

ECONOMIC CONSIDERATIONS OF UNEVEN-AGE HARDWOOD MANAGEMENT

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INTRODUCTION

Uneven-age management or partial cutting methods as described in this paper allow foresters to manage eastern hardwood stands and harvest forest products without clearcutting. These methods can involve regular periodic harvests, at least for the short term, based on stand conditions and growing-site capabilities. We are not going to make the decision as to which is the better system: even-age or uneven-age management. This is not always a viable question for foresters because in many cases landowners make the decision--No clearcutting!

We hope to provide some information, based primarily on our experience, that will help answer the question: What can be done to improve the economic feasibility of uneven-age timber management in eastern hardwood stands?

We all have our own reasons why we prefer a certain harvest system or cutting method for a given forest or stand condition. As we know, the management recommendations should be based on the stand conditions, site potential, owner objectives, available resources, and markets. Also, we have focused our thoughts toward economic considerations as related to timber resources. Other resources will be mentioned, but emphasis throughout the text is toward the production of quality hardwood timber.

When discussing forest management harvesting practices for hardwood sawtimber stands, foresters have to be familiar with several harvesting methods to meet a variety of landowner objectives. Silvicultural harvesting options for establishing new forest stands include clearcutting-type methods (even-age management system) with a number of modifications and partial-type cutting methods (uneven-age management system). Three partial type methods--single-tree selection, diameter-limit, and financial maturity (Trimble et al. 1974)--are practical options to consider for managing eastern hardwoods. Each method offers some flexibility in field use and can be economical. We describe these methods and present some broad economic guidelines for applying them.

Often foresters may have another option in managing eastern hardwoods, particularly where stands have not been previously managed. An intermediate or improvement cut commonly called "conditioning cut" could be done. In this cut, undesirable tree species, stems of poor

quality, and some of the high-risk old residuals are removed to begin to reduce the overall stand variation. Many of the stems removed are from the lower canopy but no consideration is given for the establishment of regeneration. When managers use this kind of "partial cut", they can delay their commitment to either the uneven-age management or even-age management systems. However, for the remainder of this paper, we are committed to the partial-cutting methods for uneven-aged stand management.

A basic point for uneven-age management concerns age and dbh classes. The uneven-age concept is based on the periodic establishment and development of trees of different ages. In reality, we tend to look at tree size as an indication of age. But this is not true for most current hardwood stands. In second growth eastern hardwoods, tree size is not an indication of age (Gibbs 1963). Most of these unmanaged stands are predominantly the same age--second growth. The typical uneven-aged stand structure distribution curve, number of trees to age classes, is expressed as the reverse "J-shaped" curve. However, we commonly see this relationship as number of trees to dbh classes. In reality, most of our second growth even-aged stands also approach the "J-shaped curve" (number of trees--dbh class). There are a few stands where tree size indicates tree age.

The only valid uneven-age management practice we will discuss in the "textbook sense" is single-tree selection. Two other practices, diameter-limit and financial maturity, will also be included as partial cuts. Another uneven-age practice, group selection, will not be discussed since small clearcuts are usually made and for the purposes of this paper, we think it fits better in the even-age management discussion. Also, it is very difficult (maybe impossible in practice) to apply the classical group selection for a long period using volume control. In practice, it is more realistic to use area control when determining the number of openings to establish for each cutting period.

RESEARCH EXPERIENCE

Most of our experience with partial-cutting practices is from research areas on the Fernow Experimental Forest near Parsons, West Virginia. The oldest study areas contained second-growth hardwoods that were 40 to 45 years old when management began in 1949; however, most of the second-growth stands were less than 60 years old when these studies were initiated. Studies were installed on a variety of growing sites ranging from site index 60 to 80 for northern red oak. Usually, these stands had at least three age classes--predominantly second-growth trees that came in after the early logging, some old residuals that were not cut during the 1905-1910 logging era, and a few trees established from 1930 to the late 1940's following the death of the American chestnut.

Initially, study areas were managed using individual-tree selection or diameter-limit practices. Some of the original study areas were then managed using financial maturity guidelines after the first or second periodic harvest. Altogether, research areas dealing

with partial cutting total about 1,000 acres on 24 separate study areas. Each area has been harvested at least twice with one area approaching the fifth cutting cycle in 1988.

Partial-cutting practice areas on the Fernow demonstrate several variations for each practice. Cutting cycles include 10-, 15-, and 20-year periods. Financial maturity management is demonstrated on areas where the assumed alternative real rate of return is 3, 4, or 6 percent. A diameter-limit of 17.0 inches dbh is replicated on site indexes of 60, 70, and 80. A diameter-limit of 15.5 inches dbh is also demonstrated on an excellent growing site. Individual-tree selection has been practiced on various growing sites that influence residual basal area and maximum tree size goals. In addition to a variety of partial-cutting practices, the Fernow Experimental Forest offers some of the oldest continually managed hardwood stands in North America.

TYPES OF PARTIAL-CUTTING PRACTICES

Single-tree Selection

In the woods, high grading, diameter-limit cutting, thinnings, improvement cuts, and "selective" cuts have all been referred to as selection. While all of these practices are a form of partial cutting, they are not single-tree selection. In fact, true single-tree selection practice done for several cutting periods is hard to find (nearly nonexistent).

What sets a selection practice apart from other partial cutting practices? In other practices, the harvested material is usually from the larger sawtimber-size diameter classes. In selection practices, the objective is to attain and then maintain a given number of trees per acre throughout a range of dbh classes in sawtimber and occasionally poletimber trees. The selection method is used to periodically remove some sawtimber and/or poletimber trees throughout a range of dbh classes. Our approach is to cut the stand using number of residual trees per dbh class as goals--a way to control stand structure. These residual tree goals are determined by the stand characteristics and management objectives. A common way is to use residual basal area, determine the largest diameter tree to grow, and q-values (Smith and Lamson 1982).

In the classical single-tree selection concept, the cuts are heavy enough to establish reproduction and stimulate residual trees to develop into larger diameter classes. This has to be done at each cutting period. At the same time, the cuts have to be conducted on a periodic sustained yield basis and also be economical. However, if the cuts are too heavy, periodic yields are not met or stem quality is reduced. Usually a cut of 2,500 to 3,500 board feet per acre (International Rule) is economical, especially where an acceptable road system was previously established. With growth rates known, or closely estimated, a cutting cycle can be set to maintain sustained yield.

Based on our experience at the Fernow Experimental Forest where periodic selection cuts have been done from two to four times, the

periodic cut of 2,500 to 3,500 board feet seems easy to attain. Our initial cuts 25 to 35 years ago removed from 30 to 50 percent of the sawtimber volume (trees 11.0 inches dbh and larger). Cutting cycles of 10 years are very feasible on oak site index 70 or higher, while a 15- to 20-year cycle seems acceptable on the site index 60 areas. Between each cutting period, these areas accumulated about the same or more stand volume than was present at the initial cut.

Several periodic selection cuts are usually necessary before the desired number of trees per dbh class can be attained. However this desired residual number of trees per acre is only a goal. We know that when using the selection method, tolerant species will dominate future stands. The selection method should not be used unless most of these tolerant species are commercially valuable such as: beech, sugar maple, and red maple.

Diameter-limit

If the truth were known, diameter-limit or a variation, is the most practiced partial-cutting method in eastern hardwood stands. In this practice, timber is commonly sold by stump height diameter. All sawtimber size products are cut above the indicated diameter.

Diameter-limit cutting is the periodic removal of trees above a minimum stump diameter or dbh. Normally no cutting or cultural practices are done in the pole or sawtimber stand below the minimum cutting diameter. A 12- to 14-inch stump diameter-limit is commonly used because trees of these diameters are generally large enough to return a profit at the mill. Periodic diameter-limit cuts can be set up on a long-term basis depending on the minimum tree size and the length of cutting cycle.

Some of the attributes of the diameter-limit cutting are that the development of the residual stand is left to chance and there is no means of regulating the periodic volume removed. Both good and poor trees below the diameter limit continue to grow and tolerant species often dominate future stands. Cull trees below the diameter limit are not removed and sometimes cull trees above the diameter limit are also not removed. However, a diameter-limit cut is used because it is easy to apply in the woods. Often the landowner verbally tells the logger the minimum cutting diameter and no marking is done. Also, logging and milling costs are lowered when the minimum diameter is set to eliminate cutting or winching of the small, low-value trees. This may make it easier to negotiate a timber sale compared to other partial-cutting practices where cut trees are marked and some of the marked trees have negative timber values.

In general, foresters do not have favorable comments about the diameter-limit concept. Their main concern is the reduction of stand quality through stand high grading. Foresters contend that high-quality stands cut a few times can quickly be reduced to low-quality stands. Initially, the faster growing trees are cut, and dying or damaged trees below the minimum diameter are not cut. Tree species that produce epicormic branches might suffer degrade by

diameter-limit cutting. Also, movement of trees below the minimum cutting diameter in the sapling-poles-sawtimber classes is left to chance development.

In stands on the Fernow being managed by diameter-limit cutting, we are not seeing a major destruction of the stands, at least for the short term. We are in the process of publishing results of a 15.5-inch dbh diameter-limit on an excellent site (red oak site index 80) using a 20-year cutting cycle. After more than 30 years, volume production has been about 8,000 board feet per acre per cutting period, and we expect this production will continue for at least another 30 to 50 years. Tolerant species in the intermediate and overtopped crown class respond and improve in form more rapidly than anticipated (Trimble 1968). We also have some 17-inch diameter-limit cuts for a range of site indexes (60 to 80). Initial 17-inch diameter-limit harvests removed from 40 to 75 percent of the merchantable sawtimber, averaging about 5,500 board feet per acre. Second harvests removed about 30 to 75 percent of the merchantable volume, averaging about 3,000 to 4,000 board feet per acre. Some of the study areas have been cut a third time, and so far the 17-inch diameter-limit is removing about half the volume, averaging 6,400 board feet per acre on site index 70 and above.

Old residuals accounted for much of the sawtimber volume in the initial diameter-limit cuts. In stands with site indexes 70 and 80, second-diameter-limit harvests were made 15 years later. The cutting cycle was set at 20 years in stands with site index 60 because of slower growth on poorer sites. As was true in the selection cut, the diameter-limit cut also averaged about the same or a higher volume at each periodic cut (one area about 900/acre less) than was present at the initial cut 25 to 35 years ago.

Sometimes the diameter-limit method can be used as a first cut in hardwood stands and a different practice used in future harvest cuts (Trimble 1971). Cultural practices can also be done to remove cull and undesirable trees above the minimum cutting diameter. In our opinion, if a high diameter-limit is practiced, with a few minor adjustments, the diameter-limit can be an acceptable method for a long time, and that statement awakens the sleepy-eyed and needs to be read again. Often second-growth hardwood stands 80 years or older contain many stems 18 inches or larger. A high diameter of at least 18 to 20 inches dbh may be a desirable recommendation for landowners with partial cutting as their objective. And we expect these higher diameter limits to continue to produce an acceptable economic volume for several future cutting periods.

Financial Maturity

In practice, the financial maturity concept is applied like a flexible diameter-limit based on species, site quality, and an acceptable percent rate of return. Rate of return is based on value and volume growth response. An adaption of this concept for sawtimber stands is described by Trimble et al. (1974) where the concept is combined with an improvement cut in the sawtimber stand to achieve silvicultural goals. Trees that exceed a selected rate of return due

to rapid growth or quality are left in the stand to grow unless they are high risk. Trees earning less than this rate of return are financially mature and can be cut. For this partial cutting practice, current tree dbh and anticipated growth determine potential real rate of return. Diameters that correspond to financial maturity for each species are determined prior to marking the stand (Table 1). In the field, species, dbh and tree characteristics determine whether an individual tree is cut or retained.

Table 1.—Financial maturity cutting diameters for Appalachian hardwood species by red oak site index and selected rate of return

Species	2%			3%			4%			5%			6%		
	80	70	60	80	70	60	80	70	60	80	70	60	80	70	60
MINIMUM CUTTING DIAMETERS (2-inch dbh)															
Yellow-poplar	26	26	24	24	22	22	20	18	18	20	18	18	18	18	18
Beech	24	22	22	22	20	20	20	18	18	20	18	18	18	18	18
Black cherry	32	30	30	28	26	24	22	20	18	20	20	18	18	18	18
Red maple	32	30	30	28	26	24	22	22	18	20	20	18	18	18	18
White ash	30	28	28	26	24	24	22	20	18	20	20	18	18	18	18
Sugar maple	32	32	30	28	28	24	22	22	18	20	20	18	18	18	18
Red oak	26	26	24	24	24	22	22	22	20	22	20	20	20	18	18
White oak	24	22	20	22	20	20	20	18	18	20	18	18	18	18	18
Chestnut oak	24	24	22	22	22	20	20	18	18	20	18	18	18	18	18
Other long-lived species	26	26	24	24	24	22	20	20	28	20	20	18	18	18	18

This adaption of the financial maturity-silvicultural concepts also involves residual basal area guidelines for various site indexes and rates of return. For example, on oak site index 80, the recommended residual basal area (RBA) is somewhere between 70 and 85 ft² per acre in trees over 11.0 inches dbh. If the stands have never been managed (cut), then the residual basal area after the first cut should favor toward the higher level. A 10-year cutting cycle is used for good sites, and 15 years is suggested for stands on oak site index 60 areas.

In many stands, the current stand conditions are such that a forester cannot achieve the desired landowner rate of return in a single cut or if done, the stand would be drastically cut, creating an uncertain future. Also, if a stand has a large number of poor-quality trees, removing all or most of these poor-quality trees may be the only initial cut option. After the poor trees are removed, the residual stand meets the basal area guidelines. Thus, no trees would be cut at the indicated diameter-limit for each species.

On the Fernow, we also have a range of financial maturity cut areas on stands with an oak site index 70 using a 10-year cutting cycle. The rates of return range from 3 to 6 percent (Table 1). In general, at the initial cuts about 15 years ago, we removed about 30 percent of the stand volume depending on the stand rate of return. The only periodic cut yielded more than 4,300 board feet per acre, and the

stands just before the 10-year cutting period averaged more volume than the initial stand. We think economic cuts with the financial maturity concept can continue for an unlimited number of cutting periods. The species composition will be dominated by the tolerant species, but due to some occasional openings in the crown, intolerant species are being regenerated and a few develop into the overstory stand.

ECONOMIC CONSIDERATIONS--PARTIAL-CUTTING METHODS

What are some of the general economic attributes of partial-cutting practices? We do not intend to discuss the economics of each practice. Instead, we plan to discuss some of the major concerns and offer suggestions on how to improve partial cutting methods.

Partial Cutting Changes Species Composition

It is neither good silviculture or economics to use partial-cutting practices unless desirable commercial tolerant species are present or can be established in the stand. Sustained yield cannot be achieved if commercial sale volumes do not accumulate between periodic harvests. Partial-cutting methods favor the development of tolerant regeneration. Once the current intolerant species in a second growth stand are cut these trees will be replaced primarily by tolerant species. In general, selection cutting practices favor reproduction of tolerant species (75 to 90 percent) like beech, sugar maple, and red maple. Depending on the minimum cutting diameter and crown-opening size, diameter-limit cutting tends to create crown openings that favor some intolerant regeneration. However, diameter-limit cuttings will promote a stand of mostly tolerant species (60 to 75 percent).

Making heavy removals and lengthening the cutting cycle could result in some reproduction of more intolerant stems. Modifying partial-cutting practices to reproduce more intolerants has some economic benefits too. Since tolerant species usually have slower growth rates and less total volume per tree than intolerant species, future stand production will be less, and residual tree goals for the selection practice will probably need to be modified. For example, intolerant hardwood species such as red oak, yellow-poplar, black cherry, and white ash are more valuable per unit of volume than tolerant hardwoods such as beech, sugar, and red maple.

Partial Cuts Can Be Economical

Landowners can earn competitive rates of return managing hardwood timber using a partial-cutting practice. On the Fernow Experimental Forest, a 15.5-inch diameter-limit practice earned 13.7 percent and two selection practices earned 9 percent (market rates) over a 34-year period (Smith and Miller 1987). Other studies have shown that partial-cutting practices can be expected to earn from 4 to 6 percent real rates of return (McCauley and Trimble 1972, Reed et al. 1986). We think at least a 4 percent real rate of return can be achieved using periodic partial-cutting practices.

Another economic benefit of partial cutting is that landowners receive periodic returns. Returns in the initial harvest may be relatively low if the area lacks access roads. Once roads are in place, however, later harvests will be more profitable. Landowners who use partial-cutting practices instead of clearcutting can expect harvest revenues every 10 to 20 years. This is particularly attractive to landowners who can foresee additional periodic harvest revenues in their lifetime.

Partial cutting also allows the landowner to retain many management options. Most hunting and other recreation opportunities remain intact under partial cutting. The presence of residual timber also improves the esthetic value of the forested property. If the landowner decides to sell both land and timber, the residual timber and esthetic values will attract a range of potential buyers. The residual timber also serves as a form of savings the landowner can withdraw if needed. Conversely, clearcutting could postpone recovering these revenues for at least 40 years—first commercial thinning.

WELL-PLANNED ROADS INCREASE RETURNS

Logging roads are an essential part of timber management. In the Appalachian mountains, most timber harvesting operations require two kinds of bulldozed road: skid roads and haul roads. For a given mile of road, about 90 percent of road length is for skidding only, while about 10 percent is a more costly haul road. Skidroads cost about \$1,200 per mile, while minimum standard haul roads average \$8,100 per mile including culverts but without gravel (Kochenderfer et al. 1984). The resulting weighted average cost of logging roads is about \$1,900 per mile. Research has shown that a mile of bulldozed road provides logging access to about 20 acres of timber land (Kochenderfer 1977). Thus, the total cost of access roads within a particular forest management unit is about \$100 per acre.

In most markets throughout Appalachia, landowners cannot expect a significant return from the first partial harvest in an area lacking access roads. In fact, initial partial harvests in unmanaged stands may result in breakeven operations. Stumpage revenues are used to compensate the logger for road construction costs. Subsequent harvests will provide positive returns because roads are in place.

Roads are permanent so it is important to consider residual road value in locating roads prior to the initial harvest. Poor planning increases the cost of using access roads in future harvests. Often it is necessary to build additional roads to correct problems resulting from poor road location. Well-planned roads cost less to maintain after logging. Good planning might reduce total road length and does reduce grade which in turn reduces logging cost and the cost of post-logging activities such as seeding and installing water breaks.

Because the initial partial harvest in roadless areas does not yield high revenues, it is important to plan the best road location for a given area. Plans should include the entire management unit and layout should be influenced by adjacent tracts. Building all logging

roads in the initial harvest also reduces construction costs and increases residual road value. Landowners have access to the property between harvests and opportunities for firewood sales as well as hunting, fishing, or other recreational outdoor uses. Good roads also improve management planning because landowners can visit their property and recognize management opportunities between harvests. After the initial cut, a landowner may be well satisfied with a tradeoff of no stumpage for good road access. No doubt well-planned roads are a strong foundation for future returns in partial cuttings.

RESIDUAL STEM DAMAGE IS A CONCERN

Foresters are concerned about frequent cutting cycles (10 to 20 years) and associated periodic logging damage to residual trees when using partial-cutting methods. Though most of their concern is with degrade on the butt log of pole- and sawtimber-size trees, damage to sapling stems is also a concern since the future stand is strongly dependent on this source of vegetation. We have found that damage is usually concentrated in the sapling stems. Even if all the damaged stems die, an adequate number of undamaged stems remain for future stand development to achieve stand structure goals for single-tree selection. Wounds to larger trees are not a major cause for concern with short cutting cycles because wounded trees can be harvested before significant losses in value occur (Lamson et al. 1985). Also, many of the logging wounds are confined to the stump portion of the butt log. Logging damage to residual trees increases with intensity of cut and increase in slope percent. In many areas damage to residual trees can be reduced and loggers know what to do. It is primarily a matter of more thought and work by the logging crew at a greater expense to the landowner.

Unfortunately with partial cuts, logging damage to some residual trees must occur. There are several suggestions for reducing residual stand damage during partial cuts. However, the landowner must realize that for some of these suggestions logging cost will increase, and the net result is the landowner will receive less stumpage. In an effort to try to minimize logging damage during partial cuts, confine logging equipment to skidroads. Allowing the logger to move at random on the more gentle topography increases logging damage to residual trees. On steep topography, logging equipment must stay in the skidroads. However, when possible leave fender trees to ensure the load stays in the skidroad. If the logger pulls cable, there would be more control of the tree during winching and damage to the residual stand would decrease by having a greater distance between skidroads and keeping the equipment on the road. Also, if shorter tree lengths are winched and skidded, damage to the residual trees would be less too. When possible, log during the summer to late winter seasons since tree bark is tighter and not as prone to removal as in the spring. Take the time to examine a few local logging jobs. Select a logger that will leave the residual stand in good shape and provide acceptable future road access. Even if this good logger offers less stumpage, the quality of the logging may result in more money to the landowner in the future. Good loggers are well-known within a local area.

SHORTER CUTTING CYCLES ARE PREFERRED

Eventually, the question of length of cutting cycles is based on periodic volume growth and economic cuts. If a volume of 2,500 to 3,500 board feet is needed for a minimum economic cut in mountainous topography, then the stand must produce between 250 to 350 board feet per acre per year for a 10-year cutting cycle or about 170 to 235 board feet per acre per year for a 15-year cycle. Of course, as the volume for the minimum economic cut increases to 4,000 or more, the per-acre volume production must increase if short cutting cycles are desirable. An acceptable approach is to use short cutting cycles of 10 years on better sites (oak site index 70 or higher) because per-acre volume production is higher. On lower sites, a 15- or 20-year cycle is acceptable. Based on our experience, cutting cycles of less than 10 years are not economically practical even on the better sites.

The time between periodic harvest cuts influences the net returns associated with partial-cutting practices. In general, net present stand value increases with shorter cutting cycles. Shorter cutting cycles (10 to 20 years) result in more frequent revenues to the landowner. Also, shorter cycles provide more of an opportunity to salvage mortality and less opportunity for butt-log degrade from logging damage.

Of course, with shorter cutting cycles, less volume is harvested at a given cutting period, and this could result in less logging damage to residual trees. With short cutting cycles, wounded trees that do not callus (heal) properly can be removed before major losses in volume and value occur. Shorter cutting cycles also tend to yield a larger average size product than longer cycles. Trees have more opportunity to respond during frequent release.

Longer cutting cycles would result in an increase in volume removed during each cutting period and would be more economical to the logger. However, longer cutting cycles increase stand damage losses by increasing the volume removed at each cutting period and by increasing the length of time damaged trees must remain in the residual stand. The key to length of cutting cycle is providing cuts that are economically attractive based on periodic growth (site productivity) and local markets.

INVENTORIES ARE NEEDED FOR MARKING

For the selection harvest method, it is important to have periodic inventories to develop stand tables. Stand tables are used to determine actual number of trees available for cutting (surplus trees) and trees that should not be cut (deficit trees) in given diameter classes. Once an inventory is available and residual tree goals determined, the actual marking can be done using a cut ratio concept (Smith and Lamson 1982). For example, a cut ratio for the 12-inch dbh class could be 1:4; that is, the marker should try to cut one out of every four 12-inch trees seen on the area. But remember this approach of cutting all surplus trees is not always applicable during the early cutting periods. Overcutting can easily occur. Also, data for number

of trees to cut per diameter class are available as well, and number of trees to cut for the total marking area are available. We prefer 2-inch stand tables, but 4-inch tables will work.

As with any job, basically the better the inventory the better the results. Ideally, a 10-percent inventory would be the maximum needed but most inventories are considerably less so this has to be good enough. We simply cannot afford anything better.

Normally, a diameter limit does not require much of an inventory or marking. About the only information that would be helpful is an estimate of the volume and acres of the sale area. Usually the logger or buyer examines the area and determines if the timber is worth buying. If so, the landowner and buyer agree on a minimum cutting diameter and perhaps the felling of cull trees above this cutting diameter. Trees in the stand are not marked. Normally, the logger does the "picking and choosing". However, with some refinements such as increasing the minimum cutting diameters and/or removing culls and undesirable trees below the minimum diameter, marking becomes necessary.

For the financial maturity method, an inventory of the stand is necessary to develop a stand table. Also, an inventory estimating the trees that would be removed for silviculture (improvement cut) is necessary. Both the stand and silviculture inventories are easily done together. With both inventories available, the forester is able to determine the residual stand before marking the cut through use of site index and desired rate of return. Stand marking is also necessary with this cutting method.

RAISE THE MINIMUM CUTTING DIAMETER?

When applying a diameter-limit to stems smaller than 16 inches dbh, most trees with the potential for a butt-log grade 1 are eliminated. If we assume that the grade increase is based on an increase in diameter, which it normally is, the selling price for grade 1 sawlogs is significantly higher than for grade 2, 3, or lower quality logs. Thus, butt logs on residual trees where the minimum cutting dbh is less than 16 inches have little opportunity for this "several fold" increase in value because most are cut before they become eligible for grade 1. For an 18-inch db sugar maple log, grades 1, 2, and 3 correspond to a value ratio of 7:4:1, respectively. That is, the grade 1 is worth 7 times more than a grade 3 while grade 2 is worth 4 times grade 3. Veneer compared to sawlogs would be higher too. Future dollars are lost to the landowner by selling trees that are currently low value due primarily to size. Of course, the overriding assumption is these smaller trees will respond. We know that tolerant species will respond and so will the intermediate tolerant species such as oak.

Based on change in tree value, it is good business to leave the trees having the potential to increase in butt-log grade or even veneer material. For sawlog-size trees, this means cutting to at least a minimum dbh of about 16 inches or stump diameter of 19 inches. The increase in tree value with size results from changes in butt-log grade

and diameter growth as well as increased volume. This relation is similar for all hardwood species sawn for lumber, though there is considerable variation among species in actual tree-value increases. In the financial maturity cutting method, the minimum cutting diameter is 17.0 inches dbh for some species, but it is 19.0 inches or higher for most species. Using diameter-limit cuts with a few changes or flexible diameter following financial maturity guidelines have the potential to improve current diameter-limit cutting practices (Smith et al. 1979).

MANAGING POLETIMBER WILL IMPROVE FUTURE STAND VALUE

For partial cuts, trees 10- to 12-inches dbh and larger are usually the minimum acceptable size for sawtimber products. There is no problem in applying partial cut methods such as single-tree selection when markets for sawtimber and poletimber products are available. However, where markets are not available for poletimber products, we suggest that the landowner strongly consider at least removing some cull trees (leave a few for wildlife) and possibly undesirable trees. Fell these trees during logging. It makes little sense to continue to concentrate growth on poor trees until they become large enough to cut during a commercial operation. Also, once the cull trees are eliminated for the first time in a previously unmanaged stand, future cull tree removal is minimal.

Managing unmerchantable poletimber in the individual-tree selection practice results in cutting from 15 to 20 additional trees per acre during logging. Felling undesirable poletimber at each cutting cycle virtually eliminates culls after one or two cutting cycles. At each cutting cycle, the logging contractor can be instructed to fell the marked poletimber trees while the area is logged for merchantable sawtimber. The additional cost to fell 15 to 20 pole-sized trees per acre amounts to about \$10 per acre. In some cases, the logging contractor may not require compensation for felling unmerchantable poles marked for cutting. The benefits of managing poles include slight improvements in species composition and log quality of trees growing into merchantable sawtimber. Managing poles also provides an opportunity to influence spacing of future sawtimber trees.

For diameter-limit and financial maturity methods, we suggest removing some cull trees and undesirable tree species below the minimum diameters. This is particularly important if a high minimum diameter is used where no cutting is done in the small sawtimber. There will be something left in the residual stand to manage. There is no reason to continue to concentrate growth on cull trees or undesirable species in the poletimber and sawtimber stand. Growth should be concentrated on the higher value, more desirable species and trees.

In one study on the Fernow, a selection stand managed for both poles and sawtimber was worth 33 percent more than a similar stand managed for sawtimber only after 34 years (Smith and Miller 1987). We think a significant portion of this difference was due to the quality of poletimber growing into sawtimber trees throughout the study

period. Growing space that would be occupied by undesirable poles was redistributed to selected desirable poles and advanced regeneration. This area had the highest percent volume in trees with grade 1 or 2 butt logs and the highest stumpage. Total periodic harvest volumes were very similar, species composition similar, and current residual stands were only 800 board feet per acre apart. Yet, the current residual stand stumpage per acre was \$1,214 (poletimber-sawtimber management) and \$890 per acre (sawtimber management only).

RECOMMENDATIONS - SUMMARY

We have discussed three partial-cutting harvesting methods with one, single-tree selection, being the only recognized uneven-age management harvest practice. Of the three practices--selection, diameter-limit, or financial maturity--the partial cutting method that has the highest overall potential for field application is the financial maturity silviculture method. This harvest method is applied as a flexible diameter-limit based on species, site index, and desired rate of return. However, if you are using single-tree selection successfully, continue to use it. If you are using a diameter-limit, we recommend raising the minimum cutting diameter to at least 16 inches dbh and preferably higher. When possible, remove cull trees and undesirable species that are below the minimum cutting diameter including stems in the poletimber stand.

No doubt we have surprised several people by not totally endorsing the selection practice. Briefly, here is why we recommend the financial maturity practice. Esthetics is satisfied, some intolerant species will develop in the stand and in our opinion, there are sufficient basal area and volume guidelines to prevent overcutting the stand. With reasonable stand and silvicultural (improvement cut) inventories, foresters know what the residual stand will be before going to the field to mark or cut a stand. Another big plus for the financial maturity concept is the use in field application. The minimum cutting diameters are high, and the actual field marking is not too difficult.

As mentioned at the beginning, we are not going to decide what harvesting system should be recommended. In most cases, we hope foresters will have an input in determining what harvesting system and methods to use for a particular property or stand. However, no harvest system or harvest cutting method should be recommended as a standard for all situations. Nature and previous land use, topography, soil, nutrient and moisture regimes will not permit individual trees or stands to develop uniformly.

There are several ways to manage forest stands, and basically we are saying that there are no definite "rules of thumb" or single procedure for managing them. Foresters have to use a variety of silviculture tools in managing stands. The whole basis for these silvicultural decisions start with the landowner and what objectives "must" be satisfied before any stand management is allowed to occur. We hope the silvicultural and biological aspects of the stand do not have to be sacrificed for unsound management practices. Certainly, the

landowner should become well informed of tradeoffs when using the different harvesting methods.

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