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A COMPARISON OF YIELD STUDIES OF SLASH PINE IN OLD-FIELD PLANTATIONS

Abstract. --This report compares three yield studies of slash pine in old-field plantations. Similarities and differences in yield are discussed. Within the range of sample data common to all studies, yield estimates are similar; major differences occur only in extrapolated values.

Extensive planting of slash pine (Pinus elliottii var. elliottii) has produced a large acreage of manmade forests. Efficient timber management planning and execution for these stands require some knowledge of growth rates and total production at given points in time. Length of rotation, volume of wood flow, rates of return, acquisition and investment policy, taxes, and other management aspects relate either directly or indirectly to productive potential as measured in wood yield.

Although estimates of yield for natural slash pine stands were available, they were not applicable to plantations because uniformity of stocking distribution in manmade forests produces stands different from those established by nature. Also, the utility of existing yield tables was restricted since they applied only to "well-stocked" stands. Age and site were the only stand variables employed in the construction of these early tables.

Since 1950 several different researchers have studied cubic yield in planted slash pine stands. Variable-density yield tables were constructed from all these studies. Although sampling procedures were generally similar, the overall samples varied somewhat and predicted yields were divergent at certain points. This paper compares three yield studies of slash pine in old-field plantations and outlines similarities and differences.

THE YIELD STUDIES

BARNES

The first tables of cubic yield for planted slash pine were published by Barnes.[1] His study included 101 plots covering the range of typical slash pine in Florida. Barnes included in his yield equation various functions of age, site, and stand density and interactions of these parameters.

[1] Barnes, R. L. Growth and yield of slash pine plantations in Florida. Univ. Fla. Sch. Forest. Res. Rep. 3, 23 pp. 1955.

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STUDY 107[2]

In 1959, the Southeastern Forest Experiment Station developed yield tables of slash pine in old-field plantations from a sample taken throughout the Middle Coastal Plain of Georgia and the sandhills of South Carolina.[3] This sample included 308 plots with 95 percent being 20 years of age and under; in fact, 69 percent were 17 years of age and under. The following regression removed 86 percent of the variation in yield:

$$\text{Log of yield in cubic feet} = 8.95384 - 17.80865\,\frac{1}{\text{age}} - 0.01849(\text{site index}) - 0.44864 \log\left(\frac{\text{Square feet per tree}}{\text{percent survival}}\right) - 155.47183\,\frac{1}{\text{site index}}$$ [4]

Biological relationships must be the guiding factor in the formation of yield models such as this. The mathematics of tree growth are not simple and clear- cut, however, and developing a reliable equation can be tricky and difficult. Different functions of some stand variables may be, or appear to be, equally effective but will produce differing results. For example, in the preliminary analysis of the Study 107 data, the quadratic function of site was added to the regression model containing the linear form of site, and this increased the amount of variation removed. However, calculated yields from the resulting regression model showed mean annual growth to culminate in relation to site within the range of sites included in the sample. Although the basic fit of the regression model within the main body of sample data was improved, the relationship was unrealistic between site and growth as portrayed by the prediction mechanism. As a corrective measure, the reciprocal of site was substituted for the quadratic function; the fit was just as good and it removed the absurdity of growth culminating in relation to site within the range of the sample data. Although the situation in this instance was quite clear --after careful inspection of predicted yields--the choice of action is not so clear-cut in many analyses.

The above example explains, to some extent, why results can differ between two separate studies of essentially the same characteristics. Varying judgments of the people involved account for some of the difference, and most samples differ to some extent. Barnes' sample, for example, was confined mostly to relatively wide spacings (8 by 8 feet and

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[2]We derived this name from the number of the research paper series in which results were published.

[3]Bennett, F. A., McGee, C. E., and Clutter, J. L. Yield of old-field slash pine plantations. USDA Forest Serv. Southeast. Forest Exp. Sta. Pap. 107, 19 pp. 1959.

[4]Throughout this paper site index will be based on an index age of 25 years.

above) simply because few close spacings were available. On the other hand, 36 percent of the Study 107 sample was in spacings 6 by 8 feet and closer, and included spacings as narrow as 4 by 2 feet. Most of the close spacings were found in the Carolina sandhills.

DIAMETER DISTRIBUTION

The latest yield tables for slash pine plantations were developed from predicted diameter distributions.[5] This study covered the largest geographical area of any previous study and included 478 sample plots. Sample plantations ranged from the Fall Line in Georgia to Tampa, Florida, thence to the western panhandle of Florida, southeastern Alabama, and eastern Mississippi. Diameter distributions were developed by first establishing maximum and minimum diameters for various age- site-density combinations. Then a family of frequency curves was developed for estimating the proportion of trees in each diameter class between the extremes. After developing heights for each of the diameter frequency distributions, volumes were calculated for each diameter class and a per-acre volume estimate was produced by summing diameter-class volumes.

DISCUSSION

An outstanding feature of these three studies is the similarity of yields through age 18 for stands of 400 trees per acre and less (figures 1 and 2).[6] In the three studies, the maximum difference among the tables of yield for 400-tree stands at age 18 is about 5.0 cords; but generally the difference is considerably less. Yield estimates in the Diameter Distribution and Barnes studies are also similar through age 25; in fact, on sites 60 and lower, differences between these two yield estimates up to age 25 are minor for 600- and 800-tree stands (figures 3 and 4). In all three studies, yield estimates for stands of 600 to 800 trees on sites 70 and 80 are reasonably close through age 17.

The trend of the Study 107 curves 'is upward through age 20. The reciprocal of age with 2 negative coefficient, as contained in the Study 107 equation, produces a curve which never reaches a given upper limit so it must eventually reverse its trend. In fact, the extrapolation from age 20 to 25 shows the beginning of this reversal. This is the reason for including extrapolated yields for the Study 107--to illustrate the curve form in relation to the age variable. Actually, the upper portion of Study 107 curves is not a complete extrapolation since there were 16 plots above age 20, with four 24 years of age and older.

Because yields are based on a threshold diameter of 5 inches, heavy ingrowth in the close spacings between 10 and 20 years could conceivably affect the growth pattern of these stands in later years, as expressed by the Study 107 yield equation. According to the published diameter distributions, in 2 stand of 600 trees per acre on site 70 about 180 trees grow

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[5] Bennett, Frank A., and Clutter, Jerome L. Multiple-product yield estimates for unthinned slash pine plantations--pulpwood, sawtimber, gum. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-35, 21 pp. 1968.

[6] Yields at age 25 for Study 107 are extrapolated values; although yields at age 25 were published in the Barnes table they are in essence also extrapolated.

from nonmerchantable to merchantable size during the 10- to 20-year period, or an average of 18 per year. Ingrowth during the 20- to 25-year period amounts to only four trees per acre annually. The widely spaced stands experience much less ingrowth after age 10 and practically none after age 15. Diameter distribution patterns indicate that a stand of 200 trees on site 70 will have only two to three trees below 5 inches at age 10; the same stand on site 60 will have only 10 trees below merchantable size at age 30. It seems evident that ingrowth during the 10- to 20-year period will influence growth in dense stands much more than in widely spaced ones. And, with the small sample of dense stands above age 20 in Study 107 the pattern of growth and yield in the close spacings, after ingrowth ceased or was reduced considerably, was under little pressure to change. Consequently, this accelerated growth rate could be reflected in extrapoiated yield estimates for the denser stands.

The reverse of an apparent overestimate in Study 107 tables for the higher densities above age 20 seems to be illustrated by the Barnes study. As calculated in the Diameter Distribution study, the average periodic annual height growth is 1.6 feet, or 8 feet during the 5-year period, from age 20 to 25 in a 600-tree stand on site 70. The 8 feet of height growth account for almost half the volume increase of 2.22 cubic feet per tree over the 5-year period.

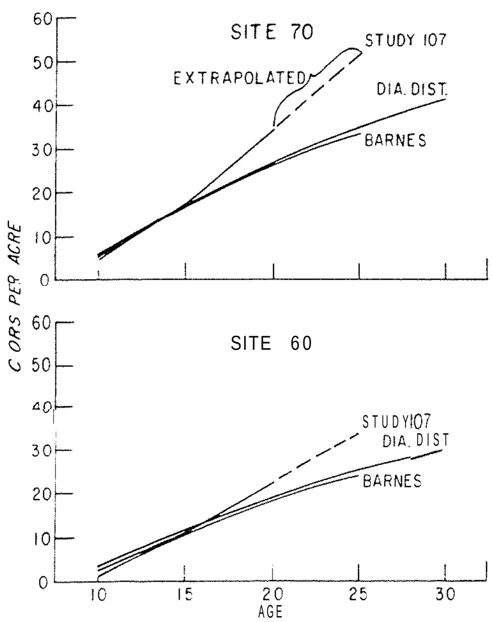

Figure 1. --Comparison of yield estimates for a stand of 200 trees per acre on sites 60 and 70.

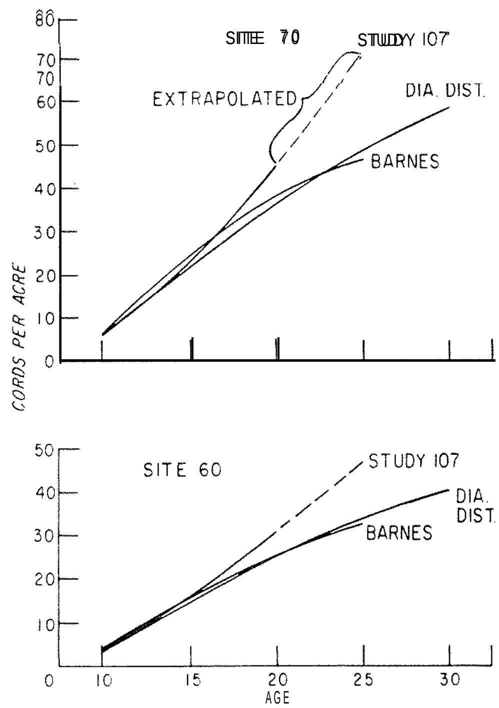

Figure 2. --Comparison of yield estimates for a stand of 400 trees per acre on sites 60 and 70.

Although it is not possible to determine periodic annual growth for the average tree from the Barnes data, the logical assumption is that the height growth pattern developed from the Diameter Distribution data would apply since the ares sampled included all of the Barnes study area. If so, the Barnes tables appear tc underestimate the yield increase during the 20- to 25-year period for the higher densities. For example, the study estimates an average diameter increment of 0. 6 inch during the 5-year period for the 600-tree stand on site 70. This estimate alone, which seems reasonable enough, would account for the total volume increase as portrayed by the predicted yields at ages 20 and 25.

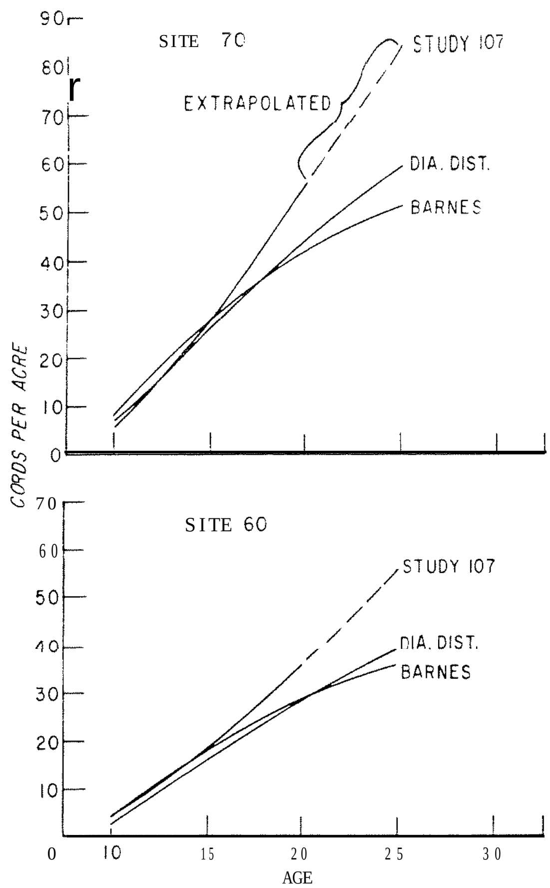

Figure 3. --Comparison of yield estimates for a stand of 600 trees per acre on sites 60 and IO.

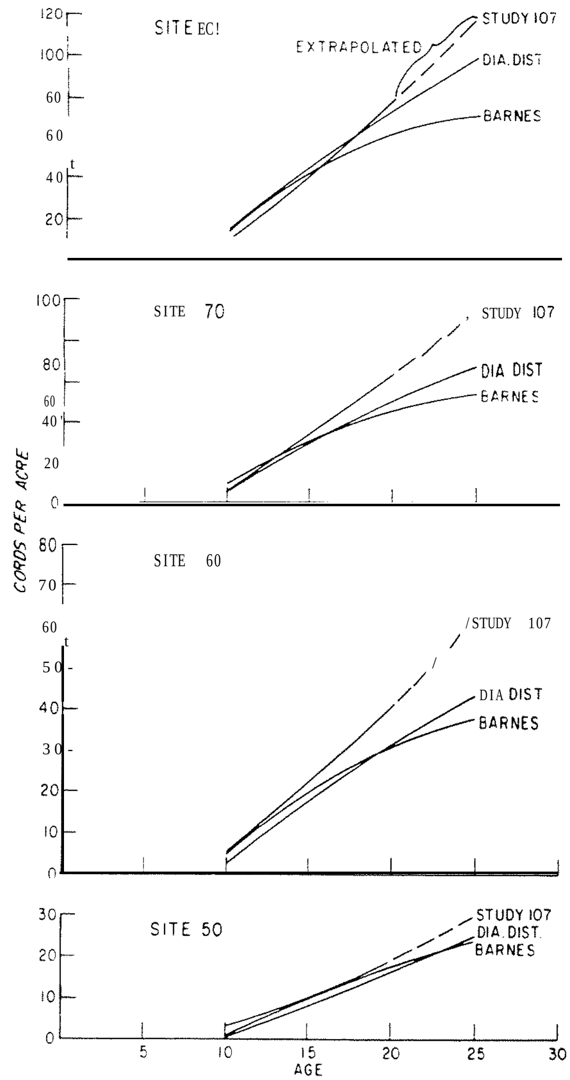

Figure 4. --Yield comparisons for a stand of 800 trees per acre on sites 50, 60, 70, and 80.

Comparison of the three studies indicates the Diameter Distribution estimates are most accurate for higher densities at the older ages. One reason for this is that the volume of each surviving tree is accounted for, and although there is error involved in predicting the distribution of the surviving stand, the error in volume estimate is not likely to be as great as that originating with a predictive mechanism that forecasts a lump-sum voiume. Also, the possibility of an exaggerated growth rate at the older ages, partially as a result of growth relationships developed at younger ages, is eliminated, And forecasting diameter distributions does not involve merchantability limits, so ingrowth, as applied to merchantable volume, does not exist. Although merchantable volume ingrowth occurs at the younger ages in yields calculated from diameter distributions, yield in later years is unaffected by this early inflated growth rate since cubic volume yield at any point in time is determined by calculating a volume for each tree.

The Diameter Distribution yield estimates were independently evaluated by Burkhart.[7] Predicted volumes on 114 randomly selected plots in south Georgia and north Florida were compared with volumes measured on the plots. Average measured volume for the 114 plots was 20.5 cords per acre; the average estimated voiume was 20.3 cords. Variation between measured and predicted volumes was greater, of course, on an individual plot basis, and one should not necessarily expect a very ***small*** sample to reflect the degree of accuracy illustrated above,

In summary, through age 17 the three estimates of yield are quite close. The differences at age 20 are larger, but not excessive except for the higher densities on the higher sites. Within the range of sample data common to all studies, the estimates of yield are generally compatible. It is only in extrapolated values that major differences occur. The Diameter Distribution study is the only one with an appreciable sample beyond age 20, for even the widely spaced stands of 300 and fewer trees per acre, and the only study with a sample beyond age 25. For this reason, its use is recommended in plantations older than age 20 and especially recommended for yield estimates of higher densities at older ages.

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[7] Burkhart, H. E. Evaluation of a volume estimation technique for slash pine plantations. Unpublished thesis, Univ. Ga.

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