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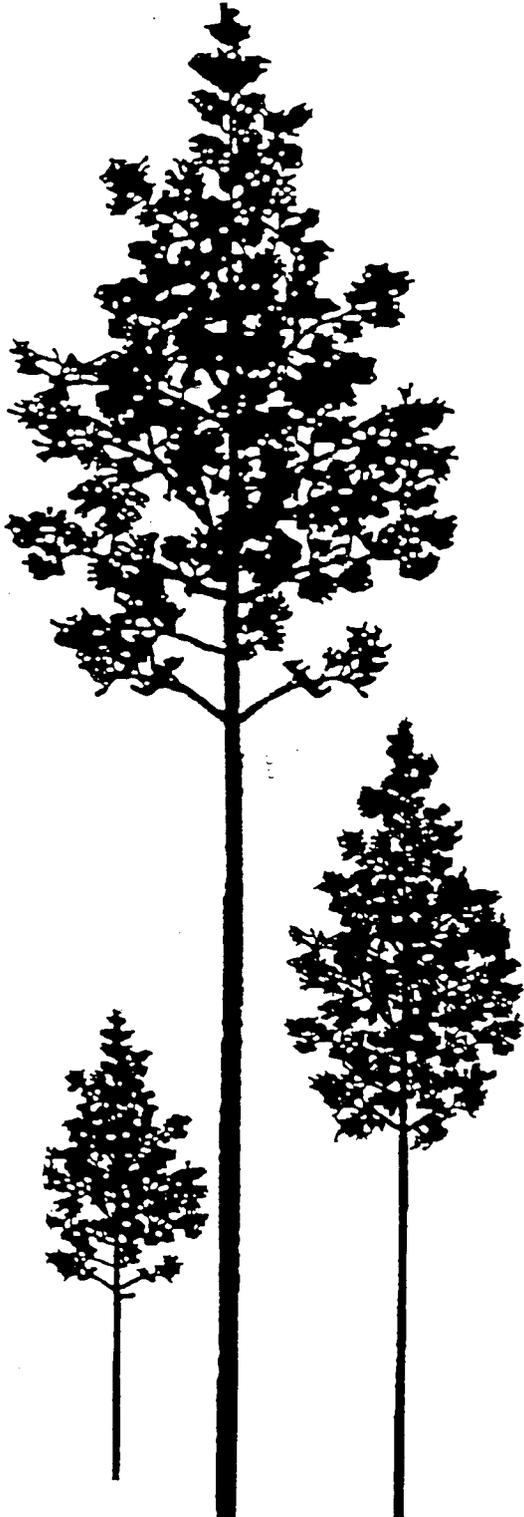


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GROWTH REDUCTIONS IN SHORT-ROTATION LOBLOLLY AND SLASH PINES IN CENTRAL LOUISIANA--10TH YEAR RESULTS

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GROWTH REDUCTIONS IN SHORT-ROTATION LOBLOLLY AND SLASH PINES IN CENTRAL LOUISIANA--10TH YEAR RESULTS¹

James D. Haywood and Allan E. Tiarks²

Abstract—A 22-year-old loblolly (*Pinus taeda* L.) and slash pine (*P. elliottii* Engelm. var. *elliottii*) research plantation was clearcut and replanted with the same species to compare tree growth between the two rotations. Both pine species were more productive in the first than the second rotation through 10 growing seasons. Loblolly pine productivity was especially reduced on replanted plots that had been disked or disked and bedded 32 years earlier. However, reductions in growth and yield occurred on all treatment plots for both species.

INTRODUCTION

We recently reported that second-rotation plantations of loblolly (*Pinus taeda* L.) and slash pines (*P. elliottii* Engelm. var. *elliottii*) on silt loam soils in central Louisiana were growing more slowly than those in the preceding generation (Haywood 1994). That report was based on height growth in 7-year-old stands that were only beginning the rapid growth period common for these species. We are now reporting on the development of these plantations after 10 growing seasons. The effects of repeated rotations on diameter, basal area, and stand yields are even more apparent.

METHODS

Study Area

The study area, in Rapides Parish, Louisiana, contains Beauregard (Plinthaquic Paleudult, fine-silty, siliceous, thermic) and Caddo (Typic Glossaqualfs, fine-silty, siliceous, thermic) silt loam soils (Haywood 1994). Natural stands of longleaf pine (*P. palustris* Mill.) and hardwoods were clearcut in the 1920's. A cover of grasses and scattered hardwoods developed and was maintained by periodic burning. Prior to pine planting, the area was burned to reduce the grass rough, and the woody vegetation was cut and removed.

Plot Establishment, Treatments, and Management

At the beginning of the first rotation, four blocks of six plots (treatments) each were established in a randomized complete block design. Blocking was

based on surface drainage. Each of the 24 plots was 144 by 108 feet (0.36 acre), and contained 18 rows spaced 8 feet apart. Seedlings were planted 6 feet apart within rows.

Within blocks, the six plots were randomly assigned one of two species, loblolly or slash pine, and one of three site preparation treatments. Treatments were: (1) **Burn-only**—all plots were burned in 1960 to facilitate planting, (2) **Burn-disk**—plots were treated with an offset disk harrow in the fall of 1960 and again in July 1961 to control established grass competition, and (3) **Burn-disk-bed**—after disking, the plots were double bedded in September 1961 by making two passes with a bedding harrow. Beds were spaced 8 feet apart, and the height from furrow-to-crest averaged 20 inches before setting; after 15 years, the beds were 10 inches tall. Graded, nursery-grown, bare-root, 1-0 loblolly and slash pine seedlings were hand planted in rows on their respective plots in February 1962.

During the first rotation, grasses were the initial principal competitors with the pine trees. Some woody competitors were present, principally southern bayberry (*Myrica cerifera* L.). The loblolly pine plots were thinned to a basal area of 84 ft²/acre and the slash pine plots to 78 ft²/acre after the 13th growing season (Haywood 1983). By 1981, total outside-bark stemwood production averaged 4,780 ft³/acre on the loblolly and 4,390 ft³/acre on the slash pine plots.

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All plots were clearcut in August 1983, after 22 growing seasons. Logging equipment was not allowed on the plots, and tops and limbs were left in place. After harvest, the entire study area was prescribed burned to remove logging residue and facilitate planting. The burn-disk and burn-disk-bed plots were not retreated mechanically so the influence of the initial site preparation treatments could be evaluated during the second rotation.

In February 1984, the plots were hand planted the second time with graded, nursery-grown, bare-root, 1-0 loblolly or slash pine seedlings. The seedlings were planted between stumps in the original planting rows.

During the second rotation, all plots were rotary mowed yearly between the rows of pine trees to control the size of woody competitors, and the debris left in place. Woody vegetation was cut down in the planted rows during the 9th growing season. This was done to keep woody plant competition from negatively affecting pine tree growth more than it did in the first rotation.

Measurements and Data Analysis

Ten rows of 10 trees each were measured in the center of each plot. In the first rotation, tree measurements included total height, taken at ages 1 to 10, 13, 15, and 20 years, and diameter at breast height (d.b.h.), taken at ages 5 to 10, 13, 15, and 20 years. In the second rotation, tree measurements included total height, taken yearly, and d.b.h., taken yearly beginning at age 5 years. In both rotations, height poles were used to measure tree heights for at least the first seven growing seasons and diameter tapes were used to measure d.b.h. A clinometer was used to measure tree heights at age 10. The d.b.h. and height data were used to calculate outside bark total stem volumes for loblolly (Baldwin and Feduccia 1987) and slash (Lohrey 1985) pines.

Pine survival, height, d.b.h., basal area, and volume data were subjected to analysis of variance using a split-plot model with rotation as the main plot effect, site preparation as the subplot effect, and four blocks (Probability > F-value=0.05) (Haywood 1994).

Precipitation data have been collected in the general area of the research plots since 1952. For the first 10 years of both rotations, the monthly total precipitation values were used to calculate winter/spring (January, February, March, April, May, and June) and total yearly precipitation. The winter/spring and total yearly

precipitation data, which do not vary across blocks or treatments, were analyzed for differences between rotations (Haywood 1994). Also, a Kruskal-Wallis test was used to compare the distribution of winter/spring and total yearly precipitation during the first 10 years of each rotation (Probability > Chi-square=0.05).

On March 18, 1993, foliar samples were collected from five dominant and codominant trees per plot. The samples were taken in the upper one-third of the tree crowns. The samples were oven-dried at 158°F (70°C) for 24 hours, weighed, and ground in a Wiley mill. After sulfuric acid/cupric sulfate digestion, nitrogen, phosphorus, and potassium were determined by ammonium probe, colorimetry, and atomic absorption spectrophotometry, respectively.

Treatment differences in 1993 concentrations of nitrogen, phosphorus, or potassium in the loblolly or slash pine foliage were identified through analysis of variance (Probability > F-value=0.05). Rotation was not a variable in these analyses.

We wanted to determine if nutrient concentrations in the living foliage were related to pine growth responses (dependent variables) during the second rotation. We therefore developed linear regression equations with the concentrations of nitrogen, phosphorus, and potassium in the living needles as the independent variables. The equation form was: pine growth variable= $b_0 + b_1(\text{nutrient concentration})$.

RESULTS

Initially, the second-rotation pine seedlings were taller, but after four growing seasons, the first-rotation loblolly pines were 24 percent taller and the first-rotation slash pines were 18 percent taller on average than the second-rotation trees (figs. 1,2). Height differences continued to increase thereafter, with the height differences between the two rotations averaging 11.0 feet for loblolly and 3.5 feet for slash pine by age 10 (table 1).

Both pine species also had significantly greater diameter growth and yield in the first rotation than in the second (table 1). The first-rotation loblolly pine stands had averages of 1.1 inch greater d.b.h., 1.6 ft³ more volume per tree, 48 ft² more basal area, and 1,280 ft³ more volume per acre than the second-rotation stands. The first-rotation slash pine stands had averages of 0.5 inch greater d.b.h., 0.7 ft³ more volume per tree, 121



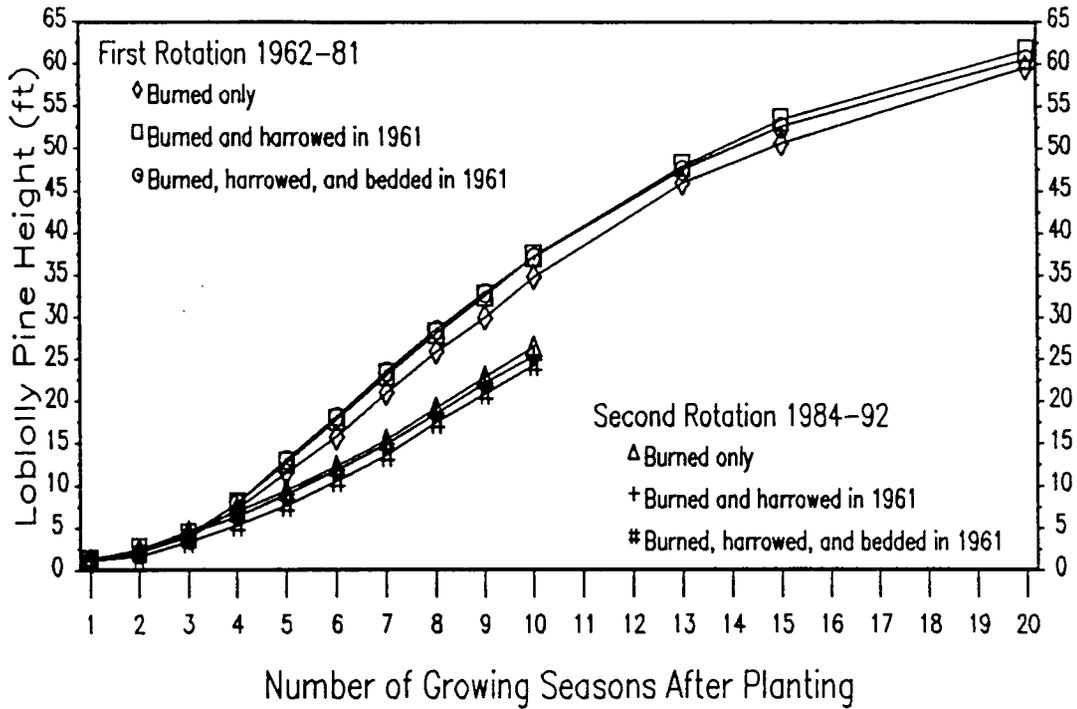


Figure 1—Height growth of planted loblolly pines in the first and second rotations on silt loam soils in Louisiana.

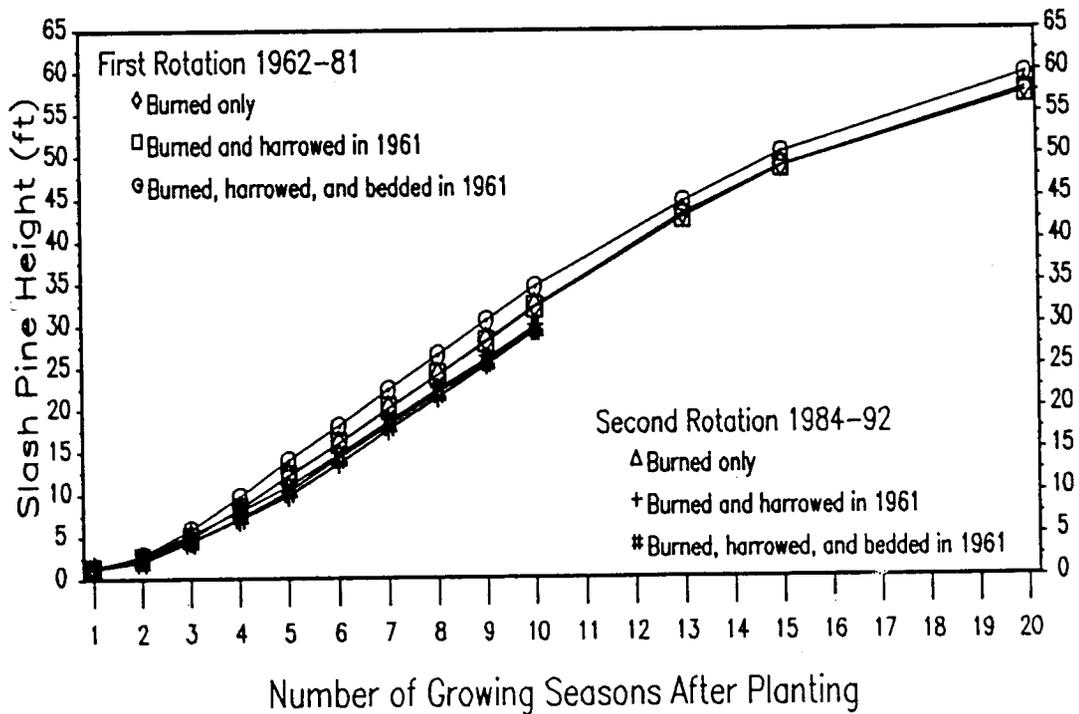


Figure 2—Height growth of planted slash pines in the first and second rotations on silt loam soils in Louisiana.

Table 1. Mean total height, d.b.h., and outside-bark volume per tree and number of pine trees, basal area, and volume per acre in the first and second rotations for 10-year-old loblolly and slash pine, and the probabilities of greater F-values based on the analyses of variance

Rotations and treatments	Species											
	Loblolly pine						Slash pine					
	Total height	Volume		Number		Basal area	Total volume	Total height	d.b.h.	Volume per tree	Number per acre	Basal area
feet	in	ft ³	count	ft ² /ac	ft ³ /ac		in.	ft ³	count	ft ² /ac	ft ³ /ac	
First Rotation												
burn-only	34.8	5.3	2.93	660	103.5	1,912	32.2	5.1	2.63	731	105.5	1,913
burn-disk ¹	37.3	5.4	3.14	785	125.8	2,467	32.1	5.1	2.58	710	102.2	1,836
burn-disk-bed	37.2	5.3	3.06	806	126.3	2,465	34.6	5.3	2.93	753	116.2	2,212
	36.4	5.3	3.04	750	118.5	2,281	33.0	5.2	2.71	731	108.0	1,987
Second Rotation												
burn-only	26.5	4.3	1.58	747	79.6	1,174	29.9	4.7	2.06	647	78.8	1,328
burn-disk	25.4	4.2	1.43	701	71.3	996	29.3	4.7	2.07	583	71.8	1,190
burn-disk-bed	24.3	4.0	1.23	681	61.6	833	29.4	4.6	1.95	601	69.9	1,154
	25.4	4.2	1.41	710	70.8	1,001	29.5	4.7	2.03	610	73.5	1,224
Sources of variation (probability > F-value)												
Rotation	0.0001	0.0011	0.0002	0.3626	0.0005	0.0003	0.0219	0.0185	0.0228	0.0692	0.0119	0.0116
Main effect error - mean square	.9656	.0498	.0342	8718.3	54.346	24684	3.6387	.0669	.1523	11394	235.72	113897
Treatment	.4520	.2592	.5071	.4527	.2079	.0719	.1881	.8907	.7074	.5903	.3215	.2934
Rotation by treatment interactions	.0040	.3250	.1688	.0256	.0004	.0001	.1374	.4244	.2685	.7126	.0777	.0844
Subplot effect error - mean square	1.2937	.0436	.0599	4957.8	57.244	21572	1.9564	.0576	.0899	6885.1	68.412	43384

¹The disking and bedding treatments were only applied in the first rotation.

more trees per acre, 35 ft² more basal area, and 763 ft³ more volume per acre than the second-rotation stands.

Significant rotation-by-treatment interactions were evident on the loblolly pine plots for total height, number of trees, basal area, and volume per acre (table 1). During the first rotation, the loblolly pine trees on the two sets of mechanically prepared plots had 2.5 feet more height with 136 more trees, 23 ft² more basal area, and 554 ft³ more volume per acre than trees on the burn-only plots. In the second rotation, these relationships were reversed. The loblolly pines on the burn-only plots had 1.7 feet more height with 56 more trees, 13 ft² more basal area, and 260 ft³ more volume per acre than trees on the two sets of mechanically prepared plots.

No statistically significant rotation by treatment interactions were evident for slash pine. However, the bedded plots were the most productive in the first rotation, yielding 299 ft³/acre more volume than the burn-only plots at age 10 (table 1). In the second rotation, the burn-only plots were the most productive, yielding 174 ft³/acre more volume than the bedded plots.

During the first rotation, 70 tons of wood and bark containing 17 lbs P/acre were removed from the study area in intermediate and final harvests, but only about 2.2 lbs P/acre were added to the soil in atmospheric deposition (McClurkin and others 1987, Tiarks and Haywood 1993, Tiarks and others 1991, USDA Forest Service 1982). Foliage sampled from both species was deficient in phosphorus in the second rotation (Tiarks



1983, Tiarks and Shoulders 1982, Wells and Allen 1985) (table 2). Foliage nutrition of both loblolly and slash pine varied little among treatments, but loblolly pines on the bedded plots may have had a greater concentration of phosphorus than trees receiving the other two treatments. The concentrations of nitrogen, phosphorus, and potassium in loblolly pine were greater than the concentrations of these nutrients in slash pine, that result was expected (Tiarks and Shoulders 1982).

Table 2.—Nutrient concentrations in the foliage of loblolly and slash pines sampled in March 1993

Species and treatments	Nutrients		
	Nitrogen	Phosphorus	Potassium
	-----g/kg-----		
Loblolly pine			
burn-only	11.6	0.90	3.44
burn-disk ¹	12.3	.90	3.17
burn-disk-bed	12.5	.98	3.22
	12.1	.93	3.28
Slash pine			
burn-only	8.9	0.70	3.44
burn-disk	9.7	.70	3.30
burn-disk-bed	9.3	.68	3.21
	9.3	.69	3.32

Sources of variation	(probability > F-value)		
Loblolly pine			
Block	0.2481	0.4547	0.7129
Treatment	.7012	.1664	.5737
Error Mean	2.5231	.00306	.13876
Square			
Slash pine			
Block	0.2604	0.8927	0.0955
Treatment	.4023	.8240	.7688
Error Mean	.60861	.00417	.19769
Square			

¹The disking and bedding treatments were only applied in the first rotation.

It appeared pine growth and yield through 10 growing seasons of the second rotation might be associated with concentration of foliar nutrients. However, coefficients of multiple determination (R^2) were less than 25 percent for all of the linear regressions, regardless of pine species, dependent growth variable, or independent nutrient variable (data not shown).

Simple climatic models may help remove some of the variability associated with rotational growth differences (Allen and others 1991). The first year of both rotations had above-normal precipitation when compared to the 42-year average of 57.9 inches. However, average total yearly precipitation over the first 10 years of both rotations was below normal, with the first rotation averaging 54.1 inches/year, and the second rotation averaging 57.5 inches/year. There were no statistically significant differences in average yearly precipitation or in the distribution of yearly rainfall over the two 10-year periods.

The amount of precipitation during the winter/spring months averaged 30 inches over the last 42 years. Winter/spring precipitation was somewhat greater during the second rotation (31.4 inches) than the first rotation (26.2 inches) (Probability > F-value=0.1588), and there may have been some differences in the distribution of precipitation over the two 10-year periods (Probability > F-value=0.1509). The first rotation had above-average winter/spring precipitation in the 1st, 5th, and 10th years, but the winter/spring precipitation was below normal in other years. The second rotation had above average winter/spring precipitation amounts in the 6th through 10th years, but winter/spring precipitation was below normal during the first 5 years.

DISCUSSION

Many potential factors may be involved in growth decline, and it often is not practical to measure all likely factors in hopes of identifying the correct ones. For example, we did not measure soil variables at the beginning of the first and second rotations, so we can only speculate about possible relationships between soil productivity and declines in pine growth and yield. However, even if soil data were available, the only way to prove the causes for decline in pine productivity would be to correct for potential deficiencies by imposing a complex of treatments. In the next rotation, we plan to replant the slash pine plots with loblolly pine and broadcast diammonium phosphate and potassium as a remedial treatment.

Growth decline is not always the consequence of human activities. Eriksson and Johansson (1993) reported that increased nitrogen deposition in Europe probably increased Norway spruce (*Picea abies* (L.) Karst.) growth in the second of two consecutive rotations in Sweden. Nitrogen is normally a growth-limiting nutrient in most forest ecosystems in Sweden. Detrimental management practices in the broadleaf

forests that predated the first rotation of Norway spruce stands (protracted cattle grazing and utilization of woody debris as fuel) may have also contributed to the slow rate of stand development in their first rotation.

Silt loam forest soils in Louisiana are normally deficient in phosphorus, and intensive production of wood in short rotations may worsen such deficiencies (Dyck and Skinner 1990, Wells and Jorgensen 1977). From estimates of atmospheric deposition minus the amounts removed during harvests, we speculate that over 14 lbs P/acre were lost from this site during the first rotation.

Loblolly pine is known to be more sensitive to phosphorus deficiencies than slash pine on Aquult and Udult soils in the lower West Gulf Coastal Plain (Tiarks and Shoulders 1982). The greater growth decline among loblolly than slash pines suggests, therefore, that phosphorus nutrition may be a factor. If this speculation is correct, phosphorus fertilization well might restore or increase yields (Allen 1987, Dyck and Skinner 1990, Tiarks 1983).

Burning the logging residue prior to planting the second rotation may have adversely affected pine productivity. Squire and others (1985) recommended retention of pine litter and logging residue as sources of nutrients, organic matter, and mulch to maintain site productivity on infertile sandy soils in the next rotation. Retention of litter on planting sites has increased the growth of loblolly pine seedlings and saplings in other studies (unpublished data).

Despite yearly variation in precipitation, the cumulative height curves seemed to be unaffected by precipitation differences (figs. 1,2). Therefore, rainfall was probably adequate for tree growth every year.

CONCLUSIONS

Our study clearly demonstrates declining yields in successive rotations on fairly productive soils that yielded 230 ft³/acre/year of pine volume during the first rotation (Haywood 1983). Loblolly was more affected than slash pine. Although loblolly pine responded positively to mechanical site preparation in the first rotation, the reduction in growth on the same plots in the second rotation was significantly greater than that on burn-only plots.

Several obvious potential contributors to second-rotation growth decline do not seem important in this

study; differences in precipitation patterns, logging damage, changes in competitive species, and the planting stock used in both rotations provided a wide range of genetic material.

We think that the loss of phosphorus is at least a partial reason for observed growth declines. The net removal of phosphorus and other nutrients could be reduced by lengthening the rotation or shredding and spreading bark, limbs, and tops over the site during harvests. Given the economic constraints faced by most landowners, fertilization seems like a more attractive alternative or additional practice on similar sites where short rotation intensive management is preferred.

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