Shortleaf Pine-Bluestem Habitat Restoration in the Interior Highlands: Implications for Stand Growth and Regeneration

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Abstract—*National Forest managers in the Interior Highlands of Arkansas are restoring 155,000 acres of unburned shortleaf pine stands to shortleaf pine-bluestem habitat. Habitat restoration consists of longer rotations, removal of midstory hardwoods, and reintroduction of fire. A study was installed in the spring of 2000 to evaluate shortleaf pine regeneration and overstory stand growth under treatment. At this point in the study, there is no difference in milacre stocking of pines related to number of growing seasons after burning. Analysis suggests that residual basal areas below 50 ft*^{2} *per acre will be needed to develop sufficient advance growth of shortleaf pine to ensure regeneration when regeneration cutting is implemented. Over a four-year period, growth in treated and control stands is substantially less than that predicted from growth models developed in this forest type. However, there are no significant differences in growth over four years between treated stands and the control stands.*

Introduction

The Ouachita Mountains cover approximately 6.6 million acres in western Arkansas and eastern Oklahoma, of which 85 percent is forested. Nearly 40 percent of the area is in forest stands dominated by shortleaf pine, which comprises 46 percent of the live-tree volume, 50 percent of growing-stock volume, and 67 percent of sawtimber board-foot volume on timberlands in the region; over half of the shortleaf pine volume in the region is found on National Forest land (Guldin and others 1999).

These shortleaf pine forests evolved with fire. Historical accounts and General Land Office records suggest that at the time of European colonization, the forest was more open than it is today, and fires no doubt contributed to that low density (Foti and Glenn 1991). Both wildfires and fires started by Native Americans were probably common. But since the 1930s, fire suppression has been extremely effective in the region. Fire return intervals prior to European settlement were on the order of from two to 40 years. Today, fire return intervals average 500 years or longer (Foti and others 1999), although the recent and widespread increase in the use of prescribed burning in contemporary forestry practice may alter this rate downward in the future.

As managers on National Forest lands seek to restore natural patterns and processes to the shortleaf pine ecosystem, the reintroduction of frequent surface fires is critical to success. Fire exclusion and conservative approaches to thinning second-growth shortleaf pine and pine-hardwood stands have produced stands that have more pines, and more hardwoods especially in the smaller size classes, than would be expected if fires had continued to burn

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over the past seven decades. This is at odds with descriptions in the literature that refer to open woodlands of pine and hardwood, with big bluestem (*Andropogon gerardii*) and other grasses in the understory (Foti and others 1999). Among the prominent advantages for this restoration is the attendant benefits that would be provided for restoration of a healthy population of the endangered red-cockaded woodpecker (*Picoides borealis*).

The Ouachita National Forest completed a Forest Plan Amendment in 1996, encompassing 155,000 acres of national forest land in western Arkansas and eastern Oklahoma in Management Area (MA) 22. The goal of the new MA22 is to implement restoration of the shortleaf pine-bluestem ecosystem, to implement the direction of the Region 8 RCW Environmental Impact Statement, and to maintain and enhance other associated resource values and attributes. Management Area 22 has been a resounding success with resource managers and the public. For it, the Ouachita NF received the Chief's Award for Forest Stewardship in 2001. And the National Audubon Society honored the project with its designation as a nationally Important Bird Area in 2002.

The prescriptions include removal of most midstory hardwoods, thinning from below in overstory and midstory pines, and reintroducing surface fires on a one- to three-year return interval. These treatments have been effective in restoring many underrepresented species in the landscape, such as purple coneflower (*Echinacea pallida*), bobwhite quail (*Colinus virginianus*), red-cockaded woodpecker, Bachman's sparrow (*Aimophila aestivalis*), and eastern wild turkey (*Meleagris gallopavo*) (Bukenhofer and Hedrick 1997). In addition, there is roughly seven times the preferred forage for white-tailed deer (*Odocoileus virginianus*) in treated versus untreated areas (Masters and others 1996).

The details of the restoration prescription are designed to carry the existing fully stocked second-growth pine and pine-hardwood stands to restored condition. Pre-restoration stands typically contain approximately 130 ft^2 per acre of basal area, of which 100 ft^2 per acre is in the pine component and 30 ft^2 per acre in the hardwood component; of the hardwood basal area, two-thirds is in the sub-sawtimber size class and most likely originated as a result of fire control efforts implemented in the 1930s (Guldin and others 1994).

The restoration prescription involves three components. First, the overstory basal area is reduced from 100 ft^2 per acre to approximately 75-80 ft^2 per acre using essentially a thinning from below and implemented using commercial timber sales. Those sales typically remove from 2000-3000 board feet (fbm) Scribner per acre, and are a successful and integral element of the district timber sale program. The sales generate program dollars (under the Knutsen-Vandenberg Act of 1930, as amended by the National Forest Management Act of 1976) for subsequent habitat treatments. The second element of the prescription is the removal of midstory hardwoods that have encroached in the stands as a result of seven decades of fire exclusion. Material is generally felled by chainsaws or girdled and left standing to meet standing snag requirements in the MA22 plan amendment. Finally, as the felled hardwoods decompose, a program of triennial prescribed fire is implemented. Generally, two prescribed burns can be imposed prior to the closure of the five-year window for expenditure of K-V trust funds collected in the initial thinning that triggers the process. The entire sequence of restoration would not be possible in the absence of a viable district timber management program.

In the long term, two silvicultural issues are of interest to ensure long-term productivity and sustainability of the prescriptions associated with

MA22. First, a question exists about the impacts of repeated prescribed burning regimes on the growth of the existing pine overstory. This has a bearing on the length of time needed to support supplemental thinning and eventually on the yields that might be expected when stands in the area are ultimately subject to regeneration cutting.

The second question is the exact manner by which shortleaf pine regeneration can be expected when the time comes for regeneration cutting in MA22 stands. Shortleaf pine is one of the few pines with the ability to resprout at young ages if the top is killed, a trait described in the early 1900s as an adaptation to fire (Mattoon 1915). This resprouting ability might allow the development of a reproduction cutting method based on an understory storage bank of pine seedlings and saplings that can be relied upon to respond to release, if the overstory basal area is substantially reduced below fully-stocked levels. Under proper conditions, this advanced pine regeneration could be quickly released with overstory removal. That would provide for more reliable reforestation than relying either on shortleaf pine's inconsistent annual seed production or on the timing of a site preparation prescription designed to catch whatever seedfall is available in a given year.

The question, then, is to characterize the growth and yield of shortleaf pine stands under restoration, and proper conditions and silvicultural prescriptions under which shortleaf pine advance growth can be obtained and accumulated in light of the triennial regime of prescribed fire currently being used in the pine-bluestem restoration prescription. In this paper, a first look is provided at observed growth in shortleaf pine stands, and on the differences in pine regeneration size, density, and stocking after one, two, and three seasons of growth after prescribed fire in stands being managed under the shortleaf pine-bluestem restoration prescription.

Methods

Study Area

This study area is located on the Poteau Ranger District of the Ouachita National Forest. Twelve stands were randomly selected for inclusion in the study; they are all mature stands dominated by shortleaf pine and contain a minor and varying proportion of hardwoods. Site indices vary between 55 and 65 feet (base age 50 years), and stand age varies from 55 to 70.

Treatments

Nine of the stands are under active prescriptions for shortleaf pine-bluestem restoration, and three are in nearby stands comparable in age and site quality but which have not been subject to the restoration treatment. The nine treated stands had all been subject to treatment for at least five years; treatment included midstory reduction (hardwood midstory trees were chainsaw-felled), a low thinning of light intensity in the pine overstory, and had been burned at least twice using dormant-season fires. Three of the stands had last been burned during the 1999 dormant season, three during the 1998 dormant season, and three during the 1997 dormant season. Thus, treatments were identified as one (B1), two (B2), and three (B3) years after burning, respectively; the control treatment (C) remained untreated by thinning, midstory reduction, or burning. Stands in the B2 treatment were thinned recently, and thus are excluded from the growth analysis in this paper.

Plot Measurements

Within each of the 12 stands, six plots were established on a square 4-chain x 4-chain grid. At each plot, a nested series of measurements were taken. Overstory trees, defined as trees with diameter at breast height (DBH) greater than > 9.6 inches inclusive, were sampled on a 0.2-acre fixed-radius plot. Midstory trees, defined as trees between 3.6 inches and 9.5 inches in diameter, inclusive, were sampled on a 0.1-acre fixed radius plot. Twelve milacres were established on a 13.2-foot grid within the 0.1-acre fixed radius plot, with the grid point at plot center omitted.

Overstory and midstory trees were sampled by measuring DBH to the nearest 0.1 inch and recording their species identity. Milacre measurements proceeded in a different manner using two tallies: an inventory tally and a tagged-tree tally. The inventory tally consisted of a count of all seedlings and saplings greater than 6 inches tall but less than 3.5 inches in diameter, inclusive, on each milacre. The tagged-tree tally consisted of subdividing the milacre into quadrats, identifying and tagging the tallest conifer and tallest hardwood on each quadrat (if present), and recording groundline diameter, DBH, and total height.

Data Analysis

The stem density and basal area for combined overstory and midstory trees per plot were calculated by applying the appropriate expansion factor to trees from either the 0.1-acre or 0.2-acre plot. The Shortleaf Pine Stand Simulator model (SLPSS, Lynch and others 1999) was used to calculate overstory timber volumes in the spring of 2000 and the summer of 2003, providing data on stand overstory stand growth over four years. Milacre stem density per plot was obtained by tallying the inventory of regeneration stems, applying the appropriate expansion factor per milacre, and averaging for the 12 milacres per plot. Milacre stocking of shortleaf pine was calculated from the proportion of milacres in a plot having at least one shortleaf pine. Treatment mean and standard error statistics were calculated for these variables across all plots within a treatment (n=36).

Overstory growth was analyzed by calculating the difference in total merchantable volume (ft^3 per acre), total merchantable green weight (tons per acre), and sawtimber volume (fbm Scribner per acre). Growth was also compared with that predicted over four years for the control and the treated stands using the SLPSS model. Regeneration data were analyzed using analysis of variance methods found in the SAS statistics software (SAS Institute 1990). Mean comparisons among treatments were conducted using the Student-Newman-Kuels mean comparison test.

Results and Discussion

Regeneration Differences by Treatment

Pine milacre stocking was inadequate in all treatments falling below the recommended standard of 300 trees per acre and 30 percent milacre stocking (Guldin and others 2004) and did not differ significantly by treatments (table 1). Milacre stocking varied from slightly more than 10 percent of milacres stocked with shortleaf pine in the B3 treatment to less than 1 percent in the B2 treatment; the control treatment also had 10 percent milacre stocking of shortleaf pine. At this point in the study, there appears to be no

Table 1—Means (and standard error, in parentheses) for milacre stocking and regeneration density by treatment.

Treatment	Milacre stocking -percent-		Regeneration density, all species: All species -stems/acre-		Shortleaf pine -stems/acre-		Oak spp. -stems/acre-		Other hardwood spp. -stems/acre-	
B1	6.48	a	8,245	a	287	a	5,056	a	2,903	a
	(3.73)		(699)		(174)		(812)		(481)	
B2	0.93	a	7,759	a	9	a	4,352	a	3,398	a
	(0.64)		(487)		(6)		(454)		(364)	
B3	10.18	a	7,435	a	324	a	4,148	a	2,963	a
	(2.82)		(596)		(120)		(652)		(641)	
Control	9.30	a	3,106	b	268	a	1,051	b	1,787	a
	(3.08)		(360)		(118)		(153)		(363)	

difference in milacre stocking of pines related to number of growing seasons after burning beneath the residual overstory densities found in this study.

There is a 2.5-fold increase in the number of stems of regeneration of all species as a result of treatment versus no treatment; however, there was no significant difference in total regeneration density one, two, or three years after the most recent burn (table 1). The combined treatment of thinning, midstory reduction, and fire result in this enhanced cohort of regeneration, not the number of growing seasons since the most recent prescribed burn.

This treatment pattern did not exist in the shortleaf pine component. There was no statistically significant difference in shortleaf pine regeneration density by treatment, which parallels the observation about milacre stocking of pines previously observed. Pine regeneration density varied from 324 stems per acre in the B3 treatment to 9.3 stems per acre in the B2 treatment; the control contained 268 stems per acre (table 1).

Significant differences did exist in oak regeneration density between treated stands and the control stands, but not among the treated stands. Treatment resulted in between four and five times as many oaks as were found in the control stands (table 1). Oak regeneration density varied between 4,148 stems per acre in the B3 treatment to 5,156 stems per acre in the B1 treatment, compared to 1,051 stems/acre in the control.

There was a twofold difference in the stem density of other non-oak hardwood species among the four treatments. Stem density of other hardwoods varied from 1,787 stems per acre in the control stand to 3,398 stems per acre in the B2 treatment. However, this difference was not statistically significant (table 1).

The distribution of seedling-origin stems and sprout-origin stems in the regeneration cohort varied between time since last burn versus control, but again not within the burning treatments per se. The control treatment had between three and 10 times the number of seedlings as the burn treatments (table 2), which reinforces the intuitive notion that stems of seedling origin were most likely to accumulate in the absence of burning treatments over time. Conversely, and as expected, the burn treatments resulted in a three- to four-fold increase in the number of sprouts per acre compared to the control (table 2). Although the trends in the burn treatments showed an increased number of seedling-origin stems versus the number of years after treatment, these trends were not significantly different. However, the ratio of seedling-origin to sprout-origin reproduction increased markedly across treatments—roughly speaking, 1:2 in the control, 1:20 in the B3 treatment, 1:40 in the B2 treatment, and 1:100 in the B1 treatment.

Table 2—Seedling-origin versus sprout-origin stems of regeneration by treatment.

Treatment	Regeneration density: Seedling-origin -stems/acre-		Sprout-origin -stems/acre-	
B1	83	b	8,162	a
B2	176	b	7,583	a
B3	356	b	7,079	a
Control	1,172	a	1,990	b

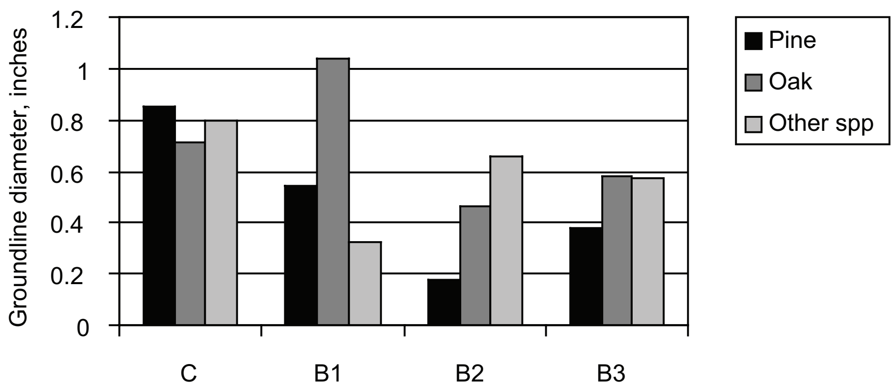

Figure 1—Differences in quadratic groundline diameter by treatment.

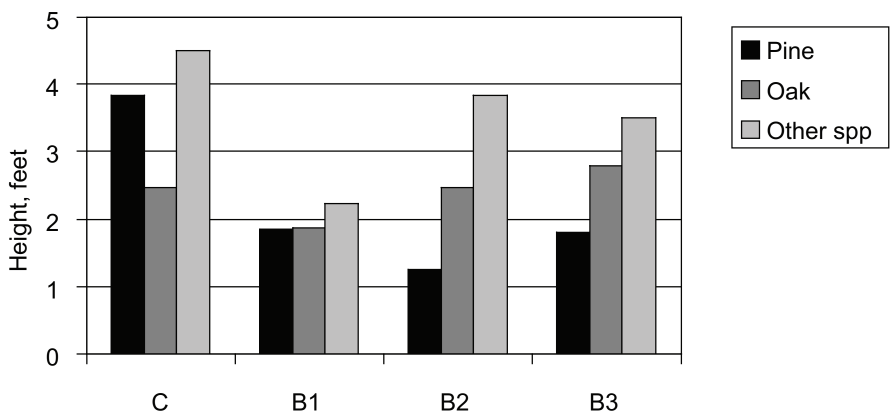

Figure 2—Differences in height by treatment.

In all but a few instances, the average size of the tallest seedling per quadrat was smaller in treated stands compared to the control stands. There was no consistent pattern in groundline diameter by treatment; in pines and oaks, the groundline diameter two years after burning was less than that one year after burning, whereas the groundline diameter was greater two years after burning in the other species category (figure 1). Similarly, height growth patterns suggest that regeneration in the control stands is generally taller than in treated stands, especially in the pine and other species component (figure 2), but trends among burn treatments are not clear. As the study matures, growth data from tagged trees measured over time will provide a better impression of regeneration development after burning.

These data are obscured by the number of observations of overstory basal area that lie beyond the range where one might expect to observe regeneration. A subset of the original data set was created that excluded all control

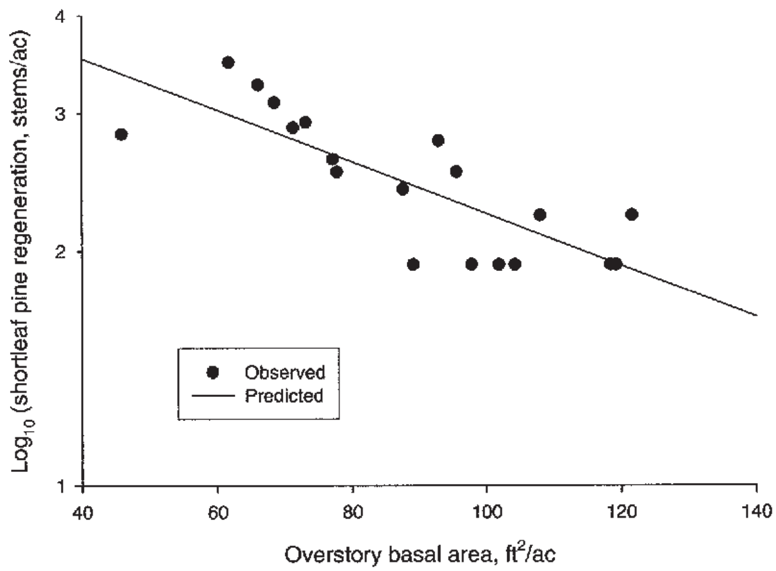

Figure 3—Relationship between overstory basal area and pine regeneration density for treated plots in the database in which milacre stocking is greater than zero.

plots and all treated plots if all 12 milacres had no pine stocking. When subject to simple linear regression, a log transformation of pine stems per acre was strongly correlated with total overstory basal area (figure 3). The predicted equation was

Log10 (SLPR) = 4.17172 – 0.01907 * (Total BA)
where
SLPR=shortleaf pine regeneration, stems/acre;
Total BA = basal area for all species, ft^2/acre; and
R^2(adj) = 0.622, Pr>F<0.0001.

Overstory Growth

After four growing seasons, there were no significant differences in volume growth between the B1 and B3 treatments and the control (table 3). Total merchantable cubic volume growth in the stands varies from -4 ft^3 per acre in the B1 treatment to 70 ft^3 per acre in the control over a four-year period. In green weight, change in tonnage varied from a slight decline in the B1 treatment to a 2.4 ton per acre increase in the control. Scribner board-foot volume changes over four years varied from an increase of 320 fbm per acre in the B1 treatment to 846 fbm per acre in the control stands.

However, growth in either control or treated stands does not appear to be at a level one would expect (figure 4). For example, the Scribner board-foot volume growth in the three treatments that is predicted using the SLPSS growth model varies from 480 to 500 fbm per acre annually. Observed

Table 3—Change in volume over four years by treatment.

Treatment	Total merch. cubic volume growth *-ft³/acre-*	Total merch. green weight growth *-tons/acre-*	Scribner volume growth *-fbm/acre-*
B1	-4.7 a	-0.2 a	320 a
B3	16.3 a	2.4 a	536 a
Control	70.7 a	6.8 a	838

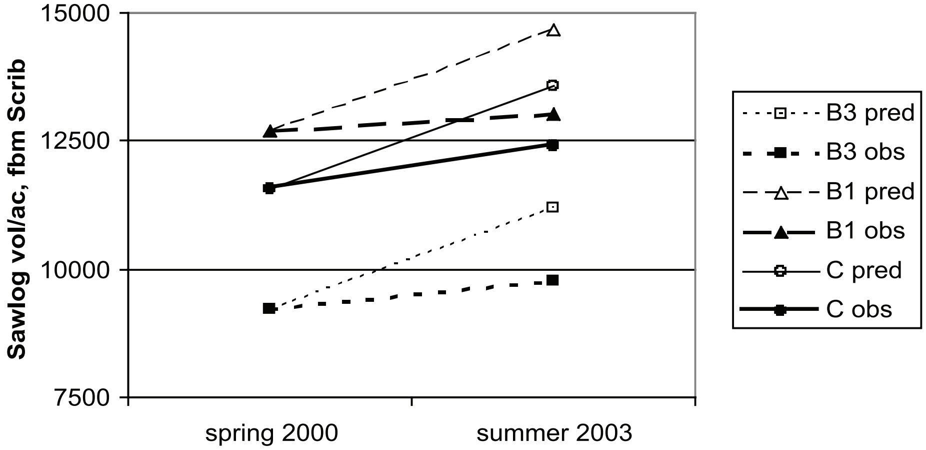

Figure 4—Board-foot volume growth, fbm Scribner per acre, in two treatments and the control. Projected growth was determined using a four-year projection with the SLPSS growth model.

growth is about 70 percent less than expected, and even the measured growth in the control stand was less than half that expected under application of the growth model.

Conclusions

Minimum stocking guidelines for shortleaf pine regeneration (Guldin and others 2004) call for 200 stems/acre and 20 percent of milacres stocked in uneven-aged stands, and 300 stems per acre and 30 percent of milacres stocked in even-aged stands. By either of these standards, obtaining a reliable cohort of advanced regeneration of shortleaf pine as a result of simply treating these stands with the traditional shortleaf pine-bluestem treatment is inadequate. Supplemental treatment of some kind will be necessary to obtain an adequate cohort of pine regeneration suitable for long-term sustainability of the stand.

One possible reason for the inadequate result under the current stands is that overstory density is greater than that required to promote the establishment of pine regeneration. When a subset of treated stands was analyzed separately based on having at least one milacre stocked with shortleaf pine per plot, significant relationships were obtained between pine milacre stem density and overstory basal area.

With lower basal areas, additional work will be needed to determine sprouting potential of different sizes of shortleaf pine regeneration, and whether the three-year burning interval must be lengthened to allow pine seedlings to grow large enough such that they will not be top-killed when the prescribed fire program is reestablished.

Additional research is required to determine the effects of treatments on stand growth. Over a four-year period, growth in either treated or control stands is substantially less than that predicted from growth models developed in this forest type. However, there are no significant differences in growth over four years between treated stands and the control stands. The growth model was developed in unburned second-growth shortleaf pine stands and may not reflect the influence of burning. In addition, a large sample of treated and untreated stands will be needed to provide a better assessment of the impacts of this restoration treatment on stand growth.

As these studies mature, the tracking of stand conditions over time will allow for better determination of whether shortleaf pine can be accumulated as advance regeneration under these stands. Ultimately, additional research will be needed to determine what combination of delay in the burning treatment and reduction in overstory basal area will result in an effective advance growth seedling bank of shortleaf pine in these restored pine-grass habitats.

Literature Cited

Bukenhofer, G. A.; Hedrick, L. D. 1997. Shortleaf pine/bluestem grass ecosystem renewal in the Ouachita Mountains. In: Transactions of the 62nd North American Wildlife and Natural Resources Conference. Washington, D.C.: Wildlife Management Institute. 509-515.

Foti, T.; Richards, L. L.; Andre, J.; Voeller, J. E. Chapter 2, Prehistoric and historic changes, p. 7-20. In: U.S. Department of Agriculture, Forest Service. 1999. Ozark-Ouachita Highlands Assessment: terrestrial vegetation and wildlife. Report 5 of 5. Gen. Tech. Rep. SRS-35. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 201 p.

Foti, Thomas L.; Glenn, Susan M. 1991. The Ouachita Mountain landscape at the time of settlement, p. 49-65. In: Henderson, Douglas; Hedrick, L. D. Restoration of old-growth forests in the Interior Highlands of Arkansas and Oklahoma—proceedings of the conference, Winrock International, Morrilton AR, September 19-20, 1990. Hot Springs, AR: Ouachita National Forest and Winrock International Institute for Agricultural Development. 190 p.

Guldin, J. M.; Baker, J. B.; Shelton, M. S. 2004. Regeneration development among a range of reproduction cutting methods in shortleaf pine and pine-hardwood stands in the Ouachita Mountains, p. 15-20. In: Guldin, James M., tech. comp. Ouachita and Ozark Mountains symposium: Ecosystem Management Research. Gen. Tech. Rep. 74. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 321 p.

Guldin, J. M.; Thompson, F. R.; Richards, L. L.; Harper, K. C. 1999. Chapter 3: Status and trends of vegetation, p. 21-72. In: U.S. Department of Agriculture, Forest Service. 1999. Ozark-Ouachita Highlands Assessment: terrestrial vegetation and wildlife. Report 5 of 5. Gen. Tech. Rep. SRS-35. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 201 p.

Guldin, J. M.; Baker, J. B.; Shelton, M. G. 1994. Midstory and overstory plants in mature pine/hardwood stands of the Ouachita/Ozark National Forests, p. 29-49. In: Baker, J. B., tech. comp. Proceedings of the Symposium on Ecosystem Management in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings: 1993 October 26-27; Hot Springs, AR. Gen. Tech. Rep. SO-112. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 259 pp.

Lynch, Thomas B.; Hitch, Kenneth L.; Huebschmann, Michael M.; Murphy, Paul A. 1999. An individual tree growth and yield prediction system for even-aged natural shortleaf pine forests. Southern Journal of Applied Forestry. 23(4): 203-211.

Masters, R. E.; Wilson, C. W.; Bukenhofer, G. A.; Payton, M. E. 1996. Effects of pine-grassland restoration for red-cockaded woodpeckers on white-tailed deer forage production. Wildlife Society Bulletin. 24(1): 77-84.

Mattoon, W. R. 1915. Life history of shortleaf pine. Bull. 244. Washington, D.C.: U.S. Department of Agriculture. 46 p.

SAS Institute Inc., 1990. SAS Procedures Guide, Version 6, 3rd edition. Cary, NC: SAS Institute Inc., 1990. 705 p.