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ABSTRACT: *The response of diameter and height of unthinned planted stands of loblolly* (Pinus taeda L.) *and slash* (Pinus elliottii *Engelm.) pine in East Texas to different classes of planting densities were analyzed. After tracking the development of diameter and height for 15 yr on a set of permanent plots representing a broad range of plantation parameters, average diameter and average height trends were observed. For both species, average diameter values were significantly larger with lower planting densities. In contrast, average height growth is insensitive to planting density at younger age classes for loblolly and at older age classes for slash pine plantations. South. J. Appl. For. 22(4):241–244.*

Choice of the number of trees per acre to plant (planting density) is a critical decision facing a plantation manager. The choice can affect the selection of a site preparation technique, planting procedures, and the genetic stock, which in turn can influence the total cost of plantation establishment. Profit on the establishment investment may be realized, if the trees are of sufficient size at harvest to be merchandised into suitable products for the anticipated markets.

The effect of planting density on tree size (diameter—measured at breast height and height—total tree height) has been investigated for several species. For young stands of loblolly pine (*Pinus taeda* L.) in Georgia, lower planting densities resulted in larger diameter trees, while height was not significantly influenced by planting density (Pienaar and Shiver 1993). Similar results were found for slash pine (*P. elliottii* Engelm.) in Georgia (Sarigumba and Anderson 1974), Choctawhatchee sand pine (*P. clausa* var. *immuginata* D. B. Ward) in the southeastern Coastal Plain of the United States (Outcalt 1986), *Eucalyptus grandis* Hill ex Maiden trees in southwestern Florida (Meskimen and Franklin 1978), and *Terminalia superba* in Nigeria (Okojie et al. 1988).

No information on planting density and tree size is available for southern pines on the western edge of the range. The objective of this study was to determine the effect of planting density on diameter and height development of unthinned planted pine trees in East Texas.

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Plantation Measurements

Observations from an array of 282 permanent plots located throughout East Texas in 196 unthinned industrial loblolly and 86 slash pine plantations were utilized in this study. Each plot consists of two adjacent subplots (separated by a 60 ft buffer). When the East Texas Pine Plantation Research Project permanent plots were installed in 1982–1984, the age of the plantations varied from 1 to 15 yr of age. From either planting records or field measurements, planting density was determined for each subplot.

After 15 yr or 5 cycles of measuring the planted pines within each plot, about 25% of the original subplots have been lost due to acts of man or nature. In this analysis, each subplot was treated as a sampling unit. As a result, from the 15 yr period, 1,601 loblolly and 720 slash subplot observations were available for quantifying the development of the planted pines.

For each observation: age was known, and average diameter (in.) of all trees and average total height (ft) of the ten tallest trees were calculated. In addition, planting density (trees per acre) was constant for each sampling unit. The nature and character of these five plantation variables are depicted in Table 1. Average planting density for both species could translate into spacings of about 8 × 8 ft, 6 × 10 ft or 5 × 12 ft.

Observations from the loblolly data set were grouped by five planting density classes (≤400, 500, 600, 700, and ≥800) and four age classes (5, 10, 15, and ≥20 yr); however, a ≤400 class was not available for the slash pine data set. Based on these data, one-way ANOVA calculations were conducted

Table 1. Characterization of the East Texas loblolly and slash pine plantation plots.

Species item	Min.	Mean	Max.
Loblolly (1,601 obs)			
Plantation age (yr)	1	11	27
Planting density (trees/ac)	363	701	1,361
Total height of ten tallest trees (ft)	2	37	100
Average diameter (in.)	0	4.7	11
Slash (720 obs)			
Plantation age (yr)	1	11	26
Planting density (trees/ac)	454	724	1,361
Total height of ten tallest trees (ft)	2	36	89
Average diameter (in.)	0	4.6	10

for each age class to test null hypotheses of no differences between average diameter and average height across planting density classes.

Effect of Planting Density on Diameter

After one-way ANOVA calculations were completed, the influence of planting density on loblolly pine diameter development can be listed as:

- Age class 5: average diameter ranged from 1.41–1.95 in. ($P = 0.5764$).
- Age class 10: average diameter ranged from 4.57–5.16 in. ($P = 0.0509$).
- Age class 15: average diameter ranged from 6.05–6.98 in. ($P = 0.0009$).
- Age class 20: average diameter ranged from 6.96–8.47 in. ($P = 0.0052$).

A visualization of the effect is depicted in Figure 1.

For age classes 5 and 10 yr, there are no statistically significant differences in diameter between the planting densities. By age class 15, diameter development for planting densities 400 and 500 is significantly higher ($P < 0.05$) than planting density classes 600, 700, and 800 trees/ac. This trend is even more evident for age class 20, where diameter decreases with increasing planting density in a definitive manner.

After statistical analysis, the effect of planting density on slash pine diameter development can be listed as:

- Age class 5: average diameter ranged from 1.64–2.36 in. ($P = 0.0291$).
- Age class 10: average diameter ranged from 4.51–5.25 in. ($P = 0.0023$).
- Age class 15: average diameter ranged from 5.85–6.92 in. ($P = 0.0001$).
- Age class 20: average diameter ranged from 6.86–9.20 in. ($P = 0.0008$).

Figure 2 illustrates slash pine diameter development.

For this species, across the age classes, the lower planting densities tended to produce trees with significantly larger diameters in a relatively consistent manner.

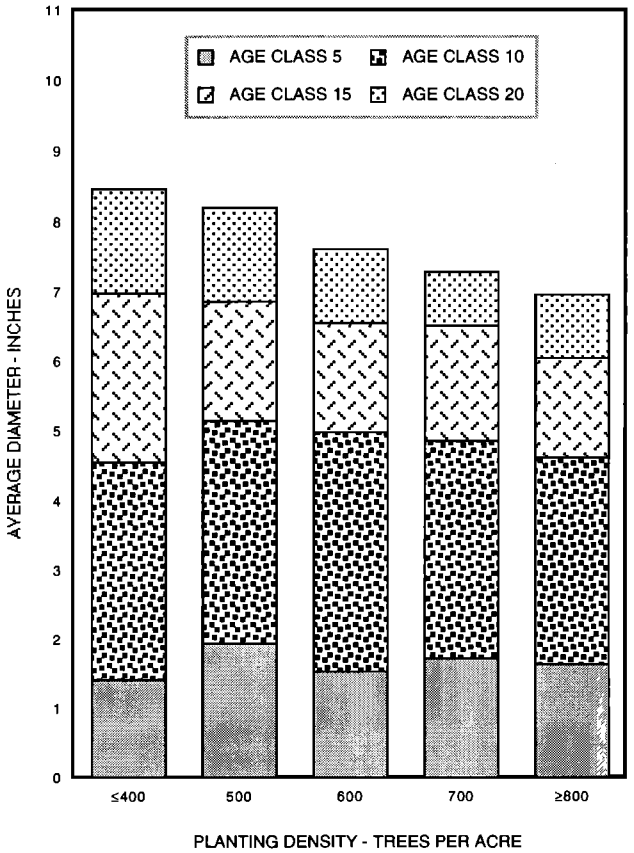

Figure 1. Average diameter by planting density and age classes for loblolly pine plantations in East Texas ($n = 1,601$ obs).

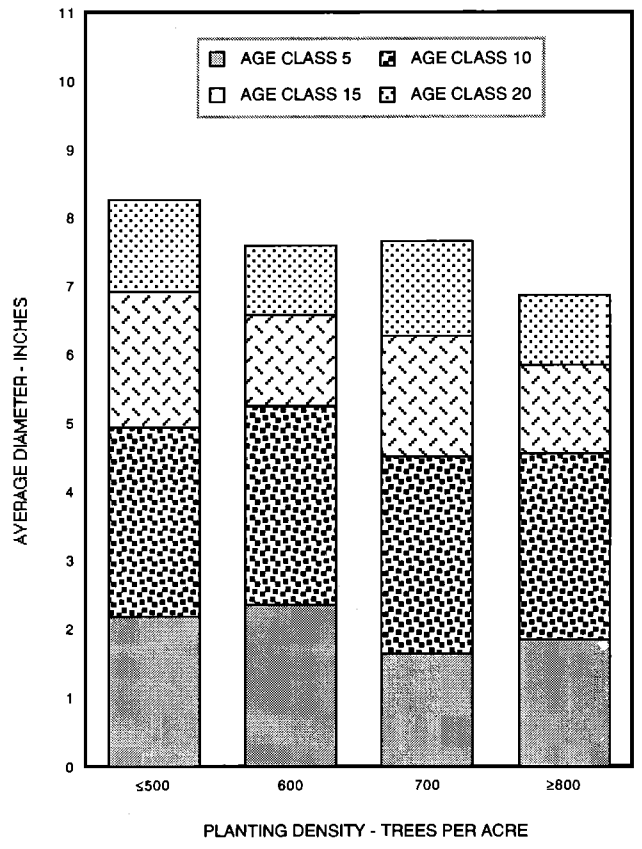

Figure 2. Average diameter by planting density and age classes for slash pine plantations in East Texas ($n = 720$ obs).

Effect of Planting Density on Height

After statistical calculations were completed for loblolly pine, the effects of planting density classes are:

- Age class 5: average height ranged from 12.38–16.42 ft ($P = 0.1840$).
- Age class 10: average height ranged from 32.83–36.79 ft ($P = 0.4841$).
- Age class 15: average height ranged from 45.25–51.13 ft ($P = 0.1204$).
- Age class 20: average height ranged from 59.19–72.50 ft ($P = 0.0008$).

A picture of the trends is shown in Figure 3.

Initially for the first three age classes, there are no statistically significant differences in height development between planting densities. By age class 20, height development for planting densities 400 and 500 is significantly higher ($P < 0.05$) than planting density classes 600, 700, and 800 trees/ac.

After the one-way ANOVA calculations were completed, the effect of planting density on slash pine height development can be listed as:

- Age class 5: average height ranged from 14.62–18.38 ft ($P = 0.0221$).
- Age class 10: average height ranged from 34.09–38.53 ft ($P = 0.0294$).
- Age class 15: average height ranged from 48.12–50.36 ft ($P = 0.6277$).
- Age class 20: average height ranged from 60.00–63.40 ft ($P = 0.5924$).

Values are presented in Figure 4.

For slash pine, the lower planting densities tended to initially produce taller trees. However, for older plantations, the distinction disappeared.

Applications

If the goal of the plantation manager is to produce loblolly and slash pine trees with larger diameters and taller heights in a more cost-effective manner, it might be prudent to plant fewer trees per acre. At these lower planting densities, trees with more content that are suitable for merchandising into products such as lumber and plywood might be available for harvesting at an earlier age than trees planted at higher densities.

If the trends presented in this study are typical for planted pines on the western edge of the southern pine region, thinnings may not be necessary to produce larger trees. Particularly, if lower planting densities were applied. However, if higher planting densities were used,

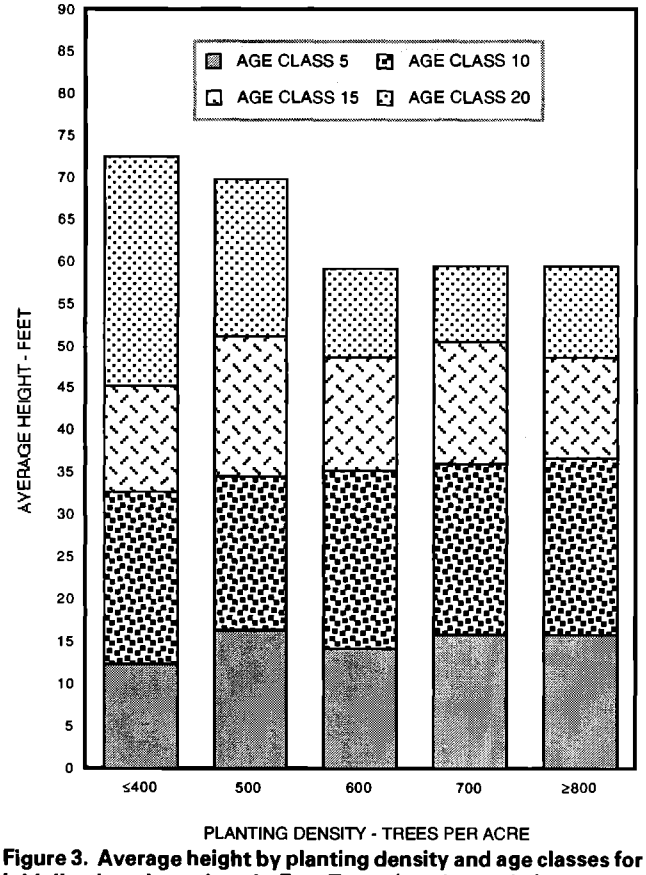

Figure 3. Average height by planting density and age classes for loblolly pine plantations in East Texas (n = 1,601 obs).

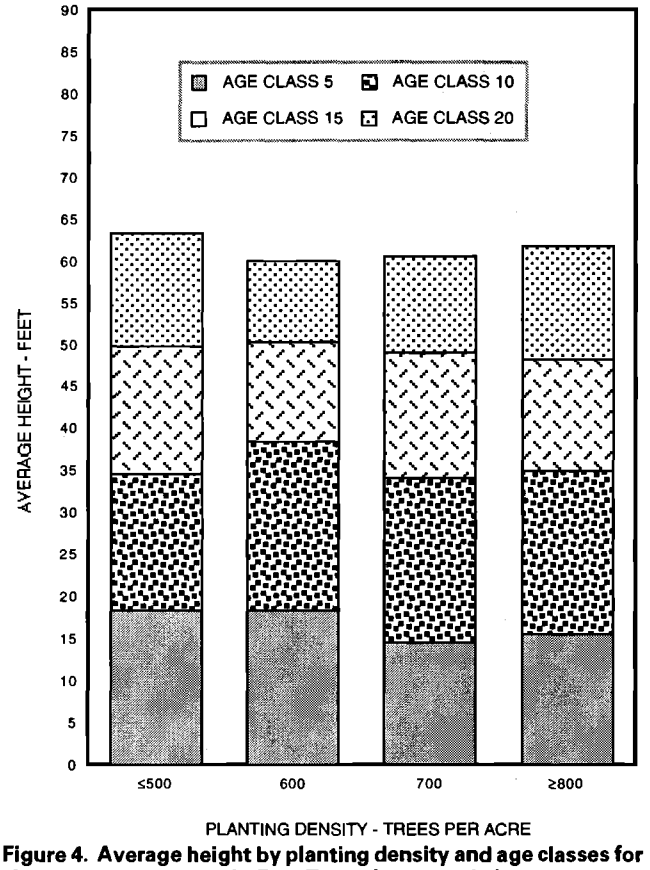

Figure 4. Average height by planting density and age classes for slash pine plantations in East Texas (n = 720 obs).

then a thinning might actually be needed to reduce density, which might eventually result in a desired tree size.

Another application of these findings might be to influence the selection of optimum rotation age. Depending on planting density, anticipated utilization of the trees and associated cash flows, rotation age can be adjusted in an attempt to grow a certain size of tree to meet these needs.

Even though the study plantations have not received intensive management practices and were established in the late 1970s and early 1980s, the height and diameter development trends presented in this paper are probably indicative of what this type of plantation can do and may even provide some guidance on how to manage intensively managed plantations.

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