Pennsylvania Woodlands

Penn State College of Agriculture, Cooperative Extension

Hardwood management for economic return

NUMBER 10

The value of hardwood logs depends on species, size, and quality. Woodland owners who wish to maximize economic return should direct their management activities toward growing large trees of high-value species to produce high-quality sawlogs and veneer logs.

PRODUCT VALUE

Log size, quality, and species determine product value. Size dictates the types of products that can be manufactured; quality affects product quality; and species affects product price (some species bring higher prices than others).

Pulpwood, used in making pulp for paper, is material with a minimum dbh (diameter at breast height) of 6 inches and a maximum of 20 inches. Fuelwood or firewood can be produced from logs of any size. Sawlogs, from which lumber is cut, are logs 12 inches dbh or larger. Veneer logs must be at least 18 inches dbh and free of defects. A more detailed description of these products is provided in *Pennsylvania Woodlands* Number 3: "Resource Evaluation."

Sawlog quality is expressed in terms of *log grade*. Grade 3 (low quality), Grade 2 (medium quality), and Grade 1 (high quality) are the commonly used rankings. Veneer logs are logs of very high quality.

Log grade is related to lumber grade. Most hardwood factory lumber is graded on the percentage yield of clear boards of specified sizes. Straightness of a log, log size, and the spacing of defects such as holes, knots, and splits are primary factors in determining log grade. Other things being equal, the percentage yield of high-grade lumber increases as log diameter increases. Grade 1 and veneer logs require that a tree be at least 16 to 18 inches dbh (Table 1).

When compared to sawlogs, fuelwood and pulpwood have relatively low value (Table 2). It makes sense, therefore, that the primary way to maximize economic return from your woodland is to maximize the quantity and quality of sawlog material on your woodland. Fuelwood and pulpwood may be by-products of your sawtimber management activities. The income from their sale can support your management efforts.

When managing for sawtimber, it also makes sense to favor high-value species. The extract from the *Pennsylvania Woodlands* "Timber Market Report" in Table 3 indicates that black cherry, red oak, white oak, and white ash bring a higher dollar return per unit volume than do red maple, other miscellaneous hardwoods, and softwoods such as pine and hemlock.

Table 1. Minimum size requirements for hardwood log grades.

Log grade	Log diameter at breast height (at 4.5 feet)	Log diameter at top of butt log (at 17 feet)
	(inches)	
Grade 3	12	9
Grade 2	14	11
Grade 1	16	13
Veneer	18	15

Table 2. Volume and value of products derived from red oak trees, 16-inch dbh, with varying stem quality. Values are based on prices reported in the Northwest region of Pennsylvania, January-March 1987.

Log quality	Volume*	Unit value**	Stumpage value
Sawlog			
Grade 1	180 bd. ft.	$268.00 per MBF	$48.24
Grade 3	180 bd. ft.	83.00 per MBF	14.94
Pulpwood	1.02 tons	1.11 per ton	1.13
Fuelwood	0.36 cords	5.00 per cord	1.80

* Sawlog volumes determined using International 1/4" scale for two-log tree; bd. ft. = board feet

** MBF = thousand board feet

Table 3 . Average log prices, by species and grade, reported by sawmills for delivered logs in the Northwest region of Pennsylvania, January-March, 1987.

	Quality			
Species	Grade 3 (low)	Grade 2 (med.)	Grade 1 (high)	Veneer (very high)
	($/MBF, International 1/4" rule)*			
Red oak	66	147	208	400+
White oak	51	89	152	350+
Black cherry	75	160	213	400+
White ash	52	126	176	350+
Hard maple	47	79	105	--
Soft maple	43	66	84	--
Yellow poplar	38	58	69	--
Misc. hdwds.**	36	51	56	--
Pine/hemlock	38	57	57	--

* MBF = thousand board feet

** Miscellaneous hardwoods include beech, hickory, basswood, and black gum

PRODUCT DEVELOPMENT

The woodlands of Pennsylvania are currently dominated by even-aged stands of 50- to 80-year-old hardwoods measuring 10 to 14 inches dbh (mainly large poles and small- to medium-sized sawtimber). Most of these stands will not reach maturity for 20 to 40 years. They're still growing at a relatively rapid rate. Many of these stands also have a good number of high-quality trees of desirable species with the potential to produce high dollar yields.

Nevertheless, these stands are increasing in value at a rate below their potential. The majority of these stands have not been managed in the past and they're overcrowded. They contain an overabundance of low-value species and poor-quality trees that compete with, and slow the growth of, the high-value trees.

Management practices aimed at growing high-value, vigorous trees to maturity as quickly as possible can substantially increase the dollar yield of your woodland. Woodland stands reach *financial maturity* when the yearly increase in total stand value begins to slow down. Financial maturity usually occurs when a high proportion of trees in a stand have reached diameters that qualify as Grade 1 sawlogs or veneer logs.

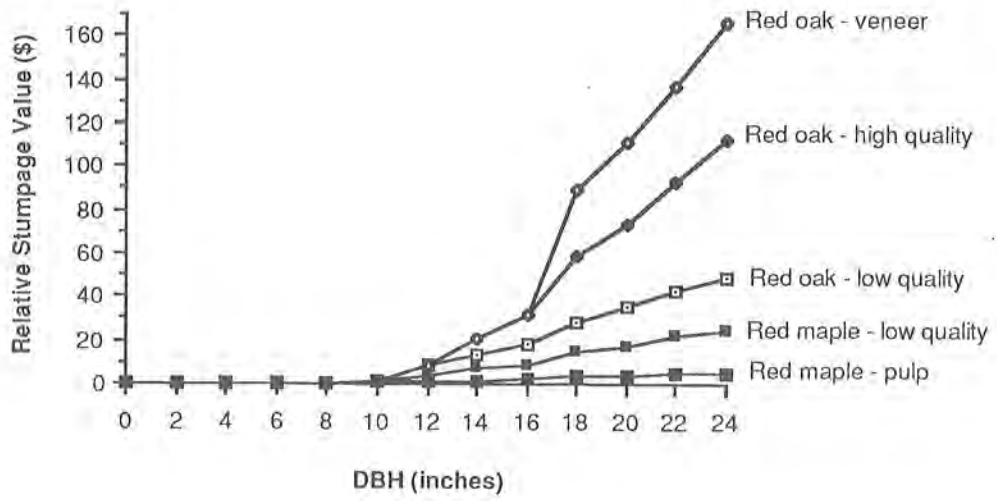
In terms of financial maturity, fast-growing trees of high quality are more promising growing stock than those that are slower in growth or poorer in quality. Economic yield from high-value species containing Grade 1 or veneer logs may be three to ten times greater than the yield from an equal volume of low-value species or trees containing low-grade logs (See figure).

Hardwood stands in Pennsylvania are generally considered mature when the dominant and codominant trees (trees whose crowns form the main canopy of the stand) range from 16 to 22 inches in diameter. Age of maturity may range from 70 to 150 years, depending on species composition, site quality, stand history, and your management activities.

At maturity, an even-aged stand contains about 80 to 120 trees per acre, and the volume of sawtimber may range from 5,000 to 25,000 board feet per acre, depending on site quality and the level of your management.

By applying the proper silvicultural treatments throughout the life of the stand, you can influence the species composition of your stand at maturity. The silvicultural treatments discussed first in this publication are *intermediate cuts*, which are cuts that are applied to immature stands. Applying intermediate cuts is also called *timber stand improvement* (TSI) because these cuts are made for the purpose of improving the stand.

Discussed later in this publication are *reproduction cuts* or *harvest cuts*, which are applied to mature stands. Reproduction cuts are made for the purpose of removing mature trees as efficiently as possible and creating favorable conditions for the new crop.



Relative stumpage value of single trees of different sizes, species, and quality classes.

Pennsylvania Woodlands Number 6: "Silviculture" provides additional information on intermediate and reproduction cuts.

TIMBER STAND IMPROVEMENT

Of the many types of timber stand improvement treatments you can apply, thinning is often the one needed most. As was mentioned above, many stands in Pennsylvania are overcrowded, and as a result, the trees are increasing in value at a rate below their potential.

Trees compete with each other for light, moisture, and nutrients. The purpose of thinning is to keep the more promising, high-value trees growing steadily by removing less desirable, neighboring, competing trees in the main canopy. The trees removed in a thinning include: trees of inferior species; crooked, leaning, limby trees; overmature trees; and diseased or injured trees.

Thinning the woodland reduces the competition. The increased availability of light, moisture, and nutrients enables the favored trees to grow faster. Favored trees will reach the size needed to produce Grade 1 and veneer logs in a shorter period.

Thinning also helps keep the woodland healthy, because faster growing trees are less vulnerable to disease and insect attack.

Thinning also increases the yield of useful by-product material from your stand. Due to competition for growing space and natural selection, not all trees in a stand survive to maturity. Thinning and using the cuttings as pulpwood or fuelwood salvages material that otherwise would naturally die anyway because of competition with other trees.

In an unmanaged stand on a relatively good site, a healthy dominant or codominant tree increases by about 2 inches in diameter every 10 years. A series of thinnings spaced at 10- to 15-year intervals may increase this growth rate by 20 to 40 percent. This may not seem like much until you multiply this increase over the length of each log and the number of trees in your stand.

By improving the growth rate of high-value trees that are currently 10 to 14 inches in diameter, you set the stage for future economic benefits. You get higher dollar returns by allowing selected trees to increase in size and improve in grade. Optimum value is usually obtained at diameters of 16 to 22 inches. The rewards for managing and delaying the final harvest can be significant. The stumpage value of a 16-inch red oak, for example, may be five times that of a 12-inch red oak (Table 4).

Diameter-limit harvests of young sawtimber stands (stands in which the majority of trees are 12 to 14 inches in diameter) often have the opposite effect of timber stand improvement. In diameter-limit harvests, the best trees are often removed, leaving behind the slow-growing, low-value species. These harvests are extremely detrimental to long-term dollar yield because many of the high-value trees are removed well before they reach their optimum value. Diameter-limit cutting provides maximum dollar return at one time and limited return over the next 50 or more years.

Table 4. Estimated stumpage value for butt log of high-quality red oak trees of different diameters. Value is based on reported stumpage prices in the Northwest region of Pennsylvania, January-March 1987.

Dbh	Maximum butt log grade	Volume of butt log	Stumpage value of butt log
		(cords)	
6	Fuel/Pulp*	0.043	$0.22
8	Fuel/Pulp	0.088	0.44
10	Fuel/Pulp	0.155	0.78
		(board feet)**	
12	3	60	$ 4.98
14	2	80	14.00
16	1	100	26.80
18	1	140	37.52
20	1	170	45.56
22	1	210	56.28

* Fuel = fuelwood
Pulp = pulpwood
** Sawlog volume determined using International 1/4" log rule

Carrying Out Timber Stand Improvement

Failure to thin leads to slowed growth and eventual stagnation. Once stagnated, trees may not respond to the release provided by thinning. Therefore, it's important to thin before competition drastically slows growth. For Pennsylvania's even-aged stands of hardwoods, competition usually becomes keen when a stand is between 40 and 60 years of age and the trees are about 4 to 10 inches dbh.

From the practical point of view, the timing of the first thinning may depend on available markets for small trees. In areas where fuelwood and pulpwood markets are strong, you can apply a *commercial thinning* (a thinning in which the removed trees can be sold) earlier than in areas where markets are weak. You can carry out TSI in younger stands that yield unmerchantable products if you're willing to do the work or have a need for fuelwood. That's known as a *precommercial thinning* because the removed trees are too small to be marketable.

When thinning a young stand, it's important not to open it up too much. Some crowding is desirable. Tight spacing forces trees to grow straight. Crowding also shades lower stems of trees, resulting in the loss of the lower branches. Clear wood is laid down over the branch scar and clear lower logs are produced.

Before any cutting is done, it's important that you make an inventory of the number, size, and quality of trees in your stand. This assessment is needed to determine whether TSI work is justified. If the stand contains only low-value, poor-quality trees, then a regeneration cut rather than an improvement cut may be necessary.

Crop trees. Before cutting, identify potential crop trees, which are trees you want to keep in the stand until the final harvest. They should be the high- or medium-value species, have good form, and be free of defects. The lower 10 to 16 feet of the crop tree stem should have few or no branches. A medium-value species that is tall, straight, and free of defects usually has a higher dollar value than a high-value species that is crooked or has other defects. Crop trees should have healthy, vigorous crowns in the dominant and codominant crown classes. Trees with many dead branches in their crowns are not likely to respond to release and should not be selected as crop trees.

It's important that the crop trees are evenly spaced throughout the stand. A mature stand is occupied by about 80 to 120 trees per acre. Ideally, you should select one crop tree every 20 feet throughout the stand. It may not be possible for you to strictly follow this spacing rule, but use it as a guide. Don't hesitate to select two high-quality crop trees within 15 feet of another. And if it's not possible to locate a good crop tree within 25 feet of another, pick the best of the trees in the area.

Removing the trees that are competing with your crop trees is the final step in the timber stand improvement process. The number of trees removed depends on the age, size, and density of trees in your woodlot, as well as on your needs and the markets for wood products.

Look at the canopy of the stand. The crown of a crop tree in small and medium pole-size stands needs three or four feet of open space on at least two sides to allow it to grow at its maximum rate. In larger pole and sawlog stands, the crowns of crop trees need ten or more feet on at least two sides.

Trees whose crowns touch the crown of the crop tree are its competitors. In most cases, by removing competitors from one or two sides, you will be providing the crop tree with the space it needs. Don't create large openings in the canopy, but do provide enough room for the crop trees to expand their crowns.

You can remove trees in the intermediate and suppressed crown classes if you have a need or market for this wood. However, removing these small trees will probably not stimulate the growth of your crop trees since their crowns aren't in competition with the crop trees. The primary benefit that results from cutting these trees is the salvage of trees that would naturally die as the stand develops.

Most of the products removed in early thinnings will be fuelwood and pulpwood. Later cuttings may also produce small, low-quality sawlogs. Initial thinnings in 30- to 60-year-old unmanaged woodlands normally yield 5 to 10 cords (12 to 25 tons) of wood per acre. Thinnings in older stands may yield 4 to 10 cords and 500 to 2,500 board feet of sawlogs per acre, depending on stocking levels and site quality.

More information on TSI procedures is provided in *Improve Your Woodlot by Cutting Firewood*, publication NA-GR-6, available from the USDA Forest Service. To get a copy, contact: USDA Forest Service, Northeastern Area, State and Private Forestry, Broomall, PA 19008.

Following a TSI cut, the crowns of the crop trees will gradually expand and fill the openings. These cuts can usually be repeated at 10- to 15-year intervals when crowding reoccurs and when the volume available for cutting will support a commercial sale.

Since the general quality and value of the materials removed during initial TSI cuts are relatively low, don't expect to get rich when selling them. The major goal is to improve the quality of your stand for a future harvest.

Getting Assistance

When its time to make timber stand improvements, seek the help and advice of professionals. Professional assistance is particularly important when your stand contains a substantial volume of sawtimber. A forester will conduct the inventory and select and mark the appropriate trees for removal.

Scheduling a visit from a Pennsylvania Bureau of Forestry service forester or a private consulting forester is a good place to start. Some of the larger forest product companies also have service foresters who can assist you with TSI work.

The *Register of Consulting and Industrial Foresters* is a publication that can help you locate a forester in your area. The register is published by Department of Environmental Resources, Bureau of Forestry. To get a copy, contact: DER Bureau of Forestry, Office of Resources Management, Evangelical Press Building, P.O. Box 1467, Harrisburg, PA 17120.

It's also important to select with care the logger or cutter who will be working on your property. A number of loggers and fuelwood cutters now specialize in stand improvement work. Select an individual who understands your objectives and has the skill and proper equipment to do the job right. The highest bidder for your wood may not always be the best choice. It's more important that your management goals are met and that the residual trees in your stand are not damaged.

HARVEST CUTS—REGENERATING THE STAND FOR FUTURE YIELD

When the majority of trees in the stand exceed 16 to 22 inches in diameter, you should begin stand regeneration cuts. You may want to regenerate the stand before it reaches maturity if the overall tree quality is poor, if the stand is heavily stocked with undesirable species, or if the stand is greatly understocked.

In contrast to thinning, a regeneration harvest provides specifically for the production of new trees. In a regeneration harvest, the mature crop of trees is removed. Regeneration harvests can yield an income of $500 to $4,000 or more per acre. Intermediate management activities, such as thinnings discussed earlier, help to ensure the highest returns at the time of the final harvest. Dollar return to the landowner is also greatly influenced by how the harvested products are marketed. Marketing procedures that maximize returns are discussed in *Pennsylvania Woodlands* Number 5: "Marketing Products from Your Woodland."

At the time of the regeneration harvest, you're naturally interested in maximizing financial return. However, at this time, you should also take your future management opportunities into consideration. Unless your stand regenerates with desired species, future economic return may be limited. Poor harvest planning may result in total regeneration failures—your stand could be totally unproductive for the next 50 to 100 years or more unless you make major investments in the site. You need successful regeneration of high-value species in order to maximize long-term economic return.

Most high-value species in Pennsylvania, such as black cherry, oak, and white ash are

shade intolerant or intermediate in tolerance to shade. For stands of these species to be successfully reproduced, forest openings must be large enough for the desired regeneration to get enough sunlight. *Clearcutting* and *shelterwood cuts* are the methods used to create the necessary openings. These cutting methods result in the establishment of *even-aged* stands.

The alternative to even-aged stands is *uneven-aged* stands. *Selection cuts*, in which individual trees or small groups of trees are removed, allow less sunlight to reach the forest floor. The selection method tends to favor the slower growing, lower value, shade tolerant and very tolerant species like beech, sugar maple, and hemlock. Selection cuts establish uneven-aged stands. High-value species that require more sunlight will often not regenerate in areas where selection cuts are made.

Table 5 lists some of the common trees of Pennsylvania, the forest type in which they are usually found, their relative value, their shade tolerance, and their moisture requirement. This type of information should be used when making decisions about your hardwood stands.

Even-aged Regeneration

Successful regeneration of even-aged stands depends on a number of factors. Even-aged regeneration cuttings should not be made until these factors are considered:

Advance regeneration. Advance regeneration includes seedlings, sprouts, and selected saplings and poles that are established in the stand before the mature trees are removed. For advance regeneration to develop into a successful new stand, it must consist of the desired species in adequate numbers.

The amount of advance regeneration needed for a successful stand depends on the size of the advance regeneration, on the species to be regenerated and, in some areas, on the deer population.

Table 5. Common trees of Pennsylvania by forest type, value, shade tolerance, and moisture requirement.

Species	Forest type	Value			Shade tolerance	Moisture requirement
		Sawtimber	Fuelwood	Wildlife		
Black cherry	NH	H	M	H	I	M
White ash	NH	H	H	M	Im	M
Sugar maple	NH	M	H	M	VT	M
Red maple	NH/OH	M-L	M	M	Im	D-M
American beech	NH	L	H	H	VT	M
Red oak	NH/OH	H	H	H	Im	M
White oak	OH	H	H	H	Im	D-M
Black oak	OH	M	H	H	Im	D-M
Scarlet oak	OH	M	H	H	Im	D-M
Chestnut oak	OH	M	H	H	Im	D
Hickory	OH	L	H	H	Im	D-M
Yellow poplar	NH	M	L	L	Im	M
Black birch	NH/OH	L	M	M	Im	D-M
Basswood	NH/OH	L	L	L	T	M
Hemlock	NH/OH	L	L	M	VT	M
Cucumber	NH	M	L	L	T	M
Quaking aspen	NH	L	L	M	VI	D-M
Black gum	OH	L	M	H	T	D-M
White pine	OH	L	L	H	I	D-M
Dogwood	OH	--	H	H	T	D-M
Black locust	OH	L	H	L	I	D-M

Type: NH = Northern Hardwoods
OH = Oak/Hickory

Value: H = high
M = medium
L = low

Shade tolerance: VT = very tolerant
T = tolerant
Im = intermediate in tolerance
I = intolerant
VI = very intolerant

Moisture requirement: D = dry
M = moist

In areas of high deer concentration, advance regeneration is often smaller in size due to heavy browsing by the deer. These smaller seedlings are less vigorous and therefore more of them are required to adequately stock the stand. Protecting the harvest area from deer with electric fencing has proved effective. This protection may be required for five to ten years, until the regeneration becomes well established. In areas of low deer concentration, there is less browsing pressure, and fewer seedlings per acre are needed to ensure the development of a new stand.

In stands of the Northern Hardwood type, 6,500 to 27,000 seedlings per acre must be present before the mature, overstory trees are removed. To regenerate maple and ash in high deer areas, a minimum of 27,000 seedlings per acre is required because these species are preferred browse. Black cherry, on the other hand, is not a preferred food and a minimum of 6,500 seedlings will successfully regenerate the stand. Seedlings need to be more than two inches tall, have at least two full-size leaves, and be well-distributed throughout the stand.

Successful regeneration of Oak/ Hickory stands may also require overcoming potential deer browsing. In addition, high-value species of oak are slow in becoming established and so must compete with undesirable tree species for a longer period of time. The strategy is to start with larger seedlings. Oak advance regeneration that is 4½ feet tall or taller can compete with other vegetation. A total of 250 large oak seedlings per acre is adequate stocking. If oak seedlings are smaller in size, a much greater number per acre are needed. But smaller seedlings may not successfully restock the site if faster-growing species are also present.

Sugar maple, beech, and hemlock are often difficult to regenerate in even-aged stands when they are in competition with faster-growing species that are shade intolerant or intermediate in tolerance to shade. It is necessary to leave 30 to 80 saplings and poles per acre if these species are desired in the new stand. Only trees with good crowns and clean, straight trunks free of epicormic branches will respond favorably to release.

Sprouting potential. Sprouting potential depends on tree species, stem diameter, and season of the year. Most hardwood species will sprout when cut. Sprouts that originate low on the stump can develop into high-quality trees and are often a primary source of regeneration.

Stump sprouts are most important in stands of the oak types. Sprouts can supplement oak seedlings for adequate stocking. In areas of high deer populations, however, sprouts may be completely destroyed.

Competing understory plants. Large numbers of certain herbaceous (nonwoody) plants and shrubs may prevent the establishment of desired tree seedlings. This vegetation competes with seedlings for light, moisture, and nutrients.

Some plant species inhibit the growth of other plants by releasing toxic chemicals. Such plants are described as *allelopathic* and the process is called *allelopathy*. The chemicals may be passed out through the foliage or the roots of these plants. Chemical supression of regeneration is most often the work of allelopathic herbaceous plants.

Herbaceous species that interfere with the establishment of desired tree seedlings include hayscented fern, New York fern, bracken fern, and many species of grasses and sedges. If more than 30 percent of the area to be harvested is covered with these plants, it's necessary to apply herbicides or mechanically remove them.

Woody plants that may cause problems include striped maple, beech root suckers, dogwood, sassafras, blackgum, hophornbeam, blue beech, mountain laurel, and rhododendron. These plants may have to be controlled to allow desired species to become established. Beech and striped maple seedlings of more than 2,100 stems per acre are also a problem.

Site limitations. Sites with a high water table may become wet after a timber harvest. Lush growth of interfering herbaceous vegetation may then occupy the site and eliminate the tree seedlings. Sites with this potential problem can be identified either by consulting soil survey descriptions or by noticing the presence of pools of standing water during wet seasons.

Areas with surface stones or rocks may limit the rooting depth of the advance regeneration. Removing the overstory on such sites may allow the shallow organic layer to dry, killing the seedlings.

Cutting method. A new stand can be regenerated by *clearcutting* if seedlings of the desired species are already present in adequate numbers. If potential problems with interfering plants or site limitations exist, you must take extra care to establish adequate regeneration before harvesting.

Clearcutting is especially useful in stands where all stems reach financial maturity at the

same time, such as plantations. Since all logging activity occurs at one time, clearcutting can reduce the risk of damage to a site. This is particularly desirable on sites that are highly erodible or in other ways sensitive to harvesting activity. Clearcutting is a cost-effective way of removing poor-quality stands. In other stands, however, clearcutting may not produce as high a profit as a well-executed shelterwood cut, because clearcutting may remove some stems before they reach financial maturity.

Use the *shelterwood method* when the stand lacks sufficient advance regeneration. With this method, you establish the new stand under the shelter of some uncut mature trees. This system gives the regeneration a better chance of becoming well established.

A two-cut shelterwood will usually work in Northern Hardwood stands. The first cut, called a *preparatory cut* or *seed cut*, removes about one-third of the stand and stimulates seed production of the remaining trees. This cut is followed in five to ten years by the *final removal cut*, in which the remaining mature trees are removed.

In Oak/Hickory type stands, advance seedlings may take as long as 20 years to develop. Control of competing vegetation is often necessary so that the oaks can become established. Undesired sapling vegetation should always be removed from Oak/Hickory stands.

In either Northern Hardwood or Oak/Hickory stands, where competing vegetation is a concern, a three-cut shelterwood is recommended. You should control interfering plants and then make the seed cut as described above. Removing the overstory in two cuts allows the regeneration to reach a larger size. The seedlings then are better able to survive after the last of the overstory is removed in the third cut.

A shelterwood cut ensures regeneration and offers the possibility of increased future dollar return. You can think of the seed cut as a late improvement cut. High-quality and high-value trees are left as the seed source. During the five or more years before they're harvested, these high-quality seed trees gain additional growth and can increase significantly in value.

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 or new seedlings may be damaged or destroyed when trees are being felled or transported.

Uneven-aged Regeneration

In the *selection method*, individual trees or small groups of trees are harvested as they mature. At the same time, some trees in all diameter classes are removed to improve the growth of the residual trees. Seedlings or sprouts grow up in the spaces created by the harvesting. Periodic harvesting and regeneration create a stand that contains trees of many ages and many sizes.

Selection cuts often have unsatisfactory results in Northern Hardwood and Oak/Hickory stands because fast-growing, valuable, intolerant species like red oak, black cherry, or white ash are removed and the site gradually becomes stocked with lower value, tolerant species like red maple and beech. These stands will lose quality, earning potential, and desirable seed sources.

The selection method is appropriate when you need a continuous supply of wood in small quantities and when you're not concerned about the possibility that the stand will become stocked with lower value species. The selection method maintains certain types of wildlife habitat and leaves a continuous forest cover that may be preferred for aesthetic reasons. This method also can help protect stream water quality. One of the major drawbacks of selection harvesting is the expense and risk of harvesting small quantities of material at frequent intervals.

Prepared by James R. Grace, Assistant Professor, Forest Resources Extension, School of Forest Resources, The Pennsylvania State University.

Issued in furtherance of Cooperative Extension works, Acts of Congress May 8 and June 30, 1914, in cooperation with the Department of Agriculture and the Pennsylvania Legislature. L. F. Hood, Director of the Cooperative Extension Service, The Pennsylvania State University.

File No. IVI1d R8M488 U.Ed. 88-73