# LONG-TERM EFFECTS OF BIENNIAL PRESCRIBED FIRES ON THE GROWTH OF LONGLEAF PINE

William D. Boyer
U.S. Department of Agriculture, Forest Service, Southern Research Station, 520 Devall Drive, Auburn, AL 36849

## ABSTRACT

The effects of several hardwood control treatments on understory succession and overstory growth have been followed for 22 years on a Coastal Plain site in southwest Alabama. The study began in 1973, with 12 treatment combinations in 14-year-old naturally established longleaf pine (*Pinus palustris*) thinned to about 1,236 stems per hectare (500 stems per acre). Four burning treatments, namely biennial burns in winter, spring, and summer plus an unburned check, were each combined with 3 supplemental hardwood control treatments: an initial chemical injection of all hardwoods, periodic cutting of all woody stems, and no treatment. Pine stands were thinned to 16 square meters basal area per hectare (70 square feet per acre) in 1990. All measures of pine growth were significantly reduced by burning. By 1995, the volume yield of 257 cubic meters per hectare (3,675 cubic feet per acre) on unburned plots significantly exceeded the average yield of 210 cubic meters per hectare (2,996 cubic feet per acre) for the 3 burning treatments, which did not differ significantly among themselves. The significant effect of fire on pine diameter and height growth did not extend beyond age 24, although effects on basal area and volume growth continued to age 30, when plots were thinned. Volume, but not basal area, growth from age 33 to age 36 was once again significantly greater on unburned than burned plots. Supplemental treatments have not yet affected pine volume growth.

*keywords:* fire effects, growth and yield, longleaf pine, *Pinus palustris,* prescribed fire, season of burn.

*Citation:* Boyer, W.D. 2000. Long-term effects of biennial prescribed fires on the growth of longleaf pine. Pages 18–21 *in* W. Keith Moser and Cynthia F. Moser (eds.). Fire and forest ecology: innovative silviculture and vegetation management. Tall Timbers Fire Ecology Conference Proceedings, No. 21. Tall Timbers Research Station, Tallahassee, FL.

## INTRODUCTION

A study to determine the long-term effects of several hardwood control treatments on understory succession and overstory growth in young, naturally established stands of longleaf pine was initiated in 1973. Combinations of fire, mechanical, and chemical treatments were applied. The objectives were to observe any effects on the growth of overstory pine as well as changes in the composition and structure of midstory and understory vegetation associated with the different treatment regimes.

Treatment effects on ground cover vegetation after 9 years have been reported (Boyer 1995), as well as on woody vegetation through the first 16 or 19 years of study (Boyer 1991, 1993). The effects of treatments on the growth of overstory pine through 10 and 19 years have also been reported (Boyer 1987, 1994). Fire treatments had significantly reduced all measures of pine growth. After 19 years, total volume yield on unburned plots exceeded that on burned plots by 24%. The continuing effects of burning treatments on pine growth during 22 years of study are reported here.

## METHODS

The study was established on the Escambia Experimental Forest (maintained by the U.S. Department of Agriculture, Forest Service, Southern Research Station, in cooperation with the T.R. Miller Mill Company) in southwest Alabama in the winter and spring of 1973 to determine long-term effects of several hardwood control treatments on composition and structure of the understory as well as on the growth of overstory pine. Study sites were on sandy upland Coastal Plain soils, primarily fine sands of the Troup series, but some Dothan, Wagram, and Fuquay series were also represented. At that time, study areas supported natural stands of longleaf pine originating primarily from the 1958 seed crop. The seedtree overstory was removed in 1961, when seedlings were 2 years old. Pine stocking averaged about 1,730 trees per hectare (700 trees per acre) in 1973, at age 14.

Three blocks were established, each with 12 square, 0.16-hectare (0.4-acre) plots. Each plot was thinned to about 1,236 well-distributed dominant or codominant pines per hectare (500 per acre). All residual pines in 0.04-hectare (0.1-acre) net plots were marked and numbered, and total height and diameter at breast height (DBH) were recorded. Residual pines averaged 6.7 meters in height and 8.13 centimeters in DBH with an average basal area of 6.9 square meters per hectare (30 square feet per acre). Average age-50 site indices estimated for longleaf pine on each of the 3 study blocks, based on heights of dominant and codominant trees most recently recorded at age 36, ranged from 23.8–25.0 meters (Farrar 1981*a*). All woody stems were counted on 9 systematically located 0.94-meter square subplots in each 0.04-hectare net plot. Initial hardwood basal area on each net plot was estimated using a 10-factor wedge prism. At that time, hardwood basal area averaged 0.83 square meters per hectare (3.6 square feet per acre).

Twelve treatment combinations were randomly as-

signed among the 12 plots in each block. Each of 4 fire treatments, namely prescribed fires at 2-year intervals in winter, spring, and summer plus an unburned check, was combined with 3 supplemental treatments. These treatments were: a one-time herbicide injection of all woody stems down to about 2.5-centimeters groundline diameter in the spring of 1973, periodic hand-clearing of all woody stems >1.37 meters in height beginning in 1973, and an untreated check.

The last fire on all study areas was a prescribed burn in January 1962. Due to heavy fuel accumulations in study areas, all 3 season of burn treatments were initiated with a dormant-season prescribed fire in January 1974.

Study plots were first reexamined in the winter of 1980, after 7 growing seasons. The height and DBH of all pines on net plots were remeasured. Individual pine tree inside-bark total cubic-meter volume was derived from DBH and height using a longleaf pine volume equation (Farrar 1981*b*). All pines >8.9 centimeters in DBH were classified as merchantable. At this examination, all net plot midstory hardwoods (>3.8 centimeters in DBH) were also inventoried, and species and DBH were recorded. Stems of smaller woody vegetation were again counted on 9 subplots within each net plot.

All plots have been similarly remeasured at 3-year intervals since 1980. Beginning in 1986, all woody stems in the 2.5-centimeter DBH class (1.5–3.8 centimeters in DBH) were included in the net plot hardwood inventory, and all smaller woody stems in the subplot inventory.

Analysis of variance was used to test for significant effects of treatments on average tree DBH and height plus stand basal area and volume at each measurement, and also periodic pine survivor volume growth (mortality excluded) during each remeasurement interval. When treatment effects were significant, Duncan's test was used to identify treatment means that were significantly different.

By 1989, overstory pine basal area on individual plots ranged from 15.4–27.1 square meters per hectare (67–118 square feet per acre) and averaged 22.3 square meters per hectare (97 square feet per acre). In order to promote optimal development of dominant residual pines and reduce natural mortality from competition, pine stands were commercially thinned in 1990 to a density of about 16.1 square meters per hectare (70 square feet per acre). Three plots with a pine density of <17.2 square meters per hectare (75 square feet per acre) were not thinned.

## RESULTS

### Pine Survival

Pines in both burned and unburned plots averaged 1,243 trees per hectare (503 per acre) after initial thinning in 1973. By 1989, before the first commercial thinning in 1990, there were 1,117 remaining trees per hectare (452 per acre) on burned plots and 1,179 per hectare (477 per acre) on unburned plots. During the first 16 years of observation, until 1989, the only significant difference in survival was that between summer-burned plots (1,063 trees per hectare) and the other 3 treatments (1,154 trees per hectare). Treatments have not affected pine survival since then.

Natural mortality from 1989 to 1995, the interval that included the thinning operation, has averaged 14.8 trees per hectare (6 per acre), or 2.5 trees per hectare (1 per acre) annually. Residual pines in 1995 averaged 638 trees per hectare (258 per acre) on burned and 539 trees per hectare (218 per acre) on unburned plots.

Table 1. Burning treatments and average longleaf pine stand characteristics at age 30.

| Season of burn | DBH[a] (centimeters) | Height (meters) | Basal area (sq. m. per hectare) | Volume (cu. m. per hectare) |
|---|---|---|---|---|
| Winter | 15.0A[b] | 16.6A | 21.8AB | 158.5A |
| Spring | 15.0A | 16.8A | 22.0B | 160.8A |
| Summer | 15.0A | 16.7A | 20.4A | 147.6A |
| No burn | 15.8B | 17.8B | 25.3C | 195.8B |

[a] Diameter at breast height.
[b] Column means followed by the same letter are not significantly different at the $P \leq 0.05$ level, according to Duncan's test.

### Fire Treatments and Stand Development

All plots were examined during the winter of 1989, at stand age 30. This was the last examination before plots were thinned in 1990. At this time, average tree size, stand density, and stand volume were all significantly greater on unburned than on burned plots (Table 1). Season of burn had no effect on average tree diameter and height, or stand volume. However, stand basal area was significantly lower on summer-burned than spring-burned plots. Commercial thinning of plots in 1990 to a density of about 16 square meters basal area per hectare (70 square feet per acre) resulted in the removal of an average of 462 trees per hectare (187 per acre) with a volume of 35.3 cubic meters per hectare (504 cubic feet per acre) on burned plots, and 633 trees per hectare (256 per acre) with a volume of 63.4 cubic meters per hectare (906 cubic feet per acre) on unburned plots.

All plots were most recently examined in the winter of 1995, at stand age 36. At this time, average tree DBH and height, and standing volume as well as total volume yield, were all significantly greater on unburned than burned plots (Table 2). Thirty-nine percent (75.6 cubic meters per hectare) of the standing volume in unburned plots was in sawlog size trees (>24 centimeters DBH), compared to 23% (39.6 cubic meters per hectare) in burned plots. Following the thinning, stand density, in terms of basal area, has not differed among treatments. Season of burn had no effect on average tree diameter or plot volumes but did affect tree height. The average height of trees on summer-burned plots was less than that on spring-burned plots, but not winter-burned plots.

In 1973, unburned stands had 9% more pine volume than stands scheduled for burning. At succeeding remeasurements, the difference in total volume yield

Table 2. Burning treatments and average longleaf pine stand characteristics at age 36.

| Season | DBH[a] (centimeters) | Height (meters) | Basal area (sq. m. per hectare) | Volume: Standing (cu. m. per hectare) | Volume: Total yield[c] |
|---|---|---|---|---|---|
| Winter | 20.2A[b] | 20.6AB | 20.9A | 178.0A | 214.9A |
| Spring | 20.5A | 21.0B | 20.2A | 173.5A | 214.5A |
| Summer | 19.3A | 19.9A | 20.4A | 171.8A | 199.6A |
| No burn | 22.3B | 22.2C | 21.1A | 193.7B | 257.1B |

[a] Diameter at breast height.
[b] Column means followed by the same letter are not significantly different at the $P \leq 0.05$ level, according to Duncan's test.
[c] Includes volume removed in thinning.

Table 3. Effect of biennial burns on periodic annual growth of longleaf pine.

| Growth interval | Treatment | Average periodic annual growth: DBH[a] (centimeters) | Height (meters) | Basal area (sq. m. per hectare) | Volume (cu. m. per hectare) |
|---|---|---|---|---|---|
| 1973–1980 | Burned | 0.488A[b] | 0.774A | 0.950A | 7.1A |
| | Unburned | 0.556B | 0.820B | 1.146B | 8.7B |
| 1980–1983 | Burned | 0.452A | 0.524A | 1.090A | 9.4A |
| | Unburned | 0.526B | 0.616B | 1.382B | 12.5B |
| 1983–1986 | Burned | 0.424A | 0.582A | 1.093A | 11.3A |
| | Unburned | 0.429A | 0.643A | 1.267B | 14.3B |
| 1986–1989 | Burned | 0.310A | 0.466A | 0.728A | 9.0A |
| | Unburned | 0.297A | 0.485A | 0.914B | 11.8B |
| 1989–1992 | Burned | 0.417A | 0.439A | 0.797A | 9.3A |
| | Unburned | 0.439A | 0.491A | 0.774A | 10.1A |
| 1992–1995 | Burned | 0.401A | 0.360A | 0.760A | 9.1A |
| | Unburned | 0.485A | 0.418A | 0.826A | 10.6B |

[a] Diameter at breast height.
[b] Treatment pairs followed by the same letter are not significantly different at the $P \leq 0.05$ level, according to Duncan's test.

increased to 24% by 1983, at stand age 24, and has ranged from 23–26% since then, averaging 23% at the 1995 remeasurement.

Supplemental treatments still had no effect on any measured tree and stand variables in 1995, even though midstory hardwoods (>3.8 centimeters in DBH) on unburned check plots had reached 526 stems per hectare (213 per acre) and 3.67 square meters basal area per hectare (16 square feet per acre).

### Change in Fire Effects with Time

The effects of fire on pine growth during each interval between remeasurements have changed over time (Table 3). Burning significantly reduced both diameter and height growth through 1983, at stand age 24, but differences since then have been relatively small and no longer significant. From 1986–1989, average diameter growth was actually somewhat greater on burned than on unburned plots. This unexpected result was probably due to the higher stand density on unburned plots, which averaged 23.2 square meters basal area per hectare (101 square feet per acre) in 1986 compared to 19.5 square meters (85 square feet) on burned plots. The average difference in height of dominant and codominant trees on unburned versus burned plots increased from 0.64 meter (2.1 feet) at age 21 to 1.71 meters (5.6 feet) at age 36. This difference, in terms of estimated site index at age 50 (Farrar 1981*a*), increased from 0.9 meter (3 feet) at age 21 to 1.8 meters (6 feet) at age 36.

Periodic annual basal area and volume growth were significantly higher on unburned than burned plots for all measurement intervals through 1989. Differences were not significant for the 1989–1992 interval, which included thinning. Volume growth was once again significantly greater on unburned than burned plots during the 1992–1995 growth interval.

## DISCUSSION

Biennial prescribed fires significantly reduced both the diameter and height growth of longleaf pines through age 24. Although diameter and height growth on unburned plots has continued to exceed that on burned plots, except for DBH growth from 1986–1989, the differences are no longer large enough to be significant.

Stand growth, both volume and basal area, continued to be significantly greater on unburned than on burned stands until stands were commercially thinned to a common density in 1990. This result was primarily due to the larger sizes attained by trees on unburned plots during the first 10 years. Although diameter and height growth of individual trees after 1983 differed little among treatments, this growth, when added to the already larger trees in unburned stands, resulted in the greater volume and basal area growth.

Over the 16 years from stand age 14–30, annual volume growth averaged 26% greater in unburned than in burned stands. Yield tables for longleaf pine (Farrar 1985) indicate that a 1.8-meter (6-foot) increase in site index alone should result in about a 10% increase in periodic annual volume growth. The 1.8-meter difference between burned and unburned stands in estimated site index can account for slightly >33% of the difference in periodic annual volume growth associated with burning. The remainder is due to differences in basal area growth. Since thinning, the difference in apparent site index can account for most of the difference in periodic annual volume growth.

Causes of the observed pine growth losses are not clear. Possibilities include crown scorch, effects of the fires on soil chemical and physical properties, impacts on fine roots near the soil surface, or damage to the cambium of young trees.

Crown scorch during the first several burning cycles appeared to remain at low to moderate levels, due in part to relatively light fuel accumulations during the 2 years between burns. As a result, no data on scorch were obtained from stand age 15–24 years. Since then, percent crown scorch has been recorded for each net plot pine for the last 6 burning cycles, from stand age 24–36 years. Average crown scorch with summer burns, at 17%, is nearly twice that with spring burns

at 9%, and more than 3 times the 5% for winter burns. Despite the higher levels of crown scorch with growing-season compared to winter burns, fire impacts on pine growth did not differ with season of burn. Scorch thus appears not to be a major factor in observed growth losses.

Follow-up observations on winter-burned and unburned study plots indicated that nutrient status of soils and pine foliage was unaffected by burning, although significant differences in some soil physical properties, especially moisture retention capacity, were observed (Boyer and Miller 1994). These differences did not seem great enough to be responsible for the magnitude of the observed growth loss. A study was initiated in 1985, in 11-year-old longleaf pine stands, to test winter and spring burns at 2-, 3-, and 5-year intervals to determine whether increases in time between burns will reduce pine growth loss and still effectively limit hardwood encroachment.

## CONCLUSIONS

Biennial prescribed fires at any season will reduce the growth of young longleaf pine stands compared to similar unburned stands. After 22 years of observation, total pine volume yield on unburned plots, at 257 cubic meters per hectare (3,675 cubic feet per acre), significantly exceeded the average yield of 210 cubic meters per hectare (2,996 cubic feet per acre) for the 3 seasons of burn, which did not differ significantly among themselves.

Differences in basal area growth associated with biennial prescribed fires account for about 67% of the observed difference in volume growth to age 30, shortly before plots were thinned. The estimated 1.8-meter difference in site index between unburned and burned longleaf pine accounts for the remainder. For the 5 years since all plots were thinned, the apparent difference in site index alone can explain most of the volume growth difference between burned and unburned plots.

The effect of prescribed fires on the growth of individual longleaf pine trees is greatest at young ages and diminishes with time. The reduction in tree height and diameter growth associated with biennial prescribed fires was too small to be significant after age 24. The differences in tree size reached by age 24, however, have been retained and can account for the continuing volume growth differences between burned and unburned plots.

## LITERATURE CITED

Boyer, W.D. 1987. Volume growth loss: a hidden cost of periodic prescribed burning in longleaf pine? Southern Journal of Applied Forestry 11:154–157.

Boyer, W.D. 1991. Effects of a single chemical treatment on long-term hardwood development in a young pine stand. Pages 599–606 *in* S.S. Coleman and D.G. Neary (compilers, editors). Proceedings, 6th biennial Southern silvicultural research conference. General Technical Report SE-70, U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station, Asheville, NC.

Boyer, W.D. 1993. Season of burn and hardwood development in young longleaf pine stands. Pages 511–515 *in* J.C. Brissette (ed.). Proceedings, 7th biennial Southern silvicultural research conference. General Technical Report SO-93, U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, New Orleans.

Boyer, W.D. 1994. Eighteen years of seasonal burning in longleaf pine: effects on overstory growth. Pages 602–610 *in* Proceedings, 12th international conference on fire and forest meteorology. Society of American Foresters, Bethesda, MD.

Boyer, W.D. 1995. Responses of groundcover under longleaf pine to biennial seasonal burning and hardwood control. Pages 512–516 *in* M.B. Edwards (compiler). Proceedings, 8th biennial Southern silviculture research conference. General Technical Report SRS-1, U.S. Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC.

Boyer, W.D., and J.H. Miller. 1994. Effect of burning and brush treatments on nutrient and soil physical properties in young longleaf pine stands. Forest Ecology and Management 70: 311–318.

Farrar, R.M., Jr. 1981*a*. A site-index function for naturally regenerated longleaf pine in the East Gulf area. Southern Journal of Applied Forestry 5:150–153.

Farrar, R.M., Jr. 1981*b*. Cubic-foot volume, surface area, and merchantable height functions for longleaf pine trees. Research Paper SO-166, U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, New Orleans.

Farrar, R.M., Jr. 1985. Volume and growth predictions for thinned even-aged natural longleaf pine stands in the east Gulf area. Research Paper SO-220, U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, New Orleans.