Four Site-Preparation Techniques for Regenerating Pine-Hardwood Mixtures in the Piedmont

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ABSTRACT. *Four variations of the fell-and-burn technique, a system developed to produce mixed pine-hardwood stands in the Southern Appalachian Mountains, were compared in the Piedmont region. All variations of this technique successfully improved the commercial value of low-quality hardwood stands by introducing a pine component. After six growing seasons, loblolly pine (*Pinus taeda *L.) occupied the dominant crown position and oaks the codominant position in fell-and-burn treated stands on poor to medium quality sites. The precise timing offelling residual stems, as prescribed by thefell-and-burn technique, may be flexible because winter and spring felling produced similar results. Although summer site preparation burns reduced hardwood height growth by reducing the length of the first growing season, they did not improve pine survival or growth. Pines were as tall as hardwoods withinfour growing seasons in burnedplots and within sixgrowing seasons in unburned plots. Additional research is needed to determine the level or intensity of site preparation needed to establish pine-hardwood mixtures over a range of site conditions. South. J. Appl. For. 21(3):116–122.*

Improving productivity on nonindustrial private forest (NIPF) lands in the Southeast is a major goal for meeting future timber demands. In the Piedmont and Mountain regions, over 68% of the commercial forestland (26.9 million ac) is occupied by hardwood or mixed pine-hardwood stands, and 7 1% of this land is owned by NIPF landowners (Bechtold and Ruark 1988). Because hardwood growth is vigorous in these regions, conversion of stands to pure pine requires extensive site preparation to control competition. Rather than spend the $150 to $250 per acre required for conversion to pure pine, most NIPF landowners choose to leave their forests unmanaged. These unmanaged forests are responsible for a large acreage of poorly stocked stands of low-quality hardwoods in the Southeast.

Although timber production may not be the primary interest of many NIPF landowners, they may be attracted to enhancing income if their forestlands can provide other benefits such as aesthetics or wildlife habitat. Establishment of pine-hardwood mixtures is a method of providing multiple benefits while improving productivity and minimizing investment (Phillips and Abercrombie 1987). However, guidelines for low-cost regeneration of pine-hardwood mixtures are limited.

Traditionally, research in mixed pine-hardwood stands has focused on pine growth reduction from hardwood competition. More recent research has presented methods of harvesting and site preparation to control hardwood competition. McGee (1986, 1989) reported high survival and rapid growth of planted loblolly pines (*Pinus taeda* L.) after harvesting low-quality hardwood stands by chainsaw to a 4 in. lower diameter limit (with and without herbicide injection of residuals) and by shearing to a 1 in. limit. In another study, hardwood sprouts overtopped planted loblolly pines in 5 yr old clearcuts unless a herbicide or release treatment was applied (Zedaker et al. 1987, Zedaker et al. 1989). Lloyd et al. (1991) showed that growth of planted shortleaf pines *(P. echinata* Mill.) improved after release at age 4, but release was not necessary for survival. In a study by McMinn (1989), naturally regenerated shortleaf, Virginia *(P. virginiana* Mill.), and loblolly pines were largely absent from areas harvested in the growing season and suppressed in areas where hardwoods were dormant-season harvested to a 4 in. diameter limit instead of a 1 in. limit.

The fell-and-bum technique (Abercrombie and Sims 1986, Phillips and Abercrombie 1987) is an inexpensive (less than $100/ac) regeneration system, which may be attractive to NIPF landowners. This technique has proven successful for converting low-quality hardwood stands to pine-hardwood

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mixtures in the Southern Appalachian Mountains. The technique includes a commercial clearcut followed by spring (early growing season) felling of residual hardwood stems (more than 5 ft tall) and a summer (late growing season) broadcast bum. Both felling and burning are designed to control hardwood sprout growth so pines can be established without eliminating hardwoods. Pines are planted the following winter (dormant season) at wide spacings (10 x 10 ft or wider) to reduce costs and allow some hardwood dominance in the stand. In previous studies, hardwoods were overtopped within 4 yr by planted shortleaf pines in the mountains (Phillips and Abercrombie 1987) and loblolly pines in the Piedmont (Waldrop 1995). Waldrop et al. (1989) found that loblolly pines overtopped hardwoods by age 7 in fell-and-bum treated areas in the foothills of South Carolina.

The fell-and-bum technique should produce results in the upper southeastern Piedmont similar to those observed in the mountains. However, the short time periods for felling (May to June) and burning (mid-July to August), as suggested by Phillips and Abercrombie (1987), limit successful application. For many landowners, prescribed burning is difficult to accomplish. Moreover, summer bums can be severe and result in excessive erosion if improperly applied (Van Lear and Kapeluck 1989, Robichaud and Waldrop 1994). Felling at other times of the year or eliminating burning may resolve these problems, but these variations of the fell-and-bum technique have not been tested. Finally, the competition between trees in young pine-hardwood stands has received limited study, and the effects of site preparation treatments on stand establishment and competition are poorly documented.

A project was established in 1987 to test the fell-and-bum technique on Piedmont sites and to compare the effects of three variations of the technique on stand composition and early growth of pines and hardwoods. This paper reports findings through six post-harvest growing seasons.

Methods

Study sites are located in two stands on the Clemson Experimental Forest in Pickens and Anderson Counties of South Carolina. These sites are similar in aspect, soil, and vegetation. All sites are classified as subxeric to xeric (Jones 1989), occur on south-facing slopes, and have slopes ranging from 7% to 10%. All soils are described as Typic Hapludults.

Before harvesting in December 1987 and March 1988, common overstory tree species included white oak (*Quercus alba* L.), southern red oak (Q. *falcata* Michaux.), post oak (Q. *stellata* Wangenh.), black oak (Q. *velutina* Lam.), scarlet oak (Q. *coccinea* Muenchh.) chestnut oak (*Q. prinus* L.), hickory (Car-ya sp.), and shortleaf pine. Stand basal area included 18.0 ft^2/ac of pines and 57.3 ft^2/ac of hardwoods. Site index for shortleaf pine (age 50) ranged from 55 to 66 ft.

A total of 87 sample plots was established in 3 replications (2 replications occur in one stand) of 4 treatments. The treatments included:

1. Spring felling of residuals over 5 ft tall followed by summer broadcast burning (the fell-and-burn technique).
2. Winter felling of residuals with summer broadcast burning.
3. Spring felling of residuals with no burning.
4. Winter felling of residuals with no burning.

Each treatment was randomly assigned to one of four treatment areas within each replication. Treatment areas were approximately 2 ac and included from 5 to 8 sample plots. Each sample plot was 1 ch x 1 ch square (1/10 ac). Plot centers were generally 80 ft apart, leaving a 14 ft buffer between plot boundaries. Before harvest, the species, diameter at breast height (dbh), and total height of all trees over 5 ft tall were recorded. Trees less than 5 ft tall were tallied by species.

Phillips and Abercrombie (1 987) suggested that sprout vigor would be reduced by felling residual hardwood stems in late spring when carbohydrate reserves in root systems are typically low. Winter felling and spring felling were used in this study to test this hypothesis. Chainsaw crews felled all residual stems over 5 ft tall. Winter felling was done during the first week of March 1988; spring felling was done during the third week of June 1988.

Burning occurred on July 7, 1988, 2 days after a rainfall of 0.5 in. Humidity at the time of burning was 50–60%, and windspeed was approximately 5 mph. Moisture content of 10 hr timelagfuels (0.25-I in. indiameter) was 12% at lO:OO A.M. and 9% to 10% after noon. Backing fires were started along the edges of the units, followed by strip-head fires to ignite the interior fuels. Disturbance by skidding and the presence of tree tops affected fuel loading which ranged from none to very heavy. Fuels consisted of large logs, old down material, freshly felled residuals, logging slash, leaf litter, and new growth.

Fuels were inventoried before and after the broadcast bum using the planar intersect method (Brown 1971). Planes, 50 ft long, were established along transects at 2 ch intervals. Azimuths for each plane were determined randomly. Along each plane, quantities, depths, and types (pine vs. hardwood) of fuels were tallied. Percentage of exposed soil was estimated by dividing the distance of exposed soil along the transect by the length of the transect.

Improved loblolly pine seedlings were hand planted by contract crews in all treatment areas during March 1989. Observations on fell-and-burn areas on the Sumter National Forest in South Carolina indicated that pines outcompete and overtop hardwoods by age 7 to 10 (Waldrop et al. 1989). Therefore, pines were planted at a wider spacing (15 x 15 ft instead of 10 x 10 ft) in this study to reduce costs and to allow favorable conditions for hardwood development.

After treatment, regeneration data were collected at the end of each of the first four growing seasons (1988-l 99 1) and at the end of the sixth growing season (1993). Measurements on hardwoods included: (1) number of seedlings and sprouts by species, (2) sprouts per stump, and (3) height of the dominant sprout on each stump. Survival and height of planted pines were measured for a 100% sample of each 2 ac treatment area. Treatment differences were compared by analysis of variance with each variable for the common species or species groups which included: loblolly pine, oak, hickory, blackgum, other hardwoods, and all hardwood species combined. Mean separation was by linear contrast (alpha = 0.05).

Results and Discussion

Fire Effects

Broadcast burns were high intensity with flames reaching heights of 10 to 15 ft where fuel loading was heavy. However, fire severity was low with exposure of mineral soil on no more than 22% of the burned areas (Table 1). Although the amount was not measured, some soil exposure can be attributed to logging disturbance.

The season of felling affected fire behavior. In spring-felled areas, dry leaves carried the fire, producing uniform burns across the entire study area. In winter-felled areas, foliage was not present when residuals were felled. Therefore, dry leaf litter was limited, and fires did not carry between slash piles. Slash piles had to be ignited separately, producing a patchy burn pattern. In a corollary study, Evans et al. (1991) found greater plant diversity and higher small mammal usage in the patchy winter-felled study areas.

Burning in spring-felled areas consumed more logging slash than in winter-felled areas. Loading of fine woody fuels (less than 0.25 in. diam) before burning was the same in both winter- and spring-felled areas (Table 1). After the burn, fine-fuel loading and the depth of all woody fuels (logging slash and felled residuals) had been reduced more in spring-felled areas than in winter-felled areas. These differences are partially explained by the presence of leaves on the stems felled during spring. After a tree is cut, the evapotranspirational function of leaves continues to remove water from the bole and branches (McMinn 1986) which increases their flammability.

Species Composition

For all treatments, postharvest species composition of regeneration closely resembled that of preharvest stands. Regeneration at the end of the 1988 growing season consisted almost entirely of sprouts of scarlet oak, southern red oak, white oak, post oak, black oak, chestnut oak, hickories, blackgum (*Nyssa sylvatica* Marsh. var. Sylvatica), sourwood (*Oxydendrum arboreum* [L.] DC.), and dogwood (*Cornus florida* L.). Primary invader species were present in the burned areas, but few or none were found in the unburned treatments. These invader species included vetch (*Vicia* spp.), butterfly pea (*Clitoria mariana* L.), fireweed (*Erechtites hieracifolia* [L.] Raf), and pokeweed (*Phytolacca americana* L.).

Table 1. Fuel characteristics and soil exposure before and after burning by season of felling.

	Winter felled	Spring felled
Weight of fine woody fuels (<0.25 in. diam)	(tons/ac)	
Before burning	0.4	0.4
After burning	0.2	0.1
Percent reduction	50	75
Depth of all fuels	(in.)	
Before burning	8.5	7.7
After burning	3.9	1.8
Percent reduction	54	77
Soil exposure	(%)	
Before burning	4.0	7.6
After burning	22.1	20.3

Hardwood species composition remained largely unaffected by treatment throughout the 6 yr study period. At the end of the 1993 growing season, differences among treatments in the number of stems per acre for hickories, blackgum, and the all-species category were not significant (Table 2). Stem numbers in the other-hardwoods category were significantly greater in burned study plots. Although stem numbers were higher for this species group during the first three growing seasons after harvest, this difference was not significant until the fourth growing season (1991).

Oak numbers were significantly smaller in burned areas at the end of six growing seasons (Table 2). This difference was an effect of plot location rather than fire because oaks were less numerous in burned plots than in unburned plots before treatment. Moreover, burning tended to increase the number of oak sprouts per stump rather than decrease them (Table 3). Numbers of sprouts per stump were significantly greater in burned plots for the oak, other hardwood, and all species groups.

Pine regeneration was counted at the end of the third, fourth, and sixth growing seasons after harvest (1990, 1991, and 1993). Survival of planted pines was generally over 65% (126/ac) throughout the six postharvest growing seasons and did not differ among treatments (Table 4). However, total pine regeneration (planted and volunteer) was significantly greater in burned plots after six growing seasons. This difference was not significant in previous years. Pine numbers decreased in unburned plots between the fourth and sixth

Table 2. Species composition of hardwood regeneration six growing seasons after harvest.

Treatment	Oak[1]	Hickory	Blackgum	Other hardwoods[2]	Total
			(stems/ac)		
Winter fell/no burn	3,724c[3]	653a	288a	3,177a	7,842a
Spring fell/no bum	3,300bc	727a	365a	3,788a	8,180a
Winter fell 'burn	2,273a	915a	175a	6,876b	10,239a
Spring fell/bum	2,335b	873a	356a	6,362b	9,926a

1 Scarlet oak, southern red oak, white oak, post oak, black oak, and chestnut oak.
2 Blackcherry (*Prunus serotina* Ehrh.), dogwood, persimmon (*Diospyros virginiana* L.), winged sumac (*Rhus copallina* L.), sourwood, yellow-poplar (*Liriodendron tulipifera* L.), and miscellaneous species.
3 Means followed by the same letter within a column are not significantly different at the 0.05 level.

Table 3. Mean number of sprouts per stump by species and treatment six growing seasons after harvest.

Treatment	Oak[1]	Hickory	Blackgum	Other hardwoods[2]	Total
Winter fell/no bum	4.9a[3]	3.9ab	1.9a	6.1a	5.2a
Spring fell/no bum	5.9ab	5.4b	1.3a	6.2a	5.8a
Winter fell/burn	6.8b	3.6a	4.1a	9.6c	7.4b
Spring fell/burn	6.4b	4.8ab	3.1a	8.0b	6.7b

1 Scarlet oak, southern red oak, white oak, post oak, black oak, and chestnut oak.
2 Black cherry, dogwood, persimmon, winged sumac, sourwood, yellow-poplar, and miscellaneous species.
3 Means followed by the same letter within a column are not significantly different at the 0.05 level.

growing seasons and increased in burned plots. This trend may suggest that volunteer pines in unburned plots were being overtopped by vines and herbaceous plants while recruitment continued in burned plots.

Tree Growth

At the end of the 1988 growing season, summer broadcast burning had reduced the height of the dominant sprout in each clump for most species groups (Table 5). Spring felling and burning reduced height more than winter felling and burning which was significant for blackgum, hickory, and other hardwoods. Spring felling without burning had little effect on height growth. Of the two components, burning had more effect on growth than did season of felling. The height of competing hardwoods on burned plots was reduced because the growing period was shorter in the first growing season after treatment, not because sprout vigor was reduced.

By the end of the sixth growing season (1993), the dominant hardwood sprout averaged over 10 ft tall in burned plots and over 13 ft tall in unburned plots. Sprouts in burned areas were significantly shorter than in unburned areas for all species and groups (Table 6). However, the additional control of hardwood growth provided by spring felling was no longer evident, except in the hickory and other hardwood groups. Hickories in spring-felled and burned plots were significantly shorter than those in winter-felled and burned plots. Within the other-hardwood group, stems in unburned areas felled in spring were significantly shorter than those in unburned areas felled in winter. Blackgum sprouts in spring felled and burned areas were significantly shorter than chose in unburned areas but were not significantly different from those in winter felled and burned areas.

Controlling hardwood growth by burning did not affect height growth of planted pines. Pine heights ranged from 12.6 to 14.0 ft (Table 6), but heights were not significantly different among treatments. In the autumn of 1993, planted pines had grown for five seasons, while hardwoods had grown for all (unburned) or a portion (burned) of six seasons. However, pines had overtopped hardwoods in all treatment plots except unburned plots that were felled in winter. Most of the pines that survived through the sixth growing season appeared healthy and should remain a major component of these stands.

Figure 1 compares height growth of hardwoods and planted loblolly pines by treatment over the 6 yr study. Hardwoods are represented by the mean of all species within a treatment. Because height growth of pines did not vary by treatment, pine heights are shown as the mean of all planted pines in all treatment areas. At the end of the 1988 growing season, hardwoods in burned treatment areas were significantly shorter than those in unburned areas because burning shortened the growing season. This difference was consistent through the end of the 1993 growing season. Hardwoods in spring-felled areas (burned and unburned) were somewhat shorter than those in winter-felled areas. However, this difference was significant only during the first growing season.

By the time loblolly pine seedlings were planted (between the 1988 and 1989 growing seasons), hardwoods were already taller (Figure 1). Pine seedlings had little height growth

Table 4. Survival of planted pines and total number of pines by treatment at the end of the third, fourth, and sixth growing seasons.

Year	Treatment	Number of planted pines surviving per acre (%)	Total number of pines per acre (planted & volunteer)
1990	Winter fell/no bum	143 (74)a[1]	214a
	Spring fell/no burn	139 (72)a	391a
	Winter fell/burn	144 (75)a	349a
	Spring fell/bum	146 (75)a	354a
1991	Winter fell/no bum	134 (69)a	297a
	Spring fell/no bum	131 (68)a	324a
	Winter fell/bum	133 (69)a	516a
	Spring fell/bum	113 (58)a	415a
1993	Winter fell/no bum	134 (69)a	216a
	Spring fell/no bum	130 (67)a	278a
	Winter fell/bum	132 (68)a	564b
	Spring fell/bum	113 (58)a	440b

1 Means followed by the same letter within a column and year are not significantly different at the 0.05 level.

Table 5. Average height (ft) of the dominant sprout by species group and treatment one growing season after harvest.

Treatment	Oak[1]	Hickory	Blackgum	Other hardwoods[2]	Total
Winter fell/no bum	3.3a[3]	1.5a	2.6a	3.5a	3.0a
Spring fell/no bum	3.0a	1.2ab	2.5a	3.4a	2.7b
Winter fell/bum	1.6b	1.1b	2.0a	1.9b	1.5c
Spring fell/burn	1.7b	0.8c	1.0b	1.6c	1.3c

1 Scarlet oak, southern red oak, white oak, post oak, black oak, and chestnut oak.
2 Black cherry, dogwood, persimmon, winged sumac, sourwood, yellow-poplar, and miscellaneous species.
3 Means followed by the same letter within a column are not significantly different at the 0.05 level.

during the 1989 and 1990 growing seasons, remaining significantly shorter than ‘hardwoods in all treatment areas. Beginning in the 199 1 growing season, however, pine height growth was more rapid than hardwood height growth. Total height of pines equaled hardwoods in burned plots by the end of the 199 1 growing season. In unburned plots, pines required two additional growing seasons to equal hardwoods in height. The heights of planted pines were not significantly different from the heights of hardwoods in unburned plots at the end of the 1993 growing season. At that time, planted pines were significantly taller than hardwoods in burned plots. These results differ from those described in an earlier report of this study. Waldrop (1995) showed that pine and hardwood heights were equal in burned plots at age 4 (199 1) and that hardwoods were taller than pines in unburned plots. Pines grew more rapidly than did hardwoods between ages 4 and 6 in all plots which caused the change in results.

These results suggest that little competition existed between pines and hardwoods during the first six growing seasons for all treatments. Even though most hardwoods were taller than pines for most of the study period, pine survival was good and height growth of pines improved after their second growing season (1990). Height growth for pines followed a sigmoid shape, beginning with slow growth (1.7 ft/yr) for 2 yr followed by 3 yr of rapid growth (3.3 ft/yr) (Figure 1). Hardwood sprouts followed a straight-line pattern for height growth, averaging 1.9 ft/yr for all treatments. Although not measured, the crown canopy was beginning to close in all treatment areas at the end of the sixth growing season. After canopy closure, increased competition may lead to significant changes in stand composition.

Summary and Conclusions

This study indicates that the fell-and-burn technique can successfully establish mixed stands of pines and hardwoods in the Piedmont region. Spring felling of residual hardwoods reduced the height growth of some species and provided fine fuels to support a uniform site preparation burn. Burns were not severe with soil exposed on only about 20% of the study area. Burning effectively controlled hardwood sprout growth by reducing the length of the first growing season. This effect remained apparent through six growing seasons. The wide spacing used to plant loblolly pines in this study provided adequate regeneration. Pines overtopped hardwoods within four growing seasons and should remain a dominant component of the future stand. Oaks, which were taller and more numerous than most hardwood species, will also be present among overstory trees.

This study also indicates that some variations of the fell-and-bum technique may be used successfully on xeric and subxeric sites. Winter felling of residual stems, followed by summer burning, produced stands nearly identical to those regenerated by spring felling and summer burning. Winter felling did not control hardwood growth as well as spring felling. However, growth reductions from spring felling lasted only one growing season and had no apparent effect on stand development. This result suggests that the precise timing of felling as prescribed by the fell-and-burn technique is not as critical for xeric and subxeric sites as once thought. Although not tested in this study, spring felling may prove beneficial for controlling hardwood competition on better quality sites or as a means of eliminating undesirable natural regeneration of Virginia pine (McMinn, 1989).

Burns in winter-felled areas were not uniform, leaving scattered unburned patches. However, because these burns top-killed most hardwood sprouts they were as effective at controlling hardwood growth as burns in spring-felled areas. The patchy nature of these burns may help meet some objectives by increasing plant and animal species diversity and contributing to stand structural diversity by leaving more

Table 6. Average height (ft) of planted pines and the dominant sprout of hardwoods six growing seasons after harvest.

Treatment	Oak[1]	Hickorv	Blackgum	Other hardwoods[2]	All hardwoods	Planted pines
Winter fell/no bum	15.3a[3]	9.5a	8.5a	13.4a	13.8a	12.8a
Spring fell/no bum	14.9a	8.7ab	8.5a	12.2b	12.9a	14.0a
Winter fell/bum	11.7b	8.1b	6.5ab	10.3c	10.3b	13.7a
Spring fell/bum	11.6b	6.4c	2.9b	10.3c	10.3b	12.6a

1 Scarlet oak, southern red oak, white oak, post oak, black oak, chestnut oak.
2 Black cherry, dogwood, persimmon, winged sumac, sourwood, yellow-poplar. and miscellaneous species.
3 Means followed by the same letter within a column are not significantly different at the 0.05 level.

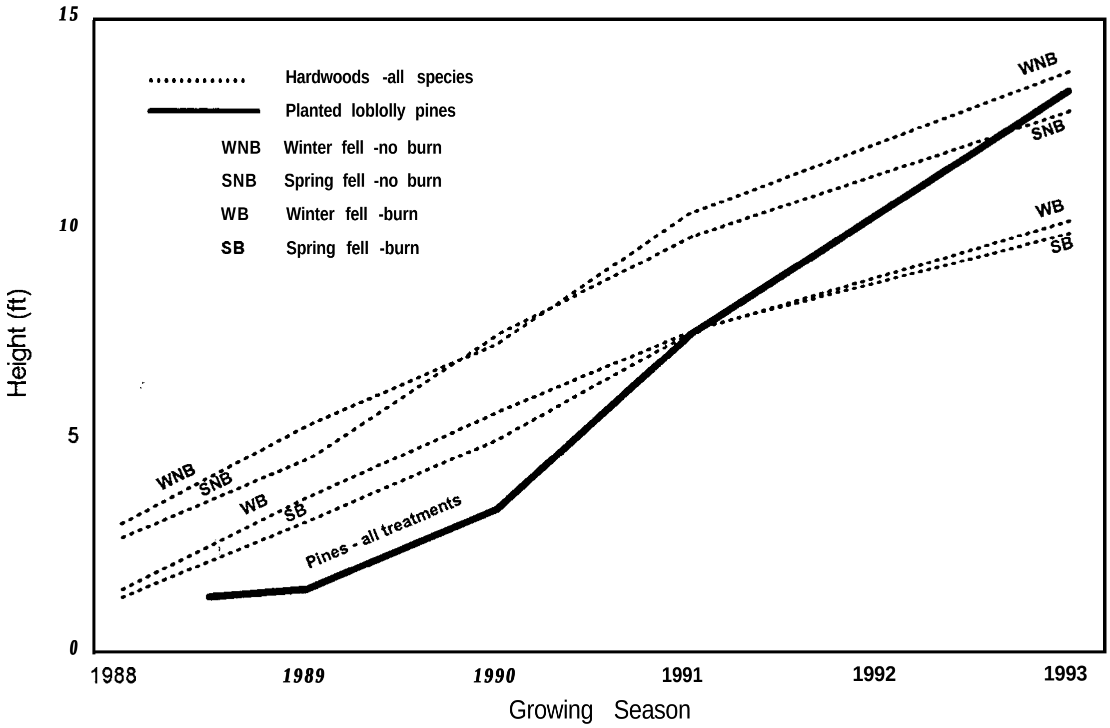

Figure 1. Mean height of all hardwood species (by treatment) and planted loblolly pines (all treatments combined) at the end of each growing season.

woody debris. However, burning in winter-felled areas was difficult because each slash pile had to be ignited separate1 y. Although erosion was not a problem in this study, other studies (Van Lear and Kapeluck 1989, Robichaud and Waldrop 1994) have shown heavy erosion after high-severity burns. Winter felling may reduce erosion by decreasing burn severity and leaving more debris dams; however, this effect has not been studied.

Pine-hardwood mixtures were successfully established in this study without site-preparation burning. Pine survival and growth in unburned areas equaled that of pines in burned areas over the 6 yr study. Planted pines in unburned areas remained shorter than hardwoods until the end of the sixth growing season. These pines should maintain their rapid growth rate and compete with most hardwoods. Moreover, pines could be planted immediate] y after winter felling without waiting an additional year for the summer burn.

This study suggests that little or no site preparation is needed on xeric and subxeric sites if a mixture of pines and hardwoods is desired. Spring and winter felling without burning were the most simple and inexpensive techniques tested and may prove most attractive to NIPF landowners. Other studies have indicated that burning, herbicide application, or release are needed to prevent hardwoods from overtopping pines. However, these studies may have been conducted on better quality sites or under different weather conditions. Moreover, conclusions in previous studies may have been made before pines had adequate time to catch hardwoods. In this study, pines were shorter than hardwoods for several years. However, pine heights either equaled or exceeded the heights of hardwoods in all treatment areas before crown closure occurred. On better quality sites, hardwoods would grow faster and crown closure could occur before the pines reached the upper canopy. Additional research is needed to determine the level or intensity of site preparation required to successfully establish mixtures of pines and hardwoods over a wider range of site conditions.

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