Pennsylvania Woodlands

Principles of silviculture

NUMBER 8

Silviculture – defined as the theory and practice of controlling forest establishment, composition, and growth – is important to today's landowners who are seeking more benefits than ever before from their woodlands. These benefits include water, wildlife, and recreation, as well as timber and other wood products. Through the use of various silvicultural practices, these benefits can be increased and can make the woodland more useful.

Nature practices its own brand of silviculture, although such natural development of the forest may take hundreds or thousands of years. Nature, of course, does not consult owners about preferences. Through silvicultural practices, a manager or owner can produce a woodland that meets objectives and can do it faster than can Nature.

SILVICULTURE FOR IMPROVED BENEFITS

Silviculture involves developing a plan for influencing the forest to grow in a certain way in order to achieve certain goals. The range of silvicultural treatments possible depends on the biological requirements and growth characteristics of the tree species present, along with the characteristics of the site where they are growing – including all of the physical, chemical, climatic, soil, and biological features of the area that influence tree development and growth. Trees require water, nutrients, carbon dioxide, and sunlight to grow. Silvicultural practices regulate the availability of water, nutrients, and sunlight to selected trees.

A number of silvicultural treatments often can be used effectively for a given woodland. The treatment chosen depends on the objectives and desires of the woodland owner. It is important to realize that no single silvicultural treatment or scheme is best for all woodlands and all owners. As long as biological constraints are respected, there often are many right ways to treat a stand silviculturally. Furthermore, primarily for sociological and economic reasons, no two landowners are likely to seek exactly the same set of benefits from their woodland. A woodland can be managed for a single dominant use, or it may be managed for multiple uses. In a woodland made up of two or more stands, each one may be treated differently. This publication emphasizes the principles of silviculture rather than specifics of application. The discussion should help the reader become more familiar with the silvicultural terms used in forestry. Some additional references are listed at the end of the unit. Other publications in this series cover certain silvicultural treatments that can be used to achieve specific objectives.

THE ROLE OF CUTTING IN SILVICULTURE

The same tool that can be used to destroy a forest can also be used to build and improve one. In the past, this tool was the axe; today, it is usually the chainsaw.

In the forest ecosystem, literally every available space is occupied by some type of vegetation. The primary way that the established forest can be altered or controlled is by killing trees and other plants. In most cases trees are killed by cutting. If the trees have no commercial value, it is cheaper to kill them by applying a chemical herbicide or by girdling them. Girdling, which involves the removal or killing of a ring of bark around the tree to block the flow of food from the crown to the roots, causes the tree to starve and die.

Most silvicultural treatments have the objective of promoting the growth of desirable species while discouraging less desirable species. In young forests, the desirable trees are nurtured by removing the undesirable ones. In mature or overmature forests, old trees are removed in order to provide room for new trees. From the silvicultural perspective, cutting trees is the primary method of establishing and tending forest stands to meet a woodland owner's objectives. Cutting trees to obtain wood products and income may be of secondary importance.

INTERMEDIATE CUTTINGS

Any cuttings or treatments applied to established immature forests for the purpose of improving them are referred to as *intermediate cuttings* and may be undertaken for any of the following reasons:

- To remove poor quality trees.
- To remove weed tree species.
- To thin the stand and increase the growth rate of residual trees.
- To free an understory of seedlings and saplings from suppression by an overstory of larger, inferior quality trees.
- To remove insect- or disease-infested trees.
- To salvage timber damaged by insect, disease, or fire.

Stand development

In order to understand the biological basis for most intermediate treatments, it is helpful to know how a natural forest stand develops. Many forest stands in Pennsylvania originated during the early part of this century, after repeated harvests for timber and fuel-wood. These harvests were in many cases followed by severe fires. Stands that originate over a relatively short period of time are referred to as *even-aged,* that is, all the trees in such stands are of roughly the same age.

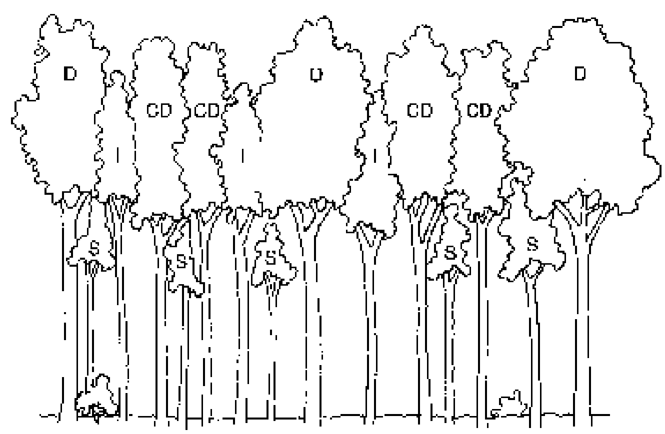
During the early stages of stand development, following heavy cutting or other disturbances, thousands or tens of thousands of small trees may be growing on an acre. As the trees get larger, they begin to compete with one another for the limited amounts of light, moisture, and nutrients. Natural selection occurs and the number of trees gradually decreases (Table 1). At maturity, only 80 to 100 trees may be growing on an acre. The trees that die during this process eventually fall to the ground and slowly decompose.

Crown position

Growth in height is the most critical factor determining the survival of forest trees. As trees begin to compete with one another, the stronger trees forge ahead, grow taller, and develop large tops or crowns. Weaker trees are crowded by their competitors, and their crowns become misshapen and restricted in size. This competition between trees for places in the forest canopy is described by differentiation of trees into *crown classes.*

Trees in a forest stand can be classified according to the position and size of their crowns in relationship to the others in the stand (see figure). *Dominant* trees are the largest trees in a stand. They have large, full crowns, and receive full sunlight from above and partial light from the sides. *Codominant* trees receive full light from above but relatively little from the sides. They have medium-size crowns and, along with the dominants, they form the upper canopy of the forest. *Intermediate* trees are shorter than those of the preceding two classes. Their crowns extend into the upper canopy layer; however, they receive very little light from above and no light from the side. *Suppressed* or *overtopped* trees are totally below the main canopy. They are the smallest trees and receive no direct sunlight.

Dominant and codominant trees grow fastest because they have large crowns that can absorb the sunlight needed for growth. Intermediate and suppressed trees grow more slowly and usually will not grow much faster even if the forest is thinned to give them more sunlight. Such trees may be genetically inferior specimens, trees that naturally grow slowly, or damaged trees. It is important to note that these smaller trees in the lower canopy are generally *the same age* as their faster-growing, more vigorous associates.



Idealized forest stand with crown classes represented.
D is dominant, CD is codominant, I is intermediate, S is suppressed.

Shade tolerance

Tree species vary in their shade tolerance – their ability to grow and reproduce in the shade of other trees. *Tolerant* trees are those capable of growing in heavy shade. Examples of tolerant trees are beech, sugar maple, and hemlock. Other species such as black cherry, paper birch, or tulip poplar require full sunlight in order to grow properly; they are referred to as *intolerant.* Species such as red and white oak, red maple, and ash can grow in moderate shade and are said to have *intermediate tolerance.*

Table 1. Average size and number of trees per acre for a typical unmanaged, even-aged, mixed-oak forest at different ages.

	Age (years)									
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
Trees per acre	3,200	1,800	930	505	342	262	215	187	150	90
Average dbh (inches)	1.2	2.4	4.0	5.9	7.5	8.8	9.9	10.7	12.2	14.8

Trees that are fittest from the standpoint of natural selection and thus destined to become dominant and codominant in natural stands, are not always the best trees from the woodland owner's point of view. Intermediate cuttings allow the woodland owner to select which trees will remain and which will die. The number of trees per acre is then reduced as it would be in a natural stand, but trees that are desirable to the owner are favored while those that are less desirable are removed (Table 2).

Table 2. Distribution of trees by diameter class before and after an improvement cut in a 70-year-old even-aged stand of oak-hickory.

Dbh class (inches)	Trees per acre		
	Before cut	After cuts	Tree
4	12	12	0
6	24	8	16
8	12	2	10
10	24	10	14
12	30	10	20
14	36	30	6
16	20	14	6
18	12	6	6
20	2	2	0
22	4	4	0

Regulating growth

The total amount of growth an acre of forest is capable of supporting is fixed and dependent on site quality (the amount of light, water, and nutrients available). Intermediate cuts generally cannot influence the total amount of growth that occurs, but they can influence how the growth is distributed in the forest stand. Growth in unmanaged stands is applied to trees of both good and poor quality; all trees grow and their volume increases at a relatively slow rate. Through intermediate cuttings, individual trees are selectively removed. Residual trees expand their crowns and grow faster by using the additional moisture, light, and nutrients made available when their competitors are removed. The total amount of growth per acre remains the same, but it is now distributed on fewer and faster-growing trees.

Redistributing the growth on fewer trees results in a stand occupied by larger, more vigorous trees. These trees are often more resistant to attack by insects and disease, and they produce more mast for wildlife. A great economic benefit also results from such treatments. A single 20-inch dbh tree with a merchantable height of 40 feet contains as many board feet as six 10-inch dbh trees of the same height. Other benefits of thinning are the salvage and use of wood that would normally be lost to natural mortality. Intermediate cuts remove trees before natural suppression occurs; a series of improvement cuttings increases the yield of a forest by 20 to 35 percent.

Foresters use a number of terms, such as *release cutting, liberation* cutting, *thinning, improvement cutting,* or *salvage cutting,* to describe different intermediate treatments referred to collectively as TSI (Timber Stand Improvement). The principle underlying all these treatments is the same: undesirable trees are cut and removed in order to promote the growth of the desirable trees. A woodland owner's objectives determine which trees are desirable (trees to leave) and which ones are undesirable (trees to cut). Terms such as WSI (Wildlife Stand Improvement) or ASI (Aesthetic Stand Improvement) might better reflect the objectives of some owners.

SILVICULTURAL HARVESTING

In every forest stand, at some point all or some of the trees reach maturity. As a tree becomes mature, height and diameter growth decrease and eventually stop. More branches die, wounds heal more slowly, and the tree's ability to resist damage by insects and disease decreases considerably. Eventually, the tree is harvested by natural forces. Certain tree species reach maturity at a relatively early age; others continue to grow for a much longer period of time. Some birches and aspen, for example, reach maturity at 50 to 60 years while many species of oak reach maturity at 150 to over 200 years.

An optimum size and age to which trees should grow can be determined for specific situations. These optimum conditions depend on the growth patterns of the species involved, site quality, economic markets available for wood products, and the objectives of the woodland owner. The period of years required to grow trees to these specified conditions of either economic or biological maturity is known as the *rotation.* The rotation for fast-growing, short-lived species such as aspen or birch used for pulp may be as short as 25 to 30 years. Slower-growing hardwoods, such as oaks, used primarily for sawtimber, commonly have rotations of 70 to 100 years.

Regeneration

When a large number of trees in a stand reach financial or biological maturity, it is time for the woodland owner to think about harvesting the old trees and replacing them with others of a new generation. *Regeneration* or *reproduction cuttings* are made for the purpose of removing old trees as efficiently as possible and creating environmental conditions favorable for the establishment of a new crop. Concern for the immediate regeneration of new trees is the most significant difference between silviculture and exploitative logging, and for this reason these treatments are referred to as reproduction cuts rather than harvest cuts.

In the Northeast, foresters generally rely on forests to regenerate themselves prior to or following cutting, either through natural seeding or by sprouting. In some cases, tree seedlings are established in a stand prior to cutting. Their presence is referred to as *advance regeneration.* In almost all cases, woody or herbaceous vegetation quickly occupies any site following a disturbance to the existing mature trees. Trees that seed naturally after an unplanned logging operation, or similar disturbances, may not be the species that the owner considers valuable. If the goal is to ensure prompt regeneration of a certain species of tree through natural seeding, then the reproduction cut is probably the most difficult silvicultural task a forester can attempt. The success or failure of this treatment will be evident in the vegetation for 50 to 100 years or more.

Planting

A forest stand established by artificial planting of tree seedlings is referred to as a *plantation.* In common forestry practice, trees are planted as one- to three-year-old bare-rooted seedlings. Conifers are planted in much greater numbers than are hardwoods. In Pennsylvania, planting is usually carried out only where natural regeneration has failed or where open land is converted to forest land.

REPRODUCTION METHODS

Choosing the appropriate reproduction method is a complex process involving ecological, economic, and sociological considerations. Here the forester's skill and perceptions are used to make trade-offs between costs and aesthetics, immediate and future needs, productivity and preservation. Some of the variables a forester and woodland owner need to keep in mind when selecting a method are:

- Biological requirements of desirable and undesirable tree species.
- Characteristics of the site, including soil, topography, moisture, and microclimate.
- Economic markets for wood products.
- Impacts of cutting on wildlife, water, recreation, and aesthetics.
- Methods of controlling damaging insects, diseases, and fires.
- Limitations of available harvesting equipment.

The three methods commonly used in regenerating or reproducing a stand of trees in Pennsylvania are *clearcutting, shelterwood,* and *selection.* Each involves removal of the mature overstory in a manner that encourages seedlings of desirable species to regenerate the stand naturally. These methods differ in the combinations of light, temperature, and moisture created on the forest floor. The clearcutting and the shelterwood methods are used to establish *even-aged stands,* and the selection method is used to create or maintain *uneven-aged stands.* An uneven-aged stand contains at least three different age classes of trees.

Clearcutting

Clearcutting is a single harvest of all trees in a stand with the expectation that a new even-aged stand will become established. All trees larger than 2 inches dbh usually are cut, including culls and trees of low quality. The silvicultural clearcut should not be confused with what is often referred to as the commercial clear-cut, which is a nonsilvicultural harvest. Commercial clearcutting removes only merchantable trees, leaving behind small, damaged, and poor-quality trees.

Clearcutting allows maximum sunlight to reach the soil surface. Intensive logging activity disturbs the forest litter layer and exposes mineral soil. Application of this method assumes that an ample supply of seedlings or seeds are already in the ground or that seed will be blown in from adjacent stands. In the latter case, size and shape of the clearcut must be restricted by the distance seed can be carried by wind.

Clearcutting favors reproduction and growth of tree species that thrive in full sunlight. These species include all the more valuable tree species in both the Allegheny Hardwood and the Oak-Hickory forest types (including black cherry, white ash, red oak, white oak, and yellow poplar). In the absence of competition, young trees are unencumbered and grow quickly. In Pennsylvania, most valuable tree species respond well to clearcutting *only if they are present as advance regeneration prior to cutting.*

The clearcutting method *should not be used* where there is insufficient advance regeneration, where ferns and grasses occupy over one-third of the site, where the water table has a potential to rise close to the surface after harvesting, where shallow soils occur over rock, or where continuous forest cover is needed to prevent stream siltation or increases in stream temperature.

From the administrative and logistical viewpoint, clearcutting is the simplest reproduction method to implement. Since residual trees are not left, less supervision of cutting is required and fewer constraints are imposed on the harvesting equipment and operation.

Many people find clearcutting to be the least desirable reproduction method for aesthetic reasons. For the first two or three years after the cut, no conspicuous growth is evident. Logging debris and slash may contribute to the desolate appearance of the site. Close scrutiny, however, often reveals a new stand of young seedlings. Soon a new stand of sapling-sized trees will occupy the site and make the area more visibly appealing. The initial visual impact of clearcutting can be tempered by strategically regulating the size, shape, and location of the cut areas so that they blend in naturally with the landscape.

Many kinds of forests are composed of natural vegetation that resulted from fire or other destructive disturbances. Clearcutting merely mimics these natural disturbances. Most of today's Pennsylvania forests resulted from what amounted to clearcutting at or near the turn of the century.

Shelterwood

When the shelterwood method is used, a new stand is established under the shelter of older trees. The old stand is generally removed in a series of two or three cuttings made at intervals of five or ten years. The new forest is considered to be even-aged.

In the first cut, trees are selectively removed throughout the stand. This cut increases vigor, stimulates seed production of the remaining trees, allows some sunlight to reach the forest floor, and prepares the site for the seed by stirring the forest floor and exposing mineral soil. New seedlings become established under the partial shade of the residual trees. Once the seedlings are well established, the remaining overstory trees are removed in one or two more cuts to free the seedlings from competition.

The trees left after the first cut serve as sources of seed and shade for the new crop. This method is best suited for intermediate and tolerant tree species that do not compete well with other vegetation when growing in direct sunlight. By regulating the severity of the first cut, this system can be adapted to all but the most intolerant species.

The shelterwood method should be used when advance regeneration of desirable species is not adequate to permit clearcutting. Regeneration may be inadequate for several reasons. The stand may be so dense that seedlings do not have adequate sunlight to survive. Ferns and other competing vegetation may grow in sufficient quantities to kill seedlings; browsing deer may destroy young trees. Competing vegetation can be controlled with an appropriate herbicide. If the deer population is excessive, it may be necessary to kill the deer, to fence them out, or to stimulate seedling growth with fertilizer.

Since the new stand is already established in the shelterwood before the old stand is completely removed, regeneration failures seldom occur, and the forest does not have the devastated, barren appearance of clearcut areas. The gradual removal of the old stand also provides maximum yield because mature trees are removed in the first cut. Vigorously growing trees can continue valuable production for a number of years while they serve as a source of seed.

One disadvantage of the shelterwood method is the need to bring logging equipment into the stand at frequent intervals. This is more costly than the one-time clearcut, and residual trees or new seedlings may be damaged or destroyed when other trees are being felled or transported.

Selection

The goal of the selection method is to create or maintain stands that contain trees representing a mixture of ages and size classes (uneven-aged). In theory, this method produces stands with equal areas occupied by mature trees (sawtimber), poles, saplings, and seedlings.

Selection cutting involves the removal of individual or small groups of trees at frequent intervals. Trees are selected for harvest on the basis of their economic or biological maturity and their relative contribution to the long-term productivity and value to the stand. Regeneration cuts and intermediate or improvement cuts are carried out simultaneously, and new seedlings or sprouts grow up in the spaces created. Smaller and low value trees are also cut to ensure proper spacing and future growth of desirable species that have not yet reached maturity. Both before and after cutting, the stand should include trees representing a wide range of diameter classes (Table 5).

Table 3. Simplified examples showing distribution of trees by dbh class, before and after harvest, using the selection method in an uneven-aged northern hardwood stand.

Dbh class (inches)	Trees per acre		
	Before harvest	After harvest	Trees cut
6	65	54	11
8	52	34	18
10	31	21	10
12	28	13	15
14	12	8	4
16	6	5	1
18	3	3	–
20	3	2	1
22	2	1	1
24	1	–	1

The periods between selection cuttings are referred to as *cutting cycles.* To ensure that a harvest is large enough to be worthwhile, cutting cycles generally range from five to twenty years.

Because relatively few trees are harvested at one time and because the forest floor is generally shaded, this method favors tree species such as sugar maple, beech, and hemlock that can reproduce and grow in low-light levels. One of the disadvantages of this method is that certain high-value intolerant and intermediate species are difficult or impossible to regenerate.

The selection method is best applied to existing uneven-aged stands. In Pennsylvania such stands are relatively rare because of past disturbances. The selection system may be applied to an even-aged stand in order to create an uneven-aged stand. This, however, is a very difficult process. It may take three or four cuttings over a period of twenty to forty years to obtain the proper distribution of size classes.

The selection method has the least visual impact of all the reproduction methods. Trees are always present on the site, and cutting activity is generally not noticeable to the passerby. However, administrative and supervising costs are very high. Proper application of the selection method requires the repeated and frequent attention of a forester. The stand has to be inspected, cruised, and marked before each cutting in order to ensure proper distribution of size and age classes. Logging operations occur at frequent intervals and must be closely supervised in order to ensure that residual trees are not damaged.

Nonsilvicultural Harvests

A number of commonly used harvesting methods should be *avoided* and not confused with the silvicultural procedures just described. Several different procedures and names are used, but most of these nonsilvicultural harvesting methods are simply variations of high *grading,* which greatly decreases the long-term productivity of any woodland. Such harvest procedures neglect the silvicultural needs of the stand and the environmental needs for proper regeneration.

In nonsilvicultural harvest systems, the selective removal of larger, high-value trees leaves behind only the smaller trees or other low-value trees of inferior species or poor quality. The *diameter-limit* cut is the most frequent type of nonsilvicultural harvest used in Pennsylvania. When using this procedure, a timber buyer contracts to harvest all timber larger than a certain diameter – usually 12 or 14 inches. The ease with which this method can be applied and the resulting high, one-time economic return make it attractive in spite of its long-term drawbacks.

Diameter-limit cutting is sometimes defended as a means of removing the larger, older trees and leaving the smaller, younger trees to grow. however, it is commonly applied to even-aged stands where the smaller trees are not younger but rather the *same* age as the trees cut. Frequently, the smaller trees are slower-growing, damaged, or inferior and less vigorous species. Many of these trees were in the intermediate and suppressed crown classes in the original stand, and they may be incapable of responding to release once the dominant and codominant trees are removed.

After one or more diameter-limit cuttings, stands are dominated by low-value, poor-quality trees. Future productivity and economic yield decrease substantially.

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