A procedure for SELECTION MARKING in HARDWOODS

Combining silvicultural considerations with economic guidelines

by George R. Trimble, Jr.
Joseph J. Mendel
Richard A. Kennell

USDA FOREST SERVICE RESEARCH PAPER NE-292
1974

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

THE AUTHORS

GEORGE R. TRIMBLE, JR., now retired, was timber management project leader for the USDA Forest Service's Northeastern Forest Experiment Station at its Timber and Watershed Laboratory at Parsons, West Virginia. He received his forestry training at the University of Maine. He worked for a number of years in watershed-management research both in West Virginia and New Hampshire, and has worked on forest-management problems in most of the northeastern states.

JOSEPH J. MENDEL, principal economist, received his bachelor of science degree in forestry from the University of Michigan in 1941, and his master's and Ph.D. degrees in agricultural economics from Ohio State University in 1963 and 1965. He also studied at the University of Wisconsin and the University of Cincinnati. He joined the Northeastern Forest Experiment Station in 1946, working first on forest surveys, and in 1952 transferred to the Washington office of the Forest Service as a photo-interpretation specialist in the Division of Forest Economics. After 6 years in Washington he accepted a position as research forester with the Central States Forest Experiment Station at Columbus, Ohio, and in 1966 transferred to the Northeastern Station, where he is now serving as a specialist in forest economics at the Station's research unit in Columbus, Ohio.

RICHARD A. KENNELL is resource management group leader in the USDA Forest Service's Northeastern Area State and Private Forestry unit, at Upper Darby, Pa. He is in charge of the cooperative forestry program in the 20-state northeastern area, which includes cooperative forest management, nursery production and tree improvement, state forest land management, and urban and community forestry. He received a bachelor of science degree in forestry at the University of New Hampshire in 1953.

MANUSCRIPT RECEIVED FOR PUBLICATION 22 JANUARY 1974

TREES TO MARK—SAWLOG SIZES
(above 11.0 inches dbh)

For All Rate-of-Return Classes, Mark:

1. Culls and near culls.
2. Trees with significant rot in the butt log.
3. Very-low-vigor trees (vigor 4).
4. Extremely rough trees with butt-log grade 5.
5. Any trees over 15 inches with butt-log grade 4.
6. Any short-lived species, such as black locust, sassafras, and butternut, unless they are unusually vigorous.

In addition, trees above a certain dbh class are marked under certain conditions. This dbh varies with the rate of return desired, by species, and in the case of oak by site quality. It also varies by crown or vigor class and is additionally affected by the likelihood of log-grade improvement. The trees to mark are those of the indicated dbh's and larger. These will be marked unless a potential grade improvement can be foreseen in the next 10 years.

Mark trees of these dbh classes and larger:

Species	Low						Medium						High		
	2%			3%			4%			5%			6%		
	80	70	60	80	70	60	80	70	60	80	70	60	80	70	60
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	18	20	20	18	18	18	18

A procedure for SELECTION MARKING in HARDWOODS

ABSTRACT

This method of applying individual-tree selection silviculture to hardwood stands combines silvicultural considerations with financial maturity guidelines into a tree-marking system. To develop this system it was necessary to determine rates of return based on 4/4 lumber, for many of the important Appalachian species. Trees were viewed as capital investments that should be liquidated when they fail to yield an acceptable rate of return. Present values of sawlog-size trees were determined by species, size, and log grades. Future values—in 10 years—were based on growth rates and projected changes in log grade. Actual stumpage values were determined, working back from standard lumber prices by deducting conversion costs. The first consideration in appraising a stand for marking is to mark for removal the poor-quality, poor-risk, and short-lived trees, then mark the good trees according to their rate of return. Tree sizes to mark were established for 2-, 4-, and 6-percent return rates. Different rates were determined by site-quality classes. Guidelines were established for satisfactory residual basal areas, and examples are given of adjustments sometimes necessary in unmanaged stands where it may not be possible with the rate of return chosen to make a profitable cut and leave a satisfactorily stocked stand.

CONTENTS

Our purpose in this paper is to describe one method of applying individual-tree selection silviculture to hardwood stands. We do not deal with the advantages of even-aged versus uneven-aged systems; but, on the assumption that the decision has been made to practice individual tree-selection cutting, we outline a specific method of doing this. The reader should not expect to get from this discussion a rationale for the practice of one type of silvicultural system over others.

The selection system we propose incorporates economic guidelines for selecting trees to cut. These economic guidelines are in the form of rates of return for individual trees. In combination with the usual silvical considerations, they can be used to determine which tree should be cut.

Application of these marking guides is limited to sawtimber-size trees—stems above 11.0 inches dbh. Where markets permit cutting of smaller trees, considerations other than those outlined here must be used to indicate which stems to cut and which to leave.

The Need for Better Guidelines in Managing Stands by Selection Cutting

If an appreciable acreage of forest land is to be managed under an uneven-aged system employing selection cutting, then it is important that we concern ourselves with the guidelines we are going to use in applying this type of silviculture. Probably most foresters would agree that selection cutting in hardwoods in the past has often been on a "seat-of-the-pants" basis, generally without adequate consideration of residual stocking, distribution of stems by diameter classes, setting cutting cycles based on potential growth rates, log quality, or even provision for reproduction. Some good selection marking has been done, but much has been inadequate.

Probably the main reason why we have not concerned ourselves more with developing better guidelines for selection marking is the nature of the stands we have been working in. For the most part, we have been marking in unmanaged second-growth stands that contain a high proportion of poor stems, many of them old-growth residuals. It is often said that such stands "mark themselves".

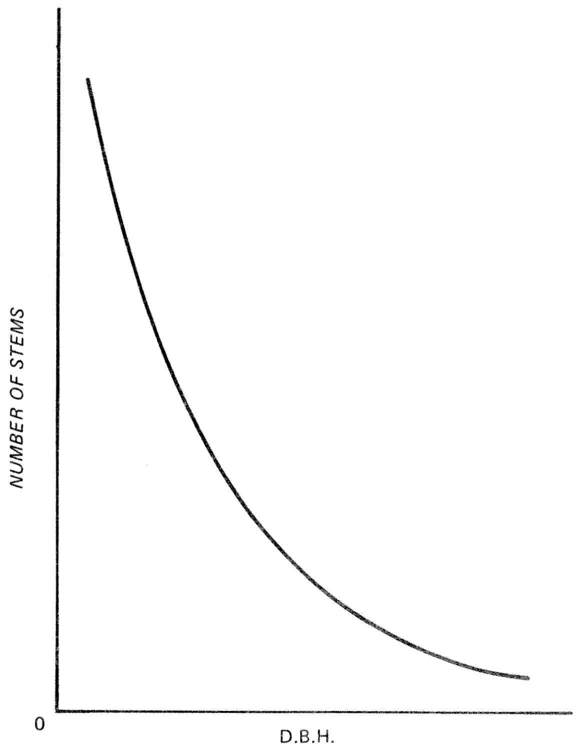
In these stands, the usual procedure has been to make an improvement cutting, combined with a thinning. All too often, the thinning has taken the form of a high-grading. Where the marking did not include too much high-grading, the stand was usually improved. However, we were not really practicing selection silviculture: we were just making a conditioning cut in an unmanaged stand, the type of cutting that could be followed by the imposition of either uneven-aged or even-aged systems.

We are now at the point where we are returning to many stands for subsequent cuttings. Many of these stands, conditioned by the first cuttings, are now ready for better planned marking. And many stands that we have not cut yet would benefit from a better planned initial cutting. This is especially true if we are to tailor our forestry more closely to specific goals.

None of this is to say that the selection system per se is new or that guidelines for its application do not exist. Selection silviculture has been applied for many years, and its principles have been reported voluminously in the literature. Guidelines covering both silvicultural and regulatory aspects of its application have been published for many timber types; many of these are recent and incorporate the latest research results.

It should be recognized that selection silviculture can be applied with many modifications. In managing forest stands under any of the modifications, however, certain procedures are implicit. Trees are designated for cutting—

Figure 1.—Schematic presentation of the typical inverted J-shaped curve illustrating the relationship between number of stems and dbh in an all-aged stand.



or for leaving—with the intention of retaining a residual stand adequately stocked for attainment of specific objectives, normally near maxium growth. Periods between cuts (cutting cycles) are based largely on growth rates. The poorer and less desirable stems are marked first for removal; so the stand is constantly upgraded. And often—particularly of late—a real attempt is made to mark through the range of merchantable diameters so as to leave a stand structure that will provide for adequate ingrowth from the lower diameter classes. The ideal structured stand has an inverted J-shaped curve when number of trees is plotted over dbh (fig.1).

Background Research on Rate of Return

In recent years, scientists of the Northeastern Forest Experiment Station have developed rate-of-return information for individual trees of the following hardwood species: northern red oak, white oak, and chestnut oak (*Trimble and Mendel 1969*); yellow-poplar and beech (*Mendel and Trimble 1969*); black cherry, red maple, and white ash (*Grisez and Mendel 1972*); and sugar maple (*Mendel, Grisez, and Trimble 1973*). This rate-of-return information was compiled for sawlog-size trees, based on a product common to each of the species—4/4 lumber. Similar information for pole-size trees or other products is not presently available.

Rate-of-return information is based on the financial-maturity concept, in which trees are viewed as capital investments that should be liquidated when they fail to yield an acceptable rate of return. Thus trees expected to exceed minimum acceptable return—because of rapid growth or quality improvement—should be left to grow, while those expected to fall below the minimum acceptable return are financially mature, and should be harvested.

To determine whether or not a tree was financially mature, we estimated its present value and its expected value 10 years in the future. Expected value is the present value plus the increase in value due to diameter growth, increase in volume, and improvement in quality over the next 10 years. The original value and the future value were then used to compute the compound interest rate of return.

Years of field work were required to determine growth rates of trees by species, vigor classes, and in some cases site quality. Additional research had to be done to determine log-grade changes by the same tree classes. Then tree values had to be determined, working back from standard lumber prices by deducting conversion costs. The methods used in arriving at rate of return and the data on which they were based are explained in the publications cited above.

Some of the findings of this work on rates of return are:

1. Rate of tree earning power in percent is less for trees of large diameter, even though actual dollar earning power will often be greater for the large trees.

2. Rate of earning power in percent is lower for trees of present high quality, even

though these trees may have higher dollar earnings.

3. Prospective earning power is greatly increased by potential improvement in tree quality.
4. Tree earning power increases markedly with increasing diameter growth rate.
5. Trees with greater merchantable height usually have slightly higher earning power.
6. Trees that increase in merchantable height have higher earning power—if the upper logs have positive values.

Items 1 and 2 above should not be interpreted as indicating that all large high-quality trees would be cut. It is true (table 1) that earning power is greater for smaller trees that have the potential for fast growth and quality improvement. However, the break-off point for even the highest rate of return, 6 percent, does not come until after the good trees have reached a minimum size to produce a grade-1 butt log. And as the desired rate of return drops, the dbh of the good trees to be retained in the stand increases.

The Development of Guidelines —A Combination of Theory and Practical Experience

The incorporation of rate-of-return information into a marking system for selection silviculture seemed particularly appropriate because the rates of return were based on individual stems. In this adaptation, it seemed best to think of the rates in terms of low, medium, and high returns rather than the absolute rates on which they are based (2, 4, and 6 percent). The primary reason for this is that the differences in prices and costs over time and from place to place can alter the actual rate of return.

It was realized that the use of rate-of-return guidelines alone for selection marking would be little better than marking for a refined diameter-limit cutting. The ideal procedure would be to integrate the concept of return into a system that was based primarily on sound silvicultural considerations, thus providing for a well-stocked high-quality residual stand. This seemed possible because financial maturity depends heavily on log quality and tree vigor.

With this in mind, we first developed a set of marking instructions based largely on silvicultural considerations. These were refined after considerable field testing. The following six classes of sawlog-size trees are suggested for removal for all rate-of-return classes and for all sites from fair to excellent:

1. Culls—marked for deadening.
2. Near-culls and trees with significant rot in the main stem.
3. Trees with butt-log grade of 5—local use logs.
4. Trees over 15 inches dbh with a butt-log grade of 4.
5. Trees of low vigor, including all overtopped trees of intolerant species.
6. Short-lived species such as black locust, sassafras, and butternut—unless they are unusually vigorous.

These then are the kinds of trees marked largely for silvicultural reasons.

But what about the good stems? How are they to be marked? The rate-of-return criteria apply to the vigorous and sound dominant and codominant trees—the crop trees. These trees will be left or cut depending on how well they meet the marker's objective in terms of the annual percentage return he sets as his goal for the next 10 years. Those that earn as much or more than the owner's expected return will be left to grow. Those that earn less will be taken. They would be financially mature. The rate-of-return marking guides were summarized from the publications cited previously (table 1). Trees equal to the dbh's shown and larger are to be marked for cutting *unless there is good prospect of a butt-log grade improvement in the next 10 years; in such cases they will be left.* The importance of log-grade improvement in increasing earning power should be stressed. As logs improve from one grade to another, their value jumps markedly.

The minimum dbh for a tree that can have a grade-1 butt log is 16 inches (grade 1 is the best sawlog grade). Because most trees below this size class that are good enough to leave under silvicultural considerations can improve in grade, the minimum dbh for removal under the rate-of-return criteria was set at 17+ inches (minimum size for an 18-inch dbh class).

Site quality makes a difference in the financial maturity dbh of trees. On the better sites, where growth rates are higher, we can leave bigger trees for any given rate of return (table 1).

To prevent understocking a stand—an important consideration in marking for any selection cutting—the marker must set a residual basal-area goal in desirable trees above the sawlog threshold—11 inches dbh. When we talk about the stand in respect to understocking, we are referring to delineated areas receiving similar treatment and marked for cutting at one time, but not every 1/4 acre or even every acre within the area. Some small patches may be heavily cut; others will hardly be touched.

Taking into account that 10 percent of the unmarked basal area may be lost to logging damage, the marking should be aimed at a residual basal area in sawtimber-size stems by site class as follows: Excellent site—70 to 85 square feet; good site—55 to 70 square feet; fair site—40 to 55 square feet. (We can assume 15 to 20 square feet in 5 to 11-inch poles for comparing these density figures to basal-area stocking guides developed for stands above 5 inches dbh.) In heavily stocked stands that have not been cut previously, the marker should strive for a residual basal area near the top of the range; in stands that have been cut at least once, he should aim for a basal area near the bottom of the range. Maintaining these residual basal areas should permit harvesting on a 10-year cutting cycle for excellent and good sites and in some situations for fair sites.

During the process of developing our marking guidelines, we field-tested our ideas as a standard procedure both on plots and on six large areas totalling about 300 acres where the marked trees were logged. This testing was done on the Fernow Experimental Forest in West Virginia in hardwood stands growing on areas of oak site indexes 80, 70, and 60 feet. We actually applied the following rates of return: 2, 4, 6, and 3 percent (we interpolated between the established 2 and 4 percent rates to get the dbh's for the 3-percent rate).

We believe that the marking method defined in this paper offers several advantages over customary marking techniques employed in all-aged silviculture.

First, it contains guidelines for more specific consideration of log quality as a factor in determining trees to cut and trees to leave. This is of vital concern in hardwood stands managed for sawlogs because in these stands log quality largely determines value.

Also, it specifically incorporates economic objectives—rate of return—without sacrificing silvical considerations.

Moreover, it is more easily applied than the classical method involving strict control of the number of trees by diameter classes.

Applicability

In appraising these guides to selection marking, a number of questions come to mind, questions that require answering if we are to apply the guides successfully:

1. Does this system of marking provide for regulation of cut—does it maintain an adequate stand structure for approximately equal cuts at fairly regular intervals?
2. Does this system provide for adequate regeneration?
3. What kind of knowledge and experience does the marker need?
4. What are the pitfalls of using this system, or in what types of stands is there a risk of failure?

Does this System of Marking Provide for Regulation of Cut—Does It Maintain an Adequate Stand Structure for Approximately Equal Cuts at Fairly Regular Intervals?

Obviously this system of marking does not provide for stand renewal by deliberately leaving a prescribed number of trees in each tree-size class, as does the more classical—and more complicated—method that tailors the residual stand to a predetermined diameter distribution. And so the system does not lend itself to as rigid control. But is its control potential adequate, and is stricter control necessary? We believe that, applied judiciously, the regulation potential of this system is adequate and that stricter control is not necessary.

First, we do not overcut the large trees in the stand—unless they are very poor. By large trees, we mean stems below but approaching financial maturity size. And if, as a first cutting in an unmanaged stand, we are forced to overcut these large stems because they are poor, we would be forced to do so regardless of the system of selection cutting. The result of this, in any case, is simply to delay the time when the stand is in equilibrium with the cutting method.

Next we remove the poor trees *throughout* the diameter range of sawtimber. In our mixed hardwood stands there will always be a number of such stems. Thus we will be providing growing space for better stems. As long as we do not understock the stand—and this is why residual-basal-area guides are necessary—we believe we will provide adequately for stand renewal, even though there are apt to be minor dbh gaps and surges. Therefore, following this method, we probably will not always be able to cut periodically the same volumes from trees of the same diameter classes.

Does the System Provide for Adequate Regeneration?

The work on individual-tree selection systems on the Fernow Experimental Forest, carried out for more than 20 years, shows definitely that we get adequate reproduction in number of stems, and that this reproduction develops. However, individual-tree selection cutting restricts the species composition of reproduction largely to the tolerants, such as the maples and beech. Diameter-limit cutting, on the other hand, because of its happenstance creation of small openings, results in the reproduction of a fair proportion of intolerants—but still a much lower proportion of these intolerants than does clearcutting or than might be desirable. Financial-maturity control, because cutting is determined in part by diameter, often results in the happenstance creation of openings suitable for the reproduction of intolerants. Thus we can expect this system to produce stands in which the proportion of intolerants is greater than in stands resulting from the usual single-tree selection marking.

What kind of knowledge and experience does the marker need?

1. The marker should be a forester experienced in the timber type—or a well-trained technician who can do the job with adequate guidance.
2. The marker should have a good working knowledge of log grades.
3. He should be able to recognize culls and serious defects.
4. He should be familiar with crown classes and indicators of tree vigor.

All the above qualifications are necessary to do a good job of selection marking under any set of guidelines.

5. Moreover, for this particular type of selection, the marker must know how to apply the rate-of-return guides.

In addition, the man who determines the rate-of-return guides to be used—whether or not he does the actual marking himself—must be able to: (1) Distinguish broad site classes, (2) recognize stand boundaries, and (3) have a good knowledge of markets in the area.

What are the pitfalls of using this system, or in what types of stands is there a risk of failure?

There are two main situations to watch out for: (1) The cutting should not appreciably understock the stand, and (2) the cutting in any given stand must—in most cases—assure a profitable harvest.

Whether or not a proposed cutting is merchantable depends on markets, amount and quality of products to be removed, and stand accessibility. These have to be appraised on the ground for each situation.

As with the application of any type of silviculture in the management of a stand, information is needed about the stand itself. If a good inventory is available, it is easy to decide whether or not a particular stand should be cut. In the absence of inventory data, cut-and-leave tally plots can be used to determine the feasibility of the proposed cutting or the necessity to adjust objectives to stand realities. A method of using cut-and-leave tally plots as a basis for the type of selection marking proposed here is illustrated in appendix I.

We have, in the following, used a number of examples to illustrate the application and possible adjustment of the guidelines to specific situations. We realize that, in many stands (if not most), it is going to take time and several cutting cycles to bring the system and the stand into equilibrium; this would be true with any selection system.

The selection system with rate-of-return guides offers a flexibility that favors adjustment to pressures for management for other forest uses than timber. For example, to produce large trees for esthetic reasons, a manager of public forest land may elect to practice the selection system by using low (2 percent) rate-of-return guidelines. Thus he could meet his esthetic objectives, harvest timber products, and get needed stand improvement done. On the other hand, a grower of stumpage for profit would probably aim his marking at a high return level, say 6 percent.

In initiating management in unmanaged stands, it may not always be possible to choose a return level consistent with ownership objectives; it may be necessary to adjust the rate-of-return level to stand conditions. Take the case of an owner who wants to make 6 percent, but who has a middle-aged stand of trees on a good site with a high proportion of the overstory just above the cutting diameter for 6-percent return. If he simply followed the guides for 6 percent, he would drastically overcut the stand. But using our method, residual-basal-area per acre requirements would preclude his making such a cut. The logical procedure for him to follow would be to make the first cut, using guides for a lower rate of return, and work up through succeeding cuts to the 6-percent level.

The converse of this situation may also occur: an owner may want to grow big trees and may be satisfied with a 2-percent return. But suppose he needs a return now from his woodlot, and present stand conditions will not support a profitable cut if he follows the 2-percent guides? His solution may be to make a cut following the 4-percent guides the first time and get to the 2-percent level later on. Again, residual stocking requirements must be considered.

Other adjustments are possible within this system. The marker may leave several culls per acre for den trees; he may favor or discriminate against species, including certain species below the rate-of-return guideline dbh's to take advantage of an especially good market; he may mark on a silvicultural basis in the 5- to 11-inch diameter understory for a pulpwood harvest; and he would almost certainly elect to deaden pole-sized culls, even though not harvesting trees below the sawlog threshold.

As an extreme example of stretching the selection system to fit an inappropriate situation, take a well-stocked even-aged stand of 75-year-old yellow-poplar on a very good site. The stand would be lacking in sufficient reproduction and small stems to support repeated operational cuts on anything like equal cutting cycles until an understory of tolerant species could be developed and grow to merchantable size. This might take over 100 years of selection cutting.

Another situation where selection cutting does not fit, and where, if initiated, would take an unusually long time to mold a suitable stand, is the case of a decadent high-graded sawlog stand. This, of course, is a classic case for clearcutting.

Neither of the last two cases are appropriate for cutting under the selection system. And, although in the first example rate-of-return guides could be used as a rough diameter-limit guide, they would have no application at all in the second.

In many cases, the 10-year cutting cycle on which the computations of financial maturity were based is unrealistic. On fair sites—site index 60 for oak—board-foot growth rates may not be high enough to support profitable periodic cuts every 10 years. And in unmanaged stands on all sites the first cut may have to be so heavy because of the necessity of removing a lot of low-grade and cull material that it would not be feasible to return for another cut in 10 years. We should realize that when the 10-year cycle is exceeded, the percentage rates no longer apply: extending the cutting cycle reduces the rate of return. And this is another reason why we prefer to use the terms low, moderate, and high rates of return.

Another factor that warrants some consideration is that the high dbh's shown for certain species under the 2-percent rate-of-return level are probably beyond average physiological maturity, and most of these large trees would be marked for silvicultural reasons before reaching these diameters. For example, few red maples will be found that are sound and vigorous at the sizes shown under the 2-percent rate-of-return level shown in table 1; that is, 32, 30, and 30 inches for site indexes 80, 70, and 60, respectively.

Summary

The need for better guidelines to practicing selection silviculture is stressed. A marking system that is based on silvical considerations, combined with economic goals, is described and justified. The marking system applies to the sawlog portion of the stand only, to those trees over 11.0 inches dbh.

The desirability of leaving an adequately stocked stand is discussed, and residual basal areas are suggested. Detailed instructions are given as to which individual trees to mark, based on tree characteristics, site quality, and owner's economic objective in terms of the desired rate of return.

Methods of adjusting the guidelines to actual stand conditions are illustrated.

Literature Cited

Grisez, Ted J., and Joseph J. Mendel.
1972. THE RATE OF VALUE INCREASE FOR BLACK CHERRY, RED MAPLE, AND WHITE ASH. USDA Forest Serv. Res. Pap. NE-231. 26 p.

Mendel, Joseph J., and George R. Trimble, Jr.
1969. THE RATE OF VALUE INCREASE FOR YELLOW-POPLAR AND BEECH. USDA Forest Serv. Res. Pap. NE-140. 27 p.

Mendel, Joseph J., Ted J. Grisez, and G. R. Trimble, Jr.
1973. THE RATE OF VALUE INCREASE FOR SUGAR MAPLE. USDA Forest Serv. Res. Pap. NE-250. 19 p.

Trimble, George R., Jr., and Joseph J. Mendel.
1969. THE RATE OF VALUE INCREASE FOR NORTHERN RED OAK, WHITE OAK, AND CHESTNUT OAK. USDA Forest Serv. Res. Pap. NE-129. 29 p.

Appendix I

PROCEDURES FOR USE OF CUT-AND-LEAVE PLOT DATA TO DETERMINE FEASIBILITY OF STAND OPERATIONS

Table 2 shows how the per-acre tallies are summarized from the cut-and-leave field tally sheets. By species and dbh class, the number of trees, volumes, and basal areas are accumulated and shown on a per-acre basis for: the total stand, the stand marked under silvicultural considerations alone, and the residual stand (total stand minus silvicultural marking).

The next step is to use the residual-stand data to estimate the additional trees that would be marked under the different rate-of-return levels. This is done for a stand on a good site (site index 70 for oak), using table 1 as a guide. Volumes and basal areas are computed for the appropriate trees to be marked for each rate-of-return level—the 2-, 4-, and 6-percent levels from table 1. The dbh's to be marked for the 3- and 5-percent levels can be interpolated from this table (and are shown in the card—appendix II). These data are then summarized in table 3 as the basis for an appraisal of the stand situation. In this table, the total volume marked for any rate-of-return marking includes the volume marked under silvicultural considerations.

Table 1.—Mark trees of these 2-inch[1] dbh classes and larger

Species	Rate of return desired								
	2 percent			4 percent			6 percent		
	Site index for oak								
	80	70	60	80	70	60	80	70	60
Yellow-poplar	26	26	24	20	18	18	18	18	18
Beech	24	22	22	20	18	18	18	18	18
Black cherry	32	30	30	22	20	18	18	18	18
Red maple	32	30	30	22	22	18	18	18	18
White ash	30	28	28	22	20	18	18	18	18
Sugar maple	32	32	30	22	22	18	18	18	18
Red oak	26	26	24	22	22	20	20	18	18
White oak	24	22	20	20	18	18	18	18	18
Chestnut oak	24	24	22	20	18	18	18	18	18
Other long-lived species[2]	26	26	24	20	20	18	18	18	18

[1] Two-inch dbh classes as follows: 18 inches (over 17 to 19 inches), 20 inches (19 to 21), etc.
[2] Not determined by research but set subjectively.

Table 2.—Per acre summary of cut-and-leave tally plots—excluding culls
[Site index of area: 70 (a good site)]

Species	Number of trees and board-foot volume by dbh classes																						
	12		14		16		18		20		22		24		26		28		30		Total		
	No.	Vol.	No.	Vol	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Volume	B.A.
TOTAL STAND																							
Red oak	5.5	352	7.1	1,015	5.2	1,139	4.1	1,214	2.4	895	1.2	540	0.7	369	0.3	181	0.2	136	....	....	26.7	5,841	....
Chestnut oak	.1	6	.2	29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.3	35	....
Yellow-poplar	.8	78	1.0	192	1.2	343	1.4	532	.5	237	.3	170	.1	66	....	....	....	....	....	....	5.3	1,618	....
Beech	.4	32	.2	28	....	....	.1	27	.1	33	....	....	....	....	....	....	....	....	....	....	.8	120	....
Black cherry	1.4	111	1.6	258	1.4	340	1.2	391	.5	204	.2	98	.1	57	....	....	....	....	....	....	6.4	1,459	....
Red maple	1.2	72	.4	56	.1	22	.1	30	.1	38	....	....	....	....	....	....	....	....	....	....	1.9	218	....
White ash	.8	64	.5	83	.2	50	.1	34	.1	42	....	....	....	....	....	....	....	....	....	....	1.7	273	....
Sugar maple	1.8	85	.6	77	.4	85	.1	29	.1	38	.3	138	.4	216	.1	62	.1	71	....	....	3.9	801	....
Hickory	.7	65	.4	72	.1	26	.2	70	....	....	....	....	....	....	....	....	....	....	....	....	1.4	233	....
Sweet birch	.5	32	.1	13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.6	45	....
Cucumbertree	.9	88	.3	58	.1	29	.1	38	.1	47	....	....	....	....	....	....	....	....	....	....	1.5	260	....
Fraser magnolia	.4	26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.4	26	....
Black locust	.3	19	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.3	19	....
Basswood	3.1	363	2.8	524	1.5	386	.7	228	.3	119	.1	47	....	....	....	....	....	....	....	....	8.5	1,667	....
Total	17.9	1,393	15.2	2,405	10.2	2,420	8.1	2,593	4.2	1,653	2.1	993	1.3	708	0.4	243	0.3	207	....	....	59.7	12,615	80.4
STAND MARKED UNDER SILVICULTURAL CONSIDERATIONS																							
Red oak	1.2	77	1.2	172	0.1	22	0.2	59	0.1	37	....	....	....	....	....	....	....	....	....	....	2.8	367	....
Chestnut oak	....	....	.1	14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.1	14	....
Yellow-poplar	.4	39	.1	19	....	....	....	....	.1	47	....	....	....	....	....	....	....	....	....	....	.6	105	....
Beech	.3	24	....	....	....	....	.1	27	.1	33	....	....	....	....	....	....	....	....	....	....	.5	84	....
Black cherry	.2	16	.2	32	.1	24	....	....	.1	41	....	....	....	....	....	....	....	....	....	....	.6	113	....
Red maple	.2	12	.1	14	....	....	....	....	.1	38	....	....	....	....	....	....	....	....	....	....	.4	64	....
White ash	.1	8	....	....	.1	25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.2	33	....
Sugar maple	.4	19	.1	13	....	....	....	....	....	....	0.2	92	0.1	54	....	....	0.1	71	....	....	.9	249	....
Hickory	.2	19	....	....	.1	26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.3	45	....
Sweet birch	.4	26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.4	26	....
Cucumbertree	.7	69	....	....	....	....	.1	38	.1	47	....	....	....	....	....	....	....	....	....	....	.9	154	....
Fraser magnolia	.4	26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.4	26	....
Black locust	.3	19	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.3	19	....
Basswood	.1	12	.1	19	1.3	334	.2	65	.2	79	....	....	....	....	....	....	....	....	....	....	1.9	509	....
Total	4.9	366	1.9	283	1.7	431	0.6	189	0.8	322	0.2	92	0.1	54	....	....	0.1	71	....	....	10.3	1,808	12.3

TOTAL STAND MINUS SILVICULTURAL MARKING

Red oak	4.3	275	5.9	844	5.1	1,117	3.9	1,154	2.3	858	1.2	540	0.7	369	0.3	181	0.2	136	....	....	23.9	5,474	....
Chestnut oak	0.1	6	0.1	14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.2	20	....
Yellow-poplar	0.4	39	0.9	173	1.2	343	1.4	532	.4	190	.3	170	.1	66	....	....	....	....	....	....	4.7	1,513	....
Beech	0.1	8	.2	28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.3	36	....
Black cherry	1.2	95	1.4	225	1.3	316	1.2	391	.4	163	.2	98	.1	57	....	....	....	....	....	....	5.8	1,345	....
Red maple	1.0	60	.3	42	.1	22	.1	30	....	....	....	....	....	....	....	....	....	....	....	....	1.5	154	....
White ash	.7	56	.5	83	.1	25	.1	34	.1	42	....	....	....	....	....	....	....	....	....	....	1.5	240	....
Sugar maple	1.4	66	.5	64	.4	85	.1	29	.1	38	.1	46	.3	162	.1	62	....	....	....	....	3.0	552	....
Hickory	.5	46	.4	72	....	....	.2	70	....	....	....	....	....	....	....	....	....	....	....	....	1.1	188	....
Sweet birch	.1	6	.1	13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.2	19	....
Cucumbertree	.2	20	.3	58	.1	29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.6	107	....
Basswood	3.0	351	2.7	505	.2	51	.5	163	.1	40	.1	47	....	....	....	....	....	....	....	....	6.6	1,157	....
Total	13.0	1,028	13.3	2,121	8.5	1,988	7.5	2,403	3.4	1,331	1.9	901	1.2	654	0.4	243	0.2	136	....	....	49.4	10,805	68.1

Table 3.—Appraisal of the stand situation

Item	Volume in trees over 11.0 inches dbh	Basal area in trees over 11.0 inches dbh	Total marked volume[1]
	Bd. ft.	*Sq. ft.*	
1. Total stand	12,615	80.4	—
2. Silvicultural marking	1,808	12.3	1,808
3. Residual	10,807	68.1	—
4. 2-percent marking	317	2.0	2,125
5. Residual	*10,490*	*66.1*	—
6. 3-percent marking	1,031	5.6	2,839
7. Residual	*9,776*	*62.5*	—
8. 4-percent marking	2,901	15.8	4.709
9. Residual	*7,906*	*52.3*	—
10. 5-percent marking	2,939	16.0	4,747
11. Residual	*7,868*	*52.1*	—
12. 6-percent marking	5,668	31.8	7,476
13. Residual	*5,139*	*36.3*	—

Conclusions:
The *silvicultural marking* is too light to be merchantable. In this particular stand, the 2-percent *marking* added to the silvicultural marking, i.e., 2,125 board feet, gives a cut of doubtful economic operability.
The *3-percent marking* will give a cut that is operable in most situations and leaves a good residual basal area (62.5 feet, which falls within the range given for this site, i. e., 55 to 70 square feet).
The *4-percent* marking will give a good operable cut but will slightly understock the residual stand.
The *5-percent level*, which in this particular stand is very nearly the same as the 4-percent marking level, will give an operable cut but will slightly understock the residual stand.
The *6-percent marking* is out of the question in this stand at present because it would drastically understock the stand.
In summation, if the owner's objective is 2 percent, he should make his first cut with a 3-percent rate-of-return marking. If his ultimate objective is 6 percent, he might start out with either 4- or 5-percent marking provided he is willing to risk slight understocking.

[1] Gross volume. Includes defect. Int. ¼-inch kerf to an 8-inch top inside bark. Gross volume figures for each rate of return include the volume marked for silvicultural reasons.

Appendix II

Mark trees of these dbh classes and larger:

Species	Low						Medium						High		
	2%			3%			4%			5%			6%		
	80	70	60	80	70	60	80	70	60	80	70	60	80	70	60
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	18	20	20	18	18	18	18

TREES TO MARK—SAWLOG SIZES
(above 11.0 inches dbh)

For All Rate-of-Return Classes, Mark:

1. Culls and near culls.
2. Trees with significant rot in the butt log.
3. Very-low-vigor trees (vigor 4).
4. Extremely rough trees with butt-log grade 5.
5. Any trees over 15 inches with butt-log grade 4.
6. Any short-lived species, such as black locust, sassafras, and butternut, unless they are unusually vigorous.

In addition, trees above a certain dbh class are marked under certain conditions. This dbh varies with the rate of return desired, by species, and in the case of oak by site quality. It also varies by crown or vigor class and is additionally affected by the likelihood of log-grade improvement. The trees to mark are those of the indicated dbh's and larger. These will be marked unless a potential grade improvement can be foreseen in the next 10 years.

For the convenience of the reader, this information is also provided on a pocket-size card inserted loosely inside the front cover.

Appendix III

Common and scientific names of species referred to in this study:

Ash, white	*Fraxinus americana* L.
Basswood	*Tilia americana* L.
Beech, American	*Fagus grandifolia* Ehrh.
Birch, sweet	*Betula lenta* L.
Butternut	*Juglans cinerea* L.
Cherry, black	*Prunus serotina* Ehrh.
Cucumbertree	*Magnolia acuminata* L.
Hickory	*Carya* spp.
Locust, black	*Robinia pseudoacacia* L.
Magnolia, Fraser	*Magnolia fraseri* Walt.
Maple, red	*Acer rubrum* L.
Maple, sugar	*Acer saccharum* Marsh.
Oak, chestnut	*Quercus prinus* L.
Oak, northern red	*Quercus rubra* L.
Oak, white	*Quercus alba* L.
Sassafras	*Sassafras albidum* (Nutt.) Nees.
Yellow-poplar	*Liriodendron tulipifera* L.

U.S. GOVERNMENT PRINTING OFFICE: 1975— 606-739:619