DEVELOPMENT OF OAK REGENERATION NINE YEARS AFTER SHELTERWOOD CUTTING AND CLEARCUTTING ON THE COASTAL PLAIN OF WEST TENNESSEE

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Abstract—Quantity, size and species composition of hardwood reproduction were compared in oak-hickory (*Quercus* spp.-*Carya* spp.) stands following clearcutting and two intensities of shelterwood cutting (leaving 40 and 60 ft^2 of basal area) on Chickasaw State Forest in the Coastal Plain of west Tennessee. Measurements were taken prior to the timber harvest and at 3-year intervals for 9 years after the harvest. The clearcut treatment had the greatest number of oaks per acre, while the shelterwood treatments had a greater proportion of oaks compared to total stems. After 9 years, the total number of stems in each treatment decreased while the percentage of oaks greater than 1-foot tall increased. The development of oak regeneration and the resulting stand dynamics are discussed based on these 9-year regeneration data.

INTRODUCTION

Concerns about the aesthetics of clearcuts have caused a renewed interest in the shelterwood method of regeneration within the even-aged silvicultural system for regenerating oaks. Several authors have prescribed guidelines for regenerating oaks using the shelterwood method (Hannah 1987, Loftis 1983, Loftis 1990, Sander 1979, Sander and Graney 1993). However, Smith (1981) states that “many shelterwood recommendations contain the statement that details are uncertain and more research is needed.” The complexity and variability of natural hardwood stands with their multitude of species, differential growth rates, varying site productivities, different stand structures and conditions, silvical characteristics, past disturbances, and previous management regimes are not amenable to a single prescription.

In theory, the shelterwood method should create the microenvironment required by oaks for successful establishment and nurturing early seedling growth. In practice, a fine line exists on how much overstory to leave in promoting oak regeneration. Heavy shelterwood cuts favor the development of fast-growing intolerant species such as yellow-poplar (*Liriodendron tulipifera* L.) rather than oaks. Lighter cuts may encourage more tolerant, less desirable species such as maples (*Acer* spp.), beech (*Fagus grandifolia* Ehrh.), and elms (*Ulmus* spp.) at the expense of oaks (Clatterbuck and Meadows 1993, Hodges 1989).

This study provides a 9-year history of the development of regeneration following three overstory treatments: clearcutting and two intensities of shelterwood cuts leaving 40 and 60 ft^2 of residual basal area. The objective of the research is to compare the regeneration dynamics between treatments in size, number and species composition. Although this is an unreplicated case study, it provides information about the oak regeneration process.

STUDY AREA

The study was conducted on a 46-acre upland hardwood stand at Chickasaw State Forest (CSF) in Hardeman County, TN, located approximately 20 miles south of Jackson in southwestern Tennessee and managed by the Tennessee Department of Agriculture, Division of Forestry. Soils are Typic Hapludults (Smithdale series), formed in loamy Coastal Plain deposits, severely eroded and moderately drained (Ditzler and others 1994). The study area is on a convex, moderately steep (8 to 20 percent), strongly dissected slope. Annual precipitation averages 50 inches, usually evenly distributed in all seasons. Average site index (base age 50) for upland oaks ranges from 75 to 80 feet (Schnur 1937).

The CSF was part of the federal Resettlement Administration purchase of land during the 1930’s. The area occupied by this study was formerly a portion of two farms. Old fences indicate that all or part of the area was grazed, cultivated, or both. Fire scars on many of the trees attest to burning before state acquisition.

Ages of the dominant and co-dominant trees range from 60 to 90 years. The predominant species are oaks: white (*Q. alba* L.), northern red (*Q. rubra* L.), scarlet (*Q. coccinea* Muenchh.), black (*Q. velutina* Lam.), and southern red (*Q. falcata* Michx.). Other species include hickories, sweetgum (*Liquidambar styraciflua* L.), yellow-poplar, American beech, dogwood (*Cornus florida* L.) and blackgum (*Nyssa sylvatica* Marsh.).

METHODS

The 46-acre stand was divided into four subunits of approximately equal size, each of which represented the stand as a whole with regard to site quality, aspect, position on slope, and slope gradient. Four treatments were imposed, one for each subunit: clearcut and three shelterwood cuts leaving 40, 50 and 60 ft^2 of residual basal area respectively in dominant and codominant trees of desirable species.

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Table 1—Treatment size, number of plots, initial stocking and summary of timber harvest volumes in 1982 at Chickasaw State Forest, Tennessee

Treatment	Area	Plots	Initial stocking	Average total volume cut	Volume/acre cut
	Acres	*#*	*Ft^2/acre*	*Board feet*[a]	*Bd.ft./acre*
Clearcut	10	23	75	110,700	11,070
40-ft^2 BA	12	23	85	34,780	2,900
60-ft^2 BA	12	26	80	15,200	1,270

[a] International ¼ inch log rule.

Before the actual timber harvest in 1982, 97 permanent, 0.1-acre plots were established over the entire 46 acres (Table 1). Plots were spaced 2.2 chains apart on parallel lines 2.2 chains apart. All stems 1.5 inches dbh and larger were recorded by species, diameter, and merchantable height (height to base of crown). Cut and leave trees were tallied for each plot. Regeneration was measured on a 0.02 acre circular plot at the plot center of the 0.1 acre plot. Height of all woody stems 1 foot and taller to 1.5 inches dbh were counted by species. All woody stems less than 1 foot were also recorded by species.

For the clearcut, all trees greater than 12 inches in diameter at breast height (dbh; 4.5 feet) were commercially harvested. The remaining stems over 1.5 inches dbh were cut and left on the site. Leave trees for the shelterwood cut were selected on the basis of species, form, vigor, and crown position class. Oaks were favored as leave trees, particularly white, northern red, southern red, and black oaks. Hickories were also favored, but were secondary to the oaks. Species such as yellow-poplar, sweetgum, American beech, and blackgum were not favored. However, trees of these species were left when necessary to maintain the required residual basal area. Midstory and understory stems in the shelterwood treatments were not intentionally cut, but may have been disturbed during the removal of overstory trees during the commercial harvest. Volumes harvested for each treatment area are presented in Table 1.

Regeneration data were collected in 1982 before the harvest and at 3-year intervals: 1985, 1988 and 1991. The data for the shelterwood cut with 50 ft^2 of residual basal area are not presented in this paper.

RESULTS

Total Stems per Acre

The clearcut unit had the greatest number of stems per acre, both less than and greater than 1-foot tall, at the time of the harvest (Table 2). Nine years later, the clearcut treatment with more than 4,700 stems/acre, increased by three times the stems over 1-foot tall, while the amount of reproduction less than 1 foot in height decreased.

Table 2—Reproduction present in three treatment areas before and 9 years after harvest, Chickasaw State Forest, Tennessee

Treatment	1982 ≤1 ft.	1982 >1 ft.	1991 ≤1 ft.	1991 >1 ft.
	----------------	*Stems/acre*	----------------	
Clearcut	4,845	1,537	2,974	4,783
40-ft^2 BA	3,193	964	5,068	2,011
60-ft^2 BA	3,216	986	3,408	657

Both shelterwood treatments had fewer stems than the clearcut treatment in 1982. The number of stems less than 1 foot in height increased for the 40 ft^2 of residual basal area (BA) treatment and remained essentially the same for the 60-ft^2 BA treatment. The total number of stems greater than 1-foot tall was approximately 2,000 stems/acre, doubling in the 9 years following the harvest in the 40-ft^2 BA treatment, but decreased from 986 to 657 for the 60-ft^2 BA treatment.

The total number of stems per acre greater than one foot in height increased dramatically between the initial measurement in 1982 to the next measurement in 1985 for all three treatments (Figure 1). The amount of reproduction decreased progressively in the clearcut and the 60-ft^2 BA shelterwood treatments during the next two measurement periods in 1988 and 1991. The 40-ft^2 BA treatment continued to increase to a measured high point in 1988, then decreased.

Species Composition

For all three treatments, the other species category, primarily of shade-tolerant species such as red maple (*A. rubrum* L.), sourwood (*Oxydendrum arboreum* (L.) DC.), blackgum, dogwood, serviceberry (*Amelanchier arborea* (Michx.f.) Fern.), sassafras (*Sassafras albidum* (Nutt.) Nees), hophornbeam (*Ostrya virginiana* (Mill.) K. Koch), and the intolerant black cherry (*Prunus serotina* Ehrh.),

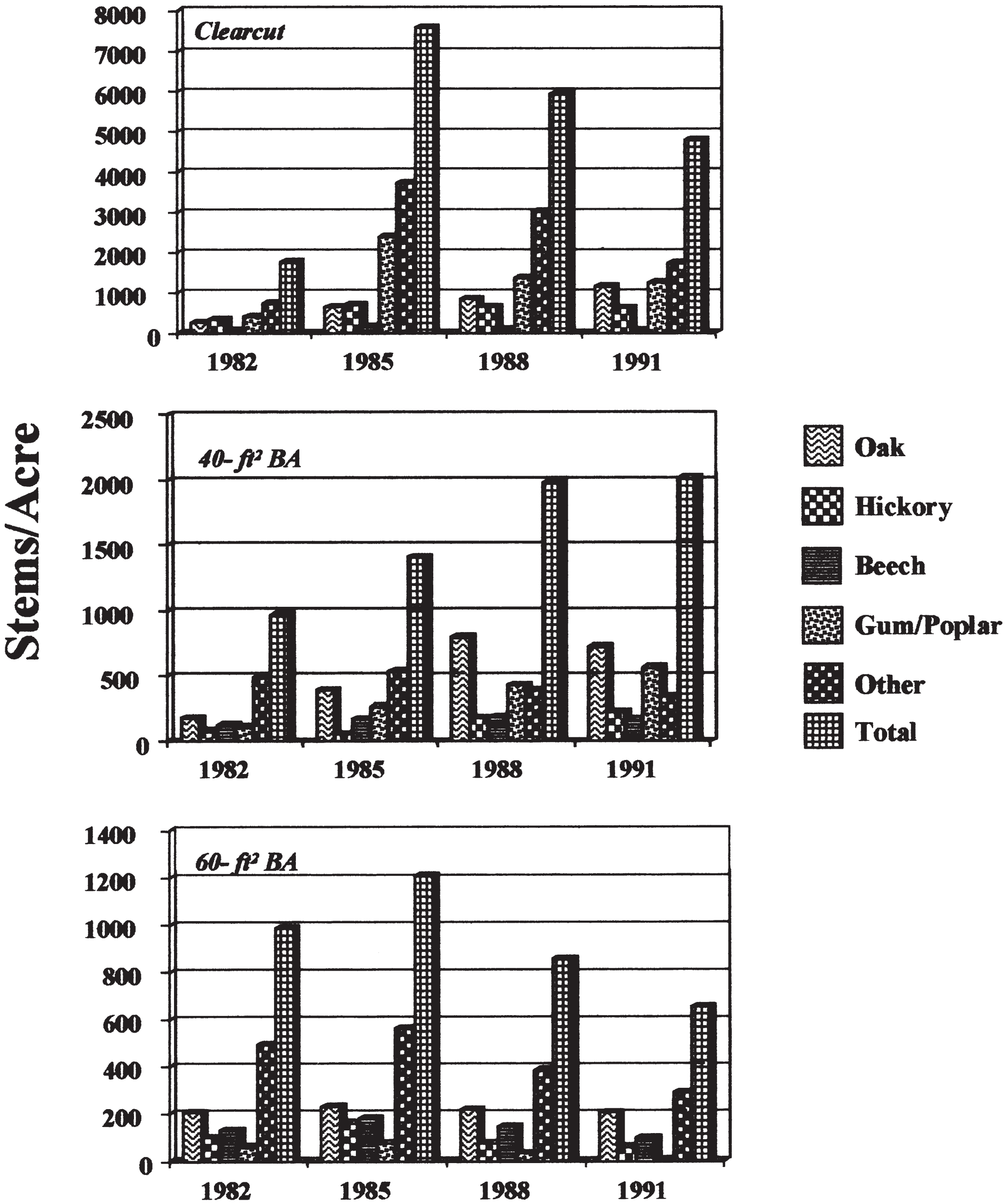

Figure 1—Stems per acre of reproduction greater than 1-foot tall for each species group by the clearcut and two shelterwood treatments for four measurements from 1982-1991, Chickasaw State Forest, Tennessee.

composed the majority of the reproduction greater than 1-foot tall before the harvest (Table 3). Oak species ranged from 14 to 21 percent of the stems, hickory from 8 to 18 percent, beech 3 to 13 percent and gum/poplar 6 to 23 percent. After 9 years, the percentage of oaks increased for every treatment. The gum/poplar percentage component increased for the clearcut and the 40-ft^2 BA treatment, but decreased for the 60-ft^2 BA treatment. Hickory remained steady after 9 years for both shelterwood treatments, but decreased for the clearcut treatment. Beech was a minor component in the clearcut treatment, but maintained or increased its presence in the shelterwood treatments. After 9 years, the other species category was still prominent in the clearcut and the 60-ft^2 BA shelterwood treatments, but decreased by more than half in the 40-ft^2 BA treatment.

The change in the amount of reproduction greater than 1 foot in height by species and by treatment for each

Table 3—Species composition of stems greater than 1 foot in height before and 9 years after timber harvest by treatment, Chickasaw State Forest, Tennessee

	1982			1991		
Species	Clearcut	40-ft^2 BA	60-ft^2 BA	Clearcut	40-ft^2 BA	60-ft^2 BA
	Percent			*Percent*		
Oaks[a]	14	18	21	24	36	31
Hickories	18	8	10	13	11	9
Beech	3	13	13	1	8	15
Gum/poplar[b]	23	11	6	26	28	1
Other[c]	42	50	50	36	17	44

[a] White, black, northern red, southern red, scarlet oaks.
[b] Yellow-poplar and sweetgum.
[c] Red maple, blackgum, black cherry, sassafras, dogwood, elms, sourwood, serviceberry, hophornbeam.

measurement period is shown in Figure 1. The number of stems per acre for each species category increased for each treatment from 1982 to 1985 except for the hickory component in the 40-ft^2 BA treatment that decreased slightly. The amount of reproduction for the gum/poplar and other species components decreased from 1985 to 1991, the oak component increased, and the hickory component remained essentially the same. Beech was not a significant species in the clearcut treatment.

In contrast, for the 40-ft^2 BA shelterwood treatment, the number of stems per acre for oaks increased from 1982 to 1988 and decreased slightly in 1991 (Figure 1). Other species increased initially, then progressively decreased in 1988 and 1991. Gum/poplar increased steadily from 106 stems/acre in 1982 to 563 stems/acre in 1991. Beech remained between 125 and 185 stems/acre for the duration of the study. Hickory slowly increased from 54 stems/acre in 1985 to 221 stems/acre in 1991.

The amount of reproduction per acre increased for each species from 1982 to 1985 in the 60-ft^2 BA treatment (Figure 1). The number of stems for each species decreased slowly after 1985. The gum/poplar component had the fewest number of stems of any species category.

Height Growth

The initial mean height measurements in 1982 for each species were similar for each of the treatment areas (Table 4). Heights for the 9 years from 1982 to 1991 increased the most in the clearcut treatment with other species (primarily dogwood and blackgum) and gum/poplar as the tallest components, followed by oaks and hickories.

Table 4—Mean heights of regeneration greater than 1 foot in height before and 9 years after harvest by treatment, Chickasaw State Forest, Tennessee

	1982			1991		
Species	Clearcut	40 ft^2 BA	60 ft^2 BA	Clearcut	40 ft^2 BA	60 ft^2 BA
	Feet			*Feet (range)*		
Oaks[a]	1.8	2.0	2.0	6.8 (1-17)	2.4 (1-6)	1.8 (1-8)
Hickories	4.2	3.1	2.8	4.0 (2-15)	3.2 (1-4)	2.3 (1-5)
Beech	4.6	5.0	3.9	—	5.8 (1-11)	3.9 (1-7)
Gum/poplar[b]	2.6	1.9	2.7	9.2 (2-15)	5.2 (1-10)	—
Other[c]	4.2	3.4	3.6	8.5 (2-22)	4.6 (1-10)	4.5 (1-14)

[a] White, black, northern red, southern red, scarlet oaks.
[b] Yellow-poplar and sweetgum.
[c] Red maple, blackgum, black cherry, sassafras, dogwood, elms, sourwood, serviceberry, hophornbeam.

Height growth was less for each species in the 40-ft^2 BA shelterwood treatment. Beech, gum/poplar, and other species were the tallest reproduction (Table 4). Hickory and oaks remained the same with little increase. The 60-ft^2 BA treatment had the least height growth. The mean height for all species decreased. Other species and the beech components were the most prominent reproduction. Gum/poplar was not a component in this treatment.

DISCUSSION

Clearcut

The total number of stems per acre increased from more than 1,500 in 1982 to more than 7,500 stems/acre in 1985, a five-fold increase (Figure 1). Most of this increase occurred in the gum/poplar component and sprouting from severed stems between 1.5 to 12 inches dbh in the other species category (dogwood, red maple, and blackgum). Clearcutting tends to initially favor the establishment and growth of shade-intolerant, fast-growing, light-seeded species such as yellow-poplar and sweetgum and sprouting stems with established root systems. The number of stems decreased from the 1985 measurement through the 1988 and 1991 measurements indicating that the site was fully-occupied and that a sorting of stems was occurring. The larger, more competitive stems were beginning to express dominance to form the upper canopy, while the less competitive stems were being relegated to the subcanopy or dying. The poplar/gum component was the most aggressive and tallest species in the overstory with the mostly shade-tolerant, other species category beginning to slip into the lower canopy. The number of oaks per acre increased steadily during each measurement period from less than 250 in 1982 to almost 1,150 stems in 1991 (Figure 1), but their mean height was shorter than the gum/poplar component (Table 4).

40-Ft^2 Basal Area

Compared to the clearcut treatment with more than 7,500 stems/acre at its peak in 1985, the highest amount of total reproduction per acre for the 40-ft^2 basal area treatment was at just over 2,000 stems/acre in 1991 (Figure 1). The 40-ft^2 per acre residual basal area cut provided space and sunlight to favor growth of species present in the lower canopy layers. The rate of increase for the total number of stems per acres decreased between the 1988 and 1991 measurement periods, indicating the gaps in the upper canopy were beginning to close, thus limiting the amount and intensity of sunlight received by lower canopy stems. The proportion of oaks and gum/poplar increased during the measurement periods for this shelterwood cut, while the other species category decreased after a peak in 1985. However, mean heights for oaks were substantially less than those of gum/poplar, beech and other species (Table 4).

60-Ft^2 Basal Area

The total number of stems per acre for the 60-Ft^2 BA treatment increased from the initial measurement in 1982 to a peak in 1985, then decreased through 1991 (Figure 1). Compared to the clearcut and 40-ft^2 BA treatments with maximums of approximately 7,500 and 2,000 stems/acre respectively, the 60-ft^2 BA reached a peak of slightly more than 1,200 stems in 1985. This shelterwood treatment had fewer trees cut in the overstory (or more trees retained) and canopy gaps were smaller allowing the canopy to close more quickly than the 40-ft^2 BA treatment, thus limiting continued growth and development of reproduction. The 60-ft^2 BA treatment after 9 years favored the development of shade-tolerant species in the understory such as beech, red maple, blackgum, dogwood and elms. The gum/poplar component averaged 7 stems per acre and heights less than 1 foot after 9 years. Oaks were present at 200+ stems/acre, but their mean heights were less than 2 feet after 9 years. Mean heights for all species categories for the 60-ft^2 BA treatment were greatly diminished compared to the other treatments.

Oak Regeneration

Oaks are present in different numbers and proportions for each treatment (Table 5). The clearcut treatment has the greatest number and size of oaks (Table 4), but the lowest proportion of stems of the three treatments. Most mature oak stands did not start as fully-stocked stands. Usually oaks are a component of mixed stands in their infancy; during stand development they emerge as the dominant or codominant species (Clatterbuck and Hodges 1988; Oliver 1980a). During the stand initiation stage (Oliver 1980b), oaks are present, but often are inconspicuous in the jungle of woody and non-woody vegetation found after clearcutting. However, some oak stems will persist and stratify above other vegetation forming a dominant canopy. Research in other areas suggest as few as 50 to 100 well-spaced oak stems per acre are needed, if those oaks are assured of becoming upper canopy trees (Clatterbuck and Hodges 1988, Oliver 1980a).

Although this study follows for 9 years the development of oak regeneration in relation to other species, the research is inconclusive whether the oaks present will become dominant or codominant trees. The data indicate that even though the oaks are smaller, on the average than other species, there are individuals (Table 4) that will be dominant with time. However, the fast growth of yellow-poplar will surpass many of the oaks (O'Hara 1986). The question then remains how many oaks are needed and how many oaks will actually succeed to become mature trees.

Table 5—Oak regeneration greater than 1-foot tall by treatment in 1991, Chickasaw State Forest, Tennessee

	Stems/acre	Proportion of total stems
	Number	*Percent*
Clearcut	1,128	24
40 ft^2 BA	680	36
60 ft^2 BA	188	31

With the 40-ft^2 BA shelterwood cutting, most species in the lower canopy benefited from the increased light duration and intensities. The cutting was heavy enough to allow species to grow and develop throughout the 9 years. Canopy closure was just beginning after 9 years. Oaks composed 36 percent of the total stems per acre (Table 5) and a greater number of stems than the gum/poplar component (Figure 1), but were less than half the average height of yellow-poplar. This treatment favored an increase in height of gum/poplar and beech. When released from the overstory, the gum/poplar and beech are positioned to become the dominant canopy. Oaks, though greater in number, are not in a position to grow with the taller species. The tallest oak individual sampled in the reproduction plots and the only individual over 6 feet tall measured 6.4 feet. Although few stems from the other species category of shade-tolerant species will be part of the overstory, most of these stems will probably be relegated to the midstory or succumb.

Loftis (1983, 1990) has successfully used the shelterwood method in the southern Appalachian mountains to increase the size of oak regeneration in relation to other species before release from the overstory. The method used was not to create gaps in the overstory, but to cut trees in the midstory to allow sunlight to filter through the overstory and not be intercepted by an additional canopy layer. This study used a different approach by not treating the midstory in the shelterwood treatments but by creating gaps in the overstory. Either method should be satisfactory if the microenvironment (primarily light conditions) created will favor the oaks at the expense of the shade-tolerant species or the faster-growing intolerant species (Hodges 1989).

The 60-ft^2 BA shelterwood treatment had the lowest mean heights for each of the species categories (Table 4). Most species groups increased in quantity from 1982-1985, then decreased as the canopy closed from the growth of the residual overstory (Figure 1). Oaks composed 31 percent of the reproduction after 9 years (Table 5), but only averaged 1.8 feet tall. The gum/poplar component was non-existent, while the more tolerant beech and other species categories were the tallest and composed a greater proportion of stems. This treatment promoted the more tolerant species at the expense of the oaks and intolerant species.

CONCLUSIONS

Both the clearcut and the 40-ft^2 BA shelterwood treatment appear to provide conditions conducive to promoting the development and growth of oak regeneration. The clearcut treatment had the greatest number of oaks, while the shelterwood had the greatest proportion of oaks in relation to the total number of stems. In both treatments, the oaks will continue to compete with the faster-growing gum/poplar component for overstory prominence. Even if oaks are not the primary component of the overstory, they will be a part of the overstory. The shade cast by the overstory in the light shelterwood cutting (60-ft^2 BA) promoted the shade-tolerant species and not the oaks.

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