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SITE AND STAND FACTORS AFFECTING HEIGHT GROWTH CURVES OF LONGLEAF PINE PLANTATIONS[1/]

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Abstract.--Some factors related to the form of height-over-age curves in longleaf pine plantations were identified from analyses of 660 periodically remeasured plots. Seventy percent of the variation among 32 plantations in form the growth curve was accounted for by stratifying planting sites into old fields, mechanically prepared and unprepared cut-over sites. Curve form was affected by site quality on prepared and unprepared sites, and by stand density on all sites.

INTRODUCTION

A major indicator of the productivity of southern pine plantations is site index at age 25 (SI_{25}), usually the mean height of dominant-codominant trees. Unfortunately, the early growth of southern pine plantations, including longleaf pine (Pinus palustris Mill.), is often so variable that use of a single set of site index curves has limited value at best and can be seriously misleading.

Often the predicted site index for a plantation changes over the years, whatever curves are used. Errors multiply as the time from index age increases (McGee and Clutter 1967). Even small errors in site-index estimates can cause large miscalculations of expected volume growth. For example, a change from 60 to 55 ft in SI_{25} reduces the projected cu-ft volume yield of a slash pine plantation at age 20 by 25 percent (Bennett et al. 1959).

Past studies suggest that height-over-age curves for southern pines established on old fields may differ not only between plantation and natural stand but also from similar stands established on cutover forest sites (Chapman 1938, Allen 1955, Bailey et al. 1973). Form of height-over-age curves may also be affected by other stand and site variables, particularly stand density (Bennett 1975, McClurkin 1976) and site quality (Beck and Trousdell 1973, Graney and Burkhart 1973).

For this study, height-over-age data from 660 remeasured plots, primarily the longleaf pine phase of the Southwide Pine Seed Source Study (SPSSS), were used to investigate how site and stand conditions affect early height growth of longleaf pine plantations.

METHODS

The SPSSS provided data from 637 of 660 remeasured plots in this study. The other 23 plots were from two separate studies in west Florida. Trees on all plots were scheduled for measurement at age 3 and 5, and at 5-year intervals thereafter although the remeasurement schedule was not always strictly met. Some plots (136) were last measured at age 20, 21, or 22. The rest were last measured at age 15 except for 67 plots last measured at age 16 or 17. In all, there were 2737 height-over-age observations.

SPSSS series 1 and 2 (planted during winter 1952-53) and series 4, 5, and 6 (planted during winter 1956-57) were represented in this study, with 34 plantings in coastal states from Texas to North Carolina. Plantings were replicated at two locations. Also, replicates were combined, making a total of 32 recognized planting locations. The parent study is described by Wells and Wakeley (1970).

At each examination, number of surviving trees and height of each survivor were recorded for individual plots. The mean height of the tallest half of surviving trees on each plot was determined and represented the dominant-codominant fraction of the stand.

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All plantations were classified into three groups according to planting-site condition: Old fields (283 plots and 1172 observations), mechanically prepared cutover forest sites (116 plots and 448 observations) and unprepared cutover forest sites (261 plots and 1077 observations). All observations combined were given a stepwise regression analysis of the form:

$$\text{Log}_{10}\ \text{Height} = b_o + b_1\ (\text{Age})^{-1/2} + b_2\ (\text{Age})^{-1} + b_3\ (\text{Age})^{-2} + b_4\ (\text{Age})^{-3} + b_5\ (\text{Age})^{-4}.$$

The analysis determined which of the included independent variables would give the best single-variable regression.

The single variable regression model considered the best was fitted to the height-over-age observations for each individual plot, resulting in 660 equations. Further analyses explored the relationship of slope coefficients for individual plots, as a dependent variable, to recorded site and stand variables. These were primarily stand density (surviving trees per acre at age 10), site quality (height of tallest half of trees per plot at age 15), and the three planting-site conditions.

Coefficients for all 136 plots through age 20-22 were compared with coefficients derived from the same plots through age 15 only. Values of slope coefficients from plots through age 20-22 differed from age-15 values by an average of only 0.7 percent. Plantation height-growth patterns in this study appeared to be well established by age 15, so all slope coefficients were pooled for analyses without regard to plantation age at last measurement.

RESULTS

The best single variable regression for all 2737 height-over-age observations was: $\text{Log}_{10}\ \text{HT} = 1.8844 - 6.1764\ (\text{Age})^{-1}$. The coefficient of determination (r^2) was 0.8484. The only other variable contributing significantly (.05 level) to the regression was $(\text{Age})^{-4}$, which, when included in the equation, resulted in an R^2 of 0.8497.

The model $\text{Log}_{10}\ \text{HT} = b_o + b_1\ (\text{Age})^{-1}$ was fitted to each individual plot: 520 (79 percent) of the resulting equations had r^2 values of 0.99 or better. Slope coefficients (b_1), with negative sign omitted, became the dependent variable in analyses of the relationship of planting-site condition, stand density, and site quality to the form of early plantation height growth.

Planting-to-planting and plot-to-plot variation in slope coefficients was high. Classification of the 32 SPSSS plantation locations into the three planting-site conditions accounted for 70 percent of the variation among plantings in average slope coefficient. The mean, standard deviation, and range of coefficient values for the 32 plantation locations are illustrated in figure 1 for each planting-site condition. Much of the remaining variation can probably be attributed to factors such as two different years of plantation establishment, varying sets of seed sources, and geographic location with its associated climatic and soil-site conditions.

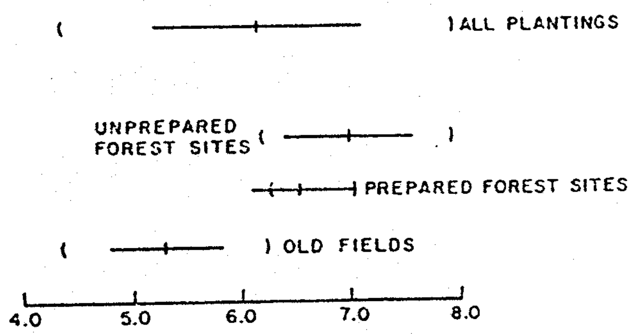

Figure 1.--Mean, standard deviation, and range of growth curve coefficients for plantings on old fields, prepared and unprepared forest sites, and all plantings combined.

Both stand density and site quality had a small but highly significant effect on growth curve coefficients. Classification into the three planting-site conditions alone accounted for 43 percent of plot-to-plot variation. Addition of stand density raised this value to 47 percent and site quality to 48 percent. Stand density affected growth curve form in each of the three planting site conditions. Site quality affected curve form only on prepared and unprepared sites, indicating that site index curves for these conditions will be polymorphic.

Planting-site condition had the greatest impact on curve form, with the largest contrast being between old fields and unprepared forest sites. The difference, for plantings with a stand density of 700 trees per acre, is illustrated in figure 2 for four site index (SI_{25}) classes. For SI_{25} of 60 ft, 10-year-old plantations on old fields are about 5 ft taller than similar plantings on unprepared forest sites. The comparatively rapid early growth on old fields can be attributed to less low competition than on unprepared cutover sites. Competition was primarily from shrubs and herbaceous vegetation because residual trees had been removed or killed in all plantations. The extreme of growth curve differences among individual plots is shown in figure 3. With a common SI_{25} of 50 ft, the difference in tree height at age 10 is 20 ft. The upper curve is an old field plot, the lower curve an unprepared forest plot. The regression r^2 values for each of these two plots were 0.999 and 0.994, respectively.

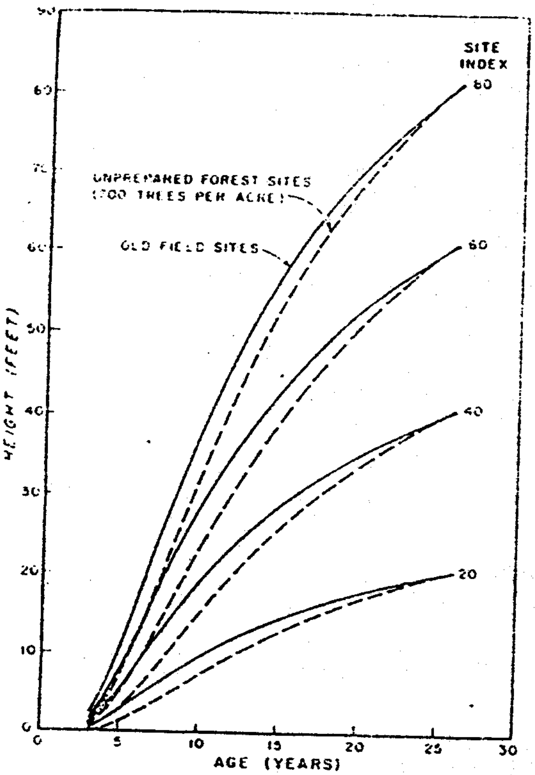

Figure 2.--Comparison of growth curves on unprepared forest sites with those on old fields for selected age 25 site index values.

Differences in growth curves between prepared and unprepared forest sites are not as great as those between old fields and unprepared sites (fig. 4). For SI_{25} of 60, 10-year-old trees on prepared sites have about a 3 ft height advantage over similar plantings on unprepared sites.

Growth curves for prepared forest sites were close to those of old fields on good sites, but differences increase as site quality declines (fig. 5). For SI_{25} of 80, there was no apparent difference in the curves, but for SI_{25} of 40, old field plantings at age 10 had about a 2 ft advantage over prepared site plantings. As noted earlier, site quality affected curve form on prepared sites, but not old fields, hence the opportunity to converge. On good sites, intensive mechanical site preparation resulted in growth equivalent to that expected on old fields. Even on poor sites, differences were relatively small.

The observed effect of stand density on curve form is illustrated in figure 6 for an old-field site, one with 250 and the other with 1200 trees per acre. Given the same SI_{25}, the curve for the high density stand is higher than that for the low density stand. The difference is not great, amounting to slightly over 2 ft at age 10 for SI_{25} of 60 ft. In this illustration, SI_{25} was set at an equal value for comparison of growth curves for each of the two stand densities. Early plantation growth for both densities on an equivalent site should be

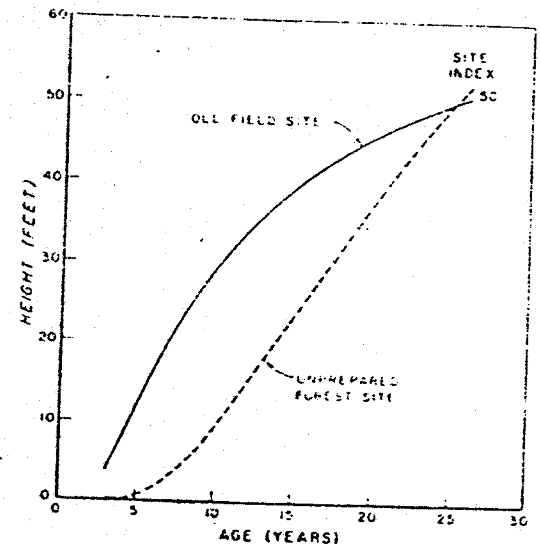

Figure 3.--Comparison of growth curves on two plots with greatest observed difference. Upper curve-old field; lower curve-unprepared forest site.

identical until canopies close. Afterwards height growth for the high density stand can be expected to fall below that of the low density stand.

CONCLUSIONS

Results of this study indicate that form of height-over-age curves are influenced by planting-site variables and stand density. The degree of intensity of preplanting site preparation apparently has the greatest impact on form of the height-over-age curves. It must be considered when attempting to estimate site quality from early plantation height growth. Site quality per se affected curve form on both prepared and unprepared forest sites, suggesting that site index curves developed for these two conditions will be polymorphic. The stand density effect was highly significant but small. So within the range of densities expected in most plantations, it will have a negligible effect and can be reasonably ignored.

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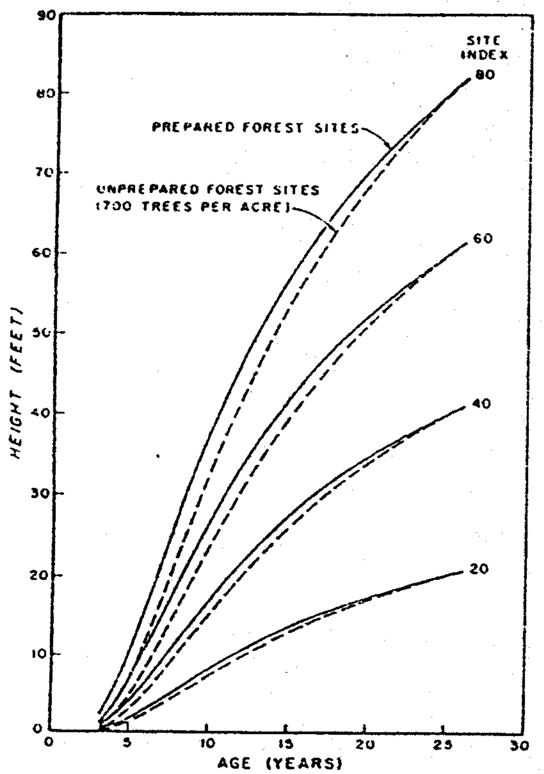

Figure 4.--Comparison of growth curves on unprepared forest sites with those on mechanically prepared sites for selected age 25 site index values.

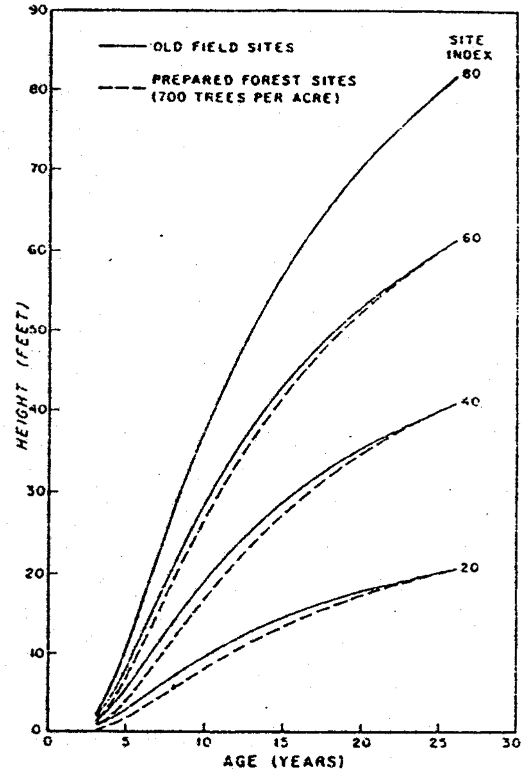

Figure 5.--Comparison of growth curves on mechanically prepared sites with those on old fields for selected age 25 site index values.

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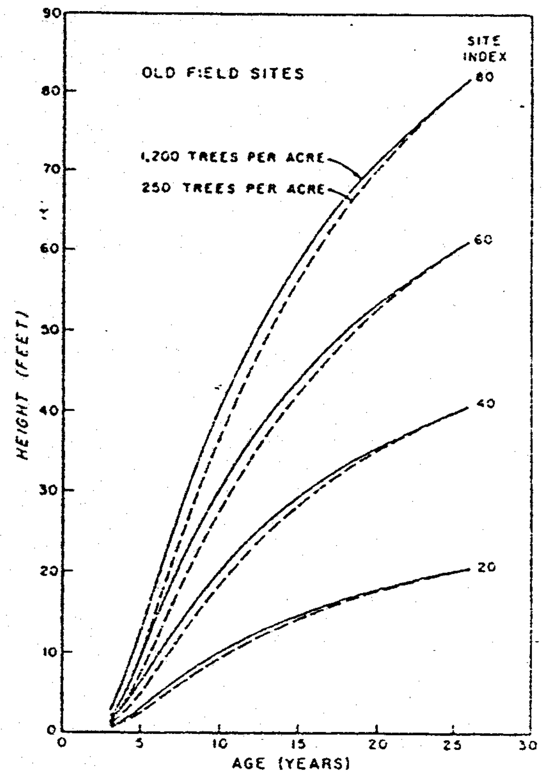

Figure 6.--Comparison of old field curves for plantings having 250 trees per acre, at age 10, with those having 1200 trees per acre.