

IMPACTS OF FIRE ON LONGLEAF PINE STAND DYNAMICS WITH DIFFERENT SEASONAL AND FIRE RETURN INTERVALS

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ABSTRACT

Fire is essential to maintain longleaf pine ecosystems, but there are concerns about the impacts of growing-season burns on these ecosystems. A study was established in 1984 in a 9-year-old naturally regenerated longleaf pine (*Pinus palustris*) stand in south-central Alabama, USA, to determine the comparative impact of both winter and spring prescribed fires with 2-, 3-, and 5-year return intervals on the growth of a longleaf pine overstory and development of a hardwood understory and midstory. For the first 6 years of the study there were no treatment effects on longleaf pine. The first treatment effects on longleaf pine growth appeared when the trees were 17–20 years old and have become more apparent with time. Mortality has been minimal, with longleaf pine survival running from 92% on the winter 3-year burns and no-burn control to 99% on the winter and spring 5-year burn treatments. There was a significant difference in diameter at breast height in 1999 with the 3-year winter and 2-year spring burn different from the no-burn treatment but not different from the other burn treatments. Total height was similar, except the significant differences carried through the 2004 measurement. Differences in longleaf pine basal area followed that of total height where the 3-year winter and 2-year spring burns were significantly less than the other treatments. Basal area was $> 5 \text{ m}^2/\text{ha}$ lower on these treatments than on the highest treatment, 5-year spring burn. Both season of burn and fire return intervals had an early and significant effect on understory hardwoods. There has been an increase in basal area in understory hardwoods with winter burns. The basal area for the no-burn and 5-year winter burn is more than twice that for the other treatments. Hardwood basal area and number of stems have declined over the previous 20 years for all spring burn treatments.

Keywords: longleaf pine, *Pinus palustris*, prescribed fire, south Alabama, spring burns, understory hardwoods, winter burns.

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INTRODUCTION

Prior to the arrival of European settlers in the United States, natural plant communities dominated by longleaf pine (*Pinus palustris*) and maintained by periodic fire occurred throughout most of the southern Coastal Plain (Frost 1993). Bartram (1791:52), an early traveler through the Southeast, wrote about these communities: “This plain is mostly a forest of the great long-leaved pine (*P. palustris* Linn.), the earth covered with grass, interspersed with an infinite variety of herbaceous plants, and embellished with extensive savannahs, always green, sparkling with ponds of water. . . .”

The landscape that Bartram and early settlers encountered was largely the result of frequent fire. Low-intensity, nonlethal fires moved through the presettlement longleaf savannas at intervals ranging from 1 to 10 years (Mattoon 1922,

Chapman 1932, Christensen 1981). These fires were ignited by a combination of lightning strikes (Komarek 1974) and aboriginal ignitions (Robbins and Myers 1992).

Longleaf pine ecosystems are uniquely adapted to frequent fire, with both regeneration of the species and understory composition dependent on regular fire intervals. However, prior research has shown there is potential for growth of young longleaf pine stands to be reduced by biennial prescribed fires, at least through age 30 (Boyer 1987, 1994). In that study, over a 9-year period from stand age 21 to 30, longleaf in unburned plots grew an average of 30% more volume than plots burned biennially. Season of burn had no significant effect on growth (Boyer 1987, 1994).

If the results of the preliminary study are robust, then economics of tree growth seems to suggest that fire should be excluded from young longleaf stands. However, frequent fire has added safety benefits for stands and resource managers. By controlling the often dense and flammable understory of these ecosystems, there is less risk of damage

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to residual forest stands and injury to forest workers. Boyer (1995) found nearly twice the amount of litter (fuel) had accumulated in unburned stands compared to burned stands, and further research by Kush et al. (2000) found this number to be 4 times that amount 14 years later. With the increase in fuel accumulation comes additional risk of damage to overstory trees. Kush (2006) reported that a low-intensity fire in a fire-suppressed old-growth longleaf pine stand killed all longleaf >80 years old. In addition, there is potential for increased mortality in larger trees as much as 2–4 years after reintroduction of fire into long-unburned longleaf stands (Kush et al. 2004).

It has been well documented that in the absence of frequent burning, the diverse ground cover of the longleaf landscape is replaced by hardwood trees and shrubs. Associated with these frequently burned ecosystems are several threatened and endangered species both plant and wildlife. Despite likely benefits to ecological values and safety, there was still concern about reported loss of growth and related volume associated with frequent burning (Boyer 1987, 1994).

To further understand the effect of fire on longleaf pine stand growth, additional research was initiated in 1984 to determine if prescribed fires at intervals of 3 or 5 years would reduce the impact on pine growth and still be reasonably effective for hardwood control. The objective of the current report is to evaluate the information gained from the study initiated in 1984 and determine the effect of winter and spring prescribed fires at 2-, 3-, and 5-year intervals on the growth of overstory pine and development of understory hardwood competition.

STUDY AREA

The study was conducted at the Escambia Experimental Forest in south-central Escambia County, Alabama, 31°01'N mean latitude and 87°04'W mean longitude. The forest is maintained by the U.S. Department of Agriculture, Forest Service, Southern Research Station, in cooperation with T. R. Miller Mill Company.

The climate was humid and mild with average precipitation of 142 cm generally well distributed throughout the year. Historically, October was the driest month, with no extended dry period in the spring. The warmest months were July and August with average daily maximum and minimum temperatures of 33° and 20°C, respectively. The coldest months were December and January with average daily temperatures of 18° and 3°C, respectively. The growing season was 250 days.

The predominant soil series on this Coastal Plain site was Troup (loamy, kaolinitic, thermic Grossarenic Kandiudults) with some Wagram, Dothan, and Fuquay represented. These soils formed in unconsolidated marine sediments of loamy sands, sandy loams, and sandy clay loams. They were very low in natural fertility and organic matter content.

METHODS

The current study was established in young longleaf pine stands regenerated by the shelterwood system (Croker 1956) and released from the parent overstory in the winter of 1976. Dated from the time of overstory removal, it was believed that most seedlings originated from the 1973 seed

crop, making the stands 9 years old when the first measurements were made during winter 1984–1985. In 1984, longleaf stands in the study areas ranged from 7,200 to 9,900 trees/ha, and dominant trees averaged 3 to 4.3 m in height. Before initiation of the study, all stands were burned in spring 1979 for competition control.

The study consisted of three blocks, each with 10 plots. Each plot is 40.2 × 40.2 m. Each plot had a central measurement area (20.1 × 20.1 m); the measurement area was surrounded by a 10-m buffer zone. All 0.16-ha plots were thinned to leave 1,000 dominant or codominant longleaf pines/ha with spacing as uniform as possible. Forty crop trees were selected to be measured on each 0.04-ha measurement plot and each measured tree was identified by a number painted on the bark.

Treatments in this study included both winter and spring burns repeated at intervals of 2, 3, or 5 years plus a no-burn (check) plot. Prescribed winter and spring burning treatments were initiated in 1985. To the extent possible, winter fires were completed in January or February, and spring fires in April or May. Fires were prescribed and executed so as to minimize crown scorch on pines. Normally, flank or strip head fires were used. Fires followed soaking rains as soon as conditions of fine fuel moisture of 7–10%, relative humidity of 35–55%, and reasonably steady winds of 5–16 km/hour were achieved.

Differences in longleaf diameter at breast height (DBH), total height, and basal area by burn treatment and frequency were examined using PROC GLM-Duncan's Multiple Range ($P < 0.05$) (SAS Institute 2003). The same tests were used to examine differences in understory hardwood density and basal area.

RESULTS AND DISCUSSION

Pine Survival and Growth

At the time of the study establishment in the fall and winter of 1984–1985, all pines had been released from the parent overstory for a period of 9 years. At this time, pines on the measurement plots averaged 5.3 cm DBH, 4.3 m in height, and a basal area of 2.4 m²/ha. An analysis of variance indicated no difference in the three variables among treatments. However, there was a significant effect of blocks on all three variables. Five of the 10 plots within one of the three blocks were on poorer sites, where site index was 3.0–4.6 m lower than the other plots in the block. Consequently, only two blocks were used in this analysis; the block that was significantly lower was omitted.

Mortality was minimal in the study. Survival ranged from 88% on the 3-year winter burn treatment to 98% on the 5-year spring burn treatment. Nearly 50% of the mortality was caused by breakage at a fusiform rust gall; most of this loss was from winds that appear to have been associated with Hurricane Opal in 1995.

Longleaf Pine Diameter Growth

As expected from Boyer's earlier study (1987, 1994), the no-burn treatment had the largest mean DBH at 19.2 cm (Table 1). However, there was only a difference of 1.50 cm between this and the lowest average DBH associated with the 2-year spring burn treatment. Through the 1994 season,

Table 1. Mean longleaf pine diameter at breast height (\pm SE) (cm) for season of burn and frequency for each measurement year on the Escambia Experimental Forest in Brewton, Alabama. Mean values without lowercase letters do not differ significantly within treatment.

Treatment ^a	Year of burn					
	1984	1987	1990	1994	1999	2004
Winter 2	5.7 \pm 1.39	8.5 \pm 1.82	10.5 \pm 2.42	13.3 \pm 3.04	15.6 \pm 3.94a	18.0 \pm 4.88
Spring 2	5.9 \pm 1.32	8.1 \pm 1.78	10.4 \pm 2.28	13.2 \pm 2.95	15.0 \pm 3.52a	17.7 \pm 4.18
Winter 3	5.7 \pm 1.43	8.8 \pm 1.85	10.9 \pm 2.40	13.3 \pm 3.02	15.9 \pm 3.26ab	18.3 \pm 3.79
Spring 3	5.4 \pm 1.53	8.9 \pm 1.51	11.5 \pm 1.83	14.4 \pm 2.39	16.8 \pm 3.00ab	18.6 \pm 3.57
Winter 5	5.8 \pm 1.39	8.5 \pm 1.56	10.7 \pm 1.92	13.6 \pm 2.54	16.0 \pm 3.20ab	18.2 \pm 3.97
Spring 5	5.9 \pm 1.57	8.7 \pm 1.85	11.1 \pm 2.17	14.3 \pm 2.69	16.7 \pm 3.25ab	19.1 \pm 3.85
No burn	5.8 \pm 1.01	9.0 \pm 1.34	11.4 \pm 1.71	14.5 \pm 2.36	17.2 \pm 2.99b	19.2 \pm 3.60

^a Winter and spring burns repeated at intervals of 2, 3, or 5 years plus a no-burn (check) plot.

there were no significant differences among the DBHs. In 1999, measured diameters on the 2-year winter and spring burns were significantly less ($P=0.0498$) than those on the no-burn plots. However, by 2004, there was no significant difference.

Longleaf Pine Height Growth

Similar to the average DBHs, there were no significant differences in height until 1999, when again, the 2-year winter and spring burn treatments were significantly different ($P=0.045$) from the no-burn (Table 2). However, they were not different from the other burn treatments. Unlike DBH, the difference in height associated with the 2-year treatment continued to 2004, with nearly a 1.7-m difference between this treatment and the no-burn. These results are similar to the findings of Boyer (1987, 1994).

Longleaf Pine Basal Area

As with DBH and height data, the first significant difference ($P=0.039$) in basal area appeared in the 1999 measurement (Table 3). At that time, the 2-year spring and 3-year winter burn treatments were different from the no-burn but were not different from other burn treatments. The 2-year spring difference was expected, but the 3-year winter was not. A possible explanation for this was the death of two trees due to lightning between the 1999 and 2004 measurements. With only 40 measurement trees, the loss of two trees is substantial. The significant difference continued in 2004. What is of most interest is that the 5-year spring burn

treatment had the highest basal area among all of the treatments, including the no-burn treatment with >29.1 m²/ha.

Understory Hardwood Density

The highest number of stems occurred on the no-burn treatment and the 5-year winter burn treatment (Figure 1). By 1990, these treatments were significantly different ($P=0.011$) from the other burn treatments. This trend continued until 1999, when the no-burn treatment (3,250 stems/ha) was significantly different from both the 5-year winter and the other burn treatments and the 5-year burn treatment (1,900 stems/ha) was different from the rest. By 2004, the 5-year winter treatment was no longer different from the other burn treatments. The loss in density was in the 2.54-cm DBH class and may be due to the hardwood midstory and longleaf pine overstory competition. In addition, there may be some confounding effect associated with time-since-last-burn; the current data set did not permit consideration of this factor. The 1999 and 2004 measurements were conducted in September while previous measurements were conducted from May through July. In addition, the year-since-last-burn and time of collection were not the same across the study; i.e., the 2-year burn plots were not always sampled at the same time-since-burn, and the same held for the other treatments.

Understory Hardwood Basal Area

Significant differences ($P=0.004$) in hardwood basal area appeared with the 1987 measurement (Figure 2). The

Table 2. Mean longleaf pine total height (\pm SE) (m) for season of burn and frequency for each measurement year on the Escambia Experimental Forest in Brewton, Alabama. Mean values without lowercase letters do not differ significantly within treatment.

Treatment ^a	Year of burn					
	1984	1987	1990	1994	1999	2004
Winter 2	4.4 \pm 1.09	7.2 \pm 1.37	10.0 \pm 1.61	13.5 \pm 1.77	15.7 \pm 2.27a	18.5 \pm 2.56a
Spring 2	5.0 \pm 1.23	7.1 \pm 1.38	9.9 \pm 1.55	13.3 \pm 1.82	15.8 \pm 2.18a	18.5 \pm 2.17a
Winter 3	4.7 \pm 1.12	7.7 \pm 1.42	10.7 \pm 1.70	14.1 \pm 2.10	17.0 \pm 2.00ab	19.6 \pm 1.76ab
Spring 3	4.3 \pm 1.16	6.9 \pm 1.29	10.0 \pm 1.39	13.8 \pm 1.51	16.1 \pm 1.86ab	19.2 \pm 2.20ab
Winter 5	4.7 \pm 1.15	7.4 \pm 1.23	10.4 \pm 1.24	14.0 \pm 1.40	16.2 \pm 1.65ab	19.2 \pm 1.91ab
Spring 5	4.8 \pm 1.39	7.5 \pm 1.50	10.4 \pm 1.50	14.2 \pm 1.46	16.7 \pm 1.68ab	19.4 \pm 1.89ab
No burn	4.7 \pm 0.88	7.6 \pm 0.83	10.7 \pm 0.86	14.7 \pm 1.06	17.3 \pm 1.28b	20.2 \pm 1.38b

^a Winter and spring burns repeated at intervals of 2, 3, or 5 years plus a no-burn (check) plot.

Table 3. Mean longleaf pine basal area (\pm SE) (m^2/ha) for season of burn and frequency for each measurement year on the Escambia Experimental Forest in Brewton, Alabama. Mean values without lowercase letters do not differ significantly within treatment.

Treatment ^a	Year of burn					
	1984	1987	1990	1994	1999	2004
Winter 2	2.6 \pm 0.13	5.7 \pm 0.27	8.9 \pm 0.17	14.2 \pm 0.42	19.7 \pm 0.02ab	25.5 \pm 0.55ab
Spring 2	2.6 \pm 0.17	5.4 \pm 0.06	8.7 \pm 0.19	14.0 \pm 0.19	18.4 \pm 1.29a	23.8 \pm 1.28a
Winter 3	2.7 \pm 0.31	6.2 \pm 0.91	9.5 \pm 1.78	13.9 \pm 1.79	19.0 \pm 2.25a	23.7 \pm 3.43a
Spring 3	2.5 \pm 0.04	5.9 \pm 0.41	9.6 \pm 0.26	15.0 \pm 1.17	21.2 \pm 2.23ab	27.7 \pm 2.55ab
Winter 5	2.8 \pm 0.88	5.8 \pm 0.70	9.2 \pm 0.57	14.8 \pm 0.01	20.5 \pm 1.37ab	26.6 \pm 2.05ab
Spring 5	2.9 \pm 1.18	6.1 \pm 1.89	9.7 \pm 2.12	16.2 \pm 1.89	22.3 \pm 1.49ab	29.1 \pm 0.55ab
No burn	2.7 \pm 0.00	6.5 \pm 0.33	10.3 \pm 0.55	16.6 \pm 1.05	23.2 \pm 1.73b	28.5 \pm 1.63b

^a Winter and spring burns repeated at intervals of 2, 3, or 5 years plus a no-burn (check) plot.

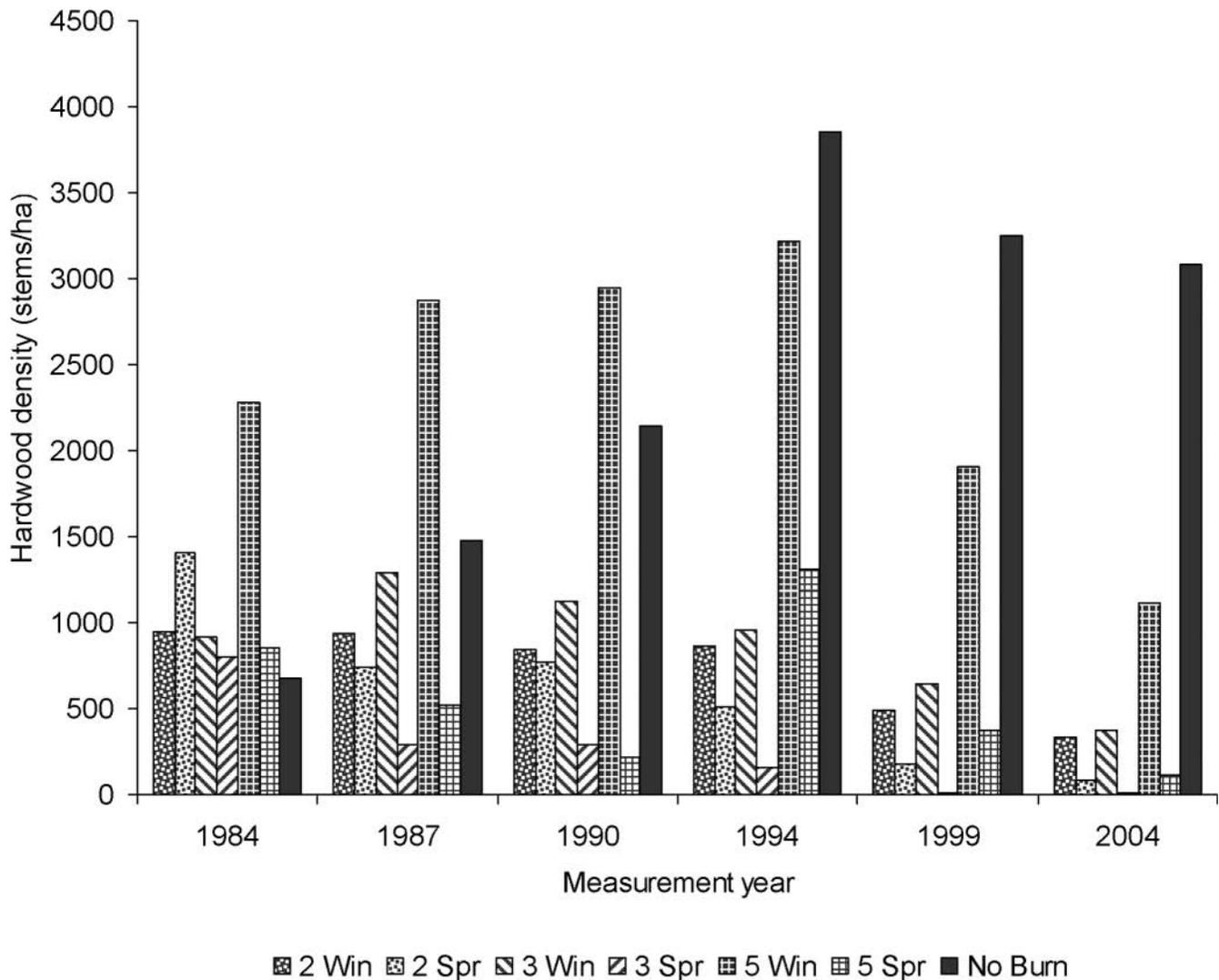


Figure 1. Average understory hardwood density (stems/ha) for season of burn and frequency for each measurement year, on the Escambia Experimental Forest in Brewton, Alabama. Treatments: winter (2 Win, 3 Win, 5 Win) and spring burns (2 Spr, 3 Spr, 5 Spr) repeated at intervals of 2, 3, or 5 years plus a no-burn (check) plot.

no-burn and 5-year winter burn treatments were significantly different from the other burn treatments. These treatments had more than twice the basal area compared to the other treatments. The difference continued through the 2004 measurement.

Hardwood Species Composition

All spring burns had less hardwood development over the measurement period than the winter burns. The 5-year burn cycle had a higher density than the 2- and 3-year burn cycles.

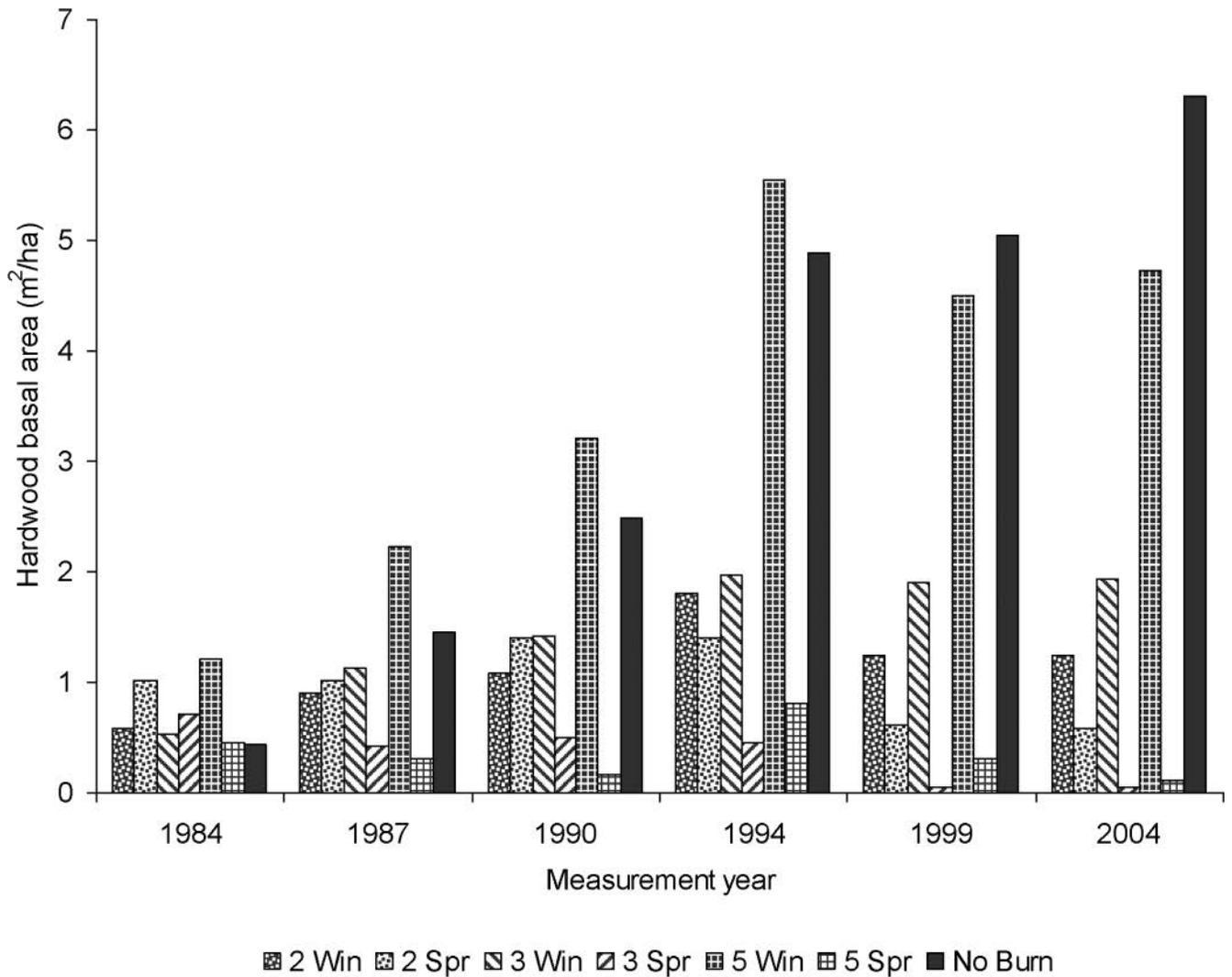


Figure 2. Average understory hardwood basal area per hectare (m²) for season of burn and frequency for each measurement year, on the Escambia Experimental Forest in Brewton, Alabama. Treatments: winter (2 Win, 3 Win, 5 Win) and spring burns (2 Spr, 3 Spr, 5 Spr) repeated at intervals of 2, 3, or 5 years plus a no-burn (check) plot.

The overall species composition of the hardwoods changed very little over the study. In 1984, 71% of all stems (>1.0 cm DBH) were six species of oak, with bluejack (*Quercus incana*) and water oak (*Q. nigra*) alone making up 51% of all hardwood stems; dogwood (*Cornus florida*) constituted 18%. A pool of 25 species made up the remaining 11%. By 2004, all oaks dropped to 58% of the total number of hardwood stems, with bluejack and water oaks accounting for 42%, while dogwood had increased to 24% and all other species to 18%.

As expected, species other than oaks and dogwood were most prominent on the unburned treatment, where they made up 27% of all hardwood stems. On all burned plots combined, species other than oak and dogwood made up 13% of all hardwood stems. Most of these represented encroachment into the 2.54-cm DBH class. When considering only stems in the 5-cm and larger (>3.8 cm) DBH classes, species other than oaks and dogwood comprised just over 3% of the total, all on winter-burned plots. On all

spring-burned plots, only oaks and dogwoods survived to reach the 5-cm and larger diameter classes. The principal effect of season of burn was the reduction in number of hardwood stems with spring burns. The most notable change in species composition among the oaks was the decline in water oak from 54% of all oaks on winter-burned plots to 26% on spring-burned plots. The difference was made up by small increases in the percentage of bluejack, southern red (*Q. falcata*), and turkey oaks (*Q. laevis*) on spring-burned plots.

CONCLUSIONS

Boyer (1987) reported a significant reduction in pine growth associated with all biennial burning treatments when compared to the no-burn treatment. Though all but one of the burn treatments had lower basal areas than the no-burn treatment, there was a lack of a significant difference in that study. Therefore, it was unexpected that the 5-year spring

treatment in this current study would have more basal area than the other treatments, including the no-burn treatment. The 5-year burn treatment may have been enough to keep the hardwood competition under control, allowing for improved pine growth. In addition, for reasons unknown, growth loss in this study has not been as substantial when comparing the biennial burn in this study with Boyer's earlier work. There has been some thought that it might be due to fireline intensity and/or method of firing. However, efforts were made to burn the different studies under the same conditions and, in many cases, plots in both studies were burned the same day with the same firing technique.

There are several factors that, although not readily apparent, must be remembered when examining these data. First is the time-since-last burn. For example, the second spring burn preceded the 1990 measurement by a few months while the 1995 spring burn occurred after the 1994 measurement. This has potential to have tremendous impact on the number of hardwood stems reported in a given inventory period. Second, this study is limited to young, even-aged longleaf pine stands, so results may not be applicable older stands, or uneven-aged systems. And finally, the study is limited to a Coastal Plain site in South Alabama that is of medium site quality. Glitzenstein et al. (2003) reported differences, based on geography and perhaps soil, in effects of fire regime on open pineland ground layer. In their study, similar fire regimes on sample areas in South Carolina compared to North Florida resulted in differences in ground-layer composition. It is possible that geography may also influence effects of fire regimes on pine growth and/or hardwood control.

Frequent prescribed fire of low to moderate severity significantly reduces fuel loads and reduces the likelihood that target stands and neighboring properties may be damaged by prescribed burns that become unpredictably intense due to heavy or uneven fuels. In addition, such unpredictability can pose additional dangers for fire crews on the ground. Chapman (1932:333) wrote: "In the longleaf pine type of the south (and nowhere else in North America to the writer's knowledge) fire at frequent but not necessarily annual intervals is as dependable a factor of site as is climate or soil. The conception of a climax type as one which has reached a stage of permanent equilibrium or perfect adaptation to these constant factors of site should include the longleaf pine type of the south, which presents by far the greatest area and most permanent characteristics of any climax to be found in the United States." We must remember that fire has always been a part of the longleaf pine ecosystem. Longleaf pine is adapted to, and dependent on, periodic fire for its continued survival in nature.

Prescription of fire interval will impact longleaf pine growth and will differ by season of burning. Burning is required to reduce fuel loads and hardwood encroachment in longleaf pine stands. Hardwoods were not controlled by the 5-year winter interval in this study. Pine growth was negatively impacted by frequent spring burns. These results suggest that winter burns with 2- to 3-year intervals or spring burns with 3- to 5-year intervals are acceptable.

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