Soil-Site Relations of Old-Field Slash Pine Plantations in Carolina Sandhills[1]

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THIS PAPER provides a means for predicting the height growth of slash pine plantations on old-field sites in the Sandhills of North and South Carolina, an area now largely abandoned for agriculture. Slash pine has been planted in this area during the past 25 years and has become the preferred planting species. Survival has been generally good, and many stands have been strikingly productive. Growth has varied enough, however, to indicate that indiscriminate planting of slash on these deep sands is not warranted.

The present study was one of a series which have been made on deep sand soils in the Southeast. Although Knudsen (*4*) had studied the soil-site relations of natural slash pine stands, plantations had not been investigated until Barnes and Ralston (*1*) determined the effect of soil characteristics for planted slash pine in Florida. When extended to Georgia plantations, the Florida estimating equation proved applicable to most upland soils except shallow or imperfectly drained ones (*5*). McGee later made an independent study of slash pine plantations in the Middle Coastal Plain of Georgia (*6*). Unlike prior studies, the present investigation sampled slash pine plantings beyond the species' natural range. The South and North Carolina Sandhills include the northenmost slash pine plantations on marginal sand soils.

FIG. 1.—A 17-year-old slash pine plantation on an old-field site in the South Carolina Sandhills.

The Data

Measurements were made on 127 plots in plantations throughout the area shown in Figure 2. Nearly all plots were in stands that had been established on old fields. Plantations on cleared scrub-oak areas were sought but few were found that were old enough to be included in this study. The plots' site indices (based on height 25 years after planting) were found to range from about 40 to 80 feet. Stand ages ranged from 9 to 27 years (Table 1).

The plots, which were fundamentally designed to supply information for volume and yield tables (*3*), were mostly 8 planting spaces square, though where survival had been poor, plots were larger. A plot was not taken unless the trees were at least 9 years old, unthinned, with no evidence of crown scorch from fire, and without recognizable differences in age, height, or spacing.

Most of the plantations sampled were on Kershaw, Lakeland, and Norfolk soils. These are generally characterized by light to medium gray A_1 horizons of loose sand, zones of light gray to pale yellow loose sand to loamy sand, and one, or sometimes several, layers of subsoil distinguished by finer textures and generally darker shades—yellowish to reddish brown. The subsoils have textures ranging from loamy sand to sandy clay loam and occur 12 inches to 10 or more feet below the surface.

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[1]Based on research for a master's thesis at the School of Forestry, Duke University, under the direction of Dr. C. W. Ralston, assistant professor of Forest Soils. The study was a cooperative project of Duke University and the Southeastern Forest Expt. Sta., Forest Service, U. S. Dept. Agric.

TABLE 1.—NUMBER OF PLOTS BY AGE AND 25-YEAR SITE-INDEX CLASS

Plot age class (years)	Site-index class 40 feet	50 feet	60 feet	70 feet	80 feet	Total
9-12	1	1	5	11	3	21
13-17	0	2	28	23	1	54
18-22	0	9	26	14	0	49
22-27	0	1	0	2	0	3
Total	1	13	59	50	4	127

Soil profile descriptions were made at two posthole sample points on a diagonal of each plot. An effort was made to reach a layer of fine texture, for Barnes and Ralston, as well as McGee, had demonstrated correlations between site index and depth to this layer. When fine-textured soil was not encountered with the posthole digger, a bucket auger was used to determine whether such a layer existed within 10 feet of the surface. In holes where fine texture was not found, a depth of 10 feet was arbitrarily assigned for statistical analysis. Composite soil samples were taken from each horizon. Supplemental measurements of surface horizons and litter were made at three other points on each plot. Major physiographic attributes were also recorded.

In the laboratory each fine-textured subsoil sample was analyzed by the Bouyoucos hydrometer method. In profiles with no layer of fine texture within 10 feet, analyses were made of all horizons below the A_1. The largest clay content thus obtained was used in the regression analysis.

For very sandy A_1 horizons, ignition in a muffle furnace was found to furnish satisfactory determinations of organic matter.

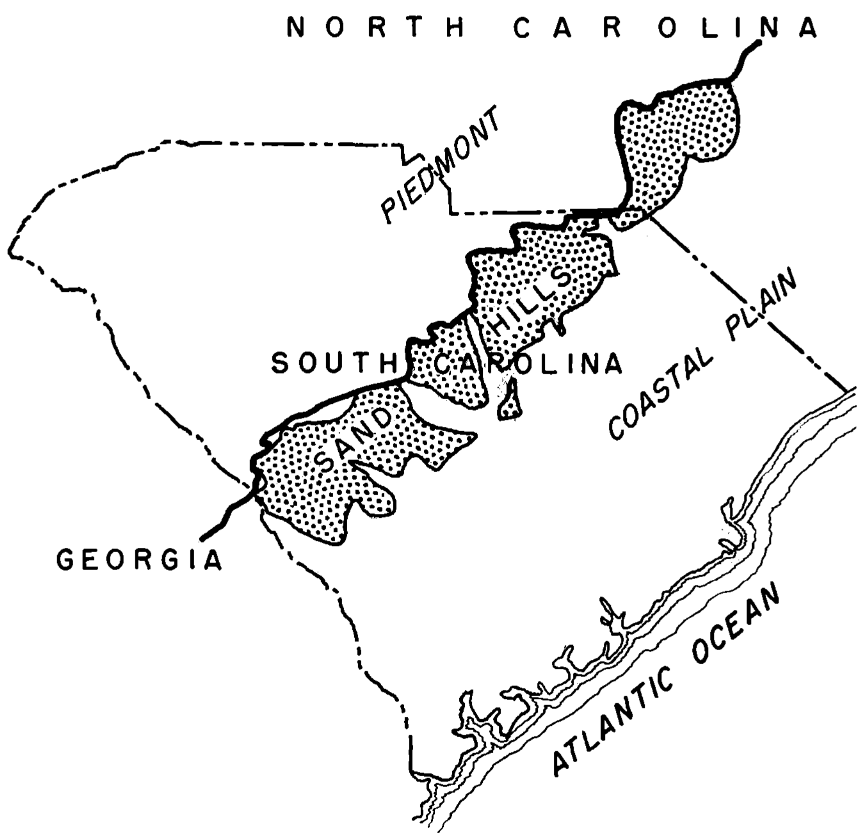

FIG. 2.—Sandhills region of South and North Carolina.

For samples with a texture heavier than sand, it was apparent that the clay content influenced the organic-matter determinations by ignition, and values from wet combustion tests were used instead. An index of total organic content was calculated by multiplying the percentage of organic matter by the thickness of the A_1 horizon.

Reliable estimates of soil effects can be obtained from variations, independent of age, in total tree height. The average height-age relationship of the plantations was expressed in a form similar to that proposed by Schumacher (*7*):

$$\text{logarithm of total height} = a + b\left(\frac{1}{\text{age}}\right)$$

The deviations of individual plot values from this average height curve were often large and represented a quantitative expression of all other factors affecting tree growth. To find whether a portion of the variations was related to soil characteristics, the basic height-age equation was modified by the addition of soil variables.

The variables in this analysis were:

$x_1 = \dfrac{1}{\text{age}}$, where the age was plantation age plus one year in the nursery.

$x_2 =$ thickness of A_1 horizon.

$x_3 =$ depth to fine-textured horizon.

$x_4 =$ percentage of clay in fine-textured horizon.

$x_5 =$ total organic-matter index (x_2 times percent of organic matter).

$x_6 =$ topographic position ($+1$ for ridgetops and upper slopes, -1 for lower slopes and flats).

$x_7 =$ (depth to fine texture).^{2}

$x_8 =$ (depth to fine texture) $\dfrac{1}{\text{age}}$.

$x_9 =$ (depth to fine texture)^2 $\dfrac{1}{\text{age}}$.

The significant variables in the regression analysis, in addition to the reciprocal of age, were: x_7, the square of depth to fine texture, and x_2, the thickness of the A_1 horizon, both significant at the one-percent level. The equation for these variables is:

$$\log \text{height} = 1.987 - 5.941 \frac{1}{\text{age}} + 0.008963 \text{ (thickness of } A_1) - 0.000004245 \text{ (depth to fine texture)}^2.$$

The coefficient of multiple correlation (R) of this regression is .89. Individual plot error is approximately 10.5 percent. Figure 3 is a graph of the equation adjusted to show site-index at plantation age 25. When the thickness of A_1 horizon and depth to fine texture of a soil are known, the expected stand height 25 years after planting can be read directly from the graph.

Some longleaf and loblolly pine plantations also were measured, but no independent soil-site analyses were made. Predicted heights of slash pine for the soil characteristics of each of the 44 longleaf and 31 loblolly plots were compared with the actual heights of the trees. It was assumed that the planted longleaf had remained in the grass for 3 years. Longleaf heights averaged 26 percent less than those of slash pine of comparable age on similar soils. Average heights for loblolly were about 18 percent less. Figure 4 shows the height-age curves, adjusted to plantation age, for all three species. Although the comparisons are not conclusive, it appears likely that longleaf or loblolly may not make as good 25-year height growth as slash pine on most Sandhill sites.

Discussion

The two soil factors found related to height growth, thickness of the A_1 horizon, and depth to fine texture, are the same that McGee established in Georgia.

The detrimental effect of increased depth to fine texture was much less in the Carolinas than in Georgia. The explanation may largely be in sample differences. All but one of the Carolina plots on very deep sands were in old-field plantations. Most of the few plots on such soils in Georgia were in areas cleared of scrub oaks and showed the relatively slow growth previously observed on such sites in Florida (*1*), where the difference averaged about 7 feet at age 25. Because of this, an estimating equation based primarily on a sample of old-field sites must be used with caution, if at all, in evaluating scrub-oak land.

In Georgia, McGee found a decrease in site quality on a number of plots where erosion had nearly exposed the fine-textured soil. Very few plots with extremely shallow subsoils were found in the Carolinas and the effect was not significant.

The increase of site quality with thicker A_1 horizons may be caused by the beneficial effects of organic matter, as few A_1 horizon samples had appreciable clay content. Barrett found that the total organic content, as well as thickness of A_1, was related to site quality in Georgia slash pine plantations (*2*). Neither in his study nor the present one, however, could precision in estimating site index be im-

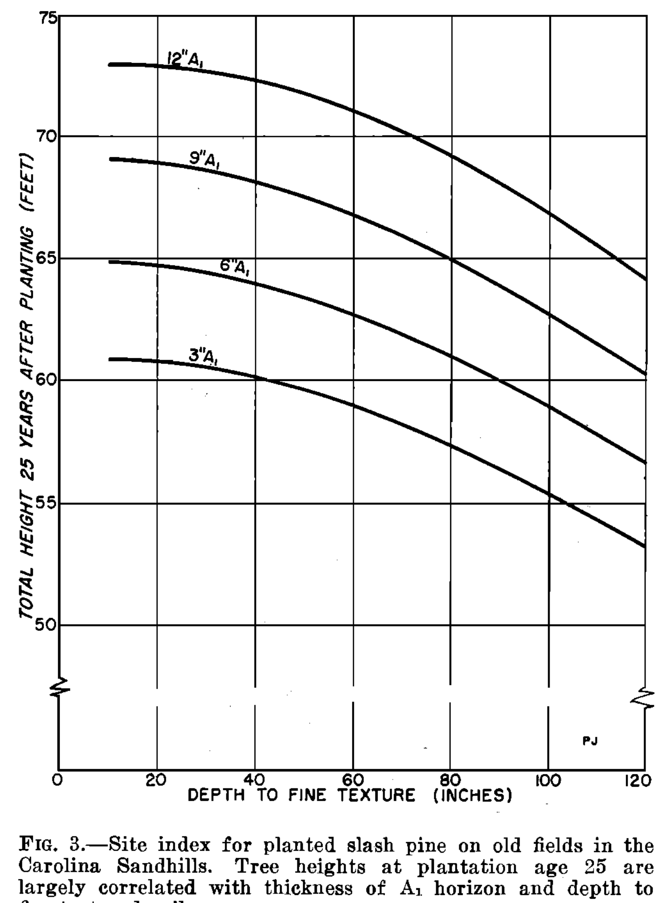

FIG. 3.—Site index for planted slash pine on old fields in the Carolina Sandhills. Tree heights at plantation age 25 are largely correlated with thickness of A_1 horizon and depth to fine-textured soil.

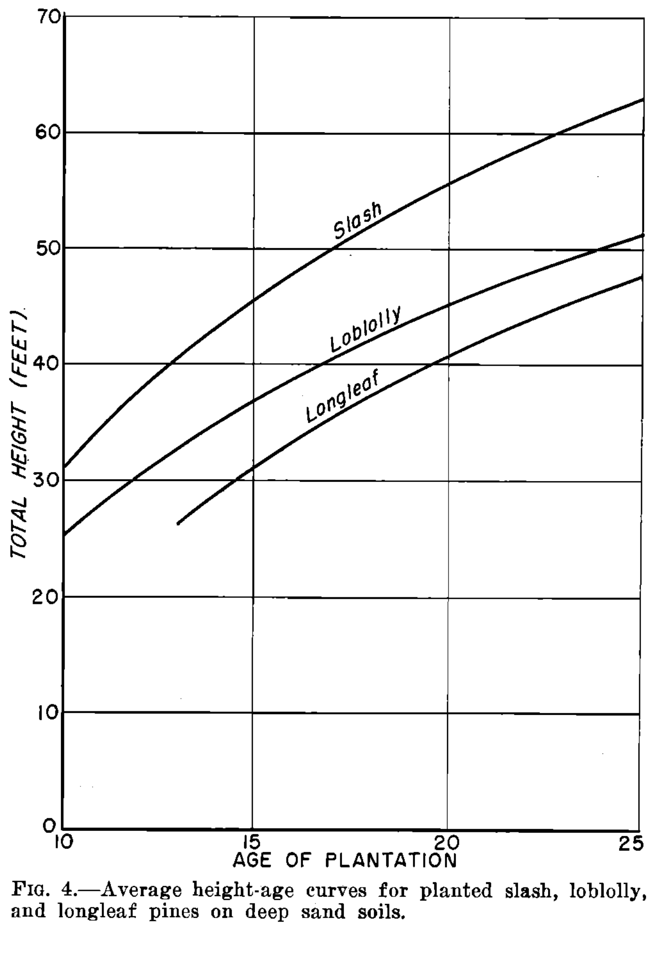

FIG. 4.—Average height-age curves for planted slash, loblolly, and longleaf pines on deep sand soils.

proved by substituting total organic matter index for the A_1 thickness or using it as an additional variable.

The reciprocal of the A_1 horizon depth in McGee's Georgia study was significant when A_1 horizons were less than 3 inches thick. In this study only three such shallow soils were found and this variable was not tested.

Factors difficult to treat statistically may have caused considerable portions of the residual error. For instance, in the summer of 1957 several of the very deep sands had water tables within the 10-foot auger depth. A number of additional plots, in which water tables were not observed in the summer of 1957, were revisited the next spring and tables were found within a few feet of the surface. Tree heights on plots with water tables were considerably greater than predicted by the analysis, but their quantitative effect could not be established from measurements taken in this study.

Tip-moth damage was observed on a few plots. Many other plantations undoubtedly had been infested while young, and—to some unknown degree—retarded in height growth. Tip-moth effects are very difficult to estimate after a few years.

In using the results, therefore, it must be remembered that the predicting equation is not applicable to scrub-oak areas. It may also be unreliable for those few sites with a depth to fine-textured layer of less than 20 inches, an A_1 horizon less than 3 inches thick, or a high water table.

Summary

Data were collected from 127 plots in slash pine plantations on old fields in the Sandhills of South and North Carolina in order to correlate height growth with soil factors.

Statistical analysis demonstrated that heights of slash plantations can be estimated from their age and two soil variables: Depth to a fine-textured horizon, and thickness of the A_1 horizon.

An estimate of 25-year site index for a prospective planting area can be made when measurements of the soil variables are inserted either into the estimating equation or into the simplified graphic solution provided in this article.

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