red Oak, Silver Maple, Swamp White Oak, White Oak, White Pine, Yellow Birch

Shade-intolerant

Light demanding species that reproduces best in full sunlight.
Aspen[2], Balsam Poplar, Black Cherry, Black Walnut, Butternut, Eastern Cottonwood, Jack Pine[2], Northern Pin Oak, Red Pine, River Birch, Tamarack, White Birch

1 Most tolerant species *2 Least tolerant species*
Note: Tolerance levels for a given species may vary during its life cycle.

Some of the key considerations in the selection of a silvicultural system include:

- **Shade Tolerance:** The ability of a given tree species to survive and grow in low light conditions under a forest canopy is referred to as its shade tolerance. This silvicultural characteristic is one of the most important considerations in the selection of a silvicultural system. Once established, most trees will maximize vigor and growth in near full sunlight. However, the amount of sunlight required for regeneration, early survival and different growth rates varies between tree species. Some species require full sunlight for their entire life cycle while others benefit from some protection in the regeneration and early establishment phases, only requiring full sunlight later to maintain growth and vigor. Still other species are able to regenerate and develop under very shady conditions, and use that ability to effectively compete with more sun-loving species.
- **Age Distribution and Stand Structure:** The age difference between individual trees within a particular stand varies. Some cover types typically regenerate all at once following a major disturbance (e.g., fire, wind events, insect and disease activity, past cutting, etc.). Others regenerate as groups following smaller disturbances, while still others regenerate almost continuously as individual trees die and create openings. As a result, the trees in some stands are essentially all the same age, while in others age varies widely. These age differences within a stand are often reflected by differences in tree heights and diameters. Trees in an even-aged stand tend to mature at the same time, while trees in an uneven-aged stand tend to mature as groups at distinct intervals or as individual trees on a relatively continuous basis.
- **Stand Condition:** Species composition, age, structure, quality, health and vigor, and spatial distribution of the trees within a stand must be carefully considered. Silvicultural guidelines and standard management systems generally are developed for typical or average conditions.

  In some cases, however, stands may exhibit a combination of low vigor, signs of significant insect and disease problems, excessive logging damage, low stocking, inappropriate age or stand structure, low tree quality, compacted or eroded soils and/or other abnormal characteristics. These stand conditions typically result from abuse, neglect or improper management practices such as high grading or diameter limit cutting. Such **degraded stands** may require modification of a standard silvicultural system to address specific stand and site conditions. Sometimes, intermediate treatments such as a series of improvement cuttings and thinnings, can restore degraded stands to acceptable and productive conditions. Other times, when degradation is extreme, regeneration methods may be needed to initiate development of an entirely new stand. The appropriate rehabilitative treatments may not be those generally recommended for the cover type, or may be applied at unusual times or in an unusual sequence.

Figure 2-7: Pulling garlic mustard before seeds set, as demonstrated by a Wisconsin Conservation Corps crew member, is an effective method to control this nonnative invasive plant.

- **Understory Competition:** The relative competitive abilities of desired species, other species, and undesirable species (trees, shrubs, and herbs that are present or could invade) should be considered. Key species-specific considerations include regeneration strategies, shade tolerance, response to release, and growth rates across variable site and stand conditions. Different silvicultural methods and systems can be utilized to encourage or discourage a particular species.

  The presence of **nonnative invasive plants**, can limit the success of potential silvicultural systems. The aggressive competitive abilities of some plants can interfere with desired regeneration and development. Specific silvicultural methods and systems must be designed to discourage the growth and spread or ameliorate the impacts of such species.

- **Herbivory**, particularly where deer populations are overabundant, can limit the success of potential regeneration methods. Selective browsing of preferred plant species can alter competitive dynamics, reducing representation of some species and facilitating the spread of others. Browsing can retard the development of or even eliminate desired regeneration. In some cases, only certain species not generally eaten by deer can be regenerated, unless intensive protection measures are implemented (e.g., fencing the forest).

- **Seed Production, Dissemination and Predation:** If regeneration is dependent on seed from the existing stand, a harvest may have to be timed to coincide with periodic seed years. Tree selection, sale shape, and follow-up seedbed preparation treatments must enhance seed dissemination, and discourage seed predation.

- **Seedbed Characteristics, Germination Requirements and Early Survival:** Some species require a mineral seedbed for germination while others are able to penetrate the litter on the forest floor and germinate in undisturbed areas. Still other species germinate best on seedbeds composed of a combination of mineral soil and humus. The germination temperature and the sunlight requirements for early survival may also be more specific for some species than others.

- **Seedling Establishment and Competition Control**: In some cases, overstory shade is needed to protect desired seedlings from excessive heating and drying during the establishment phase and/or retard the development of competing species. In others, full sun is required to maximize growth and the ability of the desired species to outperform competing species.

- **Quality Considerations:** In stands managed for high-quality sawtimber, overstory shade levels must be carefully controlled to minimize sunscald and epicormic branching and forking, while at the same time maximizing tree form and merchantable height.

EVEN-AGED SILVICULTURAL SYSTEMS

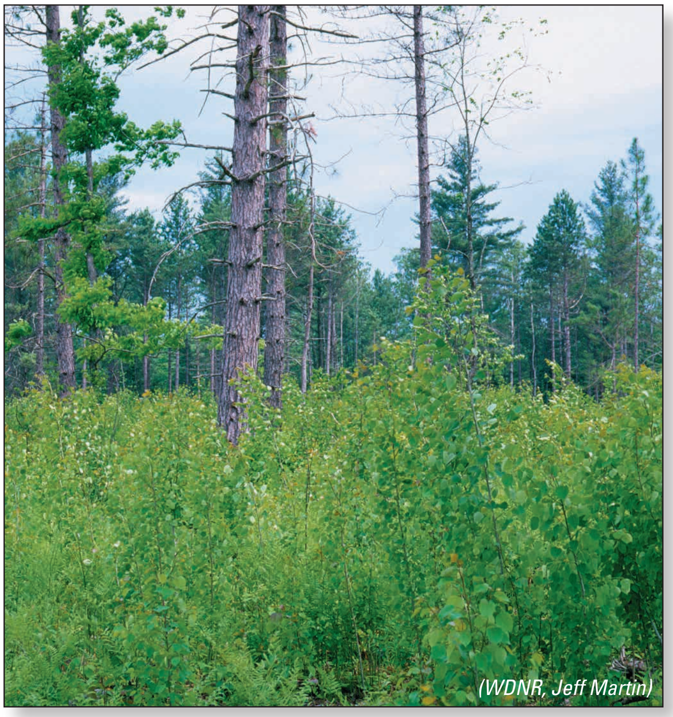
Even-aged management systems are normally used to harvest, regenerate and tend sun-loving forest cover types that grow poorly or will not regenerate in dense shade. Generally, the cover types adapted to these systems are those accustomed to regeneration and rapid domination of a site following a catastrophic disturbance such as a fire or major windstorm. Stands normally consist of trees at or near the same age. Even-aged systems are also applied to cover types dominated by shade-tolerant species when the intent is to focus on the less-tolerant component of the stand. Portions of even-aged management systems, specifically the intermediate thinning regimes, may also be used in the early stages of young northern hardwood stands to facilitate a long-term conversion to the uneven-aged system.

Even-aged Harvest and Regeneration Methods

Light requirements, growth rates and reproductive characteristics of the species to be regenerated govern the degree of overstory removal at the time of harvest. Competing vegetation and site characteristics are additional factors. The following are the generally accepted even-aged regeneration methods used in Wisconsin.

(WDNR, Jeff Martin)

Figure 2-9: A young poletimber stand of dense coppice origin aspen. As this stand continues to develop, there will be periods of natural thinning caused by competition induced mortality.



(WDNR, Jeff Martin)

Figure 2-8: This aspen stand was harvested one year ago using the coppice regeneration method. Red pine "standards" were retained to enhance ecological and visual diversity. Abundant aspen from vegetative reproduction is now established.

EVEN-AGED REGENERATION METHODS USED TO PARTIALLY SIMULATE THE DEGREE OF STAND MORTALITY THAT WOULD NORMALLY FOLLOW A SEVERE NATURAL DISTURBANCE SUCH AS A FIRE OR MAJOR WINDSTORM

These methods are primarily used with intolerant species such as aspen, red pine or jack pine that require full sunlight to ensure complete regeneration and optimum development.

- **Coppice:** (Figures 2-8 through 2-10) A method designed to naturally regenerate a stand using vegetative reproduction. The overstory is (nearly) completely removed. Generally, there is no residual stand left, other than a limited number of reserve trees or standards, as excessive residual can interfere with the regeneration, and is not necessary to shelter the regenerated stand. This method differs from the other even-aged regeneration systems (clearcut, seed-tree and shelterwood) in that the regenerated stand is derived from sprouting rather than a seed source.

Figure 2-10: A 50-year-old aspen stand. This mature aspen stand will be regenerated using the coppice method.

- **Clearcut:** (Figure 2-11) A method used to regenerate a stand by the removal of most or all woody vegetation during the harvest creating a mostly or completely open area leading to the establishment of an even-aged stand. Regeneration can be from natural seed produced by adjacent stands or trees cut in the harvesting operation. Clearcuts are also used prior to direct seeding or replanting for artificial regeneration systems.

  This method differs from the seed-tree and shelterwood 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 felled tops of harvested trees.

Figure 2-11: This central Wisconsin stand of mixed jack pine and "scrub" oak was clearcut within the past year.

- **Seed-tree:** (Figures 2-12 and 2-13) A method designed to bring about natural reproduction on 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 three to 10 per acre) are left and the residual stocking is not enough to sufficiently protect, modify or shelter the site in any significant way. Seed-trees may be removed after establishment or left indefinitely.

This method differs from the coppice method in that regeneration comes primarily from seed rather than sprouts. It differs from a clearcut in that the seed source for regeneration is 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.

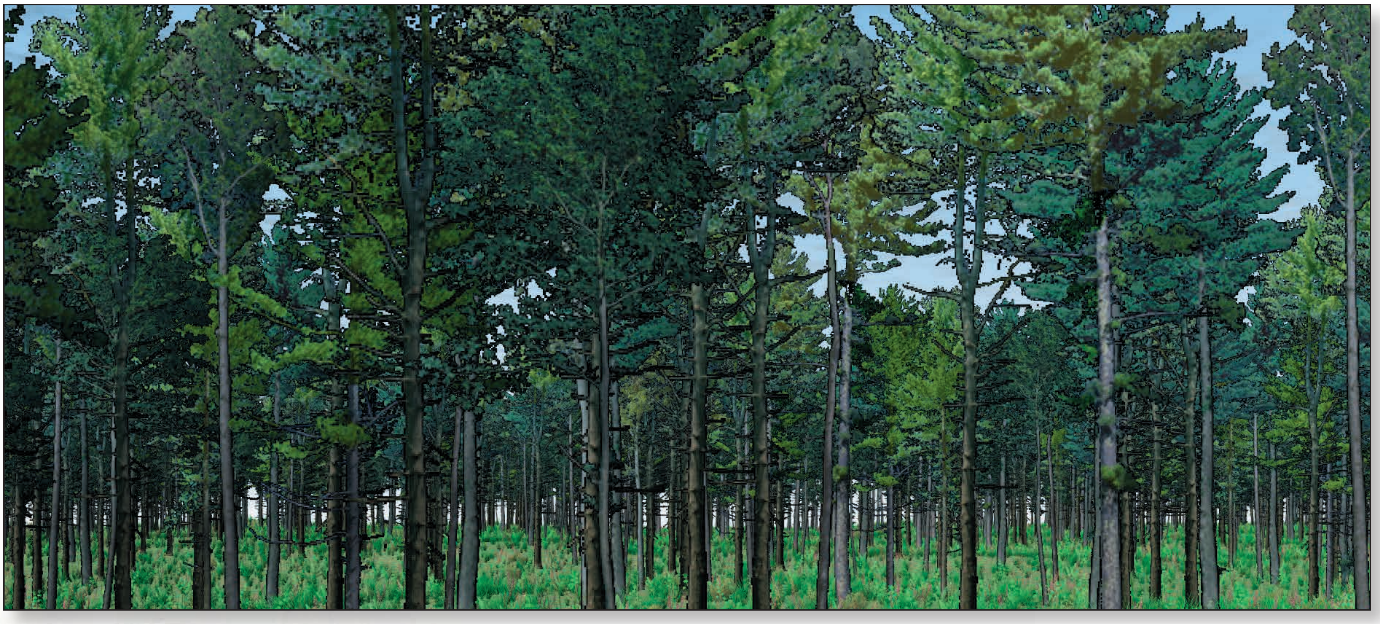


Figure 2-12 (Seed-tree A): A mature forest of mostly white pines mixed with smaller amounts of northern red oak and red maple. Seed-tree harvesting is one method used with even-aged species that require full sunlight for regeneration. All trees in such stands are generally ready for harvest at the same time, but sufficient advanced regeneration is not usually present. *(Figure Credit: Computer-generated simulation by Andy Stoltman)*

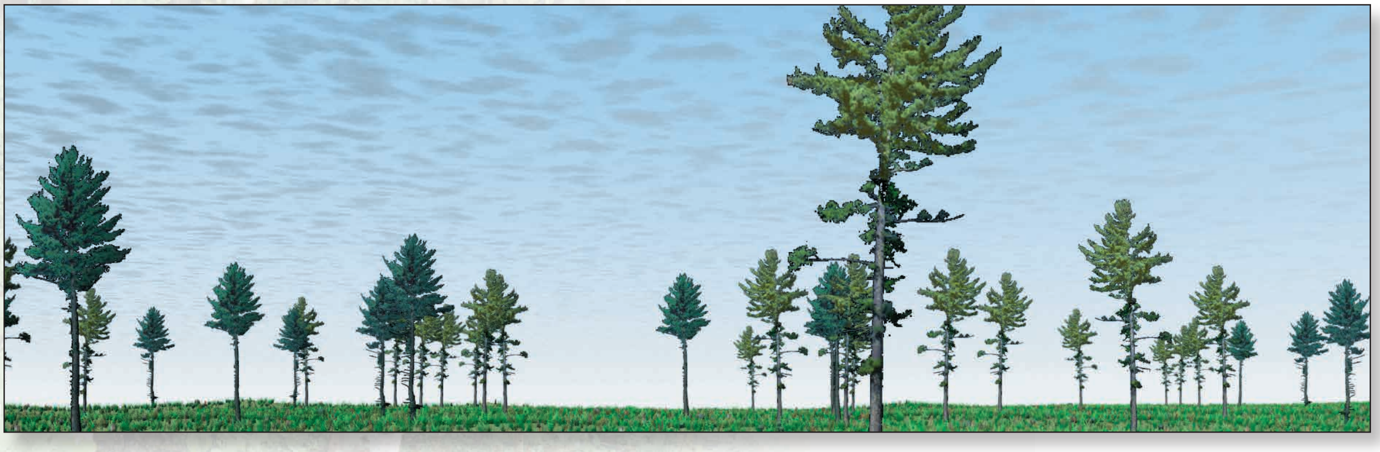


Figure 2-13 (Seed-tree B): White pine residual following a seed-tree regeneration harvest leaving about three to 10 trees per acre as a seed source to renew the stand. *(Figure Credit: Computer-generated simulation by Andy Stoltman)*

EVEN-AGED REGENERATION METHODS USED TO PARTIALLY SIMULATE NATURAL DETERIORATION OF THE OVERSTORY OVER TIME

These methods are tailored to more tolerant species that require partial shade and/or an abundant seed source for optimum regeneration, but once established need full sunlight for survival and full development (such as white pine and oak).

- **Shelterwood:** (Figures 2-14 through 2-19) A 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. This method normally involves gradual removal (usually in two or three cuts) of the overstory. The overstory serves to modify understory conditions to 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. The most vigorous trees are normally retained as the overstory, and the less vigorous trees removed.

A successful shelterwood harvest often requires the removal of intermediate or suppressed saplings and poles (often of less desirable species such as elm, ironwood or red maple) because the smaller understory trees will suppress development of vigorous seedlings of the preferred species.

Initial shelterwood cuttings 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. At that point, the remaining overstory is completely removed.

This method differs from clearcutting and coppice methods in that the next stand is established on the site before overstory removal. It differs from a seed-tree cutting in that the overstory serves to protect the understory as well as distribute seed. Finally, an even-aged shelterwood harvest differs from uneven-aged selection methods in that it promotes an even-aged stand structure.

Figure 2-14: May apples and other ground vegetation have begun to resprout following the first shelterwood cut (seed cut) in this red oak stand. Logging slash was removed and the ground scarified to provide improved conditions for light-demanding oak acorns to germinate.

Figure 2-15 (Shelterwood A): A dense stand of mature oak sawtimber and associated hardwoods before harvest. Notice the uniformity in size and age in the overstory, and the lack of regeneration.

(Figure Credit: Computer-generated simulation by Andy Stoltman)

Figure 2-16 (Shelterwood B): An oak forest soon after the first stage of a shelterwood harvest. The overstory has been opened up to allow sufficient light penetration for seed germination. Enough shade has been retained to prevent excessive drying of the seedbed and enhance early survival and establishment of the new seedlings. (Note: In some situations, post-harvest treatment of the understory with herbicides or mechanical scarification may be needed to control competition or prepare the seedbed.)

(Figure Credit: Computer-generated simulation by Andy Stoltman)

Figure 2-17 (Shelterwood C): The same stand after five years. Notice the regeneration developing as a result of the increased light penetration.

(Figure Credit: Computer-generated simulation by Andy Stoltman)

Figure 2-18 (Shelterwood D): An oak stand after the second stage (overstory removal) of a shelterwood harvest. After approximately 10 years, adequate regeneration is fully established, and the overstory has been removed to provide the added sunlight needed to maximize growth and development.

(Figure Credit: Computer-generated simulation by Andy Stoltman)

Figure 2-19: Natural regeneration after a shelterwood harvest has developed into an excellent stand of red oak poletimber, 30 years later, on the Hardies Creek Stewardship Forest in Trempealeau County.

- **Overstory Removal:** A method used to mimic the natural deterioration of the overstory but at an accelerated rate in situations where adequate regeneration is already established. The entire stand overstory is removed in one cut to provide the release of established seedlings and saplings. This method has been referred to as a natural shelterwood or a one-cut shelterwood.

  Overstory removal results in an even-aged stand structure as opposed to uneven-aged structure. It differs from the clearcut and the coppice regeneration methods in that seedling and sapling regeneration is established prior to the overstory removal. It differs from the shelterwood and seed-tree methods in that no manipulation of the overstory is needed to establish regeneration.

  Overstory removal can be applied to all forest stands being managed on an even-aged basis if desirable advance regeneration is well-established. 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 and desirability of established, advanced regeneration
  - Site capability
  - Existing and potential competition, including exotic species

In most cases, the objective of an even-aged silvicultural system is to naturally regenerate a species already present in the stand. Depending on the species involved, additional activities may be required to ensure that its germination and growth requirements are met. These may involve the use of prescribed fire, disking and other forms of scarification to expose a mineral soil seedbed to enhance seed germination and survival. Where natural regeneration is insufficient or in cases where the desired species is not present in the harvested stand, artificial regeneration by tree planting or direct seeding may be required.

The basic description of all the even-aged methods includes harvesting the stand through complete overstory removal and initiation of a new stand. However, these systems can incorporate the retention of reserve trees to provide continuity between stands and a variety of potential ecological and social benefits. Depending on the species being regenerated, reserve tree retention can be designed to provide minimal interference with the growth and timber productivity of the new stand. Reserve tree retention during even-aged rotations is a generally recommended sustainable forestry management practice (see Appendix A).

Even-aged Tending Methods

Tending operations implemented in young stands usually are non-commercial. **Timber stand improvement (TSI)** generally includes the **intermediate treatments** of pruning and release. **Pruning** is usually applied to improve timber quality and value, although it can also be utilized to control disease, improve aesthetics, or improve stand accessibility. **Release** treatments are designed to free young trees from undesirable competing vegetation to improve stand composition, growth and quality.

Thinning and improvement are intermediate treatments implemented in older stands with larger trees that often offer commercial opportunities. **Thinning** entails the removal of trees to temporarily reduce stocking and concentrate growth on the more desirable trees. Thinnings are applied primarily to improve diameter growth, manipulate structure, enhance forest health, recover potential mortality, and increase economic yields. **Improvement cutting** is the removal of less desirable trees of any species primarily to improve composition and quality. Typically, improvement is applied coincidentally with thinning.

Specific applications of intermediate treatments depend on landowner goals and objectives, economic constraints and opportunities, site capability, stand development, and the silvics/ecology of the desired species and their competitors. Intermediate silvicultural treatments are discussed in detail in Chapter 16: Intermediate Silvicultural Treatments.

In most even-aged stands, intermediate treatments are generally applied relatively consistently across the stand. These thinning practices can be modified (spatially) and temporarily applied in even-aged stands where the long-term management objective is conversion to uneven-aged management. For example, in even-aged small sawtimber-sized northern hardwood stands, even-aged thinning guides can be applied to most of the stand, however, some regeneration gaps can be created to initiate the development of an uneven-aged structure. Following one or more of these modified even-aged thinnings with canopy gaps, later operations are then based on uneven-aged selection management guidelines (simultaneous thinning, harvest and regeneration).


(WDNR, Jeff Martin)


(WDNR, Jeff Martin)

Figure 2-20 and 2-21: The importance of tending an even-aged stand is illustrated by comparing these two plots in the famous Star Lake thinning experiment started by Fred Wilson with red pine planted in 1913. Figure 2-20 (left) shows the poor growth and mortality in the plot that was never thinned. The adjoining plot, Figure 2-21 (right), shows the impact that periodic thinnings (every five to 10 years starting in 1943) can have on red pine.

Even-aged Harvest Considerations

Under even-aged silvicultural systems, entire stands are harvested all at once or over a relatively short period when they reach a given age. The term rotation is used for the period of years required to grow timber stands to a specified condition of maturity. The age of the stand at the end of the rotation period when it is normally harvested is called the **rotation age**.

Traditional rotation ages are set at a period in time when average annual volume growth reaches its maximum. For a given stand, there is usually a period of time when harvests will maximize the timber produced per year over the rotation. This age range can vary, depending on factors such as species, site characteristics, management regime, and products produced. This traditional timber rotation age range is normally established for each individual forest cover type reflecting prevailing regional or local conditions. For example, red pine in Wisconsin maximizes annual volume growth at 60 to 120 years old.

Sometimes, stands are rotated at younger ages, reducing maximum timber production in order to increase economic returns to the landowner. Sometimes, stands are rotated at older ages, reducing maximum timber production in order to increase other social and ecological benefits for the landowner; examples of potential benefits include desired aesthetics, diverse wildlife habitat, increased biodiversity, and additional protection of soil, water, or cultural resources. Other reasons to alter rotations may include property level and landscape-level considerations (e.g., rotation ages may be shortened or lengthened in order to increase age class diversity on the property).

Eventually, the trees in an even-aged stand will reach old age. Old trees grow slowly, and eventually timber volume losses from decay and death will outstrip growth. As tree mortality progresses within the stand, a once even-aged stand will slowly develop an uneven-aged stand structure.

The actual rotation length for a specific stand can vary depending on a number of factors:

- **The average growth rate and life span of the species involved.** A typical rotation age for a stand of aspen, for example, is 45 to 60 years. A typical rotation age for an oak stand may be two to three times as long.
- **Site productivity.** More productive sites support increased growth rates for a longer period of time. As a result, the period of positive mean annual growth is also extended, increasing the optimum rotation age. Different rotation lengths are typically employed across the range of site productivity.

(© Jeff Martin, JMAR Foto-Werks)

Figure 2-22: Red pine is a good example of a species amenable to modification of rotation age to reflect site productivity, product goals, and landowner non-timber objectives.

- **Silvicultural practices** can influence the pattern of growth and the age when growth is maximized. For example, manipulating the number of trees per acre, from planting through final thinning, influences tree vigor and the distribution of growth. Dense, unthinned stands managed for small diameter products maximize growth while relatively young. Fully stocked stands that are regularly thinned to maintain crop tree vigor to produce sawtimber maximize growth when older. Regular thinning shortens the period of time to reach a specified diameter, but also maintains vigor and high growth rates for a longer period of time.

- **Insect and disease concerns.** The level of mortality and decay caused by insects and disease is a prime factor in net growth. Insect and disease outbreaks can significantly reduce stand growth, and in extreme cases, cause such extensive mortality that they determine rotations.

- **Landowner goals.**
  - **The type and quality of timber products desired.** Pulpwood takes a shorter time to produce than sawlogs, which must be larger in diameter. High quality sawlogs and veneer logs require even more time, since they are typically grown to still larger diameters and at higher density levels to control stem form and limit defects.
  - **Economic considerations.** Changes in supply and demand in general, market values, specific customer requirements, and internal infrastructure demands can all result in modified rotation ages.
  - **Management for other (non-timber) forest resources.** Forest management goals may emphasize non-timber resources such as aesthetics, recreation, wildlife habitat, biodiversity, and protection of soil, water, and cultural resources. Timber rotations could be altered to maintain, protect or enhance non-timber resources.

Figure 2-23: White pine stand that has reached rotation age for the site it is on. The first cut (seed cut) of the shelterwood regeneration method has been applied.

UNEVEN-AGED SILVICULTURAL SYSTEMS

Uneven-aged management systems are normally used to harvest, regenerate and tend forest cover types that will regenerate and grow under partial shade. Stands managed under uneven-aged systems are normally comprised of three or more age classes. These cover types are adapted to regenerate under partial canopies following minor disturbances like individual tree mortality, or a moderate disturbance such as a wind storm that would damage up to one-third of the stand, felling trees as individuals, groups and in small patches. Uneven-aged systems are designed to partially emulate such disturbances.

Even shade-tolerant species grow most vigorously in relatively free-to-grow conditions with near full sunlight, assuming other growth requirements, like soil moisture, are met. As a result, regeneration and most vigorous growth typically occur in small- to medium-sized canopy openings. The number and size of openings created through uneven-aged management are dependent on species composition, size class or acreage regulation, and tree rotation age or size. Normally, these systems are used to manage stands containing mixed trees of all ages, from seedlings to mature trees. They are also used to convert even-aged stands into an uneven-aged structure.

Uneven-aged Harvest and Regeneration Methods

Stand regeneration is achieved by periodically manipulating the overstory and understory to create conditions favorable for the establishment and survival of desirable tree species. Canopy openings for regeneration are created by removing individual trees with large crowns, groups of trees, and small patches of trees. Smaller openings favor shade-tolerant species, whereas the larger patches generally favor mid-tolerant species.

In general, stands managed under uneven-aged systems regenerate as a result of manipulation of light levels during the harvest process. In some cases, non-commercial removal of additional cull trees or poorly formed saplings may be needed to further enhance regeneration in specific areas which are not opened up through the normal selection process.

Thinning, regeneration and harvesting usually occur simultaneously (time), but may vary across the stand (space). The harvested trees are essentially replaced by growth on the younger trees left in the stand. These silvicultural systems are designed to maintain an uneven-aged stand condition by periodically regenerating new age classes (cohorts), while manipulating the multi-aged and multi-sized structure of the overstory to facilitate continual development of quality growing stock. For more information, see the Wisconsin DNR *Silviculture Handbook, 2431.5*. The handbook can be found at: ***dnr.wi.gov – keyword "silviculture."***

With the uneven-aged silvicultural systems, the tree selection decision (to retain or cut) considers a number of factors, including those illustrated in Figures 2-24 through 2-26.

Figure 2-24: Species Desirability

Figure 2-25: Tree Quality

Figure 2-26: Desired Age and Size Class Distribution

The following are generally accepted uneven-aged silvicultural systems used in Wisconsin:

- **Single-tree Selection:** (Figures 2-27 and 2-29) Individual trees of various size and age classes are periodically removed to provide space for regeneration, and promote the growth of remaining trees. To recruit and release regeneration, trees are removed singly and in small groups, creating canopy gaps less than 0.1 acres in size. Each regeneration opening (canopy gap) covers an area equivalent to the crown spread of one to several large trees. The spacing of canopy gaps is irregular, based on the location of large harvested trees and small groups of undesirable trees. The overstory provides a seed source, and modifies understory conditions to create a favorable environment for the reproduction, competition and growth of certain species. This system favors the regeneration and maintenance of shade-tolerant species.

  Residual stand stocking is regulated by size or age class and generally maintained at a specified level to promote development of high-quality timber and fully utilize the site. Trees are selected for removal from all size classes (to achieve desired residual density levels) following recognized order of removal that considers tree risk, crop tree release, tree vigor, tree quality, species composition, and spacing. The goal, particularly in the northern hardwood cover type, is to achieve an optimum distribution of size and age classes so each contains a sufficient number of quality trees to replace those harvested in the next larger size class.

Figure 2-27: Single-tree selection. This 25-year-old canopy opening is being captured by young yellow birch trees.

Figure 2-28 (Single-tree Selection A): An uneven-aged northern hardwood stand which has not been harvested in 15 years. The basal area is approximately 120 square feet per acre.

(Figure Credit: Computer-generated simulation by Andy Stoltman)

Figure 2-29 (Single-tree Selection B): The same stand following a single-tree selection harvest. Trees have been removed from across the range of age and size classes to maintain an uneven-aged structure. The residual basal area is about 84 square feet per acre.

(Figure Credit: Computer-generated simulation by Andy Stoltman)

Figure 2-30: One-third acre group selection harvest in a central hardwood stand shortly after the harvest was completed.

- **Group Selection:** Trees are periodically removed in groups to create conditions favorable for the regeneration and establishment of new age classes (cohorts). Canopy openings to recruit or release regeneration may range in size from 0.1 to 0.5 acres. The smallest canopy openings are one-tenth acre, equivalent to a 75 foot diameter circular opening; this size can be large enough to recruit some mid-tolerant species, as well as stimulate vigorous shrub and herb competition. The largest canopy openings are one-half acre, equivalent to a 167 foot diameter circular opening; this is approximately two-times tree height. The overstory provides a seed source, and modifies understory conditions to create a favorable environment for the reproduction, competition and growth of certain species. This system favors regeneration and maintenance of shade-tolerant and mid-tolerant species; shading effects will vary across the canopy opening. The distribution of regeneration openings may be regular, or irregular depending on variations in stand condition, such as the age, size, vigor, quality, composition, and health of groups of trees.

Acreage regulation determines the number of canopy openings. Groups of trees are harvested at rotation age creating new canopy openings. In addition, regeneration recruited by past cutting may require release, and the remainder of the stand is thinned. Many small cohorts of trees must be tracked to evaluate rotation, site preparation and regeneration, release, and thinning of different aged groups. Regeneration cuts, release, thinning, and harvesting usually occur simultaneously (time), but are variable across the stand (space).

In general, northern hardwood stands dominated by large crowned tolerant species (e.g., sugar maple and beech) do not require the creation of large group openings to provide sunlight for regeneration, and individual trees are harvested as they mature using the single-tree selection method. However, some of the less-tolerant species commonly associated with sugar maple (e.g., basswood, yellow birch and ash) can benefit from the group selection method to enhance recruitment and growth of new seedlings if appropriate steps are taken to control competition.

Figure 2-31: One acre patch selection harvest in a central hardwood stand shortly after the harvest was completed.

- **Patch Selection:** Trees are periodically removed in patches to create conditions favorable for the regeneration and establishment of new age classes (cohorts). Canopy openings to recruit or release regeneration are greater than 0.5 acres in size, and typically less than two acres in size. The smallest canopy openings are larger than one-half acre, which is equivalent to a 167 foot diameter circular opening (approximately two-times tree height). The overstory provides a seed source and partially modifies understory conditions. 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, regeneration recruited by past cutting may require release, and the remainder of the stand is thinned. Many cohorts of trees must be tracked to evaluate rotation, site preparation and regeneration, release, and thinning of different aged patches. Regeneration cuts, release, thinning, and harvesting usually occur simultaneously (time), but are variable across the stand (space).

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. Relatively large regeneration openings may be fairly exposed and plant competition can be fierce. Site preparation and follow-up release may be needed to establish desired regeneration.

Uneven-Aged Tending Methods

In uneven-aged silvicultural systems, tending operations are not as clearly distinguished from rotation harvest and regeneration operations as in even-aged systems. Harvest and regeneration are perpetual operations, rather than occurring once during a stand's rotation, so tending must also be integrated and not temporally separated. In addition, uneven-aged stands typically have a spatially patchy age structure that may require patchy applications or variations of intermediate treatments.

Release treatments are designed to free young trees from undesirable competing vegetation to improve stand composition, growth and quality. These treatments can be applied to regeneration openings created by any selection system, although costs associated with the location and treatment of scattered regeneration patches may be prohibitive. They are generally most needed and feasible where the objective is to facilitate the survival, growth and development of seedlings and saplings of mid-tolerant species growing in larger openings created through application of the group and patch selection systems. In addition, as canopy crowns expand over time, previously created canopy openings may need to be re-opened or expanded to maintain the vigorous growth of young trees. This release operation can be conducted concurrently with other periodic cutting operations.

Thinning is an intermediate treatment that entails the removal of trees to temporarily reduce stocking to concentrate growth on the more desirable trees. Thinnings are applied primarily to improve diameter growth, manipulate structure, enhance stand vigor, recover potential mortality, and increase economic yields. **Under the uneven-aged silvicultural system, thinnings are implemented concurrently with periodic harvest and regeneration operations.** Stands are normally re-entered on an eight- to 20-year cutting cycle depending on landowner objectives, economic constraints and opportunities, site quality, tree growth rates, stand development, and the silvics of the desired species. Specific target stand stocking levels (density management) by size or age class are very important to tree growth and quality development. Often, small groups or patches of essentially even-aged trees can be recognized and treated. Tree selection is based on a recognized order of removal that considers tree risk, crop tree release, tree vigor, tree quality (timber), species composition, and spacing. Additional criteria can also be employed to enhance wildlife habitat, biodiversity, water quality, and aesthetic values. Temporary **improvement cutting** may be needed to improve composition or quality in stands that have been previously unmanaged, neglected or poorly managed.

Figure 2-32: When the uneven-aged system is used, an optimum maximum tree diameter class is determined for each stand.

Uneven-aged Harvest Considerations

Harvests in uneven-aged stands occur regularly. The normal cutting cycles range from eight to 20 years. The interval is based on site quality, species, growth rates, removable volumes, and landowner goals relative to each stand.

In the patch and group selection systems, once stands are regulated, even-aged harvest considerations apply to the rotation of groups and small patches. Usually, trees are also harvested throughout the majority of the stand during thinning operations following crop tree release and order of removal concepts. However, these methods do allow for stand level variations in regeneration, composition, structure, and silvicultural practices over space and time.

In the single-tree selection system, individual trees are removed from each size (or age) class as needed to achieve the desired level of stocking. When selecting which trees to remove within each diameter class, the primary factors considered are risk, crop tree release, vigor, quality, species, and spacing. In addition, an optimum maximum diameter class is determined for each stand based on the following considerations:

- **Site Productivity:** Higher quality sites can support increased growth rates. Trees can reach a given diameter faster, but increased vigor may also allow trees to be carried to a larger diameter before growth rates decline significantly and before degrade/decay becomes a major factor in tree value.
- **Average Growth Rates and Life Spans of the Species Involved:** Stands managed by single-tree selection may contain a variety of different species, each potentially having a different optimum maximum diameter class.
- **Landowner Goals:** Maximum diameter classes can be increased or decreased depending on specific landowner goals.
  - **Type and Quality of Products Desired:** A decision to focus on sawtimber, veneer or both may influence the selection of an optimum maximum diameter class.
  - **Log Grade:** As a particular high-quality crop tree gets larger, it becomes more economically valuable. The value increase is due to more than just the additional volume accumulated as the tree grows. As a tree passes though a number of threshold diameters, it increases in grade and value dramatically. The values of sawlogs depend more on grade than volume. Larger diameters are required for the higher grades, which can bring two to three times the value of lower grade logs. Attaining veneer size can result in another major increase in tree value (see Figure 9-6, page 9-7).
  - **Economic Considerations:** Changes in supply and demand in general, market values, specific customer requirements, and internal infrastructure demands can all result in modified rotation ages (maximum diameter class).
  - **Management for Other (Non-timber) Resources:** Forest management goals may emphasize non-timber resources such as aesthetics, recreation, wildlife habitat, biodiversity, and protection of soil, water, and cultural resources. The optimum maximum diameter class can be altered to maintain, protect or enhance these non-timber resources.

The Wisconsin DNR *Silviculture Handbook, 2431.5* provides three stocking guides for northern hardwood stands managed by single-tree selection. The traditional guide is based on a maximum diameter class of 24 inches (or trees 20 inches diameter and larger) and attempts to optimize the production of sawtimber quantity and quality. An alternative guide is based on a maximum diameter class of 18 inches (or trees 15 inches diameter and larger) and may facilitate increased economic returns (under certain economic scenarios). Another alternative guide is based on a maximum diameter class of 30 inches (or trees 25 inches diameter and larger) and can facilitate increased production of specific non-timber resources. Both alternatives may sacrifice optimal sawtimber productivity (quantity and quality) in order to increase other benefits.

Reaching the optimum maximum diameter class is not a primary criterion for tree selection. Other marking criteria (risk, vigor, quality, species, spacing, and basal area stocking levels) guide the selection of trees to retain and remove. Vigorous, low risk, high-quality trees may be retained well beyond the top diameter, for example, if stocking in the maximum diameter class is too low or other higher risk, lower vigor, or poorer quality trees are removed instead.

Flexibility exists in the selection of an optimum maximum diameter class. The diameter class chosen, however, is a key factor in the determination of the optimum number of trees needed in each of the other various diameter classes – from the smallest to the largest – to ensure that quality trees are available to replace those harvested.

PASSIVE OR NON-MANAGEMENT OPTIONS

Figure 2-33: Passive management is the most appropriate approach with fragile plant communities such as this relic white pine stand on cliffs in a stream-side riparian zone.

Some landowners and resource managers choose to "let nature take its course" on some forestland. In such cases, they make a conscious management decision to not actively manipulate the vegetation. This passive management is not considered a silvicultural system since it does not involve manipulation of vegetation.

Landowners and managers have different reasons for choosing to not actively manipulate vegetation. They may wish to protect and preserve fragile or special sites or communities (e.g., cliff communities, springs, groves of large old trees, and cultural sites). They may wish to develop habitat for specific wildlife that prefers relatively undisturbed forests. They may enjoy the appearance (aesthetics) and the recreational opportunities. Philosophical reasons may include the desire to allow nature to develop free of human impacts. Wilderness areas and some research control sites may be passively managed.

The concepts of "preservation" and "natural dynamics free of human impacts" are relative. Forests are dynamic communities that are continuously changing and adapting to external inputs and internal disturbances. Natural processes like forest succession, plant competition, structural development, wildlife and insect activity, tree aging and decay, windstorms, and fires will cause changes in forest composition, structure and function over time. Forests cannot be maintained in a static, unchanging condition. Also, there are no forest ecosystems undisturbed by human activities. Human disturbance has occurred through atmospheric composition and inputs, fire control, management of wildlife populations (intentional and unintentional), introduction of nonnative invasive species, recreational use, other human uses, etc. Passively managed forests will continue to change and will be subjected to human impacts, however, these changes and impacts often will be different than in actively managed forests.

Passive management does require monitoring, and certain events may necessitate the implementation of some short-term active practices. Examples include control of nonnative invasive plants, fire management, disease and insect management, wildlife management, recreation management, removal of diseased or weakened trees that pose safety hazards, and loss of attributes desired by the landowner. Passive management requires an understanding of the effects of natural processes and the impacts of other human activities (internal and external to the forest) on the development of the forest. This knowledge will facilitate the achievement of landowner objectives, and minimize the chances of counterproductive results or unintended consequences. In some situations, a blend of passive management and active silvicultural treatment may most effectively achieve landowner goals.

SILVICULTURAL SYSTEMS SUMMARY

As discussed in previous sections of this chapter, each of the silvicultural systems and regeneration methods has a number of variations that can be employed to tailor them to the specific species and sites involved. The choices can be confusing, but hopefully this summary will help sort things out.

EVEN-AGED SILVICULTURAL SYSTEMS

(Normally Used for More Sun-loving Species)

CLEARCUT

A complete overstory removal designed to facilitate regeneration by natural seeding, direct seeding or planting.

COPPICE

A complete overstory removal (clearcut) designed to promote regeneration through sprouts and suckers.

OVERSTORY REMOVAL

A complete removal of the overstory in a single harvest (clearcut), applied to any even-aged cover type if adequate regeneration is already established (used to release a new stand).

SEED-TREE

All overstory trees, except for about three to 10 seed trees per acre, are removed to facilitate regeneration by natural seeding.

SHELTERWOOD

A complete overstory removal in two to three harvests spaced over a period of years. The residual trees from the first cut serve to modify understory conditions to create a more favorable environment for reproduction and provide a seed source. They are removed when the regeneration is established.

NOTE: Reserve tree retention during even-aged rotations is a generally recommended sustainable forestry management practice (see Appendix A).

UNEVEN-AGED SILVICULTURAL SYSTEMS

(Normally Used for More Shade-tolerant Species)

SINGLE-TREE SELECTION

Individual trees are harvested from all size classes on a recurring cycle. Regeneration occurs naturally in the canopy gaps, less than 0.1 acres in size, created by harvesting one to several trees.

GROUP SELECTION

Trees are removed (rotated) in groups, 0.1 to 0.5 acres in size, on a recurring cycle. Regeneration occurs naturally in the openings created.

PATCH SELECTION

Trees are removed (rotated) in small patches, greater than 0.5 acres in size, on a recurring cycle. Regeneration occurs naturally in the openings created.

SIGNIFICANCE OF TABLE 2-1 TO THE WISCONSIN COOPERATING FORESTER PROGRAM

Table 2-1 summarizes the regeneration methods and silvicultural systems that are generally recognized as acceptable and widely applied in Wisconsin. The designations are substantiated in forestry research literature and further elaborated in the Wisconsin DNR *Silviculture Handbook, 2431.5*. Under the framework established by NR 1.213(3) b, Wisconsin Administrative Code, all forest management and timber harvesting assistance provided by the Wisconsin DNR and Cooperating Foresters must be consistent with the sideboards established in Table 2-1. Exceptions will be granted only if a science-based management commitment describing an alternative method is submitted to and approved by the Wisconsin DNR in advance. Additional information on conditionally recommended and alternative regeneration methods by cover type is also presented in the *Silviculture Handbook*. Procedures regarding management commitments can be found in Chapter 21 of the Wisconsin DNR *Private Forestry Handbook, 24705.21*.

FOREST COVER TYPES[1]	NATURAL REGENERATION METHODS							
	Coppice	Clearcut	Seed Tree	Overstory Removal	Shelterwood	Patch Selection (0.5 to 2.0)	Group Selection (0.1 to 0.5)	Single-tree Selection (less than 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[2]		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.

Table 2-1: Natural Regeneration Methods by Forest Cover Type for Wisconsin

SALVAGE HARVESTS

Figure 2-34: Forest management plans are often modified by natural disturbances like this major wind storm in a northern Wisconsin hemlock stand.

In addition to regeneration harvests employed as part of a silvicultural system, salvage harvests may be carried out as part of an overall forest management program. Unlike regeneration harvests, which are also designed to facilitate regeneration of the new stand, salvage harvests are geared only to the recovery and use of dead or dying trees that would otherwise go unharvested. Wind events, fire, flooding, insect and disease activity, and weather extremes can all wreak havoc on the best of forest management plans. High-quality trees can have significant economic value and often justify a salvage effort. Removal of infected trees is sometimes necessary to prevent additional mortality.

It should also be remembered, however, that dead and dying trees are part of the overall forest system, and provide a number of benefits to wildlife and other ecological processes. Decisions to conduct or not conduct a particular salvage operation are often a balance between potential economic return, impact on stand silviculture, risk of wildfire, cost of salvage, and the ecological value of leaving the trees in place. When mortality is significant, a regeneration strategy should be developed to facilitate regeneration, based on current conditions and landowner goals.

UNSUSTAINABLE HARVEST METHODS

A silvicultural system is a planned program of treatments over the life of a stand. Other cutting methods exist primarily to maximize short-term economic gain, and are not part of a long-term plan to ensure regeneration of a healthy, vigorous stand on a sustainable basis.

The following examples of unsustainable cutting methods are not an all-inclusive list. These methods may result in a new stand of trees, but due to the lack of consideration of specific species requirements, they often lead to stand degradation and are not considered generally accepted silvicultural practices that result in sustainable forestry.

- **Economic clearcutting**, where any tree of economic value is cut with no consideration for site, silvics of the species involved or regeneration needs. This practice differs from a clearcut in the even-aged silvicultural system where all trees are harvested, regardless of value, in order to ensure residual shade and competition does not hamper the regeneration and development of a new stand.
- **Diameter limit cutting** is cutting 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 silvicultural system.
- **High grading** (Figures 2-35 and 2-36), also referred to as "selective logging," is the practice of cutting only the largest, most valuable trees in a stand and leaving low value and poor quality trees to dominate. This practice is NOT the same as a single-tree selection regeneration harvest described in the silvicultural systems section (see page 2-24). High grading is not designed to enhance the quality and reproductive potential of the residual stand, but does attempt to maximize immediate revenue. The term "selective logging" is sometimes used intentionally by unscrupulous loggers to create false expectations on the part of landowners.

It is emphasized that economic gain and sustainability ARE compatible. Using creativity and imagination in the application of sound silviculture will best achieve both goals in the long-run.

Figure 2-35: Before

Figure 2-36: After

Figures 2-35 and 2-36: The figures above depict the results of a typical "high grade." All the larger trees with the greatest economic value have been removed leaving only poor quality trees behind. No consideration was given to size and age distribution, residual stocking levels or regeneration needs.

(Figure Credits: Computer-generated simulation by Andy Stoltman)

MANAGEMENT PRESCRIPTIONS

As the previous sections of this chapter describe, the basic question of "what to grow and how to grow it" is not as simple as it may first appear. Indeed, the answer can involve the collection and evaluation of a great deal of information, and the consideration of a number of alternative strategies. **In the end, the question – "what to grow and how to grow it" – must be answered clearly, logically and completely.** This final step in the decision-making process can be compared to the last phase of designing a new home – the development of a blueprint which spells out in detail exactly how your vision transfers to clear, specific action. The silvicultural counterpart to that blueprint is a management prescription.

A **management prescription** or recommendation is a detailed description of a specific treatment or cutting scheme designed to implement a specific stand management objective. Prescriptions describe the individual activities necessary to implement the overall silvicultural system in a given stand.

A **forest management plan** is written for entire properties and identifies general landowner goals as well as other property and landscape information. The more detailed plans also identify specific stand management objectives, and the series of management prescriptions describing specific actions needed for all stands for an entire operational period (see Chapter 10: Forest Management Planning).

It is important that a management prescription reflect all relevant factors and be written in a clear, logical fashion. Less complex prescriptions are normally written in a narrative format. More complex prescriptions involving a number of interdependent activities with the outcomes of each leading to different pathways may include a decision tree or diagram (see Figure 2-37).

The development of a detailed management prescription for a given stand is a complex process. It requires a thorough understanding of the landowner's goals and objectives, silviculture, silvics, capabilities and limitations of the resource, and collection and evaluation of considerable vegetative and site data. Since each stand is unique, a forester and possibly other resource professionals should be involved to provide technical assistance.

MANAGEMENT PRESCRIPTIONS: FACTORS TO CONSIDER

1. Landowner's Objective

- Is it sustainable?
- Were all opportunities considered?

2. Assess Biological Characteristics

- Site capabilities
- Past disturbances
- Current vegetative condition and potentials (species composition and succession; stand structure, quality, and growth)
- Stand vigor
- Presence and severity of invasive plants, insects, and diseases

3. Consider Relevant Environmental, Cultural, Social, and Economic Factors Such As:

- Aesthetics
- Recreation
- Wildlife
- Biodiversity and presence of endangered species
- Water and soil quality
- Landscape scale issues (critical habitat, percentage of land in a cover type, etc.)
- Regulations (statutes, rules or local ordinances)
- Traditions (possibly related to ethnic heritage) and cultural resources
- Markets
- Community viability

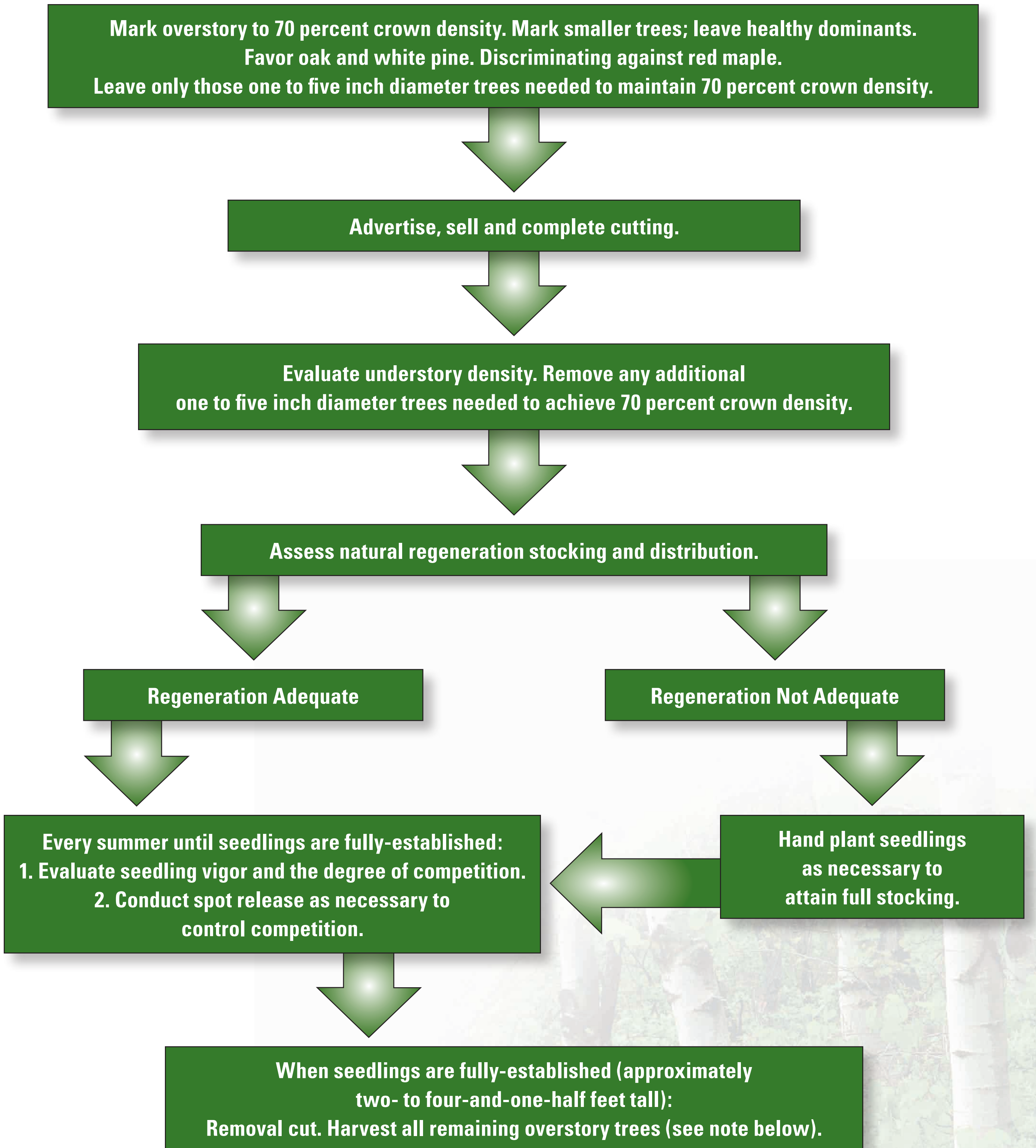


Figure 2-37: An example of a management prescription designed to implement a shelterwood regeneration harvest in a mature red oak stand. (NOTE: This particular management prescription has a strong timber management focus. To enhance sustainable forestry goals, a portion of the residual overstory (five to 15 percent) could be retained as reserve trees during the final removal cut to provide for a continuous supply of mast and increased habitat diversity.) There is a significant amount of flexibility available to tailor a silvicultural system to meet various needs as long as the primary objective to regenerate the stand is not compromised.

RESOURCES FOR ADDITIONAL INFORMATION

These resources are specific to the information in this chapter only. Refer to the Resource Directory for additional resources related to this chapter.

APPROACHES TO ECOLOGICALLY BASED FOREST MANAGEMENT ON PRIVATE LANDS

Approaches to Ecologically Based Forest Management on Private Lands. Kotar, J., University of Minnesota Extension Service, Publication NR-604, 1997. ***www.na.fs.fed.us/spfo/pubs/misc/ecoforest/toc.htm***

THE DICTIONARY OF FORESTRY

The Dictionary of Forestry. Helms, J. A. (Editor), Society of American Foresters, 1998.

FOREST DYNAMICS AND DISTURBANCE REGIMES: STUDIES FROM TEMPERATE EVERGREEN – DECIDUOUS FORESTS

Forest Dynamics and Disturbance Regimes: Studies from Temperate Evergreen – Deciduous Forests. Frelich, L. E., Cambridge University Press, Cambridge, UK, 2002.

NATURAL DISTURBANCE AND STAND DEVELOPMENT PRINCIPLES FOR ECOLOGICAL FORESTRY

Natural Disturbance and Stand Development Principles for Ecological Forestry. Franklin, J. F., R. J. Mitchell, and B. J. Palik, U.S. Department of Agriculture Forest Service, Northern Research Station, GTR NRS-19, 2007. ***nrs.fs.fed.us/pubs/3293***

THE PRACTICE OF SILVICULTURE: APPLIED FOREST ECOLOGY (9TH EDITION)

The Practice of Silviculture: Applied Forest Ecology (9th Edition). Smith, D. M., B. C. Larson, M. J. Kelty, and P. M. S. Ashton, New York: Wiley, 1996.

SILVICS OF NORTH AMERICA: 1. CONIFERS 2. HARDWOODS AGRICULTURE HANDBOOK

Silvics of North America: 1. Conifers 2. Hardwoods Agriculture Handbook 654. Burns, R. M. and B. H. Honkala (technical coordinators), U.S. Department of Agriculture Forest Service, Washington D. C., 1990. ***na.fs.fed.us/spfo/pubs/silvics_manual/table_of_contents.htm***

SILVICULTURE: CONCEPTS AND APPLICATIONS

Silviculture: Concepts and Applications. Nyland, R. D., New York: McGraw-Hill, 1996.

SILVICULTURE HANDBOOK

Silviculture Handbook. Wisconsin DNR, Publication Number 2431.5, Madison: Wisconsin DNR, 2010. ***dnr.wi.gov – keyword "silviculture"***

NOTE: Figures 2-12, 2-13, 2-15, 2-16, 2-17, 2-18, 2-28, 2-29, 2-35 and 2-36 use computer-generated simulations to depict various harvest methods listed in Table 2-1 (see page 2-32). The images were produced by Andrew Stoltman as part of the Forest Visualization at Multiple Scales for Management project at the University of Wisconsin-Madison, Department of Forest Ecology and Management.

WISCONSIN DEPARTMENT OF NATURAL RESOURCES
NOTICE OF FINAL GUIDANCE & CERTIFICATION

Pursuant to ch. 227, Wis. Stats., the Wisconsin Department of Natural Resources has finalized and hereby certifies the following guidance document.

DOCUMENT ID

FA-20-0005

DOCUMENT TITLE

Wisconsin Forest Management Guidelines

PROGRAM/BUREAU

Forest Economics and Ecology, Applied Forestry Bureau

STATUTORY AUTHORITY OR LEGAL CITATION

S. 823.075, Wis. Stats. & NR 1.25, Wis. Admin. Code

DATE SENT TO LEGISLATIVE REFERENCE BUREAU (FOR PUBLIC COMMENTS)

2/10/2020

DATE FINALIZED

4/6/2020

DNR CERTIFICATION

I have reviewed this guidance document or proposed guidance document and I certify that it complies with sections 227.10 and 227.11 of the Wisconsin Statutes. I further certify that the guidance document or proposed guidance document contains no standard, requirement, or threshold that is not explicitly required or explicitly permitted by a statute or a rule that has been lawfully promulgated. I further certify that the guidance document or proposed guidance document contains no standard, requirement, or threshold that is more restrictive than a standard, requirement, or threshold contained in the Wisconsin Statutes.

Carmen Hardin — March 27, 2020

Signature — Date