United States
Department of
Agriculture

Forest Service

**Northeastern Forest
Experiment Station**

Research Paper NE-696

Method for Applying Group Selection in Central Appalachian Hardwoods

Gary W. Miller
Thomas M. Schuler
H. Clay Smith

Abstract

Public concern over the adverse visual impact of clearcutting has heightened interest in developing and testing alternative regeneration practices for central Appalachian hardwoods. When applied properly, group selection, which entails making small openings within a timber stand at regular intervals, can meet aesthetic goals while providing suitable light conditions to reproduce shade-intolerant species. Volume control and residual stand density are used to regulate periodic cuts, which include volume removed to create openings plus volume removed between openings to improve the quality and distribution of the residual stand. In central Appalachian hardwoods, openings must have a minimum size of 0.4 acre; all stems 1.0 inch d.b.h. and larger are cut to reproduce desirable shade-intolerant species. Maximum opening size is based on aesthetic requirements or other management constraints. Where reproduction of shade-intolerant species is acceptable, openings can be as small as a space occupied by a few trees. Openings should be located using the *worst first* approach to give the growing space occupied by mature trees or risky trees to faster growing, desirable regeneration. The residual stand between openings should be improved by cutting poor-quality or high-risk trees. The recommended residual basal area in sawtimber-size trees (11.0 inches d.b.h. and larger) is related to northern red oak site index (SI): 70 to 85 ft²/acre for SI 80, 55 to 70 ft²/acre for SI 70, and 40 to 55 ft²/acre for SI 60. These field-tested methods can help forest managers initiate group selection in second-growth Appalachian hardwoods. Guidelines are presented for computing the cut, determining size, location, and number of openings, and marking the stand.

The Authors

GARY W. MILLER is a research forester with the forest management research project at the Northeastern Forest Experiment Station's Timber and Watershed Laboratory, Parsons, West Virginia. He received B.S. and M.S. degrees from West Virginia University and a Ph.D. degree from Virginia Polytechnic Institute and State University. He has conducted research on silviculture and forest management since 1981.

THOMAS M. SCHULER, research forester, received a B.S. degree in forestry from Purdue University and an M.S. degree in silviculture from Colorado State University. He joined the forest management research project at the Northeastern Station's Timber and Watershed Laboratory at Parsons in 1992.

H. CLAY SMITH, retired, was Project Leader at the Northeastern Station's Timber and Watershed Laboratory at Parsons. He received degrees from West Virginia University and Purdue University and joined the USDA Forest Service in 1962.

Manuscript received for publication 6 June 1994.

Cover Photo: Small opening created by a group-selection harvest in central Appalachian hardwoods

USDA FOREST SERVICE
5 RADNOR CORP CTR STE 200
PO BOX 6775
RADNOR PA 19087-8775

March 1995

Introduction

Public concern over the adverse visual impact of clearcutting has heightened interest in developing and testing alternative forest management systems for central Appalachian hardwoods. Useful alternatives must meet two major objectives: 1) reduce negative visual impacts of cutting all trees over a large area, and 2) provide biological conditions for regenerating and maintaining a variety of commercial hardwood species. Critics of clearcutting have suggested using an uneven-age silvicultural practice such as group selection to meet these objectives.

Group selection, which entails making small openings every 10 to 20 years, often meets aesthetic objectives while providing suitable light conditions to perpetuate many commercial hardwoods, including desirable shade-intolerant species (Leak and Filip 1977). However, group selection is not a widespread practice, primarily because forest managers lack field-tested application guidelines. In addition, research results are needed to evaluate the effectiveness and efficiency of group selection in achieving management objectives. This report describes a practical method for initiating group selection in second-growth central Appalachian hardwoods. Guidelines cover inventory requirements, regulation of the cut, placement and size of group openings, and silvicultural treatments of residual trees between openings. Preliminary results on reproduction in group openings and productivity of logging operations are provided.

Although the suggested approach is not the only means of applying group selection, it does conform to accepted definitions of the practice. From the start, it is assumed that the forest manager has weighed other alternatives and decided that group selection is best suited for his or her management objectives. Given that group selection is the chosen alternative, the guidelines presented here focus primarily on how to do it. They have been developed for use in central Appalachian hardwoods, though the techniques can be modified for use in other forest types based on local growth estimates and stocking requirements.

Background

Group selection was described early in American forestry literature (Roth 1902). Yet today there is considerable debate among forest managers about how to define and apply this silvicultural practice. To fully appreciate group selection, it is helpful to review related practices and the way in which they can help meet various management goals for a particular hardwood stand.

Selection practices, including single-tree and group selection, are regeneration cutting methods used to develop or maintain trees of different ages within a stand. They are designed to maintain at least three age classes in an individual stand. Eventually, for a particular stand, tree size is proportional to tree age within a species group. Group selection can be viewed as a variation of single-tree selection. With both methods, periodic cuts establish and develop reproduction, improve stand structure and quality, and control residual stocking for sustained yield. However, they differ in how these periodic cuts are made and their effect on species composition, diversity of habitat, and aesthetics.

The distinctive feature of group selection is that openings are created in the stand by periodically removing trees in groups (Fig. 1). Opening size can range from a single large tree crown to whatever maximum size meets aesthetic and management objectives. However, opening size affects species composition and development of regeneration following harvest (Smith 1981). Periodic cultural treatments also improve growing stock established previously and even control pest species such as grapevines. Guidelines for applying this practice are flexible because many cultural practices can be applied in different parts of the stand during each periodic cut.

Single-tree selection and similar partial cutting practices in Appalachian hardwoods promote mainly shade-tolerant regeneration such as sugar maple, red maple, and American beech (Miller 1993). In fact, single-tree methods are sustainable only where commercial shade-tolerant species can be established with each periodic cut. Other desirable species such as black cherry, yellow-poplar, and oaks in the central Appalachians require light conditions found in openings at least 150 feet in diameter (Smith 1981), approximately twice the height of mature, codominant trees in the region. Thus, group selection has the potential to regenerate a much greater variety of species. Compared with single-tree selection, group selection also offers the following advantages (Smith 1986):

- There is less damage to residual growing stock during periodic cuts.
- Trees growing in dense groups in openings have better form.
- Wildlife habitat is more diverse within a stand.
- Patches of low-quality trees are removed and replaced by new reproduction in only one periodic cut.
- Sale preparation and logging are more economical.
- Openings made at each cut can be monitored as recognizable age classes.

There often is confusion about the difference between group selection and patch cutting. Patch cutting and group selection are distinct practices used to regulate regeneration, growth, and yield in a given stand. These practices promote an uneven-age structure within the stand using area control or volume/stand density, respectively. With patch cutting, area control is used to regulate the stand, clearing equal areas (total acres) each cutting cycle so that the entire stand is cut over in the equivalent of one even-age rotation. Also, the acreage of individual openings must be measured to control the cut. With group selection, the cut is regulated by volume control and residual stand density; the area of individual openings need not be measured. In both practices, opening size varies according to stand conditions, and maximum opening size is set by management objectives.

In reality, both group selection and patch cutting lead to an

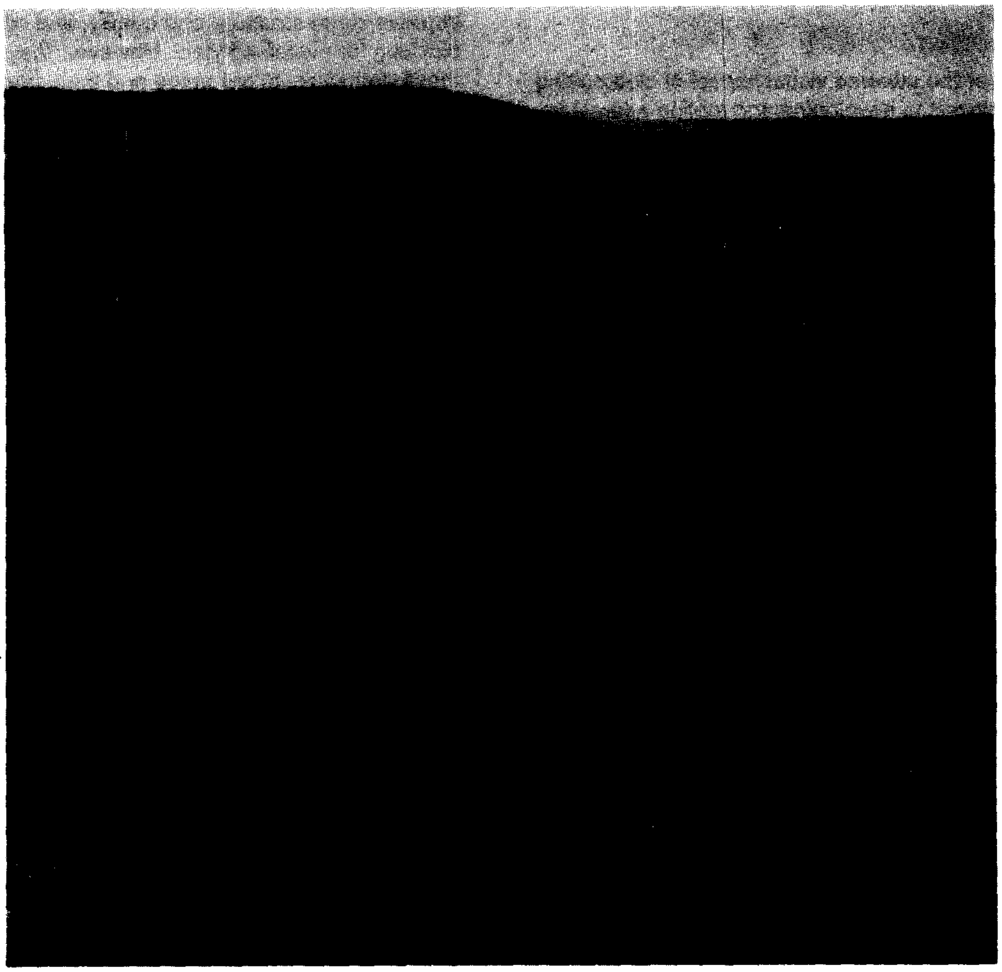

Figure 1.--This landscape illustrates group selection on the left, single-tree selection in the center, and young clearcuts on the right.

uneven-age stand structure if applied within the boundaries of a particular stand. A range of age classes is created as a result of regeneration established following periodic cutting treatments. Consequently, the differences between group selection and patch cutting are better defined by the methods used to determine the size, shape, and location of the openings, as well as the amount of volume removed and the frequency of periodic cuts.

Without question, group selection can be applied as an intensive stand management practice, and is effective in helping meet multiple objectives. The following suggestions are offered to help forest managers develop practical and useful field methods for applying group selection to meet a range of specific objectives.

An example is presented throughout the discussion to clarify suggested procedures. Data for the example were obtained from a 31-acre stand on site index (SI) 70 for northern red oak on the Fernow Experimental Forest near Parsons, West Virginia. Previously unmanaged, the stand contained 85-year-old, second-growth central Appalachian hardwoods. Skid roads were built independent of the cutting practice to provide access from an existing haul road adjacent to the stand (Fig. 2).

Getting Started

With group selection, merchantable volume is removed periodically every 10 to 20 years depending on management goals and stand conditions. The periodic cut includes volume from groups of trees removed to create openings plus that from individual trees removed to improve residual stand quality (improvement cut). To prepare for each periodic cut, an inventory is needed to develop a stand table by 2-inch-diameter class (Table 1). This information is used to regulate the volume and basal area removed and to develop guidelines for marking individual group openings.

It is important to estimate the improvement cut during the initial inventory (Table 1). Volume in the improvement cut includes high-risk and undesirable trees that must be

Table 1.–Initial inventory and estimated improvement cut in 85-year-old central Appalachian hardwood stand on SI 70 for northern red oak

Species	D.b.h. class (inches) 12	14	16	18	20	22	24	26+	Total	Basal area	Volume
	Number of trees/acre									Ft^2/acre	Mbf/acre
Hickory	1.4	1.4	1.0	0.6	0.4	0.1	0.1	0.0	5.0	6.0	0.9
White oak	1.0	1.4	2.0	2.1	1.5	0.8	0.6	0.4	9.8	17.8	2.8
Chestnut oak	4.9	4.8	4.6	3.2	1.9	1.0	0.5	0.3	21.2	30.2	4.5
Red oak	2.5	2.8	2.4	2.6	2.2	1.2	1.7	2.2	17.6	36.5	5.7
Yellow-poplar	0.4	0.5	0.7	0.3	0.5	0.1	0.1	0.0	2.6	4.4	0.9
Black cherry	0.2	0.6	0.4	0.3	0.2	0.1	0.1	0.2	2.1	3.1	0.5
Sugar maple	0.7	0.5	0.3	0.1	0.0	0.1	0.1	0.3	2.1	3.4	0.5
Red maple	1.0	0.6	0.2	0.1	0.0	0.1	0.0	0.0	2.0	3.0	0.2
Others	2.5	1.4	1.5	0.6	0.4	0.0	0.0	0.0	6.4	9.6	1.4
Total	14.6	14.0	13.1	9.9	7.1	3.5	3.2	3.4	68.8	113.0	17.4
Estimated improvement cut	1.3	1.4	1.6	1.4	0.5	0.5	0.2	0.2	7.1	10.9	1.7

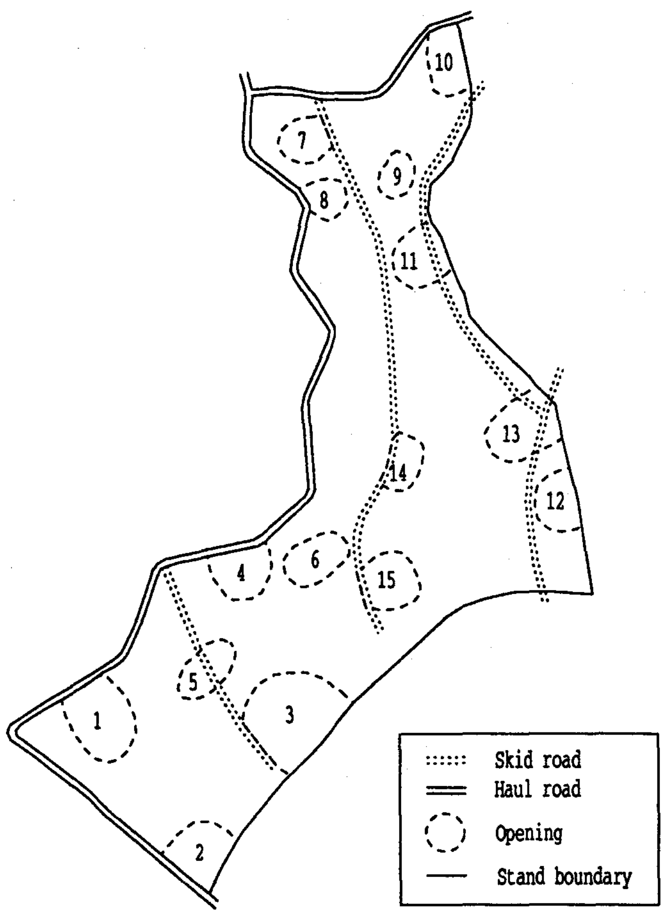

Figure 2.–Location of group openings and skid roads in a 31-acre Appalachian hardwood stand.

removed in the current cut to increase the quality of the residual stand (Table 2). The improvement cut includes individual trees (not in groups) that are removed between group openings throughout the stand.

By reviewing the initial stand table and the estimated

Table 2.–Marking guidelines for improvement cut–sawtimber-size classes, 11.0 inches d.b.h. and larger

For individual trees, mark:

1. Culls and near culls, unless needed for other resource goals
2. Trees with significant rot (40 percent or more) in the butt log
3. Low-grade trees that are not expected to attain sawlog quality[a]
4. Short-lived species or other species with low vigor expected to die before the next periodic cut
5. Undesirable species that conflict with management objectives

[a]Rast and others (1973).

improvement cut, the marking crew can become familiar with the unique characteristics of an individual stand. Note in the example stand that much of the merchantable volume was in northern red oaks from 20 to 26 inches d.b.h. (Table 1). During marking, clumps of these large, mature trees within the stand are potential locations for group openings. In this case, the data indicate that some openings can be made where there are clumps of trees larger than 20 inches d.b.h. Data from different stands would suggest different guidelines.

Determining the Cut

When group selection is to be used in second-growth Appalachian hardwoods, the desired total cut volume is equal to periodic stand growth. Periodic stand growth depends on stand acreage, average annual stand volume growth, and the length of the cutting cycle. Most forest managers have reliable local estimates of average stand volume growth. For second-growth central Appalachian hardwood sawtimber stands, the following estimates of volume growth by northern red oak site-index class can be used (Trimble 1968): SI 80: 400 bf/acre/yr; SI 70: 300 bf/acre/yr; SI 60: 200 bf/acre/yr.

Length of cutting cycle depends on site productivity, volume needed for an operable cut in local markets, and desired characteristics for the residual stand. In most central Appalachian hardwood stands where access roads are in place, harvests averaging at least 2.0 to 2.5 Mbf/acre with a minimum total volume of 20 Mbf (International 1/4-inch rule) are considered operable. In managed stands, the minimum cutting cycle is 10 to 15 years depending on site productivity.

Short cutting cycles result in a more variable stand, with age classes closer together and lower cut volumes. Longer cutting cycles entail greater cut volumes per acre. This may be more attractive to buyers but the resulting stand is less variable with age classes farther apart. Thus, length of the cutting cycle is influenced by the combination of site productivity and management factors.

Once the cutting cycle is defined, the maximum cut volume for the stand is determined by multiplying estimated growth times stand acreage and cutting cycle length. For the example stand, a 31-acre stand on SI 70, the maximum cut would be about 186 Mbf every 20 years (Table 3):

Maximum volume cut = annual bf growth/acre x stand area x cutting cycle:

186 Mbf = 300 bf/acre/yr x 31 acres x 20 years

The total cut includes both volume removed in group openings plus volume removed between openings to improve the residual stand. Before actual marking begins, the estimated improvement cut is subtracted from the maximum cut to determine how much additional volume can be removed in openings without overcutting the stand. Based on the example stand inventory, the improvement cut from individual trees will total about 53 Mbf over the entire stand, and the remaining cut from group openings should not exceed 133 Mbf (Table 3).

In addition to computing the desired cut volume, adequate residual stocking must be maintained to assure sustained yield of desirable merchantable products in the future. For applying group selection in Appalachian hardwoods, residual stand basal-area goals for sawtimber-size trees (11.0 inches d.b.h. and larger) by northern red oak site class are: SI 80: 70 to 85 ft²/acre; SI 70: 55 to 70 ft²/acre; SI 60: 40 to 55 ft²/acre.

These basal area guides assume that the residual stand will contain 15 to 20 ft²/acre in poletimber trees 5.0 to 10.9 inches d.b.h. and that logging damage may reduce residual basal area by as much as 10 percent (Trimble and others 1974).

The maximum cut basal area is simply the actual sawtimber basal area determined in the initial inventory minus the desired residual sawtimber basal area given previously. Maximum basal area cut = initial stocking - desired residual stocking:

43 ft²/acre = 113 ft²/acre - 70 ft²/acre

Similar to the guidelines described for volume, basal area in the estimated improvement cut is subtracted from the maximum basal area cut to determine how much additional basal area can be removed to create group selection openings without overcutting the stand. In the example, the estimated improvement cut will remove about 11 ft²/acre; the remaining cut from group openings should not exceed 32 ft²/acre (Table 3).

Placement of Openings

A good rule of thumb for locating group openings is *cut the worst first*, that is, cut parts of the stand where potential growth or returns are low compared to other parts of the stand. Large, mature trees (even those of good quality) continue to grow but have lower rates of return than smaller trees with the potential to become good-quality trees (Miller and Smith 1993). For instance, in second-growth Appalachian hardwood stands, clumps of trees more than 18 to 20 inches d.b.h. are candidates for removal due to declining rates of return. Also, parts of the stand occupied by undesirable species or poor-quality trees have lower revenue potential. In both cases, group openings should be placed so that growing space is given over to new, more desirable reproduction. In future cuts, it is helpful to locate new openings against older openings to eliminate narrow bands of branchy, low-quality trees.

Table 3.--Example computations for determining initial group selection cut in 31-acre, 85-year-old, central Appalachian hardwood stand on northern red oak SI 70

Marked cut	Volume Mbf/acre	Volume Mbf/stand	Basal area
			Ft²/acre
Maximum total cut	6.0[a]	186.0[b]	43.0[c]
Estimated improvement cut[d]	1.7	52.7	10.9
Estimated cut in groups[e]	4.3	133.3	32.1

[a]Periodic growth/acre = 300 bf/acre/yr x 20 years.
[b]Periodic stand growth = 300 bf/acre/yr x 20 years x 31 acres.
[c]Maximum cut basal = initial basal area - minimum residual basal area.
[d]Obtained from stand inventory.
[e]Estimated cut in groups = maximum total cut - estimated improvement cut.

The initial inventory also will provide information that can be used to locate openings. Some d.b.h. classes may have surplus trees, more than needed according to residual number-of-tree goals for uneven-aged stands (Smith and Lamson 1982). Removing trees in surplus d.b.h. classes, particularly those growing in clumps where it is convenient to make an opening, improves the residual stand structure for sustained yield.

Although adhering to a residual number-of-trees goal is not a primary concern when marking a group selection cut, it is useful to make certain that the stand will continue to produce regular timber yields. Removing all surplus trees can result in overcutting, particularly when the improvement cut is heavy. The key is to cut surplus trees when possible, but first concentrate on improving the residual stand, harvesting mature trees, and regenerating undesirable portions of the stand.

Size of Openings

The size (area) of a group selection opening varies with management and silvicultural objectives and the biological requirements of desired reproduction. Openings can be as small as the crown of a single codominant tree or as large as aesthetic requirements allow. Keep in mind that not all openings need to be large enough to favor shade-intolerant reproduction. In fact, aesthetic objectives may require openings of different sizes and shapes. Forest managers must define clearly the stand goals for species composition and aesthetics, and then decide how many openings must exceed the minimum size to achieve those goals.

If the improvement cut between openings requires a relatively high-volume removal, it is better to reduce the number of openings in the initial cut. Once residual stand quality is improved, future cuts can focus on regenerating the desired number of intolerants by creating group openings. For shade-intolerant species to regenerate and develop in Appalachian hardwoods, openings must be 0.4 acre (150 feet in diameter) or more. A more general rule of thumb is to make openings whose diameters are at least twice the total height of mature, codominant trees expected for the forest type. Maximum opening size is related more to objectives than requirements of desired reproduction. An aesthetic goal for a particular stand usually is the reason limits on opening size are imposed. In most cases, openings up to 1 acre in size are sufficient for applying group selection successfully.

It is important to clean the openings, cutting all trees 1.0 inch d.b.h. and larger. However, for desirable advanced regeneration, guidelines could be revised to leave these trees or develop them for the future. If desirable advanced regeneration is present, such as northern red oak on better growing sites, follow guidelines for maintaining and developing these stems for the future (Loftis 1990). Plan to develop advanced regeneration in parts of the stand where group openings can be made in future cutting cycles.

Marking and Tallying the Cut

Field crews should follow several basic steps in marking group selection openings. Based on the initial inventory and experience from working in the stand, the crew first locates a potential opening using stand characteristics and regeneration goals to determine the size and shape of the opening. Flagging can be used to define the boundary of individual openings. A crew of two people can adjust the size and shape at this time to meet specific goals. Once a satisfactory opening is defined, individual trees within the opening can be marked for harvest. The marking crew should keep a running tally of cut volume and basal area using a per-tree system (Fig. 3). Local volume tables can be used to estimate volume per tree. Once the trees are marked and tallied within a group opening, the crew then searches for another potential opening and repeats the process.

The improvement cut has priority over creating openings, particularly for initial cuts in unmanaged stands. Part of the improvement cut can be marked during the initial inventory. The remainder can be marked as openings are located and marked. Once total volume or basal area marked for harvest (improvement cut plus openings) reaches the limits computed for the stand (Table 3), the mark is complete and no additional openings are needed. In the example stand, 15 openings were marked to achieve the planned cut. Opening size and shape varied, with most openings between 0.5 and 1.0 acre (Fig. 2).

Note that for the example stand, the total cut was limited by volume and not basal area. The residual basal area in sawtimber-size trees was 75 ft^2/acre (Table 4). The maximum cut volume was reached without overcutting basal area, and the residual stand structure was appropriate for an uneven-aged central Appalachian hardwood stand (Fig. 4).

Other Practices

During periodic group selection cuts, a variety of cultural practices can be scheduled for other parts of the stand. Grapevines can pose a problem on better growing sites, so make sure that periodic cuts do not encourage the vines to spread and create destructive arbors that choke out desirable trees. Where vines already pose a problem, cut existing vines and keep the canopy closed; shading prevents sprout development and the vines will die in a few years (Smith 1984). In established openings containing saplings with vines in their crowns, cut vines near groundline when the canopy has closed. Vines usually can be cut where saplings are 10 years old or when a crew can move easily among the trees.

Precommercial crop-tree release is an option for saplings growing in openings created previously. Apply a full crown release so that selected crop trees are left free to grow. Crop trees should be codominant, well-formed stems with potential to become high-value sawtimber to satisfy stand objectives. Release a maximum of 50 to 75 crop trees per acre if they are available (Perkey and others 1994).

Most cultural treatments that might be considered in young group selection openings also are applied in young even-aged stands. In group selection practices, each periodic cut can include a variety of cultural treatments in different parts of the stand because it may comprise several age classes.

GROUP SELECTION TALLY SHEET Page ____ of ____

Area____________

Date____________

Crew____________

Group Opening

#__________ #__________ #__________

D.b.h.	Bf/tree	Ft²/tree	No.	BF	Ft²	No.	BF	Ft²	No.	BF	Ft²
6											
8											
10											
12											
14											
16											
18											
20											
22											
24											
26											
28											
30											
32											
34											
				BF	Ft²		BF	Ft²		BF	Ft²
Group Totals											
Cumulative Totals											

Figure 3.--Tally sheet for estimating cumulative marked cut volume and basal area.

Regeneration

As part of a long-term study of patch cutting (area control) on the Fernow Experimental Forest, small openings are cleared every 10 years to harvest merchantable trees and establish new regeneration over a specified area of each stand. Twenty such openings, five openings from each of four stands, were surveyed to determine the species composition, abundance, and quality of hardwood regeneration present 9 and 19 years after cutting. Openings were circular and 150 feet in diameter (0.4 acre); all trees 1.0 inch d.b.h. and larger were cut at the time of treatment. Site quality for northern red oak ranged from SI 70 to 85.

Data were collected from five random survey points in five random openings in each age class and site index. At each point, all trees greater than 0.5 inch d.b.h. were tallied within a 1/100-acre plot. In all, 100 reproduction survey plots were sampled in four stands. Survey plots were categorized by site index and age for analyses. These data provide insight into the abundance and quality of regeneration that is possible using group selection where average opening size is similar (Fig. 5).

All openings surveyed had adequate reproduction for future development into sawtimber (Fig. 6). Younger openings

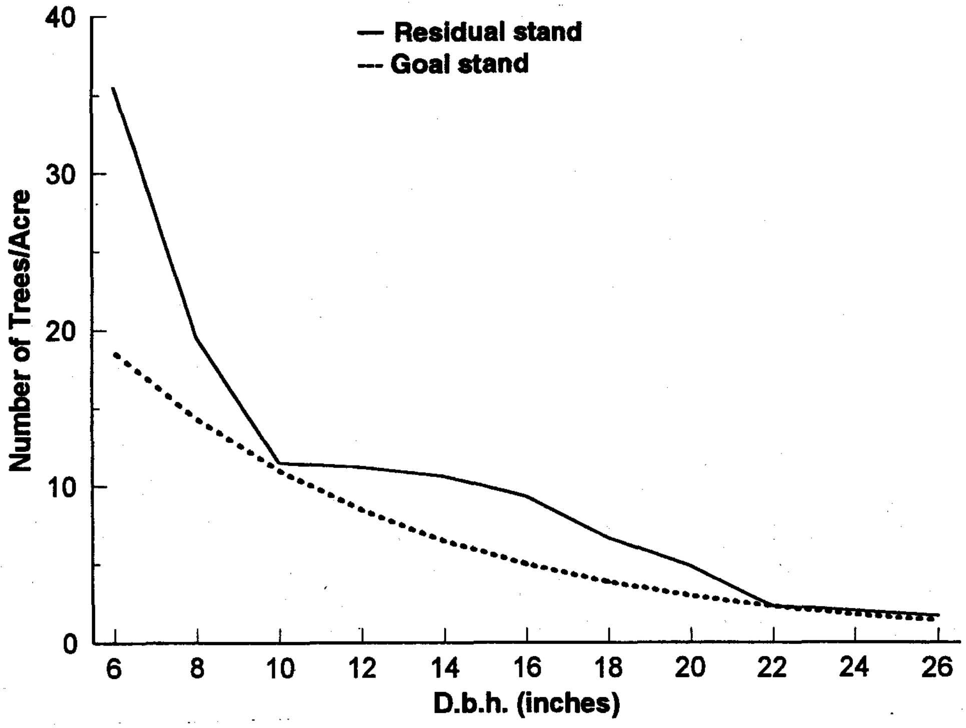

Figure 4.–Actual residual stand structure compared to recommended residual stand goal for uneven-age management (Smith and Lamson 1982).

Table 4.–Residual stand following group selection regeneration harvest in 85-year-old central Appalachian hardwood stand on SI 70 for northern red oak

Species	D.b.h. class (inches)									Basal area	Volume
	12	14	16	18	20	22	24	26+	Total		
	Number of trees/acre									*Ft²/acre*	*Mbf/acre*
Hickory	1.1	1.1	0.6	0.3	0.3	0.1	0.0	0.0	3.5	4.1	0.6
White oak	0.6	0.9	1.3	1.4	1.0	0.5	0.4	0.2	6.3	11.6	1.9
Chestnut oak	4.0	3.7	3.4	2.2	1.2	0.7	0.2	0.2	15.6	21.7	3.2
Red oak	1.9	2.3	2.0	2.2	1.8	0.7	1.2	0.9	13.0	24.2	3.8
Yellow-poplar	0.4	0.5	0.7	0.2	0.4	0.0	0.1	0.0	2.3	3.4	0.6
Black cherry	0.0	0.5	0.4	0.1	0.0	0.0	0.0	0.1	1.1	1.8	0.3
Sugar maple	0.7	0.5	0.3	0.0	0.0	0.0	0.0	0.1	1.6	1.8	0.2
Red maple	0.8	0.5	0.1	0.0	0.0	0.0	0.0	0.0	1.4	1.5	0.2
Others	1.7	0.6	0.5	0.3	0.2	0.3	0.1	0.2	3.9	5.1	0.7
Total	11.2	10.6	9.3	6.7	4.9	2.3	2.0	1.7	48.7	75.2	11.5

surveyed 9 years after cutting had 800 to 1,200 codominant stems per acre, with 60 to 70 percent classified as potential crop trees of good quality. Characteristics of good trees include straight stem, no forks below 17 feet, no evidence of disease or insect damage, no dead crown branches, and high vigor. The average height of codominant trees in the 9-year-old openings was 28 and 31 feet on SI 70 and 80, respectively. Older openings surveyed 19 years after cutting had 300 to 450 codominant stems per acre, with 70 to 85 percent classified as potential crop trees of good quality. The average height of codominant trees in the 19-year-old openings was 52 and 56 feet on SI 70 and 80, respectively.

Species composition was dominated by black birch (BIR), sugar maple (MAP), black cherry (BC), yellow-poplar (Y-P), and American basswood (BAS); white ash (WA) and northern red oak (NRO) were present in lesser numbers. Other commercial hardwoods (OTH) present included hickory, American beech, cucumber, and black locust. As trees develop within group selection openings, selected trees can be released to influence species composition as trees mature. Between age 10 and 20 years, several species have numerous good, codominant trees distributed throughout the developing group opening.

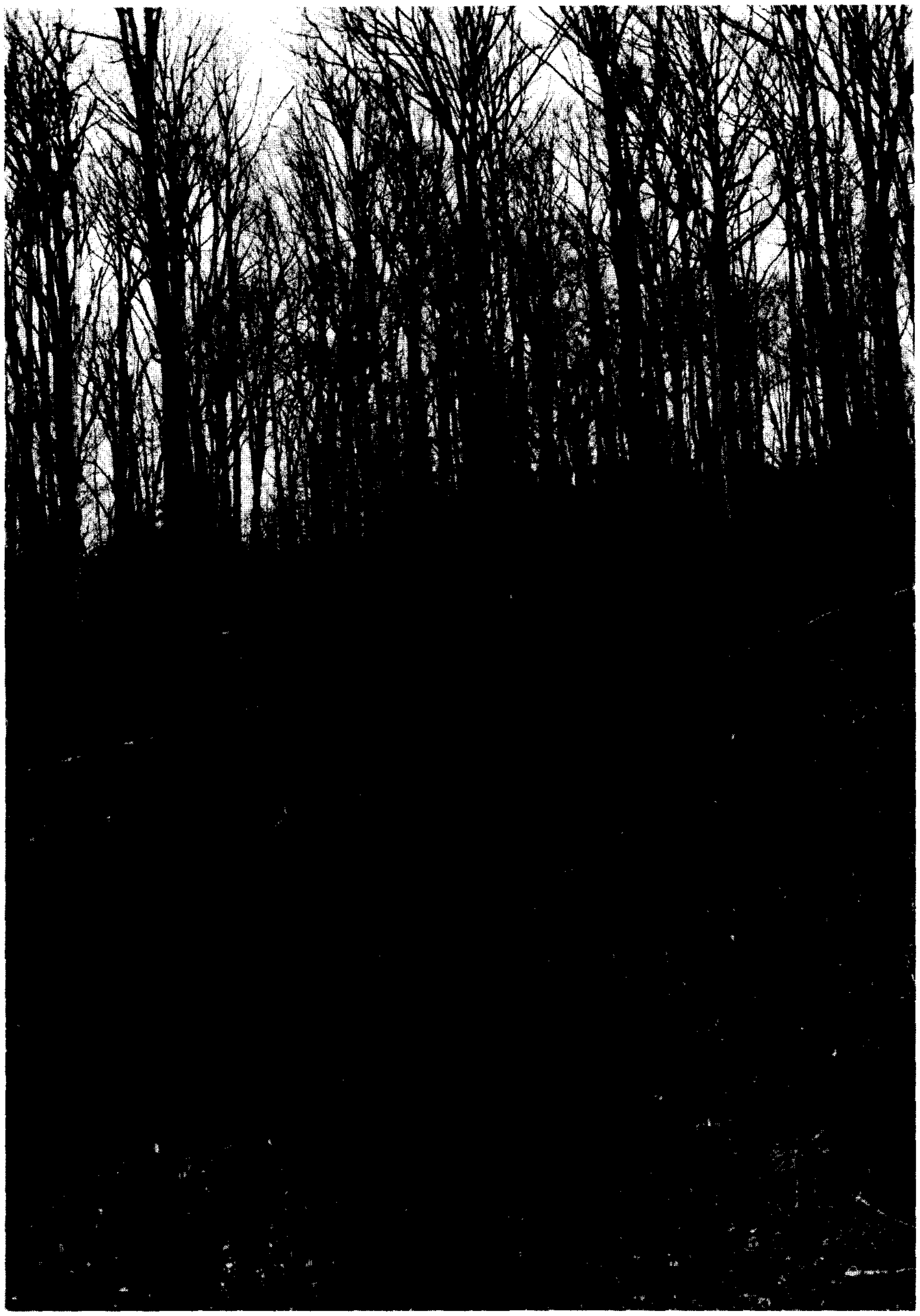

Figure 5.--Reproduction in a group selection opening 3 years after harvest.

Logging Economics

Group selection methods include a combination of logging activities within a given stand. Some parts of the stand are logged similar to a clearcut operation where all merchantable trees are felled and skidded, and nonmerchantable trees are simply felled and left on the site. Other parts of the stand are logged similar to a thinning or partial cutting in which only individual marked trees are felled and skidded. Overall logging productivity is based on the efficiencies associated with each activity. However, with group selection, the majority of cut volume is removed from openings, where logging efficiency is relatively high.

Logging productivity for clearcutting and small openings was compared on the basis of 13 logging operations on the Fernow Experimental Forest from 1984 to 1993. Stands were second-growth, mixed hardwoods on SI 70 to 80 for northern red oak. Clearcuts were in previously unmanaged 85-year-old

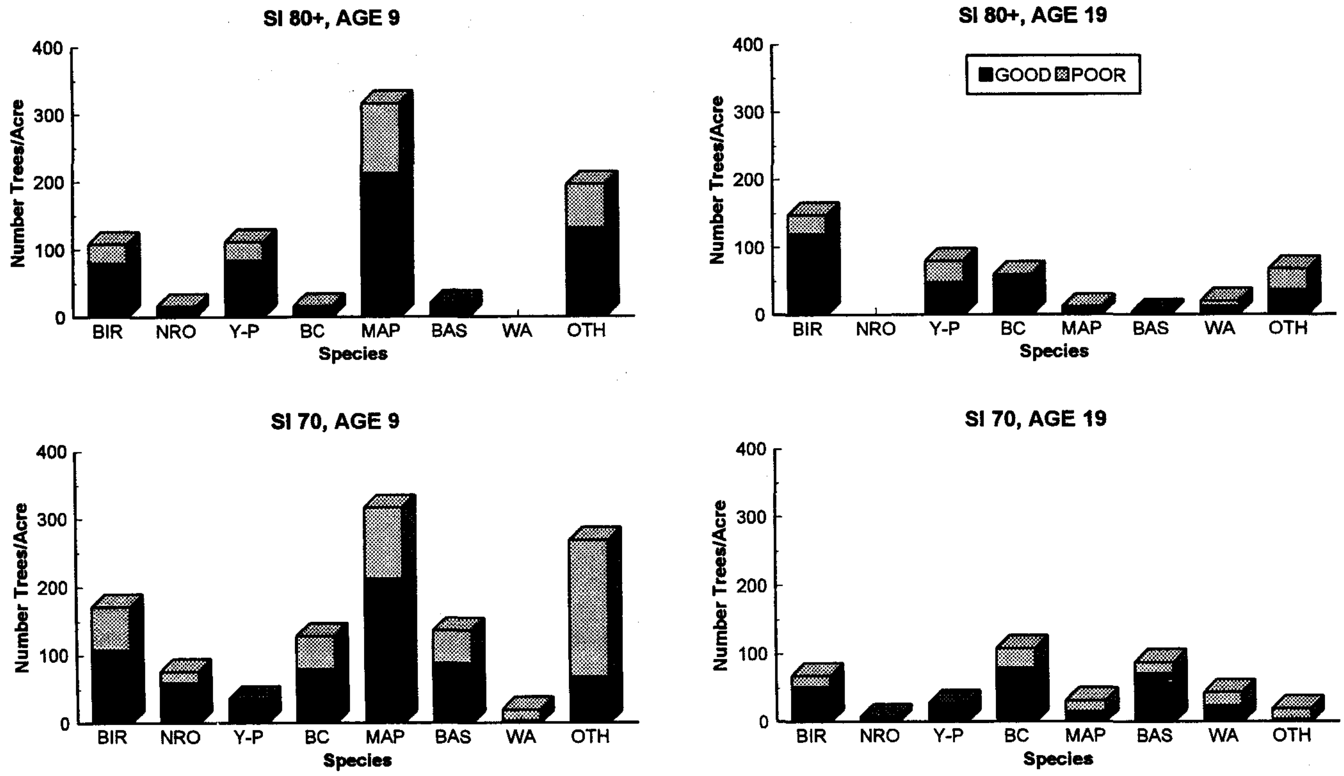

Figure 6.--Distribution of commercial, codominant trees by site index, age, and quality in 0.4-acre openings.

stands. Small openings also were made in 85-year-old stands, though some openings had been made in previous operations at 10-year intervals.

In each operation, the logging crew consisted of three people using a rubber-tired skidder, a crawler tractor equipped with a rubber-tired arch, and/or a truck-mounted crane. One crew member was responsible for felling, topping, and limbing in the woods, while the other members were responsible for skidding, bucking, and decking logs. The same crew and equipment were used to complete all logging jobs throughout the study period. Logs were skidded tree-length over distances of 200 to 2,000 feet to roadside landings. Average skidding distance was approximately equal in both treatments, averaging 589 feet. Harvest volume was based on actual log scale at the landing (International 1/4-inch rule). Labor and machine hours were recorded for each day.

Data from more than 200 work days were used to compare logging productivity associated with clearcutting and harvesting small openings (Table 5). Small openings, 0.4-acre in size, were located and marked prior to logging throughout a given stand. The number of openings in each stand ranged from 8 to 25 depending on the size of the stand. Stands logged by clearcutting ranged from 4.5 to 8.9 acres. For both treatments combined, volume totaled 1.8 million board feet, and area totalled 84 acres. In both practices, trees 1.0 inch d.b.h. and larger were felled. Trees 11.0 inches d.b.h. and larger were skidded to the landing. In addition, the group selection harvest included felling and skidding some single sawtimber trees between openings.

Observed productivity was 9.3 Mbf/day for small openings and 8.0 Mbf/day for clearcutting (Table 5). Volume per acre and volume per tree are factors that may account for higher observed productivity associated with harvesting small openings. Openings were located in part to harvest clumps of large, mature trees. This technique has the effect of increasing the average harvest volume per acre in parts of the stand where the crew actually works to clear small openings. In larger clearcuts, volume is dispersed through the stand and average volume per acre is much lower compared to operations involving small openings. In this study, harvest volume was 24.4 Mbf/acre for small openings compared with 17.9 Mbf/acre for clearcutting (Table 5). Average volume was 297 bf/tree in the small openings compared to 254 bf/tree in the clearcuts. Productivity was enhanced by both larger average product size and greater concentration of volume per unit of area in the small openings.

Logging productivity indicates that in the central Appalachians cutting practices involving small openings would not reduce stumpage prices compared to clearcutting. There are added costs associated with preparing and administering periodic sales in any partial cutting practice. The cost of inventories, marking, and sale preparation is incurred with each periodic cut. Thus, there are financial tradeoffs that must be considered when group selection practices are used. However, our experience indicates that most of these tradeoffs are linked to marking and administration of the practice and not to the economics of logging.

single-tree selection? Northern Journal of Applied Forestry. 10(1): 32-38.

Miller, G.W. 1993. **Financial aspects of partial cutting practices in Appalachian hardwoods.** Res. Pap. NE-673. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 16 p.

Perkey, A.W.; Wilkins, B.L.; Smith, H.C. 1994. **Crop tree management in eastern hardwoods.** NA-TP-19-93. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area, State and Private Forestry. 58 p.

Rast, E.D.; Sonderman, D.L.; Gammon, G.L. 1973. **A guide to hardwood log grading.** Gen. Tech. Rep. NE-1. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 32 p.

Roth, F. 1902. **First book of forestry.** Boston, MA: Ginn & Company Publishers, Aethenaeum Press.

Smith, D.M. 1986. **The practice of silviculture. 8th ed.** New York: John Wiley and Sons. 527 p.

Smith, H.C. 1981. **Diameters of clearcut openings influence central Appalachian hardwood stem development—a 10-year study.** Res. Pap. NE-476. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 8 p.

Smith, H.C. 1984. **Forest management guidelines for controlling wild grapevines.** Res. Pap. NE-548. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 33 p.

Smith, H.C.; Lamson, Neil I. 1982. **Number of residual trees: a guide for selection cutting.** Gen. Tech. Rep. NE-80. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 33 p.

Trimble, G.R., Jr. 1968. **Growth of Appalachian hardwoods as affected by site and residual stand density.** Res. Pap. NE-98. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 13 p.

Trimble, G.R., Jr.; Mendel, J.J.; Kennell, R.A. 1974. **A procedure for selection marking in hardwoods combining silvicultural considerations with economic guidelines.** Res. Pap. NE-292. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 13 p.

Miller, Gary W.; Schuler, Thomas M.; Smith, H. Clay. 1995. **Method for applying group selection in central Appalachian hardwoods.** Res. Pap. NE-696. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 11 p.

Public concern over the adverse visual impact of clearcutting has heightened interest in developing and testing alternative regeneration practices for central Appalachian hardwoods. Group selection can meet aesthetic goals while providing suitable light conditions to reproduce shade-intolerant species. Volume control and residual stand density are used to regulate periodic cuts. In central Appalachian hardwoods, openings must have a minimum size of 0.4 acre; all stems 1.0 inch d.b.h. and larger are cut to reproduce desirable shade-intolerant species. Openings should be located using the *worst first* approach to give the growing space occupied by mature trees or risky trees to faster growing, desirable regeneration.

Keywords: Uneven-age management.

Headquarters of the Northeastern Forest Experiment Station is in Radnor, Pennsylvania. Field laboratories are maintained at:

Amherst, Massachusetts, in cooperation with the University of Massachusetts

Burlington, Vermont, in cooperation with the University of Vermont

Delaware, Ohio

Durham, New Hampshire, in cooperation with the University of New Hampshire

Hamden, Connecticut, in cooperation with Yale University

Morgantown, West Virginia, in cooperation with West Virginia University

Orono, Maine, in cooperation with the University of Maine

Parsons, West Virginia

Princeton, West Virginia

Syracuse, New York, in cooperation with the State University of New York, College of Environmental Sciences and Forestry at Syracuse University

University Park, Pennsylvania, in cooperation with The Pennsylvania State University

Warren, Pennsylvania

"Caring for the Land and Serving People Through Research"

☆U.S. GOVERNMENT PRINTING OFFICE: 1995 - 651-974/00935