APP

OAK REGENERATION FOLLOWING THREE CUTTING TREATMENTS ON MOUNTAIN SLOPES IN NORTHERN ALABAMA'

Michael S. Golden, Mark R. Dubois, and Jeffery L. Stockman[2]

Abstract-Early regeneration success of upland oaks (*Quercus* spp. L.) was compared for three regeneration cutting treatments in the Sandstone Mountain Region of northern Alabama. Two 4-acre replications each of block dearcutting. strip cutting, and deferment cutting were established on north-facing slopes. The three harvesting treatments were applied in midsummer. Regeneration subplots were reinventoried in both the first and second autumns following harvest. Major oaks present were chestnut oak (Q. *prinus* L.), white oak (Q. *alba* L.). and northern red oak (*Q. rubra* L.). Milacre plot stocking of oak reproduction after the second season was related to advance reproduction stocking, topographic position, cutting treatment, harvesting damage, and cover of logging slash. Both small advance reproduction (less than 1 ft tall) and post-harvest germination contributed substantially to the post-harvest stocking of oaks.

INTRODUCTION

Oak-hickory forests cover 35 percent (7.7 million acres) of Alabama's timberland and is the principal forest type in the mountain regions in the northern part of the state (McWilliams 1992). As a group. oaks are highly desirable for landowners of this region, both as timber and for wildlife food production. However, dependable regeneration of oaks is often a problem (Smith 1993).

The objective of this study was to identify important factors that influence early regeneration success of oaks in mountain-slope mixed hardwood stands in northern Alabama. More specifically, we compared regeneration results from block clearcutting, narrow strip clearcutting, and "deferment cutting" (a form of irregular shelterwood).

METHOOS

Study Site

The study site is located on a forest industry tract in Lawrence County, AL, at 35 degrees 25 minutes north latitude. It is in the Sandstone Mountain Forest Habitat Region (Hodgkins and others, 1979). The treatments and measurement plots were placed in an upland mixed hardwood stand located on north-facing ridge shoulders and slopes of a large ridge complex oriented roughly east-to-west. Elevation within treatment areas range from about 650 to 800 ft above mean sea level. Soils are primarily residual from sandstone on the ridge shoulders and some mixture of residuum and colluvium from sandstone or a sandstone-shale mixture on the slopes. Common soil series include Apison, Albertville, Bankhead, Gorgas. Sipsey, and Townley. Slope steepness ranges from less than 5 percent on the shoulders to more than 60 percent on some middle and lower slopes. Narrow benches and short rocky drop offs (less than 10 ft drop) occur on some slopes.

Study Design

Six rectangular treatment blocks of 4 acres (400 by 440 ft) each were established along north slopes of the ridge complex, with the long axis of each block oriented roughly perpendicular to elevation contours (i.e., down slope, south to north). Two replications of each of three harvesting treatments were randomly assigned to the six blocks.

The block clearcutting treatment (CC) consisted of cutting all trees in each block larger than 1.5 inches d.b.h. For the strip clearcutting treatment (SC), all stems larger than 1.5 inches d.b.h. were felled in alternate strips approximately 120 ft wide (uncut strips the same width were left between each cut strip), oriented roughly along contours. For deferment cutting (DC). trees totaling approximately 26 ft^2 per acre of basal area were marked and not cut in the two blocks. Criteria used in marking the reserved trees were that they were evenly distributed and where possible, good quality codominant oaks. Fcr distribution. where oaks wcre not present, a small number of other species were marked and left. Commercial harvesting was conducted during July and early August. Trees were felled using chain saws and merchantable logs were skidded to loading decks on the main ridge using grapple skidders. Most of the limbing and topping was done at the felling site. Non-merchantable trees greater than 1 .5 inches d.b.h. were felled and left.

Pre-Harvest Measurements

Before harvest. a system of reproduction plots was established consisting of three equally spaced belt transects in each block, each 6.6 ft wide, extending from upper to iower edge of the block. Each belt transect was divided into 6.6 ft square segments (1 milacre). and alternate segments (odd-numbered) were established as reproduction measurement plots. Plot corners were marked with pin flags which were later replaced with ½-inch conduit afler harvesting was completed. During late spring before harvesting, all trees within each reproduction plot were counted by species and by size classes divided as follows: less than 6 inches tall, 6 inches to 11.9 inches tall, 1 ft to 3 ft tall, taller than 3 ft to 1.5 inches d.b.h., and more than 1.5 inches d.b.h. The d.b.h. was recorded for trees of the largest class. All oaks in each milacre measurement plot were tagged with plastic poultry bands, color-coded so that each individual tree was identifiable. Additionally, all trees of all species in the southwestern quarter of each milacre plot were similarly tagged for identification. The height of each tagged tree taller than 12 inches was recorded.

To characterize the preharvest mid- and overstory trees (those larger than 1.5 inches d.b.h.) of each block, three

[1] Paper presented at the Tenth Biennial Southern Silvicultural Research Conference, Shreveport, LA. February 16-18, 1999.

[2] Associate Professor. Assistant Professor. and Graduate Research Assistant. respectively. School of Forestry, Auburn University, AL 36849.

33-n wide strips. one centered on each reproduction plot transect. were inventoried. Each tree's location was mapped to a grid of quarter-milacre cells, with species, crown classification. and d.b.h. recorded. The heights of trees in every sixth cell were measured.

slope angle and azimuth were measured for each reproduction plot. initially all the plots were classified into one of seven microsite classes. These were later consolidated into four major topographic classes, namely lower slope. midslope, upper slope, and ridge shoulder.

Post-Harvest Measurements

After harvesting was completed, soil and site impacts of harvesting were rated for each measurement plot. This included a rating of the degree of litter cover and surface soil movement, amount of bare soil exposed, the amount and depth of rutting from skidder traffic, and the percentage of the plot affected. Logging slash density, percent coverage, and depth were also assessed for each plot.

In autumn after harvest, the reproduction plots were . relocated and marked with conduit stakes. Reproduction counts for plots were repeated as for the preharvest inventory. The apparent fate of all tagged stems was determined, and heights remeasured. Including that of stump sprouts. All new oak seedlings, and sprouts and new stems of all species in the southwestern plot quarter-miiacre were measured, tagged, and recorded. Multiple sprouts from a single stump were treated as one tree, wi!h the tallest stem height recorded. This remeasurement and tagging was repeated during the second autumn, approximately 15 months after harvest.

Data Analyses

In all reproduction data analyses reported here, only the reproduction plots that were located in the cut areas of the SC treatment were used. All plots in the CC and DC treatments were included, for a total of 488 plots. Preharvest mid- and overstory information was derived from the full 25 percent sample of the treatment blocks.

Simple descriptive statistics were computed using PROC's MEANS and FREQ of the Statistical Analysis System (SAS Institute *Inc.* 1990a). To utilize individual reproduction plot data, presence within each plot of one or more established oaks (those taller than 6 inches) at the 15-month measurement time was the criterion used to assess early regeneration success, with a plot being either 'stocked" or 'non-stocked".

PROC LOGISTIC of the Statistical Analysis System (SAS) for Windows, release 6.12. was used for performing logistic regression analyses (SAS Institute Inc. 1990b, 1997). Overall model fit was assessed by the chi-square probability from the log-likelihood ratio test (Hosmer and Lemeshow 7989, Menard 1995), by the proportion of variation explained as interpreted by an adjusted R^2 (Nagelkerke 1991). and by the Hosmer and Lemeshow (1.989) goodness-of-fit test (SAS Institute 1995).

For stepwise logistic regression analyses, all potential measured explanatory variables available for individual plots were tested in the initial model. These included various variable forms of oak advance reproduction (AR), slope steepness (percent), aspect (cosine transformation of Beers and others 1964). topographic position, treatment type, logging disturbance, and logging slash.

Oak AR (all oak species included) was tested as an explanatory variable in quantitative and binary forms. with various size categories examined. Number of oak AR per plot was tested in three forms: for all sizes combined, for only those taller than 6 inches. and for only those taller than 1 ft. Three binary forms of simple stocking (presence) using the same three size classes were tested. Topographic position and treatment type effects were tested in both 'dummy" and ordinal forms. For the ordinal form, topographic position was coded as lower slope = 1, midslope = 2. upper slope = 3, and ridge shoulder = 4. Treatment type was coded as CC = 1, SC = 2. and DC = 3. Logging disturbance and slash were tested both as their separate components (exposed bare soil, amount and depth of rutting; density and depth of slash) and as an ordinal variable reflecting increasing degree of logging disturbance or expected slash impact on shading (where 1 = lowest, 3 = highest).

All of the various forms of each variable were examined in multiple runs of forward stepwise selection. In all cases, the results and apparent interpretations were similar whether the quantitative. dummy. or ordinal form of variables were used. Since the binary (for advance reproduction) and ordinal forms are easier lo report and describe. *they* will be reported in the results.

RESULTS AND DISCUSSION

Pre-Harvest Tree Composition

Results of the tree inventory for all six treatment blocks combined are shown in table 1. Overall. canopy-sized trees (5 inches and larger d.b.h.) averaged 138 stems per acre and 118.3 ft^2 in basal area. Oaks (*Quercus* spp. L.) comprised the largest group, with 39 percent of basal area and 30 percent of stems. Most abundant among these were chestnut *(Q. prinus* L.), white (*Q. alba* L.), and northern red oaks (C?. *rubra* L.). Abundance of the oaks was very high on ridge shoulders and noticeably declined on lower slopes. Hickories, including red (*Carya* ova/is (Wangenh.) Sarg.), shagbark (C. *ovata* (Miller) K. Koch), and mockernut (C. *tomentosa* (Poiret) Nutt.), comprised 25 percent of basal area and 26 percent of stems. Although rare in Alabama, sugar maple (*Acer saccharum* Marsh.) was present in low numbers (8 per acre) in the overstory, and exclusively on lower slopes (table 1). Most of the oaks appeared to be approximately 65-70 years old, with scattered older trees. Site indexes (age 50) for upland oaks (Olson 1959) ranged from about 65 to more than 100 ft. Ridges and upper slope site indexes were mostly 70-80 ft and mid- and lower slopes 85-l 00 ft.

Composition of the subcanopy/understory stratum (trees 1.5 to 4.9 inches d.b.h.), which averaged 176 stems per acre, was markedly different (table 1). Sugar maple and American beech (*Fagus grandifolia* Ehrh.) were most abundant (21 and 18 percent of stems, respectively), though this abundance was most evident (even dominant) on lower slopes. Oaks, on the other hand, were scarce in the subcanopy/understory, averaging only 5 per acre. Most of these were chestnut oaks on ridge shoulders. Black tupelo *(Nyssa sylvatica* Marshall) and eastern hophornbeam (*Ostrya virginiana* (Miller) K. Koch) were also common in this stratum, both averaging 30 stems per acre (table 1).

Table I-Preharvest basal areas and stem densities of the canopy (>4.9 inches d.b.h.) and densities of the subcanopy (154.9 inches d.b.h.), harvested areas only

Species	Canopy		Subcanopy density
	Basal area	Density	
	Ft²/ac	*Stems/ac*	*Stems/ac*
Chestnut oak	22.0	20	4
White oak	12.7	13	1
Northern red oak	8.5	6	0
Black oak	1.8	1	0
Southern red oak	1.3	0	0
Scarlet oak	.3	0	0
All oaks combined	46.6	41	5
Hickories[a]	29.0	36	7
Yellow-poplar	9.7	7	1
American beech	8.5	10	32
Sweetgum	6.8	10	4
Black tupelo	4.4	9	30
Sugar maple	4.3	8	37
Red maple	2.2	4	7
Cucumber-tree	1.9	4	3
Ashes[b]	1.8	4	5
American hornbeam	.6	2	30
Elms[c]	.4	1	3
Other canopy species	1.6	1	1
Other subcanopy species	.5	2	9
Total	118.3	138	176

[a] Red (C. *ovalis*), shagbark (C. *ovata*). and mockernut (C. *tomentosa*).
[b] Mostly green (*F. pennsylvanica*), some white (*F. americana*).
[c] Winged (*U. alata*) and American (*U. americana*).

Advance Reproduction and Potential Sprouts

Since all of the hardwood species here have the potential to sprout from cut stumps, all trees were considered as potential reproduction on the site after harvesting. So. all size classes that were present within the milacre plots were included in table 2, reflecting the full “advance reproduction” (AR) potential present before harvest (Johnson 1993).

All commercial species together averaged 14,982 stems per acre in broadly-defined advance reproduction (table 2). An additional 967 per acre of noncommercial species (eastern hophornbeam, flowering dogwood (*Cornus florida* L.). eastern redbud (Cercis *canadensis* L.), American hornbeam (*Carpinus coroliniana* Walter), and sourwood (*Oxydendrum arboreum* (L.) DC.)) were present. All oaks together averaged 2,523 AR per acre, but only 222 per acre of these were in the highly desirable large seedling and sapling sizes (1 ft tall to 4.9 inches d.b.h.). Of the oaks. white oak had the highest overall numbers of AR (994 per acre), but 87 percent of these were less than 6 inches tall, and just 18 per acre were present in the large seedling/sapling sizes (table 2). Most of the white oaks were in one block. Northern red oak was highest in numbers among oaks in the large seedling/sapling sizes (117 per acre), but had less than half that of chestnut oak over all sizes (414 compared to 844 per acre).

For all sizes combined, sugar maple had the highest numbers of AR of any species, averaging 7,447 per acre overall (table 2). It was also more heavily represented in the large seedling/sapling sizes than any other species, averaging 1,264 per acre. Red maple (*Acer rubrum* L.) was present in moderate numbers overall (1,273 per acre) and in the large seedling/sapling sizes (414 per acre). Although not high in small seedling numbers, American beech and black tupelo had fair numbers in the large seedling/sapling sizes (229 and 312 per acre. respectively; table 2).

Factors Affecting Oak Stocking at 15 Months

Presence of any oak (taller than 6 inches) in a plot at 15 months after harvest (milacre stocking) was the response variable in the logistic regression analysis. The final model was highly significant and the Hosmer and Lemeshow goodness-of-fit test was non-significant (thus the hypothesis of good fit cannot be rejected). The adjusted R^2 indicated that the model accounted for about 40 percent of variation.

Table 2-Advance reproduction and cut trees in reproduction plots in the harvested areas (from 488 plots), by size class

Species	Height			D.b.h.			All sizes combined
	<6"	6" - 1'	1' - 3'	- 1.5"	1.6 - 4.9"	>4.9"	
	Number per acre						
White oak	869	94	18	0	0	12	994
Chestnut oak	611	156	41	16	4	16	a44
Northern red oak	117	178	109	4	4	4	416
Other oaks	170	72	20	4	0	2	268
All oaks	1,766	500	189	25	8	35	2,523
Sugar maple	5,260	910	752	477	35	12	7,447
Hickories	977	55	150	27	4	39	1.551
Red maple	568	285	289	119	6	6	1,273
Other commercial	129	125	129	53	6	16	459
Black tupelo	53	72	133	148	31	16	453
American beech	47	78	61	135	33	6	361
Ash	39	64	13	37	4	2	258
Yellow-poplar	0	0	2	0	2	4	8
Totai							
Commercial	9.135	2,538	1,926	1,053	13:	137	14.982
Non-commercial	156	i64	348	260	37	2	367

Advance reproduction-Five explanatory variables, milacre stocking of advance reproduction more than 6 inches tall (AR stocking), cutting treatment, topographic position, degree of logging disturbance, and logging slash cover were significant at'a chi-square probability of less than 0.03. The most influential factor was the presence of oak AR taller than 6 inches. Its parameter estimate and odds ratio were high relative to the other factors (even when scale differences are considered). In other models tested using stocking or numbers of all AR sizes or of just those taller than 1 ft, the model test statistics and the AR variable parameters were significant, but model R^2's and variable influence parameters were smaller than when the size division was at 6 inches.

With a relatively large and highly significant parameter estimate and a high odds ratio, AR stocking was the most influential factor tested. At 15 months after harvest, 38 percent of all plots in the cut areas were stocked with oaks taller than 6 inches (table 3). which is only 1 percent lower than overall preharvest reproduction stocking. Based on this close match, one might infer that post-harvest reproduction stocking was affected primarily by AR stocking. However, a detailed examination of individual plot stocking showed that 33 percent of the plots stocked with AR taller than 6 inches did not remain stocked at 15 months after harvest. Similarly, 19 percent of plots that were not stocked preharvest were stocked with at least one oak (taller than 6 inches) at 15 months after harvest. So, both mortality of AR and post-harvest germination influenced the 15-months stocking levels.

Treatment-Cutting treatment type was also identified as a highly significant factor by the logistic regression analysis. The positive slope parameter and the nature of the coding appeared to indicate an increased probability of oak stocking in the DC treatment, which was assigned the highest coded value. This influence is clearer when percent stocking was compared for pre- and post-harvest among the three treatments (table 3). By chance. the preharvest stocking among the CC reproduction plots was much lower (approximately one-half) than for the other two treatments. However, 11 percent of the CC and 15 percent of the SC preharvest stocked plots were no longer stocked at the post-harvest assessment, compared to a gain in stocking of 8 percent for the DC treatment. These numbers imply that higher mortality occurred in the CC and SC treatments and higher post-harvest establishment occurred in the DC treatment. The higher mortality was likely a result of damage from logging, further discussed below. Earlier analysis found that the clearcut, strip cut, and deferment cut areas had 25. 13. and 9 percent exposed bare soil, respectively (Dubois and others 1997). In addition to lower mortality due to less logging disturbance, there was enough post-harvest establishment from germination in the DC treatment to exceed oak stocking losses that were incurred through mortality.

Topographic position-Slope position was also a significant factor in the logistic regression model. The AR levels were strongly correlated with topographic position, increasing from lower slope to ridge (table 3).

No consistent pattern was evident among slope positions however, when preharvest to post-harvest changes were examined (table 3). Fewer oaks were present in both the overstory and understory strata of lower and midslope areas before harvest. This was likely due somewhat to the high

Table J-For oaks, change in stocking of milacre plots from preharvest (AR) to 15 months after harvest, compared for factors having a significant effect on oak regeneration success

Factor	# plots	Stocking: Preharvest	At 15 months	Change'	Change. as % of AR[b]
		Percent (number)		Percent	
AR stocking					
Overall	488	39(191)	38(185)	-1	-3
Cutting treatment					
Ciearcut	200	27(54) .	24(48)	-3	-11
strip	88	52(46)	44(39)	-8	-15
Deferment	200	46(91)	49(98)	+4	+8
Topographic position					
Lower slope	177	29(52)	29(51)	-1	-2
Midsiope	190	33(62)	36(68)	+3	+10
Upper slope	103	61(63)	50(52)	-11	-17
Ridge shoulder	18	78(14)	78(14)	0	0
Cogging disturbance					
Light	267	37(98)	44(118)	+7	+20
Medium	145	41(60)	37(53)	-5	-12
Severe	76	43(33)	18(14)	-25	58
Logging slash					
Light slash	303	43(129)	43(131)	+1	+2
Medium slash	89	36(32)	33(29)	-3	-9
Heavy slash	96	31(30)	26(25)	-5	-17

[a] As proportion of total plots in the class.
[b] As proportion of plots that were stocked at preharvest.

abundance of shade-tolerant tree species in the understories of lower and midslopes and their comparative scarcity on ridges. in sizes from 3 ft tall to 4.9 inches d.b.h., preharvest sugar maple and beech stems averaged 1,042 and 946 stems per acre on lower and midslopes, respectively. but 111 per acre on ridge shoulders. This negative relationship of oak reproduction success with more mesic and higher quality sites is consistent with that reported for oaks in other regions (Kays and others 1985. Sander and others 1984), with competition from mesic species usually cited as the major reason.

It is apparent that slope position has and will continue to correlate strongly with oak stocking on these north-facing slopes. At the 15-month measurement, the effect was primarily through influence on AR, but in the future developing stand the negative effect of intense competition from mesic species on the middle and lower slope positions may become evident. This will come from established rootstocks of tolerant species such as sugar maple and beech, and from recent seedlings of yellow-poplar. At 15 months. more than 2,400 stems per acre of sugar maple and more than 3.200 per acre of yellow-poplar taller than 1 ft were present in the lower slope plots. These will likely overtop and shade out a substantial proportion of existing oak reproduction.

Logging effects-The regression model indicated that increasing levels of logging disturbance, as evidenced by bare soil and rutting, had a significant negative impact on oak regeneration success. This is reinforced by the changes in numbers of stocked plots from pre- to post-harvest (table 3). Where logging disturbance was light or absent, there was a 20 percent increase in number of post-harvest stocked plots over those stocked preharvest, contrasting with a 58 percent decrease where logging disturbance was severe. The apparent mechanism for this negative effect was direct damage or destruction of stems and root systems. First-season oak seedling survival for this study was earlier reported to be negatively related to percent exposure of bare mineral soil (Dubois and others 1997).

The other significant factor found was residual logging slash level. The effect on regeneration stocking was negative with increasing density and depth. As used, the rating placed more emphasis on density than depth. Based on changes in stocking, pre- to post-harvest, most of the effect occurred between the light and medium slash levels, with a slight increase in stocked plots for the light slash level, but a reduction of 9 and 17 percent for the medium and heavy slash levels, respectively (table 3). Presumably, the negative effect was due to shading of seedlings by increasingly denser and deeper slash.

Effects of Advance Reproduction Size and Post-Harvest Establishment

In order to determine the effects of post-harvest establishment and also size of AR on oak milacre stocking, data from all three measurement times for the tagged oaks (taller than 6 inches) present in each plot at the 15-month inventory were examined. The "origin" of stocking for a plot was classified as being from either AR of one of the five AR size classes, or else from post-harvest germination (PHG)of seed from one of the two possible seed crops. If any of the oaks had been present before harvest. the plot stocking was considered to have originated from AR, and the plot stocking origin was further classified by the size of the oak AR at preharvest. If oaks from various sizes of AR had survived, the plot was classed by the largest AR size. If the only oaks present at 15 montns in a plot had been first tagged after harvest, stocking was classed as originating from post-harvest germination of seed. By examining the time when seedlings were first tagged, it was possible to determine whether stocking from FHG had originated from acorns present before the harvest or from acorns of the first fall after harvest. If seedlings originating from both seed crops were present, plot stocking origin was classed as being from the earlier time.

Of the 185 stocked plots overall (38 percent milacre stocking). 40 percent (74) owed their stocking to AR seedlings less than 1 ft tall. and 32 percent (60) were stocked due to PHG. Only 6 percent (12) originated from preharvest trees taller than 3 ft. with stump sprouts comprising most of this (4 percent). Two-thirds of the PHG stocking (22 percent of the stocked plots) came from the acorn crop following harvest (second season). The acorn crop for most oaks on the site appeared to be heavy that fall.

The 38 percent milacre stocking for oaks at 15 months compared very closely to preharvest AR milacre and overstory basal area stocking levels. both at 39 percent, and was higher than the 30 percent of preharvest overstory stem density. At this early time, it is impossible to predict the number of these plots that were stocked at 15 months that will contribute to the overstory stratum 30-40 years later, when many surviving oaks will be producing acorns and available for timber utilization. For 91 percent of the stocked plots, the tallest oak was still less than 3 ft tall. Stump sprouts produced the tallest reproduction. with all plots stocked from sprouts having trees taller than 3 ft. However, this comprised ordy 4 percent of the stocked plots.

The finding that advance reproduction was important in determining oak reproduction was no surprise, for this is generally accepted as the key for upland oaks (Johnson 1993). However, analyses from upland stands have usually concluded that only large, well-established advance reproduction is dependable in contributing to the future stand (Loftis 1990, Sander 1972). For seedling heights, studies from the Missouri Ozarks for assessing adequacy of oak advance reproduction have used 1 ft (Sander and others 1984) or even 4.5 ft (Sander and others 1976) as minimums for adequacy. Using 1 ft as the minimum height, only 10 percent of the cak advance reproduction measured in these plots (table 2) would have qualified.

Additionally, although oaks originating from seeds after harvest have been reported important in some bottomland stands(Golden 1995. Loewenstein and Golden 1993) this source has generally been considered unreliable in upland stands (Loftis 1990). Although the stocking from seedlings that germinated after harvest was substantial on this site, their ability to survive and contribute to the future overstory is uncertain. PHG contributed strongly to early stocking, but the ability of these late-starting seedlings to survive as competing vegetation develops is questionable. Only 5 percent of the plots stocked by PHG had oaks more than 3 ft tall.

CONCLUSIONS

The presence of at least one oak taller than 6 inches prior to harvest was the factor most strongly related to post-harvest stocking. Topographic position was related to oak reproduction stocking, but this appeared to be due to the strong effect of topographic position on stocking of advance reproduction. Cutting treatment affected reproduction stocking also, with the DC treatment resulting in a post-harvest increase in stocking and the CC and SC treatments leading to declines. This was possibly due to higher logging-induced mortality in the CC and SC. and higher post-harvest germination in the DC treatment. Logging disturbance and residual logging slash both reduced post-harvest reproduction stocking of oaks, presumably through causing direct mortality of AR. Both small AR (less than 1 ft tall) and post-harvest germination contributed substantially to the 15-month milacre stocking. although the contribution of these to the future overstory is uncertain.

ACKNOWLEDGMENTS

Thesis part of an ongoing study being conducted on property owned and managed by Champion International Corporation. Champion International personnel have contributed significantly to the study and their support is gratefully acknowledged. This research project is partially supported with a grant from the USDA Forest Service.

REFERENCES

Beers T.W.; Dress, P.E.; Wensel, L.C. 1964. Aspect transformation in site productivity research. Journal of Forestry. 64: 691-692.

Dubois. M.R.; Stockman, J.L.; Golden, M.S. 1997. Silvicultural assessment of alternative harvesting treatments in north Alabama upland hardwood forests. In: Meyer. D.A., ed. 25 years of hardwood silvicullure: a look back and a look ahead: Proceedings of the twenty-fifth annual hardwood symposium: 1997 May 7-10; Cashiers, NC. Memphis, TN: National Hardwood Lumber Association: 113-l 22.

Golden, M.S. 1995. Establishment of oak regeneration in group selection openings in a river floodplain forest. in: Edwards, M. Boyd, comp. Proceedings of the eighth biennial southern silvicultural research conference; 1994 November 1-3; Auburn, AL. Gen. Tech. Rep. SRS-1. Asheville, NC: U.S. Department of Agriculture. Forest Service. Southern Research Station: 4 13-4 18

Hodgkins, E.J.; Golden, M.S.; Miller, W.F. 1979. Forest habitat regions and types on a photomorphic-physiographic basis: a guide to forest site classification in Alabama-Mississippi. South. Coop. Service Bull. 210. Auburn. AL: Auburn University. Alabama Agricultural Experiment Station. 64 p.

Hosmer, D.W.; Lemeshow. S. 1989. Applied logistic regression. New York: John Wiley.

Johnson, P.S. 1993. Sources of oak reproduction. In: Loftis, David L.; McGee, Charles E.. eds. Oak regeneration: serious problems, practical recommendations: Symposium proceedings; 1992 September 8-10; Knoxville, TN. Gen. Tech. Rep. SE-84. Asheville, NC: U.S. Department of Agriculture. Forest Service, Southeastern Forest Experiment Station: 112-l 3 1.

Kays, J.S.; Smith, D. Wm.; Zedaker, S.M. 1985. Season of harvest and site quality effects on hardwood regeneration in the Virginia Piedmont. In: Shoulders, Eugene, ed. Proceedings of the third biennial southern silvicultural research conference; 1984 November 7-8; Atlanta. Gen. Tech. Rep. SO-54. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 137-145.

Loewenstein, E.F.; Golden, M.S. 1993. Establishment of water oak is not dependent on advance reproduction. In: Edwards, M. Boyd, comp. Proceedings of the eighth biennial southern silvicultural research conference: 1994 November 1-3; Auburn, AL. Gen. Tech. Rep. SRS-1. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 443446.

Loftis, D.L. 1990. Predicting post-harvest performance of advance red oak reproduction in the Southern Appalachians. Forest Science. 36: 908-916.

McWilliams, W.H. 1992. Forest resources of Alabama. Resour. Bull. SO-170. New Orleans: U.S. Department of Agriculture. Forest Service. Southern Forest Experiment Station. 71 p.

Menard, S. 1995. Applied logistic regression analysis. Sage Univ. Pap. Series on Quant. Appl. in the Soc. Sci., 07-106. Thousand Oaks, CA: Sage Publications. 98 p.

Nagelkerke, N.J.D. 1991. A note on general determination of the coefficient of determination. Biometrika. 78: 691-692.

Olson, D.F. 1959. Site index curves for upland oak in the Southeast. Res. Note 125. Asheville, NC: U.S. Department of Agriculture, Forest Service. Southeastern Forest Experiment Station. 2 p.

Sander, LL. 1972. Size of advance reproduction: key to growth following harvest cutting. Res. Pap. NC-79. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 6 p.

Sander, LL.; Johnson, P.S.; Rogers, R. 1984. Evaluating oak advance reproduction in the Missouri Ozarks. Res. Pap. NC-251. St. Paul, MN: U.S. Department of Agriculture. Forest Service. North Central Forest Experiment Station. l6 p.

SAS Institute Inc. 1990a. SAS procedures guide. Version 6. 3rd ed. Cary, NC: SAS Institute Inc. 705 p.

SAS Institute Inc. 1990b. SAS/STAT users guide. Version 6.4'" ed. Cary, NC: SAS Institute Inc. 846 p. Vol. 2.

SAS Institute Inc. 1995. Logistic regression examples using the SAS system. Version 6. 1st ed. Cary, NC: SAS Institute inc. 163 p.

SAS Institute Inc. 1997. SAS/STAT software: changes and enhancements through release 6.12. Cat-y, NC: SAS Institute Inc. 1.167 p.

Smith, D. Wm. 1993. Oak regeneration: the scope of the problem. In: Loflis. David L.; McGee. Charies E., eds. Oak regeneration: serious problems, practical recommendations: Symposium proceedings; 1992 September 8-10; Knoxville, TN. Gen. Tech. Rep. SE-84. Asheville, NC: U.S. Department of Agriculture, Fc est Service. Southeastern Forest Experiment Station: 40-52.