RESIDUAL STAND QUALITY FOLLOWING IMPLEMENTATION OF UNEVEN-AGED SILVICULTURE IN EVEN-AGED OAK-HICKORY FORESTS IN THE BOSTON MOUNTAINS OF ARKANSAS

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Abstract—A test of group-selection and single-tree selection was installed in 80-year-old even-aged oak-hickory stands in the Boston Mountains of northern Arkansas. Twenty-four 11-acre 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 ft^2 per acre using free thinning or structural control. Tree quality in residual stands was evaluated using U.S. Forest Service tree grades for factory lumber and Grosenbaugh tree classes. Trees 11.6 in. and larger in dbh were considered sawtimber and included in the analysis. The effects of density, cutting method, and aspect on tree grade were evaluated using 2,225 sawtimber-sized trees. Results indicate no difference among treatments due to the short time interval since cutting. However, 53 percent of sawtimber either were or have the potential to develop into high quality trees. A residual basal area of 65 ft^2 or less is more likely to effectively increase tree quality and control species composition in the Boston Mountains than an 85 ft^2 target basal area. Overall, this study indicates that there is excellent potential to improve stand tree quality in the Boston Mountains of northern Arkansas using uneven-aged silviculture.

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. To address these concerns 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. Uneven-aged methods have been suggested as an alternative. 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. For instance, 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 discussed the advantages and disadvantages of each.

Although the feasibility of these uneven-aged cutting methods with upland oak types are being investigated, most research emphasis has been on regeneration and stand structure development (Graney and Murphy 1997, Loewenstein and others 1995). However, no research has concentrated on the long-term effect of the cutting methods on tree quality.

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 (Graney and Murphy 1997). 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.

As part of objective 3, log grades and tree quality classes (tree quality classes defined using Grosenbaugh 1955 tree classes) were assigned to each sawtimber-sized tree on the growth and yield plots to assess the change in tree quality over time. This also addresses the feasibility of using the Grosenbaugh tree classes on trees in oak-hickory forests of the Boston Mountains. In this paper we describe the preharvest conditions of the sawtimber and any effect of the initial harvest treatments on the residual sawtimber component.

METHODS

Study Region

The Boston Mountains are the highest and most southern member of the Ozark Plateau physiographic province (fig. 1). They form a band 30 to 40 miles wide and 200 miles long from northcentral Arkansas westward into eastern Oklahoma. Elevations range from about 900 ft in the valley bottoms to

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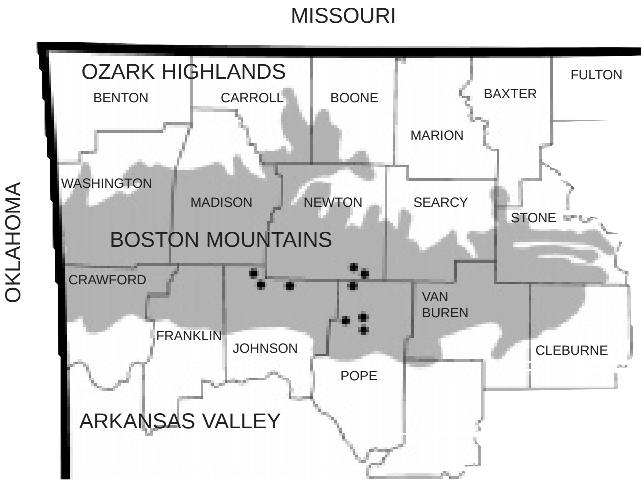

Figure 1—Location of study areas.

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.

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 northeast and southwest, residual densities are 65 and 85 ft^2/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 residual density levels are 65 and 85 ft^2/acre 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 ft^2 density level approximates the B-level of stocking for upland oak stands and should be near the optimum for stand and crop tree growth (Gingrich 1967). The 85 ft^2 density represents about 70-75 percent stocking and is appropriate for a first thinning in older stands that have relatively high stocking levels (Sander 1977).

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-acre plots were installed in nine forest stands on the Buffalo, Bayou, and Pleasant Hill Ranger Districts (fig. 1). Study plots were located on north/east and south/west facing mountain slopes and benches in oak-hickory stands representative of the sites and stand conditions that are designated for uneven-aged management by the Ozark National Forest. These plots were replicated by National Forest Districts with 8 plots established on each District. Harvesting was done 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-acre net plot plus a 66-ft buffer for a total of 11 acres (fig. 2). In addition, each 7.2-acre net plot was subdivided into twelve 0.6-acre subplots. Of the twelve subplots on each net plot, three subplots located on one end of the plot (numbers 1-3 or 10-12) were randomly selected for a separate competition control study (fig. 2) (Graney and Murphy 1997). The remaining 9 subplots were used in the regulation study.

Measurements

A complete preharvest tally of all overstory trees, dbh 5.6 in. and larger, was taken by species, tree class [per Grosenbaugh 1955 (see footnote, table 2)], and 1-in. dbh classes. This tally was used to apply the treatments.

In the postharvest phase, overstory growth and yield were measured on a series of 0.2-acre circular plots located in the center of each 0.6-acre subplot (fig. 2). On each 0.2 acre 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 the butt log of all sawtimber trees,

(4) damage to crowns and boles resulting from logging,

(5) tree quality by Grosenbaugh tree class, and

(6) age of selected dominants or codominants.

The 16-foot butt log on sawlog trees (trees larger than 11.6 in. dbh) was graded using the U.S. Forest Service log grading system (Hanks 1976). We will monitor the effects of treatments on stem quality at 5-year intervals. The plots will be cut every 10 years.

Regulation Techniques

The regulation techniques applied to the residual stand are (1) area regulation with free thinning and (2) area

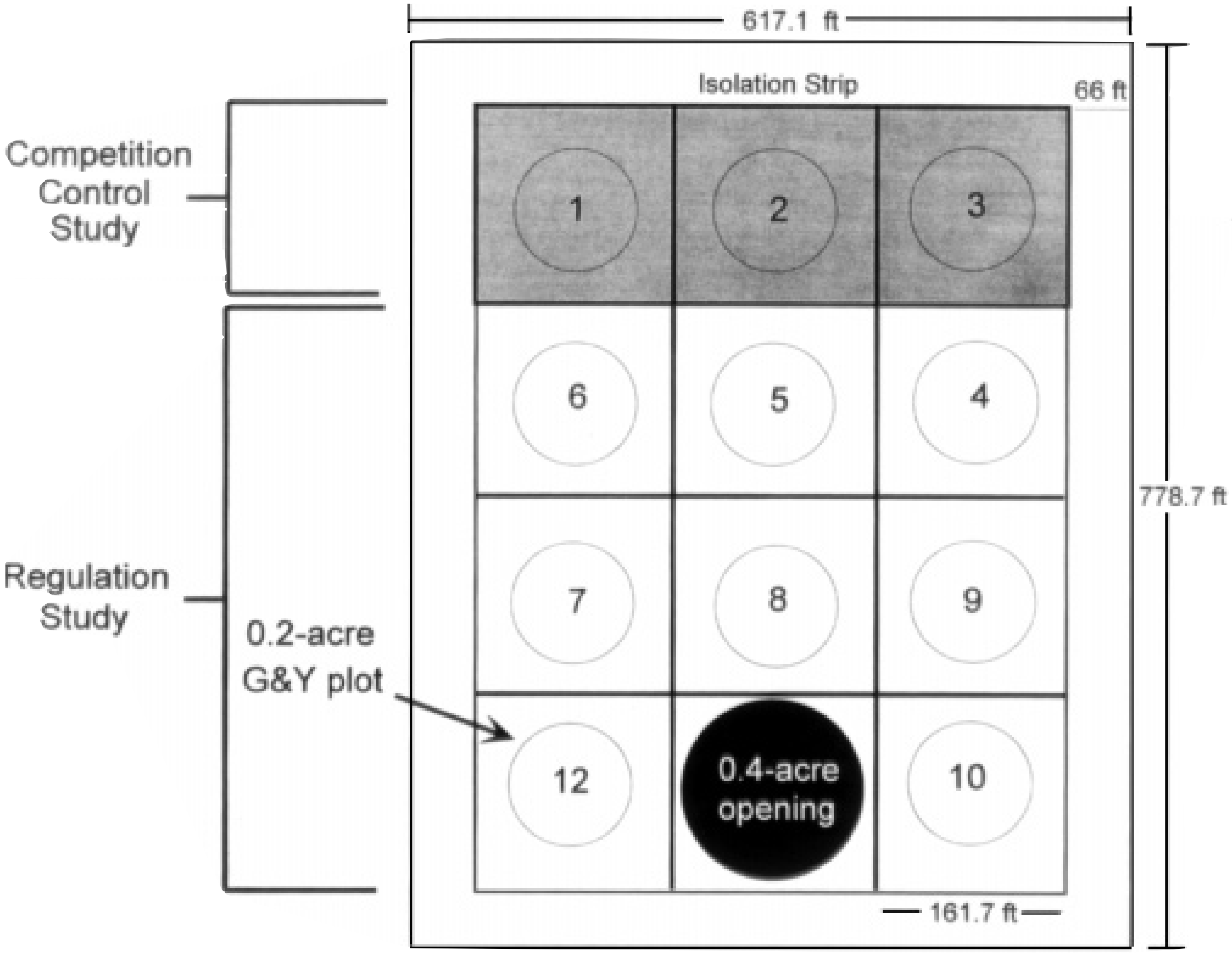

Figure 2—Layout of the plot, subplots, 0.2-acre growth plots, and group opening.

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 was approximately two times the average height in the dominant trees in the adjoining stand. This resulted in an average opening size of 0.4 acres (range 0.25 to 0.47 acres) in typical stand conditions. Selection of the initial group opening subplots were based on the presence of large reproduction or saplings of desirable species, sprouting potential of desirable species in the small poletimber class, and overstory stocking. A subsequent group opening will be created every 10 years. Group opening diameter and subplot dimensions restrictions precluded complete overstory removal in group opening subplots. Non-opening areas of group opening subplots were cut to the residual stand basal area target.

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 removed 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 thinned 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 ft^2/ac. 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.

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.

Statistical Tests

To test for differences in the proportion of grade 1 trees as the result of the treatments, a split-plot analysis was performed with the arc-sine square root transformation of proportion of grade 1 trees as the dependent variable, aspect as the main plot, and density and regulation as factors with three replications. None of the variables were significant. The results were probably confounded by 4 of the south aspect plots having site indices similar to north aspects.

RESULTS AND DISCUSSION

Preharvest Conditions

The total overstory basal area of trees ≥ 5.6 inches dbh was remarkably uniform across all plots, ranging from 92 to 114 ft^2/acre for north aspects and from 91 to 112 ft^2/acre 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.

Sawtimber basal area was slightly greater on north aspects (table 1). The basal area in desirable species was 90 percent for both aspects, and the oaks comprise 80 percent of the basal area. There were some minor differences in species mix by aspect. Basal area for red oaks and hickory was greater on north aspects, while white oak basal area averaged more on south aspects.

The tree class “grower” (Grosenbaugh 1955) designates trees that are the objective of management for quality timber. Table 2 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 are found 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.

Postharvest Conditions

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 larger reduction in the proportion of other overstory species groups (table 3). We now have about 96 percent of the residual sawtimber basal area in desirable species. The 85 ft^2 basal area treatments for both structural control and free thinning did not give as much freedom in molding species composition as the 65 ft^2 treatment, because less basal area was removed. There was also no apparent difference in species composition between the two regulation methods.

Table 1—Preharvest species composition by basal area and aspect for sawtimber trees (d.b.h.>11.5 inches)

Species groups[a]	North aspect[b]	South aspect
------------ Basal area (*square feet per acre*) ------------		
Hickory-shortleaf pine	5.3	2.9
Other overstory[c]	6.6	5.4
Ash-cherry-walnut	1.4	1.0
White oaks	19.4	24.0
Red oaks	32.4	23.3
All species	65.1	56.6

[a] Species preferred for management: white oaks, red oaks, ash, cherry, walnut, hickory, shortleaf pine.
[b] Means are based on twelve 7.2 acre plots for each aspect.
[c] Other overstory = basswood, beech, blackgum, cucumber tree, sugar maple, sweetgum.

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. In table 4, the largest reduction in basal area occurred in culls and the lower quality classes. Culls were reduced from 10 to 13 percent in preharvest conditions to 0 to 2 percent in the residual stands. Any culls that were left occurred in the 85 ft^2/acre treatment to meet this residual basal area target. 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.

Tree Grade Distribution

The 16-ft butt logs of all sawtimber-sized trees on the 0.2-acre growth and yield plots were evaluated using the U.S. Forest Service tree grading system (Hanks 1976). The total number of sawtimber-sized trees was 2,225, about a third of the sawtimber on the study areas. About 40 percent of the residual sawtimber trees were graded as 1 or 2. More of the grade 1 and 2 trees were located on north aspects (table 5). More of the grade 3 trees were located on south aspects, while the number of grade 4 trees were evenly distributed on both aspects.

There are greater differences in tree grades 1 and 2 on north and south aspects if site index is considered. Four of the south aspect plots had site indexes more comparable to north slopes. These 4 plots confounded the differences between aspects and accounted for 60 percent of the

Table 2—Preharvest structure by Grosenbaugh tree class and aspect for sawtimber trees (diameter greater than 11.5 inches)

Grosenbaugh tree class[a]	North aspect[b]	South aspect
	Basal area (*square feet per acre*)	
Grower	24.5	14.8
Sleeper	5.7	8.2
Cipher/topper/slower	28.1	26.4
Risker/killer/cull	6.8	7.2
All species	65.1	56.6

[a] 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 is 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.

Risker: 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.

[b] Means are based on twelve 7.2 acre plots for each aspect

Table 3—Postharvest species composition by aspect for sawtimber trees (diameter greater than 11.5 inches)

Species groups[a]	North aspect[b]	South aspect
	Basal area (*square feet per acre*)	
Hickory-shortleaf pine	3.9	2.1
Other overstory	1.3	1.6
Ash-cherry-walnut	0.9	0.6
White oaks	15.5	18.6
Red oaks	24.5	16.3
All species	46.1	39.2

[a] See footnote a in table 1 for species list.
[b] Means are based on twelve 7.2 acre plots for each aspect.

Table 4—Postharvest Grosenbaugh tree class distribution by aspect for sawtimber trees (diameter greater than 11.5 inches)

Grosenbaugh tree class[a]	North aspect[b]	South aspect
	Basal area (*square feet per acre*)	
Grower	23.8	14.3
Sleeper	5.7	8.1
Cipher/topper/slower	16.3	15.9
Risker/killer/cull	0.3	0.9
All species	46.1	39.2

[a] See footnote a in table 2.
[b] Means are based on twelve 7.2 acre plots for each aspect.

grade 1 and 2 trees on south aspects. The remaining south aspect plots were composed mainly of grade 3 and 4 trees.

Regulation method (free thinning versus structural control) had no apparent effect on tree grade distribution (table 5). One of the principal objectives in both free thinning and structural control was to improve the residual stand by cutting the worst trees and leaving the best ones. Thus, the results from both types of cuts were very similar. In structural control, we discriminated against poorly formed stems, low-value species, and noncommercial stems. Therefore, the residual stand structure was not always attained, but the residual stand was of better quality.

Residual basal area apparently did not affect the distribution of tree grade (table 5). Although the higher basal area treatment allowed more trees to be retained, the relative proportion of tree grades was not affected. The difference in the proportion of grade 1 trees is probably due to the marking of the structural control plots where the target structure could not be attained in the smaller diameters. Therefore, more of the larger trees were retained to satisfy density requirements.

While the proportion of quality trees was the same for the 65 ft^2 and 85 ft^2 density treatments, the economic operability of the cut and potential effects on future stand and tree quality development will vary. The 85 ft^2 target permitted removal of approximately 16 ft^2 of basal area per ac, mostly in cull and low quality trees. Although higher quality trees will be removed in future 10-year cycle cuts, basal area removed will be less than 20 ft^2 per acre and will be further reduced by mortality expected in the higher density mature stands (Graney and Murphy 1994). Increasing the numbers of grade 1 and grade 2 trees in current stands will depend on maintaining or increasing growth of pole- and small sawtimber-size stems in the higher quality (grower and sleeper) tree classes. Quality

Table 5—Postharvest distribution of sawtimber trees by tree grade, aspect, regulation method and residual basal area

	Aspect		Regulaton method		Basal area		
Tree grade	North	South	Free thinning	Structural control	65 ft^2	85 ft^2	Overall mean
	Percent						
Grade 1	16	11	13	15	11	16	14
Grade 2	29	22	25	26	24	26	25
Grade 3	32	43	36	37	39	36	37
Grade 4	23	24	26	22	26	22	24

stems in 70- to 80-year-old Boston Mountain hardwood stands respond with increased diameter growth following intermediate cutting to medium or lower stand densities (Graney and Murphy 1994). Cutting residual stands to 65 ft^2 allows more flexibility in the removal of lower quality stems and the crown release of potentially higher quality stems in the grower and sleeper tree classes.

Growers are trees that have attained or will probably attain a grade 1 butt log during their lifetime; these trees are the crop trees of management. Of the total number of trees classified as growers, 73 percent were classified as grade 1 or 2 (table 6). The primary reason that some growers are not grade 1 is that they do not yet meet the size requirements but have the potential to do so, given time. As they grow, however, they will eventually satisfy the criteria for grade 1 logs. Sleepers are trees that have good stem quality and could develop into growers if some remedial management is done, such as thinning. Trees classified as sleepers in our study were usually in the large poletimber or small sawtimber classes and could not attain log grade 1 or 2 because they did not meet the size requirements. These trees are unlikely to grow into a size class large enough to meet log grade 1 or 2 in the absence of management. Fifty-three percent of the sawtimber trees were classified as growers or sleepers, which indicates that the potential for high quality sawtimber of upland oak stands in the Boston Mountains is excellent.

CONCLUSIONS

Although 39 percent of the sawtimber trees in the study qualify for grade 1 and grade 2 trees, the 60 percent that are now growers and sleepers indicates that the potential for increase in tree quality is good. These trees are now too small to qualify for the higher grades. It will take time and management before these smaller trees reach the merchantability standards for grade 1 and 2 logs. A major reason for the relatively low proportion of higher grade stems in the 70- to 80-year-old Boston Mountain oak-hickory stands is residual stand diameter. Of the residual stand component, only 50 percent met the minimum diameter requirements for grade 1 or grade 2 logs. However, in the remaining stocking of the small sawtimber class, more than 60 percent are in the grower and sleeper classes and should develop into grade 1 and grade 2 trees as they grow into the larger sawtimber-sized classes.

One reason for the lack of differences among treatments is likely the short time interval since cutting. The high site indices for benches on some southwest facing slopes also may be masking any immediate differences. Aspect alone does not adequately separate high site index sites from low site index sites, as evidenced by the similarity of some of the south aspect plots to north aspect plots. In the Boston Mountains, productive oak sites are also associated with the deep, well drained colluvial soils commonly found on concave, gently sloping inner bench positions that are typical of upper mountain slopes at all aspects (Graney 1977).

Table 6—Postharvest distribution of sawtimber trees by Grosenbaugh tree class and tree grade

Tree grade	Grower	Sleeper	Other classes	All classes
	Percent			
Grade 1	36	0	1	14
Grade 2	37	4	25	25
Grade 3	25	42	44	37
Grade 4	2	54	30	24

The residual basal area of 85 ft^2 is likely too high to be used as an effective management tool and is not likely to produce an economically feasible sale. In the 85 ft^2 treatment the harvest consisted mainly of low quality and cull material. The residual stand of 65 ft^2 produced a harvest of merchantable material and shows promise in increasing tree quality. A residual stand of less than 65 ft^2 of basal area may enhance these effects if carefully applied. Overall, this study indicates that there is excellent potential to improve stand quality in the Boston Mountains of northern Arkansas.

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