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Interim Site-index Curves for Longleaf Pine Plantations[1]

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SUMMARY

No single set of site-index curves can be uniformly applied to young longleaf pine plantations without a sacrifice in reliability. A recent study using plantation remeasurement data indicated that planting-site condition (old fields and mechanically prepared or unprepared cutover forest sites) has a major impact on early plantation height growth. Stand density (surviving trees per acre) also affected form of height-over-age curves. On both prepared and unprepared forest sites, site quality affected curve form, so polymorphic site-index curves resulted for these two conditions. Longleaf pine plantation site-index curves for these three planting-site conditions were derived from 660 plots remeasured through ages 15 to 17 or 20 to 22 years. Modification of the curves may be necessary as more data become available.

INTRODUCTION

The early growth of southern pine plantations, including those of longleaf pine (*Pinus palustris* Mill.), is so variable that any single set of site-index curves is of limited value. Site index at age 25 (SI_{25}) usually the mean height of dominant-codominant trees at that age, is normally considered the principal indicator of plantation productivity. Site-index estimates derived from current height of young plantations are often used to evaluate the effectiveness of cultural treatments. If treatments affect the form of height-over-age curves, then estimates of site index from one set of curves will be unreliable. Economic evaluation of treatment effects on future volume yields would also be untrustworthy.

Successive remeasurement3 of young plantations, particularly from 10 to 20 years of age, often result in dramatic changes in estimated SI_{25}. Such shifts mean that the site-index curves being used are wrong for that plantation. Even small errors in site-index estimates can cause large miscalculations of expected volume growth of a plantation. A change from 60 to 55 ft in SI_{25} reduced by 25 percent the projected cubic-foot volume yield of a slash pine plantation at age 20 (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 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).

Using remeasurement data provided mainly by the Southwide Pine Seed Source Study (SPSSS), I examined factors associated with

[1]For the metric equivalent for measurements in this paper, multiply number of feet by 0 3048 to obtain meters

differences in the form of height-over-age curves of longleaf pine plantations. Analyses identified several factors related to differences in height-growth patterns. Some of these relationships were used for the sets of longleaf plantation site-index curves presented here (Fig. l-3). These are more closely associated with specific site and stand conditions than are any existing site-index curves. Refinements can be made with later remeasurement data.

DATA BASE

Of 660 plots in this study, 637 were from the SPSSS and 23 from two studies in north Florida. All plots were scheduled for measurement at plantation ages 3 and 5 and at 5-year intervals thereafter, although this schedule was not always kept. 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 are 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 all represented in this study. The 34 plantings were located in all coastal states from Texas to North Carolina. Two of the 34 plantings were replicates of 2 others and were combined. So pines were planted in 32 locations. Wells and Wakeley (1970) detail the longleaf phase of SPSSS.

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 represents the dominant-codominant fraction of the stand.

ANALYSES

All plantations were classified into three groups according to planting-site condition: old fields (263 plots and 1172 observations), mechanically prepared cutover forest sites (116 plots and 488 observations) and unprepared cutover forest sites (261 plots and 1077 observations). All observations combined wnre given a stepwise regression analysis of the form: $Log_{10}Height = b_0 + b_1 (Age)^{-1/2} + b_2 (Age)^{-1} + b_3 (Age)^{-2} + b_4 (Age)^{-3} + b_5 (Age)^{-4}$. The analysis determined which independent variables would give the best single-variable regression.

When fitted to the height-over-age observations for each individual plot, the best single-variable regression for all observations combined gave 660 regression equations. Later analyses explored the relationship of the slope coefficient for each plot, as a dependent variable, to recorded site and stand variables. These were mainly 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 (table 1).

Table 1. *-Distribution of plots among stand density[1] and site quality[2] classes*

Stand density (trees/acre)	Site quality (height in feet) 10	20	30	40	50	Total
			Old Fields			
200	0	0	17	2	0	19
400	0	0	15	14	2	31
600	0	2	14	33	1	50
800	0	1	24	56	5	86
1000	0	1	20	59	8	88
1200	0	0	0	7	2	9
			Prepared Sites			
200	1	11	6	1	0	19
400	9	9	7	2	0	27
600	5	21	3	2	0	31
800	4	13	6	4	0	29
1000	0	4	5	0	0	9
1200	0	1	0	0	0	1
			Unprepared Sites			
200	2	10	8	4	0	24
400	2	10	26	11	1	50
600	3	8	38	29	0	76
800	3	9	41	27	2	82
1000	0	4	11	10	1	26
1200	0	0	0	1	0	1
Totals	29	104	243	262	22	660

[1]Surviving trees per acre at age 10.
[2]Mean height of tallest half of trees at age 15.

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Coefficients for all 136 plots remeasured through age 20-22 were compared with coefficients derived from the same plots for observations through age 15 only. Values of slope coefficients from plots remeasured through age 20-22 differed from age-15 values by an average of only 0.7 percent. Apparently plantation height-growth patterns are 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: $Log_{10}HT = 1.8844 - 6.1764$ (Age)'. The coefficient of determination (r^2) was 0.8484: standard error of the slope coefficient (b,) was 0.0499. The only other variable contributing significantly (.05 level) to the regression was $(Age)^{-4}$, which, when included in the equation, resulted in an R^2 of 0.8497.

The model Log,, $HT = b_0 + b_1$ (Age)" 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,), with negative sign omitted, became the dependent variable in analyses of how planting-site condition, stand density, and site quality affect 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 remaining variation was probably caused by factors such as two different years of plantation establishment, varying sets of seed sources (Series), and geographic location with its associated climatic and soil-site conditions.

Planting-site condition, stand density, and site quality accounted for 48 percent of the plot-to-plot variation in growth-curve coefficients. Stand density significantly affected coefficients in all three planting-site conditions. Site quality, however, affected curve coefficients only on prepared and unprepared forest sites. Regressions for each planting-site condition show how stand density and site quality affect coefficients. The predicted coefficient is Y; (T10) is trees per acre at age 10, and (H15) is mean height of tallest half of trees per plot at age 15.

Old fields: $Y = 5.831 - 0.000732$ (T10)

Prepared sites: $Y = 7.7162 - 0.001057$ (T10) $- 0.027189$ (H15)

Unprepared sites: $Y = 8.2746 - 0.000976$ (T10) $- 0.021189$ (H15).

Differences among planting-site conditions are apparently related to the type and intensity of competition from ground cover on the site. Overtopping hardwoods and brush were eliminated when plantations were established.

If all planting-site conditions have the same site index at age 25, height of old-field plantings and prepared forest sites will exceed the height of plantings on unprepared sites. The greatest difference will be reached at plantation age 8-10 years. For example, with SI_{25} of 70 ft and a density of 800 trees per acre, old-field plantings at age 9 will average 5½ ft taller than similar plantings on unprepared sites. Prepared-site plantings will average 4 ft taller. On good sites, little difference exists between curves for old field and prepared forest sites, but differences in these two planting-site conditions increase as site quality declines.

Such differences in growth-curve form will greatly affect site-index predictions from one set of curves. Consider, for example, a 15-year-old plantation on an old field with 800 trees per acre and a height of 40 ft. Longleaf pine site-index curves from U.S. Department of Agriculture, Forest Service (1976) predict a SI_{25} of 69 ft. This value is much higher than SI_{25} predicted by curves from this study-60 ft for unprepared, 57 ft for prepared sites and only 55 ft for old fields. Here, use of curves other than those for old fields resulted in inflated estimates of SI_{25}.

Errors in site-index estimations will be even greater for plantations close to 10 years old when height differences related to planting-site conditions near their maximum. For a 10-year-old plantation with a height of 30 ft and 800 trees per acre, the predicted SI_{25} for unprepared sites is 72 ft; for prepared sites is 65 ft; and for old fields, 61 ft.

Clearly, because of the way site and stand variables affect early height growth of longleaf pine plantations, use of a single set of site-index curves is impractical for adequate prediction of SI_{25} 5-15 years in advance. If site-index predictions are wrong, then volume yield projections will also be wrong, as will economic evaluations based on these projections. Someday we may be able to develop site-specific site-index curves. Meanwhile, the site-index curves developed from this study will account for some factors affecting early height growth in longleaf pine plantations.

The site-index curves here (Figs. 1-3) are for the three planting-site conditions each with 600 trees per acre at age 10. Curves for higher stand densities will be slightly above, and lower densities slightly below, the curves shown. Curves converge at index age. Because site quality is so important, site-index curves for prepared and unprepared sites are polymorphic.

The growth-curve coefficient and resulting site-index curves can be obtained from the three equations above for old fields and also for prepared and unprepared forest sites if plantation height at age 15 is known. If it is not known, the coefficient and appropriate site-index curve for a specified index height can be determined with a computer using a trial and error iterative procedure.

If the curve coefficient (b_1) is known or approximated, then SI_{25} for a given age and height, or height for a given age and site index can be obtained from:

$$\text{Log}_{10}(SI_{25}) = \text{Log}_{10}(HT) - b_1(.04 - 1/\text{Age})$$

$$\text{Log}_{10}(HT) = \text{Log}_{10}(SI_{25}) - b_1(1/\text{Age} - .04)$$

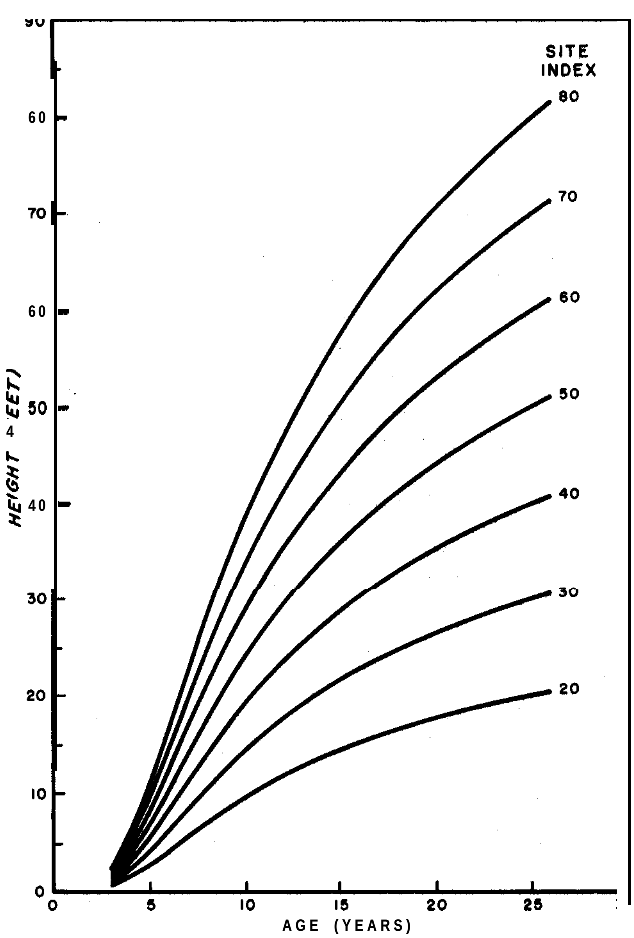

Figure 1 — *Site-index curves for longleaf pine plantations* ***on old fields.***

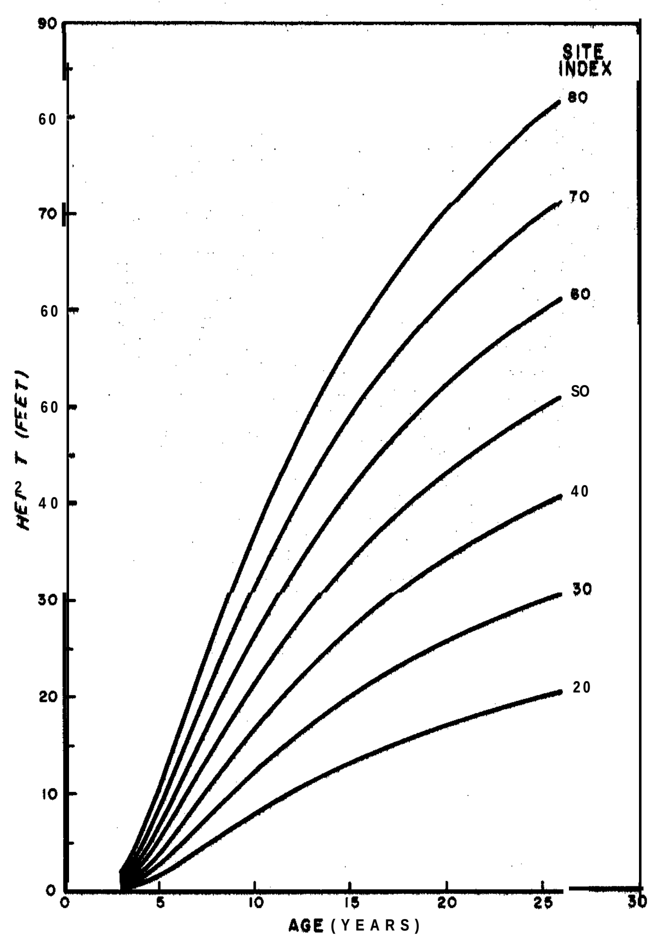

Figure 2. — ***Site-index curves for longleaf pine plantations on mechanically prepared cutover forest sites.***

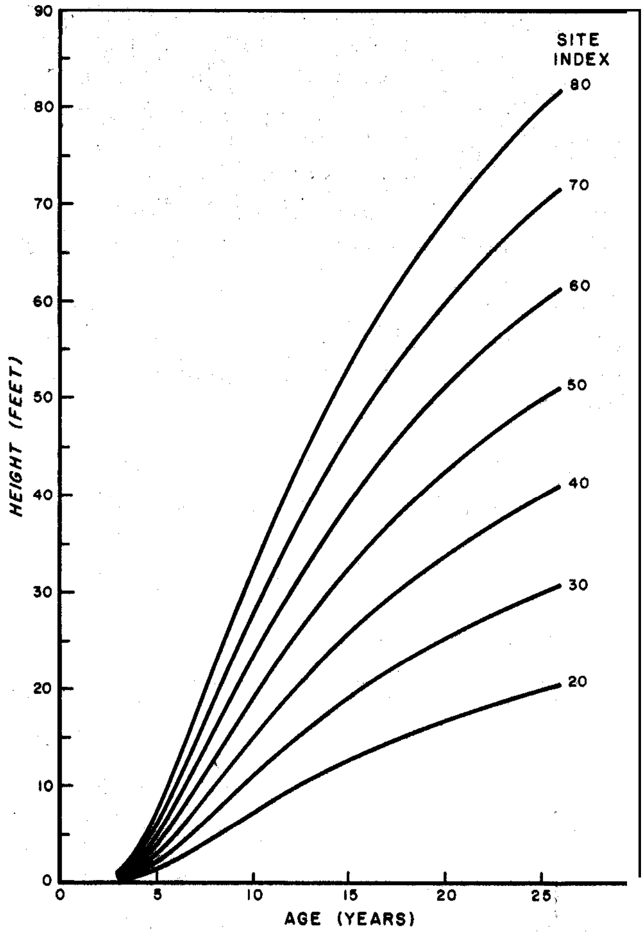

Figure 3. -*Site-index curves* ***for longleaf pine plantations*** *on unprepared cutover forest sites.*

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