OAK REGENERATION: FOUR YEARS AFTER THREE HARVESTING TREATMENTS IN A NORTH ALABAMA UPLAND HARDWOOD STAND

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Abstract-Fourth year regeneration of upland oaks (Quercus spp.) was compared within three harvesting treatments in the mountains of northern Alabama. Six four-acre experimental blocks were established on north facing slopes. Each of the three harvesting treatments (deferment cutting, strip clearcutting, and block clearcutting) was randomly assigned to two treatment blocks. Major oaks present were white oak (*Q. alba*), northern red oak (Q. rubra), and chestnut oak (*Q. prinus*). Densities and stocking levels of non-sprout origin non-overtopped oak reproduction were related to treatment, topographic position, and pre-harvest competition cover. The overall contribution of the non-sprout oak regeneration was low. Post harvest germination and advance reproduction contributed equally to the successful fourth year reproduction.

INTRODUCTION

Oak-Hickory forests cover approximately 35 percent (7.7 million acres) of Alabama's timberland with 65 percent of the Oak-Hickory forests found in north Alabama (McWilliams 1992). Upland hardwood stands have been long viewed as valuable. Some of their values can easily be associated with economics, such as the sale of timber or the lease of hunting rights. Unfortunately placing an economic value on aesthetics or wildlife benefits can be difficult. Regardless of the rationale, upland hardwood stands are important and warrant the attention of individuals interested in maintaining and managing these diverse values.

"Oak regeneration is a problem and the problem is widespread. Many of the problems can be solved by utilizing information that is already available, but there is a cost involved, which will have to be addressed by forest managers and forest landowners. Other problems with oak regeneration will require a major research commitment" (Smith 1993a).

In 1996, a permanent study was established in the mountains of northern Alabama to assess the stocking and growth of oak regeneration following three harvesting treatments: block clearcutting, strip clearcutting and deferment cutting. This paper reports on data taken after the fourth full growing season (Fall 2000). This approximates the end of the stand initiation stage, at which point an inference can be made as to the composition of the mature stand.

OBJECTIVES

Two main objectives have been developed for this study: 1) to determine which potential factors had an effect on fourth year post-harvest stand composition: and 2) to investigate which of the studied silvicultural treatments (block clearcutting, strip clearcutting, and deferment cutting) provided for the desired and adequate oak regeneration component. The overall goal of this ongoing study is to identify the influences upon oak regeneration at various times after harvest.

METHODS

Study Site

The site is located in the Sandstone Mountain Forest Habitat Region of northern Alabama on the southern Cumberland Plateau physiographic province (Hodgkins and others 1979). Major ridges typically run east to west. This tract is currently owned and managed by International Paper and is adjacent to the William B. Bankhead National Forest in Lawrence County, AL. Slopes range from five to sixty percent.

The study is located in an upland mixed hardwood forest on north facing slopes and ridge shoulders. Prior to harvest, overstory (trees larger than 5 inches dbh) density was 313 stems per acre with a total basal area of 118.3 square feet per acre (table 1). The stand was composed of a mixture of oak species (*Quercus spp.*), sugar maple (*Acer sacharum*), black tupelo (*Nyssa sylvatica*), American beech (*Fagus* grandifola), and hickories (*Carya* spp.).

Study Design

Six four-acre treatment blocks (400 by 440 feet) were established on north facing slopes. Each of the three harvesting treatments was randomly assigned to two of the experimental blocks. The block clearcutting treatment administered was a silvicultural clearcut; all stems greater than 1.5 inches dbh were cut. The strip clearcutting treatment harvested all stems greater than 1.5 inches dbh in alternating one-acre cut and uncut strips approximately 120

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Table 1-Pre-harvest overstory composition, basal area, and advance reproduction and composition of fourth year non-overtopped reproduction, oaks and other species

Fourth year Species	Pre Harvest: Overstory[a] Ft²/acre	Pre Harvest: Overstory[a] Stems/acre	Pre Harvest: Advance reproduction[b] Stems/acre	Non-overtopped reproduction[c] Stems/acre
L. tulipifera	9.7	7	2	882
A. saccharum	4.3	8	1229	492
Non-Comm	1.1	4	608	460
Other-Comm	10.7	16	182	404
N. sylvatica	4.4	9	281	363
A. rubrum	2.2	4	408	223
Fraxinus sp.	1.8	4	50	153
Carya sp.	29.0	36	177	131
Quercus sp.	46.6	40	212	112
F. grandifolia	8.5	10	196	52
Total	118.3	138	3345	3272
Q. alba	12.7	13	18	38
Q. rubra	8.5	6	113	32
Q. prinus	22.0	20	57	30
Other oaks[d]	3.4	1	24	12
Total	46.6	40	212	112

[a] Includes canopy trees greater than 5 inches dbh in the harvested areas only.
[b] AR greater than 1 foot tall and less than 1.5 inches dbh.
[c] Represents the 498 plots in the harvested areas.
[d] Mainly black (Q. *velutina*), southern red (Q. *falcata*), and scarlet oaks (*Q. coccinea*).

feet wide and roughly oriented with the contours. The deferment cuts were harvested in a similar fashion, except that a basal area of approximately 25 square feet per acre was left. The reserve trees were selected and marked based upon the criteria that they were evenly spaced, good quality co-dominant oaks (where possible), and more than likely to survive throughout the rotation. Where oaks were not present, other species meeting the criteria were marked and used as reserve trees.

Pre-Harvest Measurements

In 1996, prior to harvest the six treatment blocks were sampled by three 6.6-foot wide permanent belt transects equally spaced and running down slope. Each belt transect includes 67 milacre plots and makes up the center line of a 33-foot wide segment running east to west. This grid system runs the entire length of the block. Each odd numbered plot along the center line was established with metal conduit pipe marking the top corners and the lower boundaries were marked with pin flags. Each milacre plot was divided into quadrants to facilitate the re-measurement and successive counting of reproduction. Oak seedlings were tagged and measured in all quadrants. Counts of all non-oak tree reproduction, by species and size class, were obtained in each measurement plot at each inventory. Size classes were recorded as 1) less than 6 inches, 2) 6-12 inches, 3) 12-36 inches, 4) greater than 36 inches with a diameter less than 1.5 inches, or 5) with a dbh greater than 1.5 inches. Vegetative competition cover and site characteristics were also obtained. Ocular measurements for woody vegetative competition were made to the nearest 5 percent increment and later combined into classes of 0-10, 11-30, 31-70, and 71-100 percent. Overstory data was obtained for the entire one-half chain strip, which provided a 25 percent sample of the treatment blocks. Greater detail on the pre-harvest measurements can be found in Golden and others (1999).

Post-Harvest Measurements

Following the harvest in fall 1996, site and soil impacts were assessed and recorded for each measurement plot. Another detailed survey was conducted using the same procedures as the pre-harvest measurement. Fifteen months (Fall 1997) after harvest the stand was again re-entered and the plots re-located and re-measured, but these are not reported in this paper.

Fourth Year Measurements

In fall 2000, a fourth year re-measurement was conducted. Tagged oak reproduction was re-measured and new reproduction recorded. Non-oak reproduction was inventoried by species and competitive position. Competitive position was recorded as free to grow (FTG), crowded but not overtopped (CR), or overtopped (0). These classes were modified from Smith (1986).

Data Analyses

The data analyses reported in this paper are per acre and stocking comparisons within categories of treatment, topography, and pre-harvest competition cover. The values are derived from the tagged reproduction of non-sprout origin in non-overtopped competitive positions. Sprouts from stems larger than 1.5 inches dbh are not included. Since all oak seedlings were tagged and measured prior to harvest and at each subsequent measurement, a determination of origin could be made. Those seedlings present prior to harvest of any size were classified as advance reproduction (AR) and those seedlings germinating thereafter were classified as post harvest germination (PHG). All plots in the deferment cuts and block clearcuts were used. In the strip clearcuts, only plots in the harvested areas were used. All plots in all the treatments that were used totaled 498. Per acre values for non-oak reproduction were obtained from the non-tagged inventory.

All of the data analyses were accomplished using the Statistical Analysis System (SAS) version 6.12. Simple descriptive statistics were obtained using Proc Means and Proc Freq (SAS Institute Inc 1990).

RESULTS

Pre-Harvest Overstory Composition

The initial stand had 138 stems per acre, 30 percent oak (table 1). The basal area of canopy trees (5 inches and larger dbh) was 118.3 square feet per acre, with oaks the largest component at 39 percent. Of the oaks, chestnut oak (Q. *prinus*) was the most abundant with 50 percent of the total and a basal area of 22 square feet per acre. White oak (Q. *alba*) and northern red oak (Q. *rubra)* also comprised a significant portion of the pre-harvest stand. Remaining oaks were grouped together and classified as other oaks. Most of the oaks were 65-70 years old. From height and age measurements, oak site index was estimated as 70-80 feet (base age 50) on the ridge and upper slopes and 85-100 feet on the middle and lower slopes. Oak numbers were the highest on ridge shoulders and declined down the slope.

The pre-harvest subcanopy density (1.5 - 5 inches dbh) totaled 176 stems per acre. The most abundant species were sugar maple and American beech, which comprised 21 and 18 percent of the stems respectively. Most of the sugar maple and American beech were found on the lower slopes where they dominated the understory. The oaks averaged only 5 stems per acre. These were mainly chestnut oaks located on the ridge shoulders. The most abundant under. story species was American hornbeam (*Ostrya virginiana),* at 30 stems per acre (Golden and others 1999).

Advance reproduction

Large advance reproduction (AR), greater than 1 foot tall and less than 1.5 inches dbh, totaled 3,345 stems per acre (table 1). The oak component was low, making up 6 percent (212 stems per acre) of the total large AR. Northern red oak (113 stems per acre) was the most abundant, followed by chestnut oak (57 stems per acre) and white oak (18 stems per acre). Of the non-oak species, sugar maple was the most abundant with 1,229 stems per acre (37 percent), then non-commercial species with 608 stems per acre (18 percent), followed by red maple with 408 stems per acre (12 percent). The least abundant species was yellow poplar (*Liriodendron tulipifera*), with 2 stems per acre.

Fourth Year Non-Overtopped Composition

Overall densities for all species after four years are shown in table 1. Fourth year non-overtopped reproduction totaled 3,272 stems per acre, with the oaks comprising only 3 percent (112 stems per acre). White oak (38 stems per acre)

Table 2-Fourth year composition of non-overtopped oak reproduction in the harvested areas, within treatment, topographic location, and competition class

Factor	Plots	*Q. alba*	*Q. rubra*	*Q.prinus*	Other oaks	All oaks
		........Stems per acre........				
Cuttina Treatments						
Deferment cut	200	90	60	65	15	230
Strip clearcut	100	0	20	20	10	50
Block clearcut	198	5	10	0	10	25
Topographic Position						
Upper / ridge	121	140	74	74	25	314
Mid	192	5	10	21	5	42
Lower	174	6	29	11	11	57
Pre-Harvest Competition Cover						
O-10 pct	156	109	58	64	19	250
1 1-30 pct	253	8	16	20	8	51
31-70 pct	85	0	35	0	12	47
71-100 pct	4	0	0	0	0	0

was the most abundant, followed by nor-them red oak (32 stems per acre) and chestnut oak (30 stems per acre). Of the non-oak species the most abundant was yellow poplar, with 882 stems per acre (27 percent), then sugar maple with 492 stems per acre (15 percent). No other tree species was less abundant than the oak reproduction; American beech had 52 stems per acre, which is higher than any individual oak species count.

Among the harvesting treatments, the deferment cut had the most abundant total oak reproduction, 230 stems per acre (table 2). Of the three major oak species within the deferment cuts, white oak had the highest density (90 stems per acre) with no noticeable difference between northern red oak and chestnut oak. Non-overtopped oaks were scarce in the strip cuts and the block clearcuts (50 and 25 stems per acre respectively), with no obvious differences among major species. Among topographic classes, the upper slope and ridge shoulder positions had the highest non-overtopped oak densities (314 stems per acre). White oak was most abundant (140 stems per acre) on these positions, with no noticeable differences between chestnut and northern red oak. One obvious difference in the lower slope positions was the higher density of northern red oak (29 stems per acre). For the classification by competing vegetative competition cover, fourth year non-overtopped oak reproduction was highest in the O-l 0 percent competition class (250 stems per acre) and declined drastically with increased competition cover. White oak had the highest density (109 stems per acre) with no clear distinction between chestnut oak and northern red oak. In the 31-70 percent cover class, northern red oak had 35 stems per acre and white oak and chestnut oak were non-existent. No non-overtopped oak reproduction was established in the 71-100 percent cover class.

Fourth Year Non-Overtopped Stocking of Oaks

Stocking was defined on a plot-by-plot basis. Any plot that contained at least one oak stem in a non-overtopped competitive position was considered stocked. The overall stocking of oak reproduction was very low, only 9 percent (table 3). This extremely low level of stocking is an indication of the challenges faced by foresters and forest managers who want to perpetuate oaks as a major component of future stands.

Oak stocking was highest in the deferment cuts at 18 percent, and was only 5 and 3 percent in the strip and block clearcutting treatments respectively. Oak stocking was very low on all topographic positions, but highest on the ridge shoulders and upper slopes (22 percent). The middle and lower slope locations were stocked at only 4 and 6 percent respectively. There was no noticeable difference among the three major species within treatment and topographic position. Fourth year non-overtopped oak stocking was low at every pre-harvest competition level. The O-l 0 percent class had the highest stocking (15 percent) and the 71-100 percent class was un-stocked. The 1 l-30 and 31-70 percent classes were equally stocked at 6 percent. One noticeable difference among the three major species in the 31 -70 percent class was that chestnut oak was stocked at 5 percent while white oak and northern red oak were unstocked.

Origins of Fourth Year Non-Overtopped Oaks

Successful reproduction for this study is any stem that survived to the fourth year measurements and is in a non-overtopped competitive position. This section focuses on success related to origin. Fourth year non-overtopped reproduction was determined to have originated either from any size advance reproduction (AR) or from post harvest germination (PHG). Numbers of successful oak reproduction were very small. Of these small numbers, more than 50 percent of the non-overtopped overall oak reproduction originated from PHG (58 stems per acre). AR origin repro-

Table d-fourth year stocking of non-overtopped oak reproduction in the harvested areas, within treatment, topography, and competition classes

Factor	Plots	*Q.alba*	*Q. rubra*	*Q.prinus*	Other oaks	All oaks
		Percent stocked plots				
Cutting Treatment						
Deferment cut	200	5	6	6	2	18
Strip clearcut	100	0	2	2	1	5
Block clearcut	198	1	0	1	1	3
Topographic Position						
Upper / ridge	121	7	7	7	2	22
Mid	192	1	2	1	1	4
Lower	174	1	1	3	1	6
Pre-Harvest Competition Cover						
o-1 0 pct	156	5	3	6	2	15
1 1-30 pct	253	1	2	3	1	6
31-70 pct	85	0	0	5	1	6
71-100 pct	4	0	0	0	0	0
Overall	498	2	3	3	1	9

Table 4—Origins of fourth year non-overtopped oak reproduction in the harvested areas, within treatment, topography, and competition class

Factor	Plots	*Q. alba* AR	*Q. alba* PHG	*Q. rubra* AR	*Q. rubra* PHG	*Q. prinus* AR	*Q. prinus* PHG	Other oaks AR	Other oaks PHG	All oaks AR	All oaks PHG
		Stems per acre									
Cutting Treatment											
Deferment cut	200	35	55	15	45	45	20	10	5	105	125
Strip clearcut	100	0	0	10	10	10	10	10	0	30	20
Block clearcut	198	5	0	5	5	0	0	5	5	15	10
Topographic Position											
Upper / ridge	121	50	91	17	58	41	33	17	8	124	190
Mid	192	5	0	5	0	16	5	0	5	31	10
Lower	174	6	0	6	23	11	0	11	0	34	23
Pre-Harvest Competition Cover											
O-10 pct	156	38	71	13	19	45	19	13	6	109	115
1 l-30 pct	253	8	0	8	20	12	8	4	4	32	32
31-70 pc	85	0	0	12	35	0	0	12	0	24	35
71-100 pct	4	0	0	0	0	0	0	0	0	0	0
Overall	498	16	22	10	22	20	10	8	4	54	58

duction totaled only 54 stems per acre (table 4). The major oaks, white oak, northern red oak, and chestnut oak, originated at 58, 69, and 67 percent respectively, from PHG. Fourth-year oak stems that originated from stump sprouting are not included here, but will be addresses in another paper.

There was no clear difference in origin among harvesting methods for non-overtopped reproduction of all oaks. However, for the deferment cutting, white oak and northern red oak reproduction originated mainly from PHG (61 and 75 percent respectively). In contrast, 69 percent of the chestnut oak originated as AR. There was no notable difference among species within the strip clearcutting method. One clear difference in the block clearcutting treatments was that white oak originated 100 percent from AR. Among topographic positions, there was a notable difference in the origins of overall successful stems. The majority of all stems in the upper and ridge shoulder positions originated from PHG (61 percent), while mid slope (76 percent) and lower slope (60 percent) locations had most of the successful stems originating from AR. Among species, obvious differences among topographic positions existed. In the upper slope and ridge shoulder positions, white oak (65 percent) and northern red oak (77 percent) mainly originated from PHG, while chestnut oak (55 percent) originated from AR. In the mid slope positions all major oak species mainly originated from AR (white oak 100 percent, northern red oak 100 percent and chestnut oak 76 percent). The lower slope locations had 100 percent of the white oak and chestnut oak originating from AR, while the northern red oak (79 percent) originated mostly from PHG. There was no obvious difference in the origin of fourth year non-overtopped reproduction among pre-harvest competition cover classes for the overall successful stems. However, within competition classes there was a noticeable difference among major oak species. Within the O-10 percent competition class, the origin of successful white oak and northern red oak reproduction was noticeably higher from PHG (59 and 65 percent respectively). Conversely, the majority of chestnut oak reproduction came from AR (70 percent). Origins for white oak and chestnut oak in the 11-30 percent class are mainly from AR (100 and 60 percent respectively). In contrast, the higher percentage of northern red oak reproduction came from PHG (71 percent). The only species that had obvious differences in the 31-70 percent class was northern red oak, with 74 percent of the successful stems coming from PHG.

DISCUSSION

At only 112 non-overtopped stems per acre and 9 percent plot stocking, the oak component in the fourth year reproduction is severely reduced from that of the pre-harvest stand. It is generally accepted that large advance reproduction is necessary for successful regeneration of oaks (Sander and others 1984, Johnson 1993). It is also well established that obtaining adequate oak reproduction is more difficult on high quality sites, those greater than 70-foot site index (Smith 1993b). Overall this site presented problems in both areas. In the pre-harvest stand oak AR larger than 1 foot tall was quite low, only 212 stems per acre, and was lowest on the middle and lower topographic positions (Golden and others 1999). Site indexes were higher than 70 feet even on the upper slopes and ridge shoulders and exceeded 85 feet on the middle and lower slopes. Fourth year non-ovetiopped oak stocking and densities were low on all topographic positions, but highest on ridge shoulders and upper slope positions, which were relatively poorer, drier sites.

Fourth year non-overtopped oak densities and stocking declined in the order: deferment cutting, strip clearcutting, and then block clearcutting. A possible reason for this is the increase in logging disturbance in that same order (Dubois and others 1997, Golden and others 1999). Another possible explanation is the amount of canopy left. The impacts posed by the remaining canopy cover might be similar to a nurse tree effect or a shading effect. The leave trees in the deferment cut and edge trees in the uncut strips allowed the oaks to grow in the lightly shaded areas. Other faster growing species would have out competed the oaks if the canopy were completely removed. The origins of the fourth year non-overtopped white oak and northern red oak in the deferment cuts are mainly from PHG. Conversely, the major origin of chestnut oaks in the deferment cut was from AR. Chestnut oak can persist for many years in the understory on poorer quality sites and can react quickly to release (Burns and Honkala 1990). The higher percent of successful oak reproduction that came from PHG was surprising. However, it is possibly a reflection of the overall small AR numbers. Where the higher numbers of PHG were observed, the deferment trees remained and provided seed. In addition, white oak seed germinates in the fall and its acorns have a 50-90 percent germination capacity (Burns and Honkala 1990).

By the fourth year, a large amount of oak reproduction was overtopped by competing vegetation therefore not considered "successful". Sixty seven percent of the plots had pre-harvest competition cover exceeding 10 percent. Under this severe competition the slower growing oaks tend to fall behind. Once the canopy was fully removed, the faster growing species were able to out compete the majority of oak reproduction, overtopping it by age four.

CONCLUSIONS

Oak densities (112 stems per acre) and stocking levels (9 percent) were very low for all factors affecting fourth year non-overtopped reproduction from non-sprout origins. Oak densities and stocking percentages were highest in the deferment cutting treatments as compared to the strip and block clearcutting treatments. Higher numbers and stocking levels were also found at the upper slope and ridge shoulder positions and declined substantially on the middle and lower slope locations. As pre-harvest competition levels increased oak stocking and densities decreased. For all oaks approximately 50 percent of the fourth year non-overtopped reproduction originated from post harvest germination. The majority of white oak and northern red oak originated as post harvest germination. However, the majority of chestnut oak stems originated from advance reproduction. The contribution of the non-sprout oak regeneration to the future stand will be low. Reproduction from sprout origin will be assessed in a subsequent paper.

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