Chapter 21

Natural Regeneration

Last Full Revision: 1/04/2019
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 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.

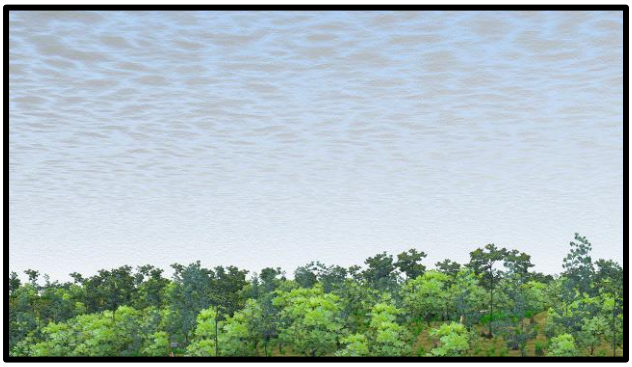
General considerations in the application of the shelterwood method are:
- Site evaluation (suitable to meet nutrient-moisture needs of species)
- Level/intensity of competition
- Overstory condition, health, and composition
- Seed tree condition (phenotype), health, and composition (form, crown class, 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.

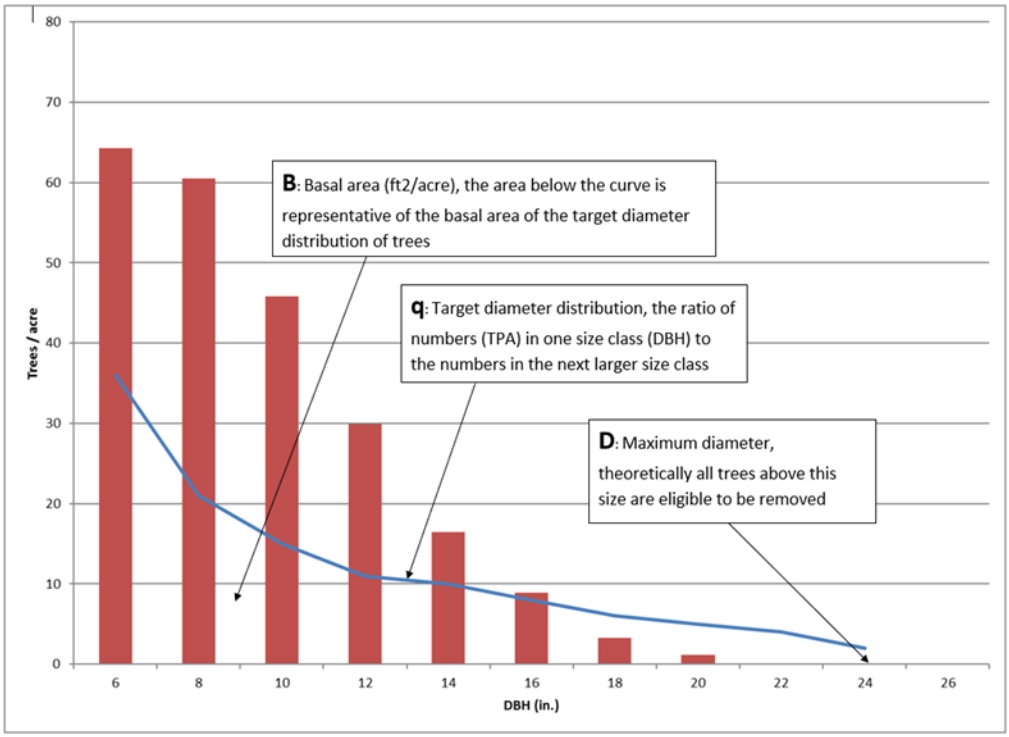


Figure 21.6. Example stand diameter distribution illustrating BDq method: B = basal area of the target diameter distribution of trees (not illustrated), D = maximum diameter, and q = target diameter distribution.

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

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

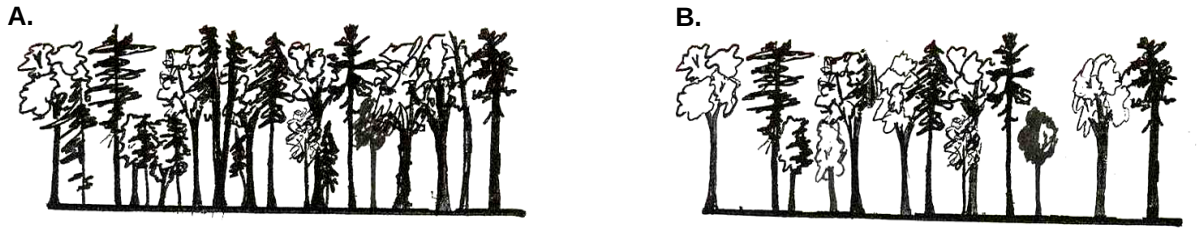


Figure 21.7. Single-tree selection – (A.) before and (B.) after cutting for harvest, thinning, and regeneration.

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
    - generally, trees retained are the most vigorous crop trees
    - 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

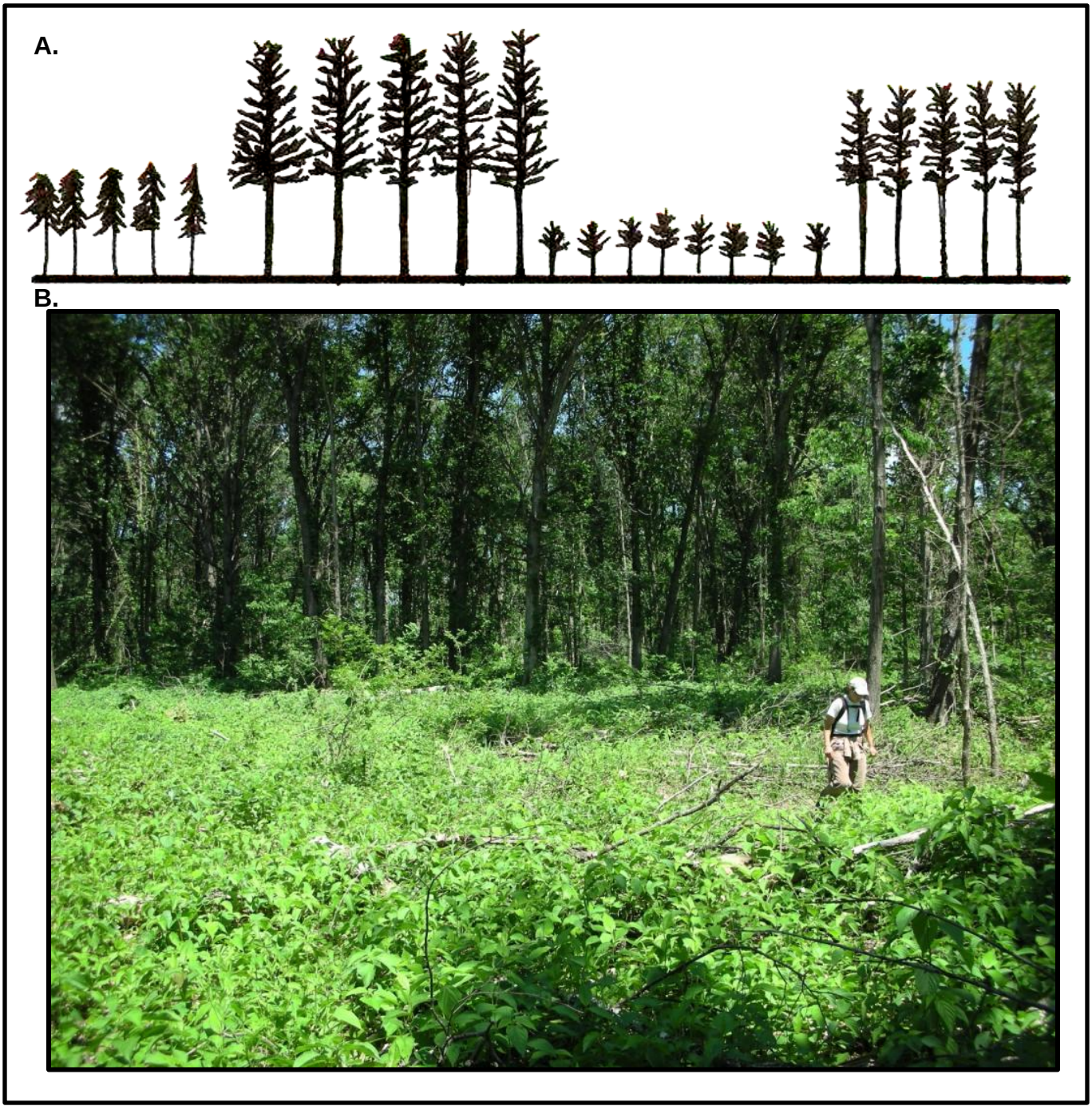


Figure 21.9. (A.) Group selection – within a regulated stand, four ¼ acre groups of different ages, (B.) A 0.35-acre group selection opening (photo by B. Hutnik, WDNR)

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
    - o generally, trees retained are the most vigorous crop trees

    - 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.

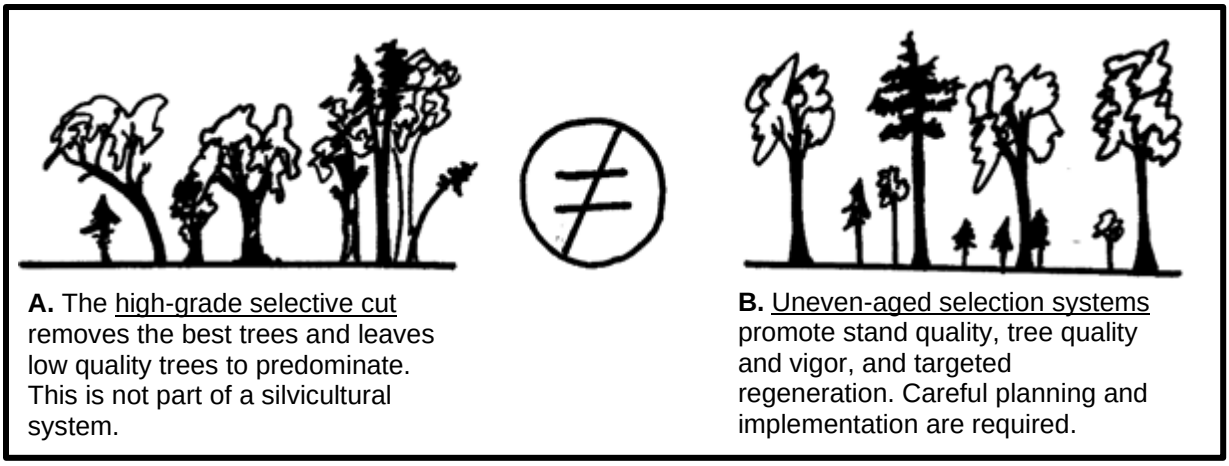


Figure 21.11. (A.) High-grade and diameter limit "selective cutting" is not the same as any of the (B.) selection regeneration methods.

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.

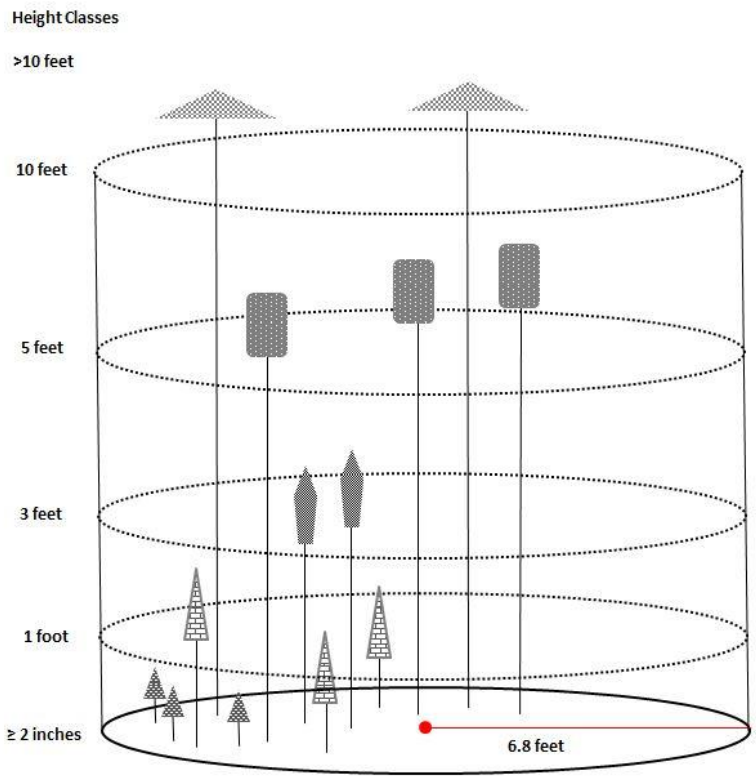


Figure 21.12. FRM plot illustration, including height classes.

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)	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

7 REFERENCES

Benzie, J. W. Cutting Methods in Mixed Conifer Swamps, Upper Michigan. Research Paper LS-4 (1963).

Benzie, J. W. Manager's handbook for red pine in the North Central States. General Technical Report NC-33 (1977). doi:10.1007/s12194-009-0066-1

Boulfroy, E. et al. Silvicultural guide for northern white-cedar (eastern white cedar). Gen. Tech. Rep. NRS-98. Newt. Square, PA, U.S. Dep. Agric. For. Serv. North. Res. Stn. 74 (2012).

British Columbia, Ministry of Forests, Forest Practices Branch. 2001. Silvicultural Systems Handbook for British Columbia. For. Pract. Br., BC. Min. For., Victoria, BC.

British Columbia Ministry of Forests and BC Environment. 1995. Silvicultural Systems Guidebook. Victoria, BC. Forest Practices Code of British Columbia Guidebook

Buckman, R. E. & Schneider, A. E. Regeneration Following Cutting in Black Spruce Swamps. (School of Forestry, University of Minnesota, cooperating with the Division of Forestry, Minnesota Conservation Dept. and the Forest Industries of Minnesota, 1952).

Buda, N. J. & White, R. G. Forest Regeneration Standards in Ontario: A Historical Perspective. NWSI Information Report IR-006 (2007).

Chen, H. Y. H. & Wang, J. R. Post-harvest regeneration of lowland black spruce forests in northeastern Ontario. New For. 31, 115–129 (2006).

Clark, F. B. & Hutchinson, J. G. Central hardwood notes. (1989).

Erdmann, G. G., Crow, T. R., Peterson, R. M. J. & Wilson, C. D. Managing black ash in the Lake States. General Technical Report NC-115 (1987).

Erdmannn, G. G. Developing quality in second-growth stands. in Proceedings of the conference on the northern hardwood resource: management and potential, 18-20 Aug (eds. Mroz, G. D. & Reed, D. D.) 206–222 (Michigan Technical University, Houghton, 1986).

Forbes, R.D. (editor). 1955. Forestry Handbook. Society of American Foresters. New York: Wiley

Godman, R. M. Northern Hardwood note - applying the shelterwood system. (1983).

Godman, R. M. & Tubbs, C. H. Establishing even-age northern hardwood regeneration by the shelterwood method - a preliminary guide. Research Paper NC-99 99, (1973).

Helms, J. A. The dictionary of forestry. (Society of American Foresters, 1998).

Jacobs, R. D. & Wray, R. D. Managing Oak in the Driftless Area. BU-05900 32 (1992).
Johnston, W. F. Manager's handbook for black spruce in the north-central states. General Technical Report NC-34 (1977).

Kotar, J. Approaches to Ecologically Based Forest Management on Private Lands. (1997).

Lancaster, K. F. & Leak, W. B. A silvicultural guide for white pine in the northeast. Gen. Tech. Rep. NE-41 041, (1978).

Larouche, C., Kenefic, L. S. & Ruel, J.-C. Northern White-Cedar Regeneration Dynamics on the Penobscot Experimental Forest in Maine: 40-Year Results. North. J. Appl. For. 27, 5–12 (2010).

Leak, W. B. Stocking of Northern Hardwood Regeneration Based on Exponential Dropout Rate. For. Chron. 45, 344–347 (1969).

Marquis, D. A. Assessing the adequacy of regeneration and understanding early development patterns. in Managing northern hardwoods - proceedings of a Silvicultural Symposium 143–159 (State University of New York, College of Environmental Science, 1986).

Michigan Department of Natural Resources. Forest Regeneration Survey Manual. (2009).

Ministry of Forests Forest Practices Branch. Silvicultural Systems Handbook for British Columbia. (2003).

Minnesota Department of Natural Resources. Regeneration Monitoring - Procedures and Standards. (2016).

Nyland, R. D. Silviculture : concepts and applications. (McGraw-Hill, 1996).

Perala, D. A. Manager's handbook for aspen in the north-central states. General Technical Report NC-36 (1977).

Perala, D. A. & Alm, A. A. Regenerating Paper Birch in the Lake States with the Shelterwood Method. North. J. Appl. For. 6, 151–153 (1989).

Safford, L. O. Silvicultural guide for paper birch in the northeast (revised). Res. Pap. NE-535 535, (1983).

Sander, I. L., Johnson, P. S. & Rogers, R. Evaluating oak advance reproduction in the Missouri Ozarks. Research Paper NC-251 (1984).

Sander, I. L., Johnson, P. S. & Watt, R. F. A guide for evaluating the adequacy of oak advance reproduction. General Technical Report NC-23. St. Paul, MN: U.S. Dept. of Agriculture, Forest Service, North Central Forest Experiment Station (1976).

Smith, D. M. The Practice of Silviculture. (Wiley, 1962).
Tubbs, C. H. Natural Regeneration of Northern Hardwoods in the Northern Great Lakes region. (1977).

USDA, F. S. Chequamegon-Nicolet Forest Regeneration and Certification Standards. (2004).

Zasada, Z. A. Reproduction on cut-over swamplands in the Upper Peninsula of Michigan. Sta. Pap. 27 (1952).

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.

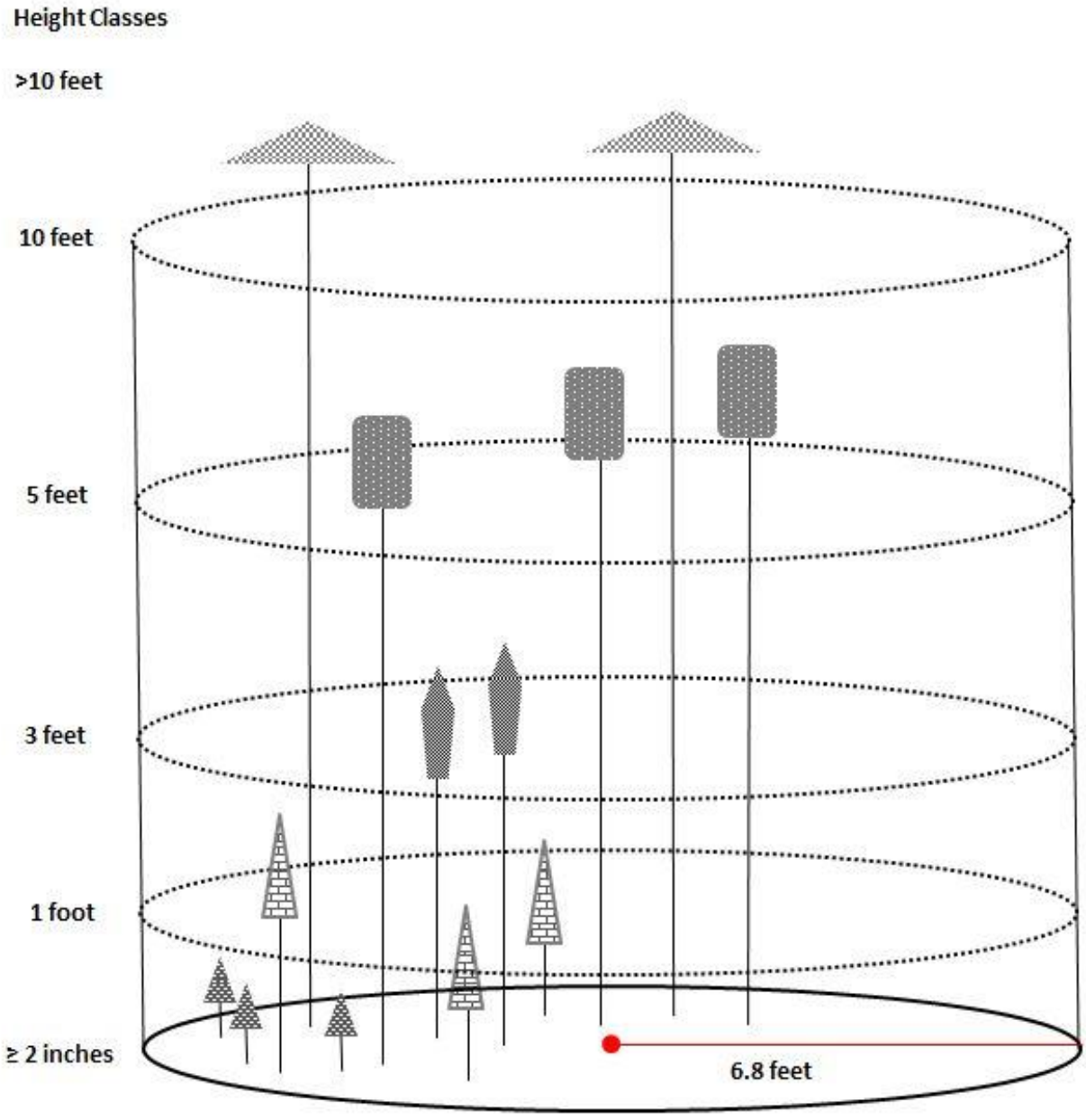
3) Overstory Shading - Note the potential available light for understory trees by recording **full sun**, **partial**, or **shade** in the *overstory shading* space on the datasheet.

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.