

AN EVALUATION OF UNEVEN-AGED CUTTING METHODS IN EVEN-AGED OAK-HICKORY STANDS IN THE BOSTON MOUNTAINS OF ARKANSAS

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Abstract: A test of group-selection and single-tree selection cutting methods was installed in 80-year-old even-aged oak-hickory stands in the Boston Mountains of northern Arkansas. Twenty-four 11-ac study plots were installed in well stocked stands representing north or east and south or west aspects. Stands between group openings were cut to residual basal areas of 65 and 85 ft² using free thinning or structural control. This paper describes (1) the effect of aspect on preharvest stand structure and species composition, (2) preharvest reproduction composition, and (3) the effect of cutting method and density treatments on residual stand structure. The implications of existing stand structure and cutting method efficacy are also discussed.

INTRODUCTION

Public concern over the dramatic visual impact of clearcutting has stimulated interest in alternative forest management systems for upland oak forests in the Midsouth. Acceptable alternatives should avoid the negative visual impacts of clearcutting and must provide the biological conditions necessary for regenerating and maintaining the oaks and other valuable hardwood species. While modifications of shelterwood cutting (Sander and Graney 1993) satisfy the visual and biological requirements, it suffers a "guilt of association" by being an even-aged method. Critics of clearcutting and other even-aged methods have suggested uneven-aged silviculture cutting methods (group selection or single-tree selection) to meet visual and biological objectives.

Uneven-aged cutting methods are designed to create and maintain at least three age classes within the stand. In single-tree selection, all trees marked for cutting are selected for removal based upon their individual merit. But in group selection, the trees removed in regeneration cuts are selected as a group or aggregate, not as individuals; however, the trees removed between the group openings are selected on individual merit. Group selection can be considered a variant of single-tree selection. Periodic cuts are required in both methods to (1) establish and develop reproduction, (2) improve stand structure and quality, and (3) control residual stocking for sustained yield. They differ in how the periodic cuts are made and their effect on species composition. Recent papers (Miller and others 1995, Murphy and others 1993) have provided an excellent description of both methods and have discussed the advantages and disadvantages of each.

Conventional wisdom has considered group selection to be more suitable than single-tree selection for shade-intolerant species, such as the oaks and other desirable species on upland sites in the Midsouth. Group-selection openings of at least 0.4 ac or with diameters at least two times the height of mature dominant or codominant trees in the stand provide the light conditions necessary for the intermediate and shade-intolerant species to compete successfully. However, as with the even-aged methods, successful development of oaks in group openings requires adequate numbers of large advance reproduction when the overstory is removed. A major problem on mesic or productive upland sites is that large oak advance reproduction is often absent or inadequate.

The single-tree selection method has been assumed to be inappropriate for managing upland oaks and other intermediate and shade-intolerant species (Sander and Clark 1971, Sander and Graney 1993). Canopy openings created in single-tree selection cutting have been considered to be too small to allow enough light for oak reproduction, but

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they do provide sufficient light for a tolerant understory to develop. While existing ecological and silvicultural literature corroborates these assertions, these studies were conducted in mesic ecosystems and included no understory or competition control treatments to favor development and accumulation of large oak reproduction.

However, the single-tree selection system has been successfully adapted to more shade-intolerant species, such as the loblolly-shortleaf pine type (*Pinus taeda* L. and *P. echinata* Mill.), by following certain principles and practices: (1) choosing a species or a species mix that is moderately tolerant in the seedling stage, (2) maintaining a residual basal area low enough to permit the establishment and development of desired reproduction, (3) selecting a cutting cycle to keep basal area levels within acceptable ranges, (4) eliminating overstory and midstory non-target competition by harvesting or manual and chemical treatments, and (5) periodically controlling understory non-target competition (usually with selective herbicides). The combination of a low basal area (one that does not exceed 75 ft²/ac at any time during the cutting cycle) and competition control results in an environment favorable for development of pine regeneration.

Johnson (1992) describes xeric and dry mesic upland sites in the Missouri Ozarks where oak reproduction accumulates over time, possibly providing a pool of large oak reproduction that would sustain an uneven-aged management system. A large industrial forest in the Missouri Ozarks has used a version of single-tree selection on xeric and dry mesic upland sites for more than 40 years, and the method appears to be maintaining a healthy, sustainable forest (Loewenstein and others 1995).

A study has been installed to evaluate effectiveness of group-selection and single-tree selection methods in mature even-aged oak-hickory stands on dry mesic and mesic upland sites in the Boston Mountains of northern Arkansas. The specific objectives are:

- (1) To test the feasibility of using group-selection and single-tree selection methods to convert even-aged oak-hickory stands to uneven-aged ones.
- (2) To test two methods of regulation and two density levels in combination with group selection.
- (3) To compare growth and yield of stands that are managed and regenerated under group selection, two methods of regulation, and two density levels.
- (4) To measure and evaluate the development of desirable reproduction in group openings and the establishment and growth of desirable reproduction in the residual stand.
- (5) To evaluate the establishment and growth of desirable reproduction with different competition control intensities, overstory densities, aspects, and types of regulation.

Objective (5) is being undertaken as an adjunct to the main study that covers the first four objectives. The main study is called the regulation study, and the adjunct is called the competition study.

In this paper, we describe the preharvest conditions and how the cutting methods and density treatments affected stand structure in the regulation study.

METHODS

Study Region

The Boston Mountains are the highest and most southern member of the Ozark Plateaus physiographic province (Figure 1). They form a band 30 to 40 miles wide and 200 miles long from north-central Arkansas westward into eastern Oklahoma. Elevations range from about 900 ft in the valley bottoms to 2,500 ft at the highest point. The plateau is sharply dissected, and most ridges are flat to gently rolling and are generally less than 0.5 mile wide. Mountainsides consist of alternating steep simple slopes and gently sloping benches.

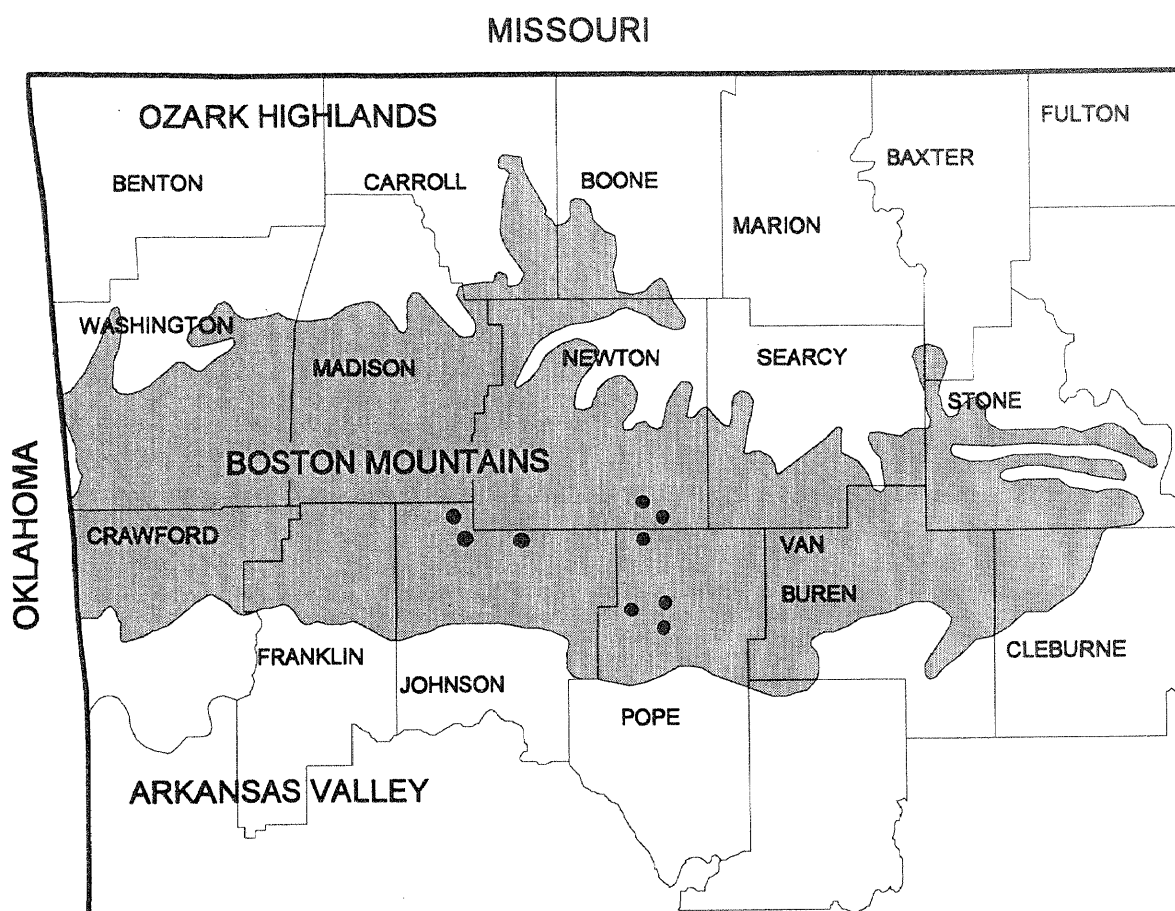


Figure 1. Location of study areas.

Soils on mountaintops and slopes usually have shallow to medium depth and are represented by medium-textured members of the Hartsells, Linker, and Enders series (Typic Hapludults). They are derived from sandstone or shale residuum, and their productivity is medium to low. In contrast, soils on mountain benches are deep, well-drained members of the Nella and Leesburg series (Typic Paleudults). They developed from sandstone and shale colluvium, and their productivity is medium to high. Rocks in the area are alternating horizontal beds of Pennsylvanian shales and sandstones.

Annual precipitation averages 46 to 48 in., and March, April, and May are the wettest months. Extended summer dry periods are common, and autumn is usually dry. The frost-free period is normally 180 to 200 days long.

Study Description

The regulation study design is a split-plot factorial layout, replicated three times, with aspect as the main plot treatment and residual stand density and regulation as sub-plot treatments. The aspects are north-east and south-west, residual densities are 65 and 85 ft²/ac, and the regulation methods are free thinning and structural control. Although the study is a straightforward test of group selection with two residual stand treatments (i.e., free thinning versus structural control), it can also be used to evaluate single-tree selection by analyzing the structural control treatment.

Stand density treatments. The two density levels are 65 and 85 ft²/ac of basal area in trees 5.6 in. and larger. The overstory density treatments were applied on the plot and buffer areas outside the group opening. The 65 ft² density level approximates the B-level of stocking for upland oak stands and should be near the optimum for stand and crop tree growth. The 85 ft² density represents about 70-75% stocking and is appropriate for a first thinning in older stands that have relatively high stocking levels. If competing subcanopy stems are effectively controlled, the higher residual stocking level might favor the development of oak reproduction and retard redevelopment of competing understory.

Regulation techniques. The regulation techniques applied to the residual stand are (1) area regulation with free thinning and (2) area regulation with structural control. Group selection will be used with area control. Assuming an 80-year conversion period and a 10-year cutting cycle, one-ninth of the area would be regenerated each cutting cycle.

Opening size is approximately 2.0 times the average height of the dominant trees in the adjoining stand. This will result in an opening size of about 0.4 ac in typical stand conditions. Selection of the initial group opening subplots were based on the following criteria: (1) presence of large reproduction of desirable species, (2) presence of saplings of desirable species, (3) sprouting potential of desirable species in the small poletimber class, and (4) overstory stocking. A subsequent group opening will be created every 10 years. Location of future openings will be based upon the presence of adequate advance reproduction.

In the first regulation method, the residual stand (the area not in group openings) was cut to the target density by free thinning. Trees were thinned in the following priority: (1) larger cull and defective trees, (2) competing trees of poor form and quality, and (3) intermediate and suppressed trees of lower quality and value. The primary objective was to improve residual stand quality and vigor.

In the second method, the residual stand was cut back to a target stand structure. The target stand structure has a minimum dbh of 5.6 in., a maximum dbh of 18.5 in., a q of 1.3 (assuming 2-in. diameter classes), and residual densities of 65 and 85 ft²/ac (Figure 2). Law and Lorimer (1989) suggested q values of 1.3, 1.5, or 1.7 for 2-inch classes in upland hardwoods, and Smith and Lamson (1982) recommended a 1.3 q -value for sawtimber production and higher q 's for smaller-product objectives. Because our objective is quality sawtimber production, we chose a q of 1.3. We selected the maximum dbh to produce a grade one butt log, also in accordance with a quality sawtimber objective. Although this target structure may be eventually created, current structure and species composition of our oak-hickory stands make the target structure impossible to attain with the first cut and could be silviculturally unsound if rigidly applied.

For example, most of our oak-hickory stands are essentially even-aged but are more irregular than typical even-aged stands regenerated from clearcuts. Our Boston Mountain stands tend to have an older-age component of 5-10 trees per acre that are generally larger than the main stand; these trees are often culls or very poor in quality. Moreover, we have many more stems in the small diameter classes (6-11 in. dbh) than are typical for even-aged stands. Many of these small stems are tolerant, noncommercial or low-value species that have increased in numbers and size as the overstory has matured. Moreover, the suppressed low-vigor stems of desirable species in these sizes have a low probability of responding to release. Therefore, rigid application of a target stand structure with no regard to the quality of the residual trees can diminish stand quality, a major offense to good silviculture.

When marking to achieve the residual structure for areas outside openings, we divided the trees into four size classes—small poletimber (6-8 in. dbh), large poletimber (9-11 in. dbh), small sawtimber (12-15 in. dbh), and large sawtimber (>15 in. dbh). We calculated the target residual basal area for each class and marked the stand to conform to the target. However, when marking in the poletimber classes, we discriminated against the noncommercial and low-value species and did not always achieve the target structure for the small poletimber class. In these cases, we left more stocking in better-quality trees in the larger classes. We did, however, leave some low vigor oak stems in the small diameter classes to evaluate survival and growth. The main goal was to leave the residual basal area in the best quality trees available on the plot.

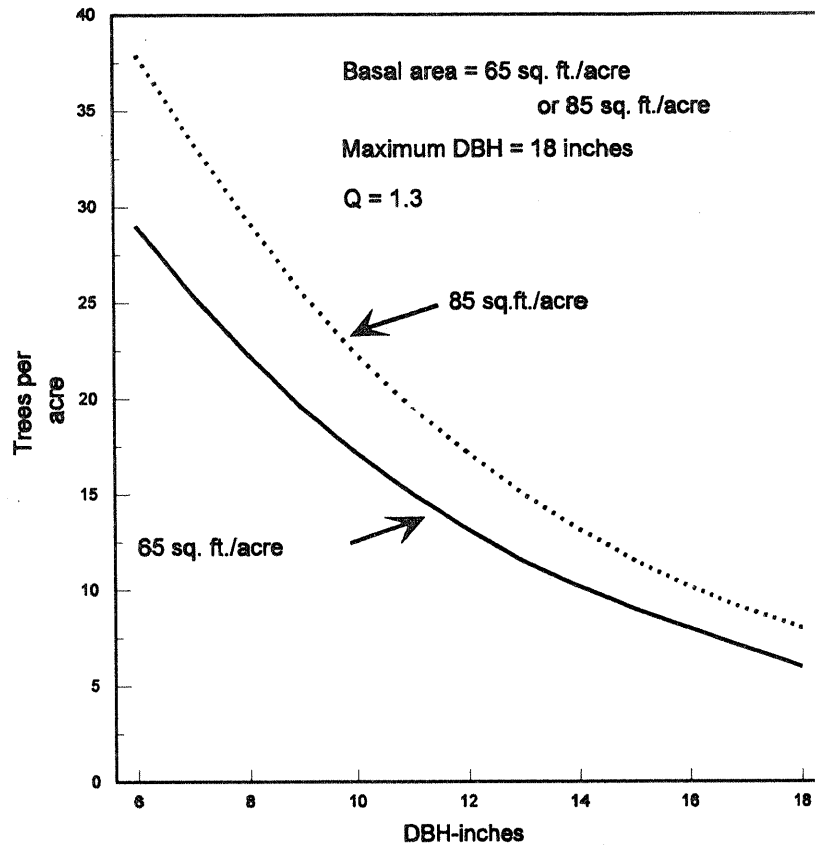


Figure 2. Target stand tables for plots regulated by structural control.

Plot location and layout. The study was installed on the Ozark National Forest in well-stocked hardwood sawtimber stands with no history of previous cutting for at least 50 years. Twenty-four 11-ac plots were installed in nine forest stands on the Buffalo, Bayou, and Pleasant Hill Ranger Districts (Figure 1). Study plots were located on north/east and south/west facing mountain slopes and benches and in oak-hickory stands that are representative of the sites and stand conditions that are designated for uneven-aged management by the Ozark National Forest.

Study plots were replicated by National Forest Districts with 8 plots established on each District according to the following schedule:

District	Number of plots by aspect		Preharvest measurements	Understory treatment	Harvest	Postharvest Measurement
	North	South				
Buffalo	4	4	Winter 1992	Summer 1992	Summer 1993	Fall 1993
Bayou	4	4	Winter 1993	Summer 1993	Summer 1994	Fall 1994
Pleasant Hill	4	4	Winter 1994	Summer 1994	Summer 1995	Fall 1995

Harvesting was accomplished by each National Forest District using standard timber sales. Logging at all study locations utilized chainsaw felling and tree-length skidding by standard rubber-tired skidders.

Sample plots consist of a 7.2-ac net plot plus a 66-ft buffer for a total of 11 ac (Figure 3). In addition, each 7.2-ac net plot is subdivided into 12 0.6-ac subplots. Of the 12 subplots on each plot, 3 subplots located on one end of the plot (numbers 1-3 or 10-12) were randomly selected for the competition study. The remaining 9 subplots were used in the regulation study.

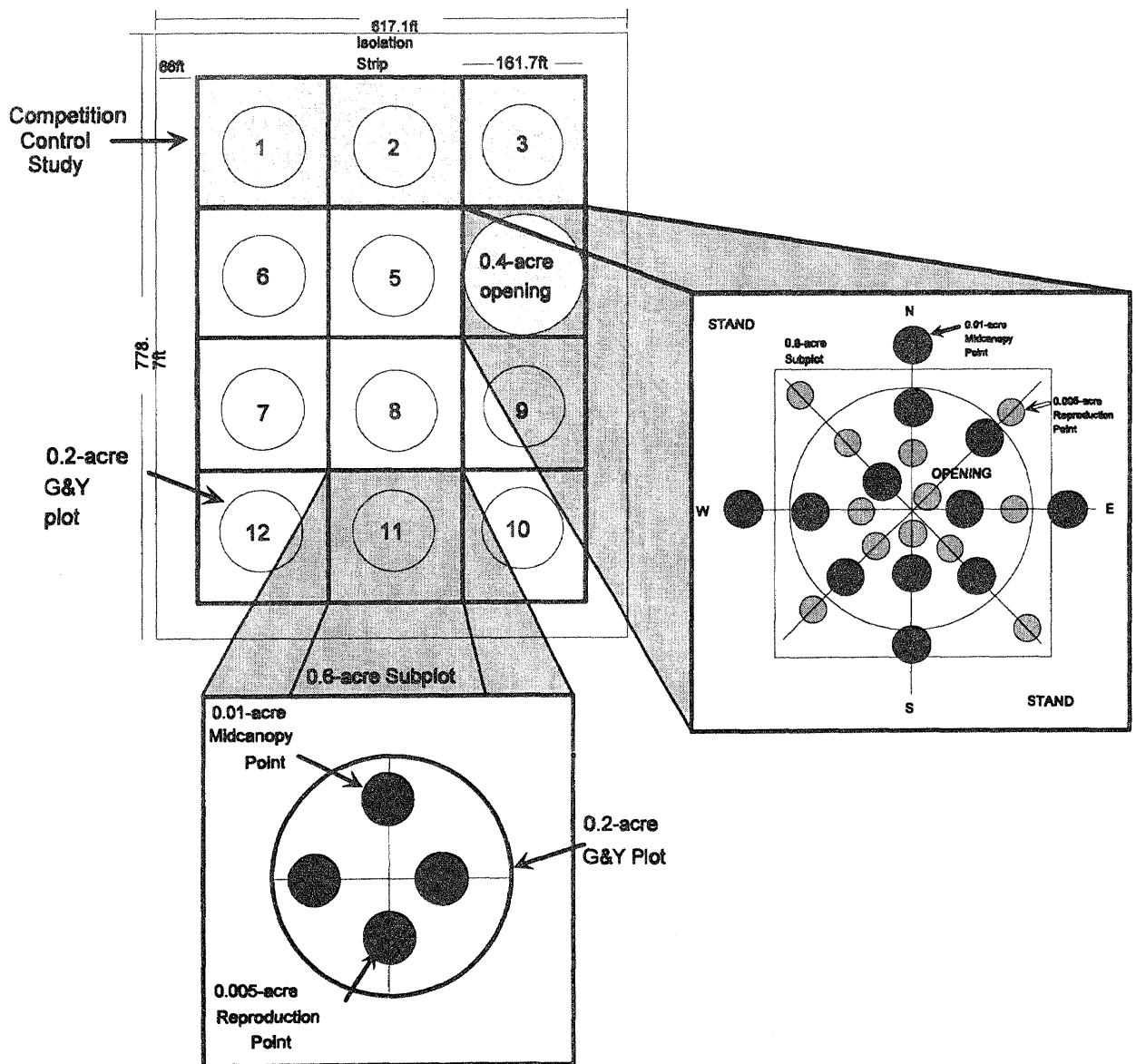


Figure 3. Layout of the plot, subplot, and sampling points for saplings and reproduction in the 0.2-ac growth plot and group opening.

Preharvest measurements. A complete tally of all overstory trees, dbh 5.6 in. and larger, was taken by species, tree class [per Grosenbaugh 1955 (see footnote, Table 3)], and 1-in. dbh classes. Saplings (0.6-5.5 in. dbh) were sampled by species and 1-in. dbh class on 48 0.01-ac sample points on each plot with 4 points permanently located within the center 0.2 ac of each 0.6-ac subplot (Figure 3). Preharvest reproduction (all stems smaller than 0.6 in. dbh) was sampled by species and 1-ft height class on a series of four 0.005-ac sample points on each subplot (Figure 3). In group opening subplots, all oak, ash, cherry, and walnut reproduction was identified and mapped on twenty-four 0.005-ac sample points (Figure 3). For these stems, height and basal diameter (1-in. above groundline) were measured to the nearest 0.1 ft and 0.1 in., respectively. The reproduction sample points are also permanently located and will serve to monitor reproduction development over time.

Competition control. Different treatments for controlling competing reproduction and midcanopy stems were applied to the residual stand and group opening:

Residual stand—Unmerchantable stems of desirable species larger than 5.6 in. dbh were cut to promote sprouting. Stems of undesirable species taller than 4.5 ft were cut, and the stumps were treated with herbicide.

Group opening—Unmerchantable stems of desirable species larger than 5.6 in. dbh were cut to promote sprouting. Stems of undesirable species taller than 1.0 ft were cut, and the stumps were treated with herbicide.

For this study, the species to be favored are: the hickories (*Carya* sp.), white ash (*Fraxinus americana* L.), black cherry (*Prunus serotina* Ehrh.), black walnut (*Juglans nigra* L.), black oak (*Quercus velutina* Lam.), northern red oak (*Q. rubra* L.), and white oak (*Q. alba* L.). Also, on poorer south and west aspect sites, shortleaf pine is considered desirable.

Postharvest measurement. Overstory growth and yield plus residual midcanopy stems were measured on a series of 0.2-ac circular plots located in the center of each 0.6-ac subplot (Figure 3). On each plot all overstory trees 5.6 in. dbh and greater were numbered and mapped by azimuth and distance from plot center. The following information was collected:

- (1) diameter to nearest 0.1 in.,
- (2) total height for a sample of trees in each 1-in. dbh class,
- (3) log grade for all sawtimber trees,
- (4) damage to crowns and boles resulting from logging,
- (5) tree quality, and
- (6) age of selected dominants or codominants.

Also, residual saplings (0.6-5.5 in. dbh) on four 0.01-ac sample points within each plot were mapped by azimuth and distance from point center and dbh measured to the 0.1 in. (Figure 3).

The influence of the group opening on the stem quality and growth of adjoining trees will be evaluated on selected sawtimber- and poletimber-sized trees bordering each opening. Eight dominant/codominant oaks and eight intermediate/overtopped oaks adjacent to the opening were selected. For each tree, species, crown class, dbh, butt log grade, and number of epicormic sprouts by 16-ft logs to 32 ft were recorded.

We will monitor the effects of the overstory and understory treatments on overstory growth and yield, subcanopy development, and reproduction survival and growth at 5-year intervals. The plots will be cut every 10 years.

RESULTS AND DISCUSSION

Preharvest Conditions

Overstory. The overstory basal area was remarkably uniform across all plots, varying from 92 to 114 ft²/ac for north aspects and from 91 to 112 ft²/ac for plots on the south aspects. The mean stand age and range for north aspects was 79 years and 71 to 93 years, respectively. Stands on south aspects were slightly younger with a mean of 74 years and a range from 68 to 81 years. Red or white oak site index on north aspects ranged from 62 to 72 ft (base age, 50 years) and 55 to 69 ft for south aspects. Mean site index was 67 ft and 62 ft for north and south aspects, respectively.

Total basal area was almost 100 ft²/ac for both aspects (Table 1). The basal area in desirable species is 90 percent for both aspects, and the oaks comprise about 80 percent of total basal area. There were some minor differences in species mix by aspect. Basal area for red oaks and ash-cherry-walnut was more on north aspects, while white oak basal area averaged more on south aspects.

Table 1. Preharvest species composition by basal area and aspect for the overstory (dbh $\geq$ 5.6 in.)

Species group ¹	Aspect ²	
	North	South
	----- Basal area (ft ² /ac) -----	
Understory species	1.5	2.9
Other overstory species	8.1	6.8
Hickory-shortleaf pine	8.2	6.5
Ash-cherry-walnut	2.2	1.4
Red oaks	43.2	34.6
White oaks	35.2	47.3
All species	98.4	99.5

¹ White oaks: White oak, post oak

Red oaks: Black oak, northern red oak

Ash-cherry-walnut: White ash, black cherry, black walnut

Hickory-shortleaf pine: Hickories, shortleaf pine

Other overstory species: Basswood, beech, blackgum, cucumber tree, sugar maple, sweetgum

Understory species: Blackhaw, black locust, buckeye, devil's walkingstick, dogwood, elm, hackberry, hophornbeam, Indian cherry, mulberry, Ozark chinkapin, papaw, persimmon, red cedar, redbud, red haw, sassafras, serviceberry, spice bush, tree huckleberry, umbrella magnolia, wild plum, witch hazel, miscellaneous understory

² Means are based on 12 7.2-ac plots for each aspect.

There were some differences in distribution of product classes by aspect (Table 2). There was more pulpwood basal area on south slopes, but the basal area for large sawtimber was greater on north slopes. These product distributions demonstrate that south aspects have more, smaller trees, while north aspects tend to have larger trees.

Table 2. Preharvest structure by product class and aspect for the overstory (dbh $\geq$ 5.6 in.)

Product class	Aspect ¹	
	North	South
	----- Basal area (ft ² /ac) -----	
Small pulpwood (6-8 " dbh)	12.7	16.8
Large pulpwood (9-11" dbh)	20.6	26.1
Small sawtimber (12-15" dbh)	32.0	31.2
Large sawtimber (>15" dbh)	33.1	25.4
All classes	98.4	99.5

¹ Means are based on 12 7.2-ac plots for each aspect

The tree class "grower" (Grosenbaugh 1955) designates trees that are the objective of management for quality timber. Table 3 shows that these crop trees are a much larger proportion of the stand on north aspects. This larger proportion occurs partly because the red oaks occur more often on north aspects, and red oaks tend to have a larger proportion of growers than white oaks. The incidence of culls and high-risk trees (riskers/killers/culls) occurs with equal proportions on both aspects.

Table 3. Preharvest structure by Grosenbaugh tree class and aspect for the overstory (dbh $\geq$ 5.6 in.).

Grosenbaugh tree class ¹	Aspect ²	
	North	South
	----- Basal area (ft ² /ac) -----	
Grower	26.5	15.9
Sleeper	16.8	19.4
Cipher/topper/slower	45.4	53.3
Riskier/killer/cull	9.7	10.9
All classes	98.4	99.5

¹ Adapted from Grosenbaugh (1955):

Grower: A merchantable tree that is vigorous and has no serious defects that would affect growth or desirability of the tree as potential sawtimber growing stock. A grower should also have the potential of developing a grade 1 butt log and have an expectancy of at least 0.90 of living until the next cutting cycle. Some people call such trees "crop trees" or "good growing stock."

Cipher: A merchantable tree whose expectancy of living for the next cutting cycle is at least 0.90, but does not meet the qualifications of a grower because of slow growth or undesirable characteristics, and is not competing with desirable reproduction or saplings. This tree can either be "financially mature" or may have limitations that disqualify it as a grower.

Sleeper: A cipher which has the potential to become a grower if it were released by removing competing trees.

Topper: A merchantable tree similar to a cipher but overtopping desirable reproduction or saplings.

Slower: The least potentially productive of several merchantable trees (but not riskers or killers—see below) competing in inadequate growing space. It should be cut in thinning.

Riskier: A merchantable tree whose life expectancy for the next cutting cycle is less than 0.90. It should be cut to salvage potential loss through mortality.

Killer: A merchantable tree infested with contagious pathogens.

Cull: A tree that is merchantable size but not salable because of defect or other factors.

² Means are based upon 12 7.2-ac plots for each aspect.

Saplings. Total number of saplings did not vary much by aspect. This component was dominated by noncommercial understory species and less desirable overstory species (Table 4). Of the preferred species, white oak and hickory were most numerous. The hickories were most numerous in the smaller sapling classes, and white oaks had the most stems in the 3 to 5 in. dbh classes.

Table 4. Preharvest species composition for saplings (0.6-5.5 in. dbh) by aspect

Species group ¹	Aspect ²	
	North	South
	----- Stems/ac -----	
Understory species	658	492
Other overstory species	104	194
Hickory-shortleaf pine	39	16
Ash-cherry-walnut	19	19
Red oaks	5	7
White oaks	30	24
All species	855	752

¹ See footnote 1 in Table 1 for species list.

² Means are based on 12 7.2-ac plots for each aspect.

Reproduction. The oak reproduction is predominantly in the <1 ft height class (Table 5). Of rootstocks over 1 ft, the majority are less than 3 ft tall, and few are taller than 5 ft. Relatively few white oak reproduction rootstocks occur on either aspect. This is unusual because white oak reproduction is usually much more numerous than red oak, and it dominates south slopes. The hickory, ash, and cherry reproduction was much more numerous in the larger reproduction size classes. Noncommercial understory species dominated other species groups in number of rootstocks on both aspects; shortleaf pine was noticeably absent.

Table 5. Preharvest species composition for rootstocks (< 0.6 in. dbh)

Species group ¹	Height class (ft)	Aspect ²	
		North	South
		----- Stems/ac -----	
Understory species	<1.0	1,534	1,838
	>1.0	2,433	1,866
Other overstory species	<1.0	219	274
	>1.0	365	446
Hickory-shortleaf pine	<1.0	510	282
	>1.0	443	259
Ash-cherry-walnut	<1.0	259	210
	>1.0	477	470
Red oaks	<1.0	885	711
	>1.0	92	145
White oaks	<1.0	265	352
	>1.0	33	43
		Stocking Value ³	
All oaks		2	3

¹ See footnote 1 in Table 1 for species list.

² Means are based on 12 7.2-ac plots for each aspect.

³ Stocking values computed from Sander and others (1984), based on 56 1/735-ac sample points per 7.2-ac net plot.

Oak stocking value (Sander and others 1984) is the contribution of reproduction to stand stocking at age 20 and is based upon reproduction size (height and ground diameter), aspect, and slope position. It is a method to determine before final harvest whether or not advance reproduction can adequately regenerate an oak stand. A stocking value of 30 or more indicates adequate oak reproduction. Based upon samples of 56 1/735-ac points per plot, the average stocking value was 2 and 3 for north and south aspect plots, respectively (Table 5). These low values indicate that oak reproduction is inadequate, and treatments are required to favor the establishment and growth of additional oaks.

Although oak stocking in the initial group openings will be low, large ash and cherry reproduction is present on more mesic sites and will supplement the oak reproduction developing from advance stems and stump sprouts. On poorer sites, existing hickory saplings and oak stump sprouts will supplement existing oak reproduction. Future openings will be installed in those subplots with adequate advance oak reproduction.

Postharvest Conditions

Overstory. The treatments affected residual species composition. The more desirable species were retained, and the other groups were discriminated against when making the cut. Therefore, there was a large reduction in the understory species and other overstory species groups (Table 6). We now have from 92 to 99% of the residual basal area in desirable species. The 85 ft² basal area treatments for both structural control and free thinning did not give as much freedom in molding species composition as the 65 ft² treatment, because not as much basal area was removed. There was no apparent difference in species composition between the two cutting techniques.

Table 6. Postharvest species composition by aspect and treatments for the overstory (dbh ≥ 5.6 in.)

Species group ¹	Residual basal area (ft ² /ac)							
	North aspect				South aspect			
	65		85		65		85	
	Free thinning ²	Structural control	Free thinning	Structural control	Free thinning	Structural control	Free thinning	Structural control
	----- ft ² /ac -----							
Understory species	0.1	0.4	1.3	0.9	0.6	0.6	1.2	1.8
Other overstory species	0.5	0.9	2.6	4.7	0.8	1.6	6.1	3.7
Hickory-shortleaf pine	4.1	4.4	8.3	9.6	4.4	4.0	5.2	5.8
Ash-cherry-walnut	0.5	1.0	1.8	2.9	0.5	0.6	0.4	2.1
Red oaks	27.4	31.5	35.9	39.4	24.9	19.6	23.2	33.5
White oaks	32.4	27.0	32.4	25.9	34.2	38.6	47.8	36.8
All species	65.0	65.2	82.3	83.4	65.4	65.0	83.9	83.7

¹ See footnote 1 in Table 1 for species list.

² Means are based on 3 7.2-ac plots for each aspect-density-regulation combination.

The treatments reduced basal area from almost 100 ft²/ac to 65 and 85 ft²/ac, and most of the reduction was in sawtimber (Table 7). The heavier reduction in the large sawtimber product class occurred because it contained more culls and lower-quality trees. A major objective was to improve residual stand quality; therefore, culls and lower quality trees had the highest priority for removal regardless of stem size. As illustrated in Table 8, the largest reduction in basal area did occur in culls and the lower quality classes. Culls were reduced from 9 to 14% in preharvest conditions to 0 to 2% in the after-cut stands. Any culls that were left occurred in the 85 ft²/ac treatment to meet residual basal area targets. The reduction in basal area was least in the grower and sleeper categories, which are the best potential crop trees. The proportion of basal area in these trees was increased.

Table 7. Postharvest product class distribution by aspect and treatments for the overstory (dbh $\geq$ 5.6 in.)

Product size	Residual basal area (ft ² /ac)							
	North aspect				South aspect			
	65		85		65		85	
	Free thinning ¹	Structural control	Free thinning	Structural control	Free thinning	Structural control	Free thinning	Structural control
	----- ft ² /ac -----							
Small pulpwood (6-8" dbh)	8.9	10.9	13.2	9.0	13.0	13.4	13.7	14.2
Large pulpwood (9-11" dbh)	18.1	16.7	19.3	15.4	21.3	19.4	22.0	24.1
Small sawtimber (12-15" dbh)	23.2	22.5	25.8	30.5	20.6	22.6	28.2	26.0
Large sawtimber (>15 dbh)	14.8	15.0	24.0	28.5	10.5	9.6	20.0	19.4
All product sizes	65.0	65.1	82.3	83.4	65.4	65.0	83.9	83.7

¹ Means are based on 3 7.2-ac plots for each aspect-density-regulation combination.

Table 8. Postharvest Grosenbaugh tree class distribution by aspect and treatments for the overstory (dbh $\geq$ 5.6 in.)

Grosenbaugh tree class ¹	Residual basal area (ft ² /ac)							
	North aspect				South aspect			
	65		85		65		85	
	Free thinning ²	Structural control	Free thinning	Structural control	Free thinning	Structural control	Free thinning	Structural control
	----- ft ² /ac -----							
Grower	22.7	26.0	24.9	29.7	15.3	13.8	18.2	14.5
Sleeper	15.8	18.2	17.8	15.6	19.7	17.9	17.4	22.5
Cipher/topper/slower	26.6	20.9	38.3	38.1	30.4	33.3	46.3	45.2
Riskier/killer/cull	0.0	0.0	1.3	0.0	0.0	0.0	2.0	1.5
All classes	65.0	65.1	82.3	83.4	65.4	65.0	83.9	83.7

¹ See footnote 1 in Table 3.

² Means are based on 3 7.2-ac plots for each aspect-density-regulation combination.

Figure 4 shows before- and after-cut stand structures by treatments. There is little apparent difference between the free thinning and structural control treatments after the initial cut for either density class. This lack of difference is the result of removing lower quality trees to improve stand quality irrespective of cutting method or residual density. Figure 4 also shows that there is a deficit of small diameter trees for both residual basal areas and aspects when compared to the target stand tables for the structural control treatments. This situation is further complicated by the presence of many smaller noncommercial or lower vigor stems that have a poor likelihood of responding to release. Many are ciphers. In marking these stands, higher priority was given to removing culls, high risk trees, trees competing with higher quality trees, and noncommercial species. Lower priority was given (1) to removing smaller, low-vigor trees that do not compete with better quality stems or (2) to attaining structure. In marking the structure plots, some low-vigor oaks in the intermediate and overtopped crown classes were also left to evaluate their response to release.

North Aspect

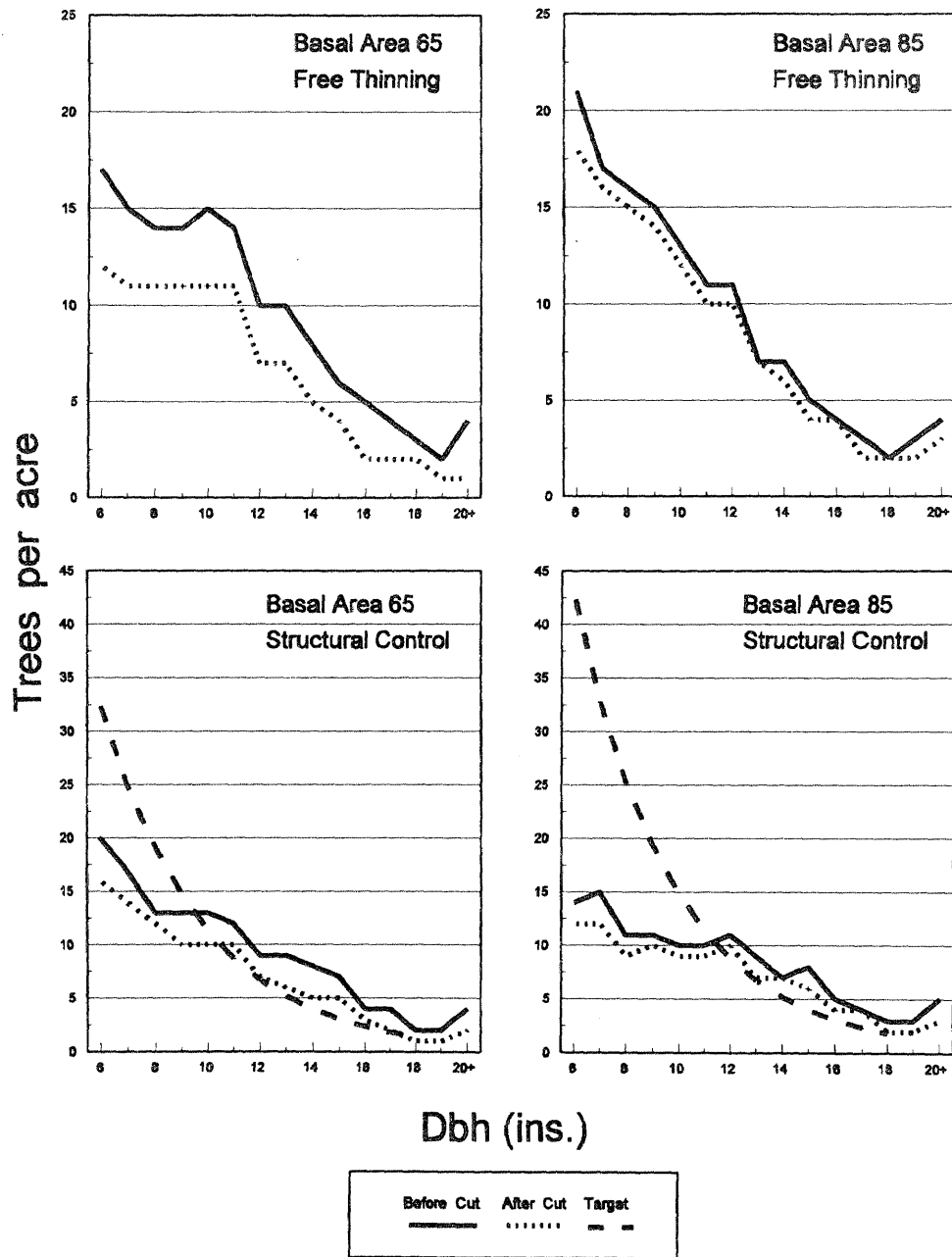


Figure 4a. Before-cut, after-cut, and target stand tables (structural control plots only) for north aspect plots by residual basal area and type of thinning.

South Aspect

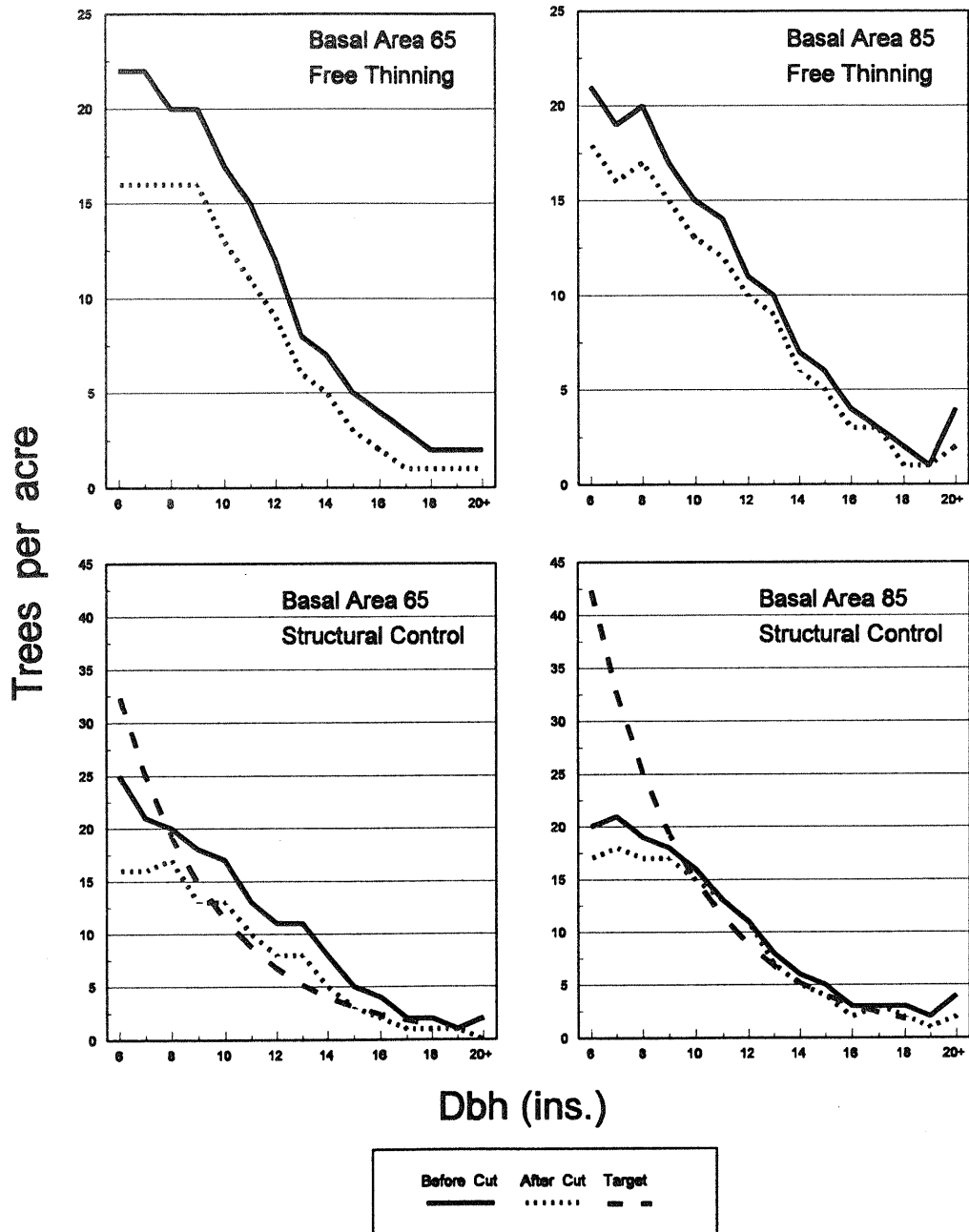


Figure 4b. Before-cut, after-cut, and target stand tables (structural control plots only) for south aspect plots by residual basal area and type of thinning.

Saplings. In addition to the deficiency in small overstory stems, there are also few residual saplings of desired species on both aspects (Table 9). Although sapling stocking standards have not been developed for uneven-aged oak-hickory stands, we would expect it to exceed at least 100 stems per acre of desired species. The number of red oak saplings is very low, while the number for white oak is somewhat greater, possibly indicating the difference in the shade tolerances between these species.

Table 9. Postharvest sapling (0.6-5.5 in. dbh) inventory by species group and aspect

Species group ¹	Aspect ²	
	North	South
	----- Stems/ac -----	
Understory species	10	8
Other overstory species	1	3
Hickory-shortleaf pine	19	11
Ash-cherry-walnut	10	14
Red oaks	3	3
White oaks	17	15
All species	60	54

¹ See footnote 1 in Table 1 for species list.

² Means are based on 12 7.2-ac plots for each aspect.

Reproduction. Reproduction was not inventoried after treatment. Competing stems taller than 4.5 ft were cut and treated with herbicide on the regulation study plots. In group openings, competing stems taller than 1 ft were cut and treated with herbicide. These treatments have been shown to be effective in increasing growth of established oak reproduction on upland sites in the Boston Mountains of Arkansas (Graney and Murphy 1995), the Missouri Ozarks (Schlesinger and others 1993), and southern Appalachians (Loftis 1990). In the Boston Mountains, other desirable species—such as black cherry and white ash—also respond significantly to competition control (Graney and Murphy 1995). While we know that some control of competing stems is required, the question is how much and how does it vary with site quality or aspect.

CONCLUSIONS

Though this study has just begun, experience gained in study installation and analysis of stand conditions before and after harvest leads to some tentative conclusions. They are:

1. Oak and other desirable reproduction on mesic and dry mesic Boston Mountain sites may be inadequate for regeneration cuts. A tolerant understory on these more mesic sites has prevented the development of adequate oak reproduction. The establishment and development of desirable reproduction will be the driving force for successful application of either uneven-aged cutting method. Therefore, understory competition control treatments are essential to promote establishment and growth of oak and other desirable reproduction. Experience with uneven-aged management of the shade-intolerant southern pines indicates that intensive competition control treatments may be required, especially on the more mesic sites.
2. Successful application of single-tree selection requires the eventual development of a well balanced stand structure. However, the present stands have a deficiency of desirable reproduction, sapling, and small poletimber trees. Filling these deficits in many cases will depend upon the establishment of desirable reproduction and its subsequent recruitment into these deficient size classes. Existing sapling and poletimber trees are of

the same age class as the overstory. They have been overtopped for a long time and generally have small crowns and low vigor. Therefore, these stems may not respond to release and possibly cannot be counted on to grow into the larger sizes as quality sawtimber. Until the development of a desirable stand structure, there will probably be no real difference between structural control and free thinning.

3. The stands before treatment had a high proportion of merchantable stems in the grower and sleeper categories, 44 and 35% of the total basal area for north and south aspects, respectively. These proportions were increased by the initial cut. Therefore, these stands have a strong potential for producing quality sawtimber, especially if residual stand quality is continually improved by subsequent cutting. Of course, the potential is much greater on the more mesic north slopes where better growth produces larger trees. The emerging market for hardwood chips in this region can give additional impetus to upgrading stand quality by providing an outlet for low-quality small material.
4. Recognizing quality is necessary for successfully applying either method to stands similar to the ones in this study. Blind, rigid application of structural control to these stands will degrade stand quality. It will be easier, perhaps, to achieve stand quality objectives using free thinning. Free thinning allows more flexibility in marking the stand because there are no stand structure constraints.
5. Residual density should be chosen with care. If the density is too high, the cut may not be operable, may not promote the growth of the residual trees, and may not afford the opportunity to upgrade stand quality. For example, the 85 ft²/ac treatment was not operable and resulted in removing only a portion of the culls and high risk trees. If the residual density is too low, stand growth can be reduced, stem quality may be degraded from increased epicormic sprouting, and rapid redevelopment of competing understory may occur.
6. Although the oaks have been traditionally favored in management in this region, a shift in species composition may be occurring that might cause forest managers to reevaluate this favoritism in some situations. This study and others (Graney 1989, Graney and Murphy 1995, Graney and Rogerson 1985) have noted the presence of large advance reproduction of cherry and ash on more mesic sites. These are also favored species in management, though their numbers will probably not dominate the stand as the oaks do now. The presence of these species may give forest managers more options, though cherry does not attain the quality and size associated with this species in other regions.

Despite the increased interest in using uneven-aged silviculture in upland oak stands in the Boston Mountains and elsewhere, we have neither a reservoir of experience in using these techniques with upland oaks nor are there studies that have matured enough to yield guidelines for management. Moreover, some fragmentary evidence indicates that single-tree selection can be used in more dry and xeric conditions with success, which contradicts accepted wisdom accumulated in more mesic situations. Hopefully, as this study and others accumulate results, the decision to use uneven-aged silviculture in this forest type will be based more on sound facts and owner objectives instead of aversion to other cutting methods and the reigning political climate.

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