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EIGHTEEN YEARS OF SEASONAL BURNING IN LONGLEAF PINE: EFFECTS ON OVERSTORY GROWTH[1]

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ABSTRACT: The effects of several hardwood control treatments on understory succession and overstory growth have been followed for 19 years on a Coastal Plain site in southwest Alabama. The study began in 1973, with 12 treatment combinations in M-year-old naturally established longleaf pine (Pinus palustris Mill.) thinned to about 500 stems/acre. Four burning treatments, namely biennial burns in winter, spring, and summer plus an unburned check were each combined with three 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 70 ft^2 basal area/acre in 1990. All measures of pine growth were significantly reduced by burning. By 1992, the volume yield of 3,222 ft^3/acre on unburned plots significantly exceeded the average yield of 2,606 ft^3/acre for the three 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 have continued to age 30. Supplemental treatments have not yet affected pine volume growth.

KEYWORDS: prescribed fire; longleaf pine; Pinus palustris; hardwood control; growth and yield

INTRODUCTION

Control of understory hardwoods within young pine stands, particularly the very intolerant longleaf pine (Pinus palustris Mill.), is expected to provide a number of benefits. These include increased growth of overstory pine, easier access within the stands, reduced cost of future hardwood control for site or seedbed preparation or other purposes, and an increased cover of grasses and other herbaceous vegetation.

A study to determine the long-term effects of several hardwood control treatments on understory succession and overstory growth was initiated in 1973. Combinations of fire, mechanical, and chemical treatments were applied. The objectives were to observe changes in the composition

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and structure of midstory and understory vegetation under the different treatment regimes, and also any effects on the growth of overstory pine.

Treatment effects on woody vegetation through the first 16 or 19 years of study have been reported (Boyer 1991, 1993). The effects of treatments on the growth of overstory pine through the first 10 years have also been reported (Boyer 1987). Fire treatments significantly reduced all measures of pine growth, and volume growth on unburned plots exceeded that on burned plots by 26 percent. Mechanical or chemical hardwood control had no effect on pine growth over the first 10 years. The continuing effects of the burning treatments on pine growth over a period of 19 years are reported here.

METHODS

The study was established on the Escambia Experimental Forest[3] in southwest Alabama in 1973 to determine long-term effects of several hardwood control treatments on composition and structure of the understory and also 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 represented also. At that time, study areas supported natural stands of longleafpineoriginating primarily from the 1958 seed crop. The seedtree overstory was removed in 1961, when seedlings were 2 years old. Pine stocking averaged about 700 trees per acre in 1973.

Three blocks were established, each with 12, square, 0.4-acre plots. Each plot was thinned to about 500 well-distributed dominant or codominant pines per acre. All residual pines in O.l-acre net plots were marked and numbered, and total height and diameter at breast height (dbh) were recorded. Residual pines averaged 22 ft in height and 3.2 inches in dbh with an average basal area (BA) of 30 ff per acre. Average age-50 site indices for longleaf pine on study blocks, based on heights of dominant and codominant trees at age 33, ranged from 77 to 81 feet (Farrar 1981a). All woody stems were counted on nine systematically located 3.1-ft-square subplots in each O.l-acre net plot. Hardwood BA on each net plot was estimated using a N-factor wedge prism. At this time, hardwood BA averaged 3.6 ft^2 per acre.

Twelve treatment combinations were randomly assigned among the 12 plots in each block. Each of four fire treatments, namely prescribed fires at 2-year intervals in winter, spring, and summer plus an unburned check, was combined with three supplemental treatments. These were: a one-time herbicide injection of all woody stems down to about l-inch groundline diameter in the spring of 1973, periodic handclearing of all woody stems over 4.5 ft in height beginning in 1973, and an untreated check.

The last fire on all study areas was a prescribed bum in January 1962. Due to heavy fuel accumulations in study areas, all three season of bum treatments were initiated with a cool winter prescribed fire in January 1974.

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[3]Maintained by the Southern Forest Experiment Station, USDA Forest Service, in Cooperation with the T.R. Miller Mill Company.

Study plots were first reexamined in the winter of 1980, after seven growing seasons. The height and dbh of all pines on net plots were remeasured. Individual pine tree inside-bark total cubic foot volume was obtained from dbh and height using a longleaf pine volume equation (Farrar 1981b). All pines greater than 3.5 inches in dbh were classified as merchantable. At this examination, all net plot midstory hardwoods (> 1.5 inches in dbh) were also inventoried, and species and dbh were recorded. Stems of smaller woody vegetation were again counted on nine new 3.1-ft-square subplots within each net plot.

All plots have been similarly remeasured at 3-year intervals since 1980. Beginning with the remeasurement in 1985-86, all woody stems in the l-inch dbh class (0.6 to 1.5 inches in dbh) were included in the net plot hardwood inventory.

Analysis of variance was used to test for significant effects of treatments on average tree dbh and height plus stand BA and volume at each measurement, and also periodic pine gross survivor 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 BA on individual plots ranged from 67 to 118 and averaged 97 ft^2 per acre. In order to promote optimum development of dominant residual pines and reduce natural mortality from competition, pine stands were commercially thinned in I990 to a density of about 70 ft^2 per acre. Three plots with a pine density of less than 75 ft^2 were not thinned.

RESULTS

Pine Survival

Pines in both burned and unburned plots averaged 503 trees per acre after initial thinning in 1973. By 1989, before the first commercial thinning in 1990, there were 452 remaining trees per acre on burned plots and 477 on unburned plots. In the first 16 years, the only significant difference in survival was that between summer burned plots (430 trees per acre) and the other three burning treatments (467 trees per acre).

Commercial thinning of plots in 1990 to a density of about 70 ft^2 BA per acre resulted in the removal of an average of 187 trees per acre on burned and 256 trees per acre on unburned plots. Mortality during the 3-year period 1989-92, which included the thinning operation, amounted to only five trees per acre on burned and two trees per acre on unburned plots. Residual pines in 1992 averaged 260 trees per acre on burned and 219 trees per acre on unburned plots.

Treatments and Stand Conditions in 1989

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).

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

Season of burn	Dbh (inches)	Height (feet)	Basal area (ft^2/acre)	Volume (ft^3/acre)
Winter	5.89a*	54.4a	95ab	2265a
Spring	5.89a	55. la	96b	2298a
Summer	5.90a	54.9a	89a	2109a
No burn	6.24b	58.3b	110c	2798b

* Column means followed by the same letter axe not significantly different at the 0.05 level, according to Duncan's test.

Season of bum had no effect on average tree diameter and height, or stand volume. However, stand BA was significantly lower on summer-burned than spring-burned plots. The supplemental treatments had no effect on measured tree and stand variables in 1989, even though midstory hardwoods (> 1.5 inches in dbh) on unburned check plots had reached 340 stems and 15.5 ft^2 BA per acre.

Stand Growth 1973-92

Stand development over the 19 years of observation, in terms of average tree dbh and height plus stand density and volume, are illustrated in Figure 1. The fewer, larger, residual trees left on unburned plots after thinning widened the prethinning difference between unburned and burned stands in average tree size.

The effects of fire on pine growth during each interval between remeasurements has changed over time (Table 2, Figure 2). Bennial bums significantly reduced both diameter and height growth through 1983, but differences since 1983 were relatively small and no longer significant. During the 1986-89 period, diameter growth was actually somewhat greater on burned than on unburned plots. This was probably due to the higher stand density on unburned plots, which was 101 ft^2 BA per acre in 1986 compared to 85 ft^2 BA per acre on burned plots. Periodic annual BA and volume growth were significantly higher on unburned than burned plots for all measurement intervals through 1989. Differences were not significant for the 1989-92 interval that included the thinning operation.

Table 2. Effect of biennial bums on periodic annual growth of longleaf pine.

Growth interval	Treatment (inches)	Average periodic annual growth Dbh (feet)	Height (ft²/acre)	Basal area (ft³/acre)	Volume
1973-80	Burned	0.192a*	2.45a	4.14a	101a
	Unburned	0.219b	2.69b	4.99b	125b
1980-83	Burned	0.178a	1.72a	4.75a	135a
	Unburned	0.207b	2.02b	6.02b	179b
1983-86	Burned	0.167a	1.91a	4.76a	162a
	Unburned	0.169a	2.11a	5.52b	205b
1986-89	Burned	0.122a	1.53a	3.17a	129a
	Unburned	0.117a	1.59a	3.98b	168b
1989-92	Burned	0.164a	1.44a	3.47a	133a
	Unburned	0.173a	1.61a	3.37a	144a

* Treatment pairs followed by the same letter are not significantly different at the 0.05 level, according to Duncan's test.

In 1973, unburned stands had 9 percent more volume than stands scheduled for burning. At succeeding remeasurements, the difference in total volume yield increased to 24 percent by 1983 and has ranged between 24 and 26 percent since then. A slight downturn occurred in 1992, due to the very small difference between burned and unburned stands in volume growth from 1989 to 1992. Future remeasurements will reveal whether this is temporary or the beginning of a trend.

The average difference in height of dominant and codominant trees on unburned versus burned plots increased from 2.1 ft at age 21 to 4.6 ft at age 33. This difference, in terms of estimated site index at age 50 (Farrar 1981a), changed from 3 ft at age 21 to 5 ft by age 30, and remained at 5 ft in 1992.

DISCUSSION

The reduction in the average height and diameter growth of longleaf pines associated with prescribed burning has continued throughout the entire period of observation, except for dbh growth during the 1986-89 period. However, differences due to burning were so small after 1983 that they were no longer significant. Stand growth, both volume and BA, continued to be significantly greater on unburned than on burned stands until stands were commercially thinned to a common density in 1990. This 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 was nearly the same for all treatments, this growth, when added to the already larger trees in unburned stands, resulted in greater volume and BA growth.

Over the 16 years from stand age 14 to 30, volume growth averaged 27 percent greater in unburned than in burned stands. Yield tables for longleaf pine (Farrar 1985) indicate that a 5 ft increase in site index alone results in a 7 to 8 percent increase in periodic annual volume growth. The 5 ft difference between burned and unburned stands in estimated site index accounts for about one-fourth of the observed difference in periodic annual volume growth associated with burning. The remainder is due to differences in basal area growth.

The cause or causes of the observed pine growth losses arc 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 two years between. bums. As a result, no quantitative data on scorch were obtained from stand age 15 to 24. Since then, percent crown scorch has been recorded for each net plot pine for the last 5 burning cycles. Average crown scorch with summer burns, at 16 percent, is nearly twice that with spring bums at 9 percent, and five times the 3 percent for winter bums. 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 bum. This suggests that scorch was not 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 (Miller and Boyer 1991). 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 bums at 2-, 3-, and 5-year intervals to determine if increases in- time between bums 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 19 years of observation, total pine volume yield on unburned plots, at 3,222 ft^3 per acre, significantly exceeded the average yield of 2,606 ft^3 per acre for the three seasons of bum, which did not differ significantly among themselves.

Differences in basal area growth associated with biennial prescribed fires accounts for about three-fourths of the observed difference in stand volume growth. The estimated 5-ft difference in site index between unburned and burned longleaf pine stands accounts for the remainder.

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.

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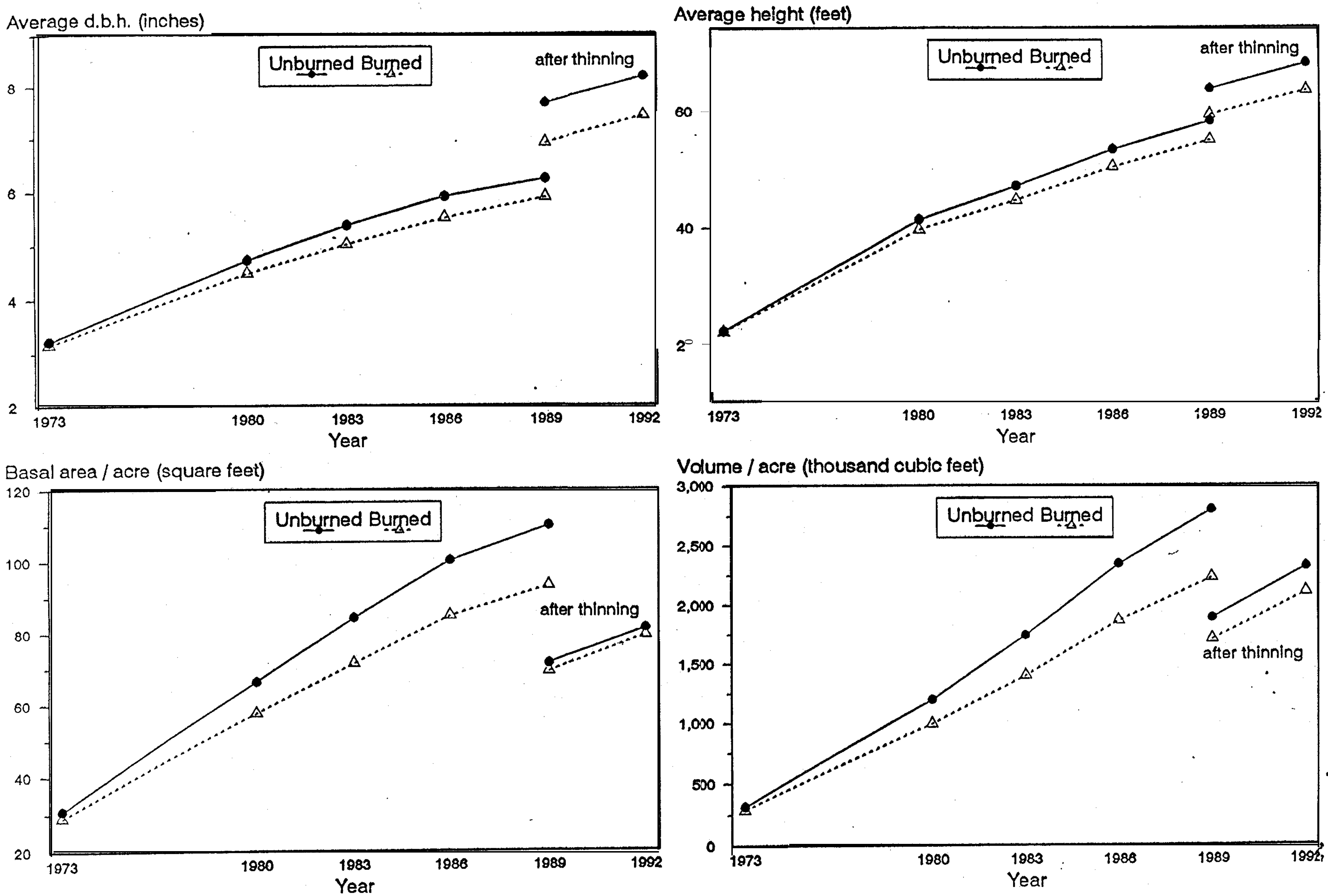

Figure 1. Effect of burning on longleaf pine tree and stand growth.

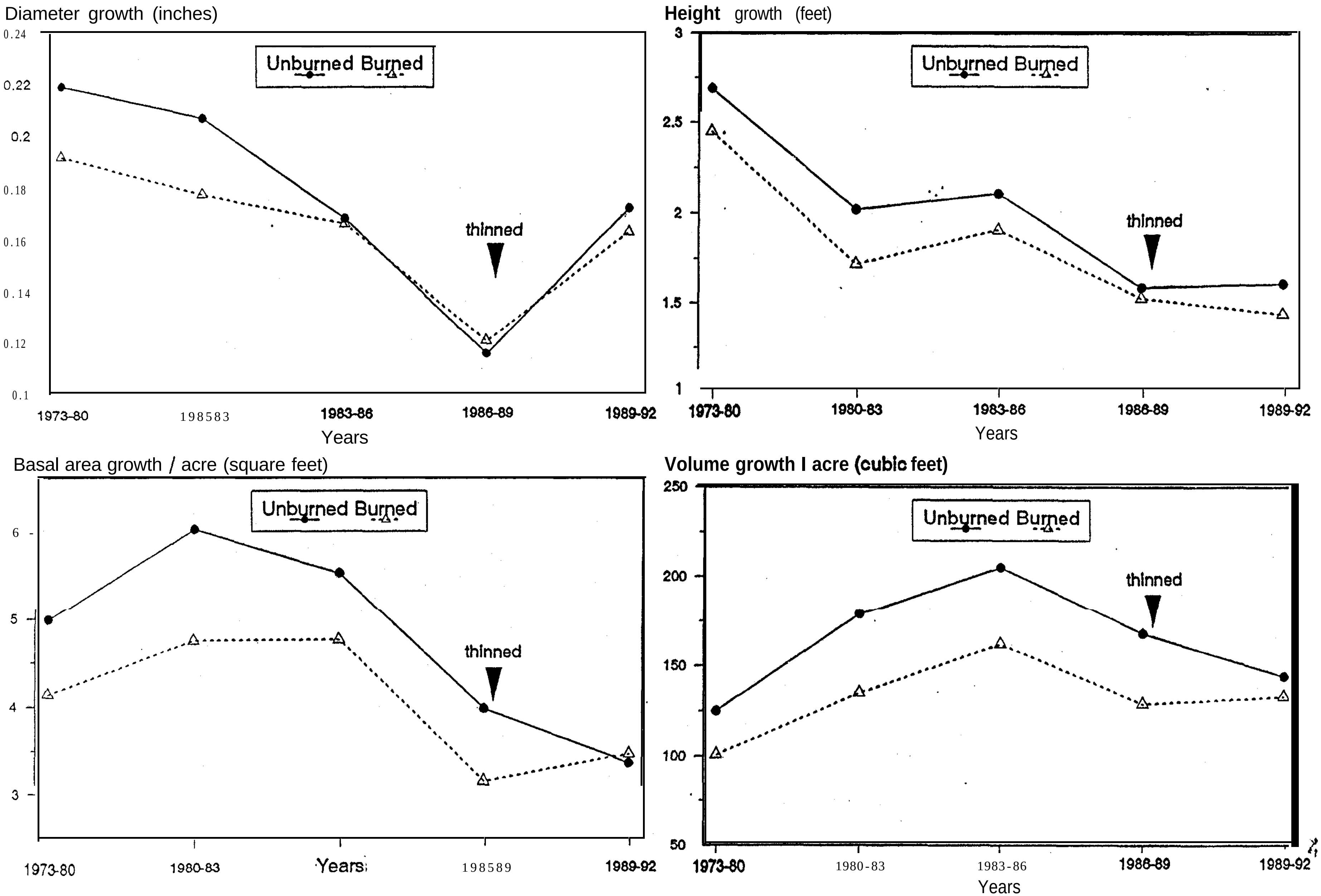

Figure 2. Periodic annual growth of burned and unburned longleaf pine.