THE POSSIBILITIES OF USING FOREST SURVEY TO LOCATE INDIVIDUAL TREES THAT ARE SUPERIOR WITH RESPECT TO WOOD QUALITY AS WELL AS FORM AND GROWTH RATE

Harold L. Mitchell, Chief

Division of Timber Growth and Utilization Relations
Forest Products Laboratory[1], Forest Service
U S. Department of Agriculture

That part of my talk today dealing with the recently completed third Forest Survey of Mississippi (1) is based largely on a progress report made by P. R. Wheeler of the Southern Forest Experiment Station and me at the 1958 Southern Forestry Conference held in Monroe, La., last March. The original report has since been published in the Forest Farmer magazine and elsewhere (2, 3), so I will give you only the highlights.

For the benefit of those of you who may not be familiar with the Forest Survey, I might point out that it is a very essential part of the total U. S. Forest Service job. Forest Survey units are located at each of our regional Forest Experiment Stations, including the Northeastern Station in Upper Darby. It is their responsibility to obtain, analyze, and keep current basic statistical information on the Nation's forest resources and industries. Most Forest Survey work is done in close cooperation with the States and industry.

In Mississippi, for example, State and industry cooperation amounted to over 35 percent of the field job. The total cost, including analysis and report writing, will run well over 250 thousand dollars which is a lot more money than any forest geneticist I know of has to work with.

The point I would like to make in this connection is that the Forest Survey organization, together with their local cooperators, are in a position to give forest geneticists some invaluable assistance on certain important jobs that the geneticists can't ordinarily afford to tackle independently on anything approaching an adequate scale. With a little encouragement, I believe that Forest Survey can be persuaded to give us a helping hand and at the same time provide their customers with more complete and useful resource information. The Mississippi Survey is a good example of how this can be done.

Under Southern Forest Experiment Station Forest Survey procedure, two permanent sample plots (or points) are established at every intersection of a 3-mile grid. The plots are pinpointed in the office on aerial photographs and field crews, using these photographs, locate the forested plots on the ground and obtain various measurements. The design is such that sampling error is kept below ±5 percent per billion cubic feet of timber.

The unique feature of this latest survey of Mississippi is that, in addition to taking the usual measurements of tree diameter, height, log grade, and the like, one increment core complete to the pith was taken at breast height from every pine tree 3 inches in diameter and over at that height tallied on every plot. Cores were taken with standard increment borers that had been precisely calibrated for bore. Core lengths were accurately measured in the fresh condition. The cores were then

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

labeled and sent to the Forest Products Laboratory in Madison for determination of specific gravity and age. In addition, percentage of summerwood, fibril angle, and perhaps other wood-quality characteristics may eventually be obtained. Field sampling and laboratory methods used to determine specific gravity by the calibrated increment borer technique are discussed in detail in a recent publication (4).

The objectives were threefold:

1. To obtain better information on intrinsic wood quality of the pine resources of Mississippi. The greatest single weakness of most resource surveys is their lack of adequate information on quality.

2. To seek out, through systematic mass sampling, living trees that are superior in wood quality as well as form, growth rate, and other desirable characteristics, so that they may be used in breeding studies and to provide scion material for seed orchards. Anyone can go to a lumber yard and find some pretty special wood, but once a tree gets to be a 2 x 4 it is a little late to breed it. The problem is to identify trees with high-quality wood while they are still alive.

3. To learn more about the effects of environmental and other factors on wood quality, so that forest managers can put this information to practical use in growing higher value trees.

Variation in Specific Gravity of Mississippi Pine

The frequency distribution curves presented in the various slides show the range of variation in increment core specific gravity found in the pine population of Mississippi. Especially noteworthy is the magnitude of the differences -- from around 0.25 to about 0.8 5. Some of this variation is due to inherent differences between individual trees within a species or racial strain. Some is attributable to sampling. And some of the variation is due to environmental and other factors that affect specific gravity. Of the anatomical features that can be determined readily, the percentage of thick-walled summerwood fibers in the annual growth ring has the strongest influence on specific gravity. Age from the pith is also highly correlated with wood density. Growth rate, volume, and diameter -- all of which are a reflection of stand density, soil moisture, and various other factors of site -- each may have some influence on specific gravity.

Specific Gravity a Key to Wood Quality

Why so much interest in specific gravity? It is because specific gravity, or wood density, is the simplest and most useful index to the suitability of wood for many important uses.

Specific gravity largely determines pulp yield from a given volume of wood. It is closely correlated with the mechanical strength of wood and is therefore a primary factor in the segregation of structural - grade lumber that commands premium prices, as well as being potentially useful in the selection of high-grade piling, transmission poles and other products and uses where high strength is of major importance. For southern pine especially, if we know the specific gravity of a log or tree, and have a measure of its size, straightness, and freedom from defects, we know just about all we need to know about its suitability for various uses, and can compute its value

The relationship between wood density and kraft pulp yields from southern pine is shown in figure 1. Note that, for every 2-pound increase in wood density, there is produced about 1 pound more of pulp. Stated another way, a cord of high-density southern pine wood will yield about twice as much kraft pulp as an equal volume of low-density wood of the same species. Because of the known variation in wood density, and the equally great variation in the solid wood content of a cord caused largely by differences in the size and straightness of the bolts, a cord is a very unreliable unit of measure so far as pulp yields are concerned. That is the chief reason why a majority of the pulp companies in the South now purchase pine pulpwood by weight.

In this work all specific gravity determinations were based on the volume of the wood when green and its weight when ovendry to eliminate variation due to differences in moisture content.

Relationship of Specific Gravity to Age

Figure 2 shows the average relationship between age and increment core specific gravity at breast height for each of the five species of pine in Mississippi. The effect of age on core specific gravity is clear-cut and highly significant. Another important finding is that the five species fall into three distinct and significantly different specific gravity groups over the entire range of ages. The longleaf-slash group has the highest average core specific gravity at any given age; the shortleaf-loblolly group is intermediate; and spruce pine ranks lowest of the five commercially important pines in Mississippi. The differences shown by the curves in figure 2 between slash and longleaf, and between shortleaf and loblolly, are significant at the extremes of age.

Converting Core Specific Gravity to Tree Specific Gravity

For more precise comparisons, it is necessary to convert the increment core specific gravity data, which apply only to the wood at breast height, to weighted averages that apply to the total merchantable volume of the boles. The reason is that specific gravity tends to decrease with height in the tree. The relationship between core specific gravity at breast height and weighted average specific gravity for the merchantable volume, hereafter termed tree specific gravity, was worked out in a study by Wahlgren and Fassnacht (5). Briefly, they used the calibrated increment borer method to determine specific gravity at breast height for 100 trees each of loblolly, slash, longleaf, and shortleaf pines covering a limited range of diameters and several sites in Mississippi. Then all trees were felled and disks cut from near breast height and at the small end of each pulpwood bolt on up the tree to a 3-inch top, The disks were sent to the Forest Products Laboratory for determination of specific gravity. From the resulting data it was possible to compute an average specific gravity for the merchantable bole of each tree.

Curves of the average relationship between core specific gravity and tree specific gravity for each species are shown in the slides. There is a high degree of correlation in all cases, and the regression equations can be used to estimate tree gravities from core gravities with an accuracy of around ±0.02 over a range of core gravities that corresponds roughly to the 20- to 50-year age range for the various species.

Figure 1.--Relationship between wood density and kraft pulp yields of southern pine pulpwood.

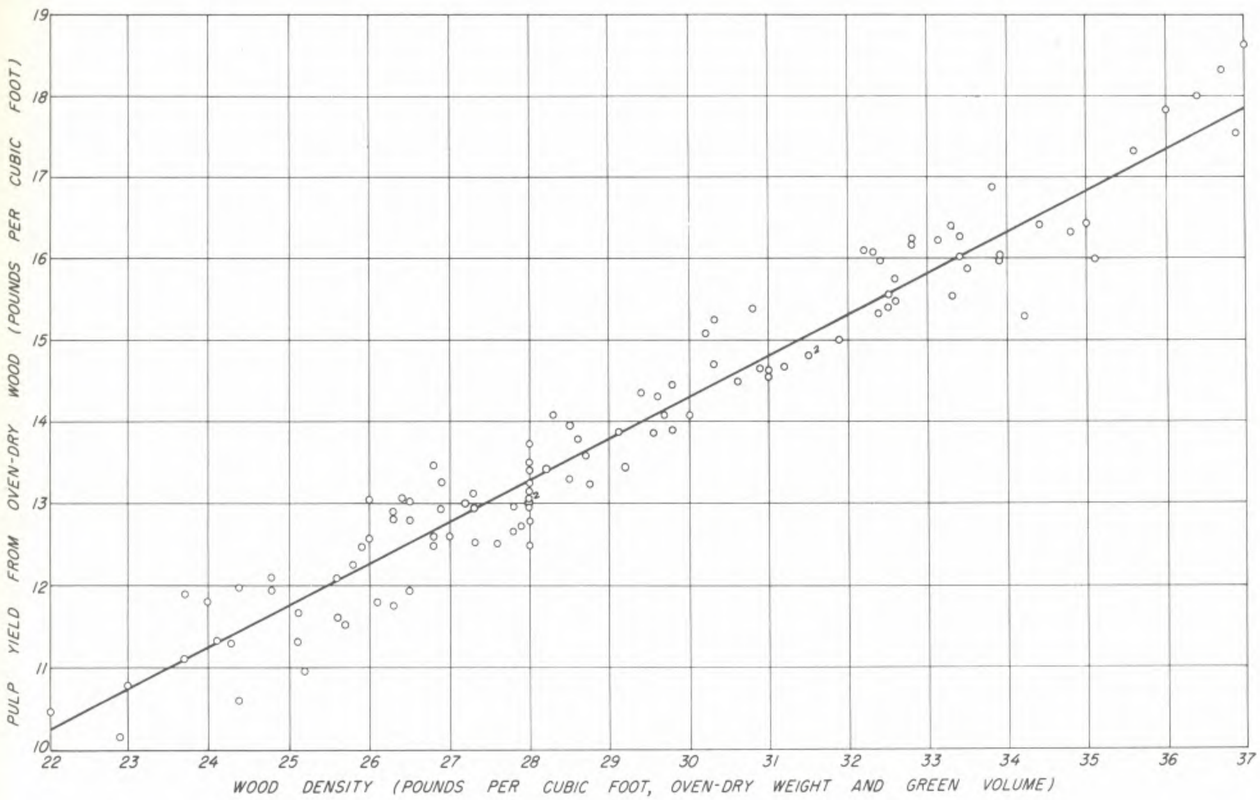
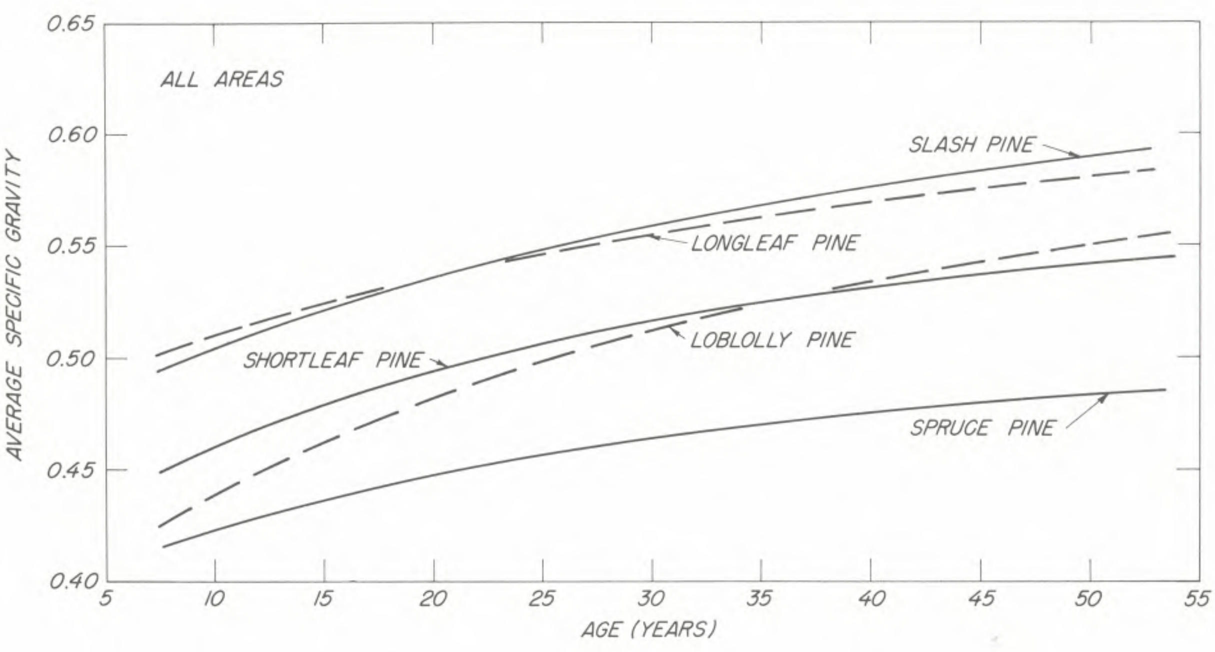


Figure 2.--Relationship between age and core specific gravity at breast height for five species of pine in Mississippi.



Differences in Specific Gravity Between Species

The comparisons made in figure 3 give an idea of the extent to which the differences in specific gravity between species are reflected in the total dry weight and value of an average cord of wood from the various species. The dry-weight data in this illustration are based on the average tree specific gravity attained by each species at 30 years of age, and an assumed constant volume per cord. Trees are prime pulpwood size at this age and are just entering the saw log class. Assumptions made for purposes of this illustration are as follows: (1) That a standard 4- by 4- by 8-foot core has a solid-wood content of 74 cubic feet, the average found in Miller's cord of 74 net cubic feet with a density of 30.70 pounds per cubic foot (the average for the five species at 30 years of age) weighs 2,272 pounds and is worth $14 per cord or $0.616 per 100 pounds (dry weight).

Note that the magnitude of the differences in dry mass or values per cord between the high-density slash and longleaf and the low-density spruce pine is on the order of 20 percent. Values for shortleaf and loblolly, thich are about intermediate in density, are approxmately 10 percent greater than those for spruce pine and 10 percent less than those for the longleaf-slash group.

An idea of how species differences in wood density might be reflected in stumpage values can be obtained by assuming that a 74-cubic foot cord of average density has an on-the-stump value of $5 per cords, or $0.22 per hundred pounds (dry weight). Pulpwood stumpage values, based upon actual wood density for the various species at the age of 30, would then be as follows: $5.43 for slash and longleaf, $4.87 for shortleaf, $4.79 for loblolly, and $4.48 for spruce pine.

North-South Variation in Specific Gravity

Inspection of the data suggests that within a species the core specific gravity tends to increase from north to south in Mississippi. Accordingly, the State was arbitrarily divided into three approximately equal areas -- north, central, and south, following existing Forest Survey units (1) to the extent possible. The data were then classified according to these areas.

The results are shown in figure 4. Only shortleaf and lobiolly, which are fairly well distributed throughout the State, can be compared on this basis. Slash and spruce pine are confined to the southern area, and longleaf largely so.

Note that the core specific gravity of shortleaf is significantly different at the two extremes of latitude over the entire range of ages. In loblolly the difference is even more pronounced above the age of 20 These differences in core specific gravity between areas, like those between species, are of course reflected in the dry weight and intrinsic value of a standard cord of pulpwood, as well as in suitability and value for structural lumber, poles, and other products.

At this point a forest farmer may well ask, "How can I be sure of getting a fair price for my pulpwood, especially my high-density wood?" In this connection it would be impractical to establish per cord or unit price differentials for pine pulpwood based on average wood density values for the various species and areas. For one thing, wood density, as has been shown, varies too greatly within species and within areas to justify application of such a system to any particular local situation. However, differences in density, as well as the equally bothersome variation in the solid wood content of a cord, are automatically taken care of when

Figure 3.--Comparison of average dry weight and estimated value of standard cord of wood from different species of pine in Mississippi at age 30.

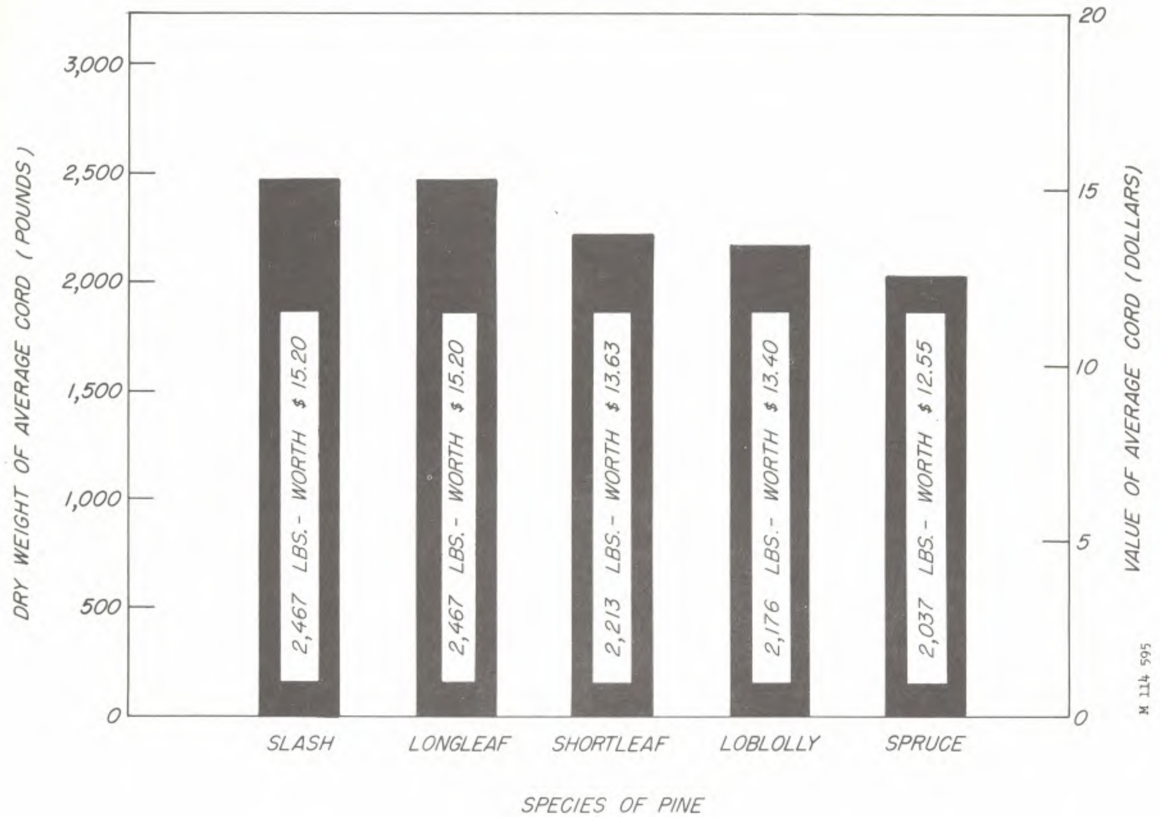
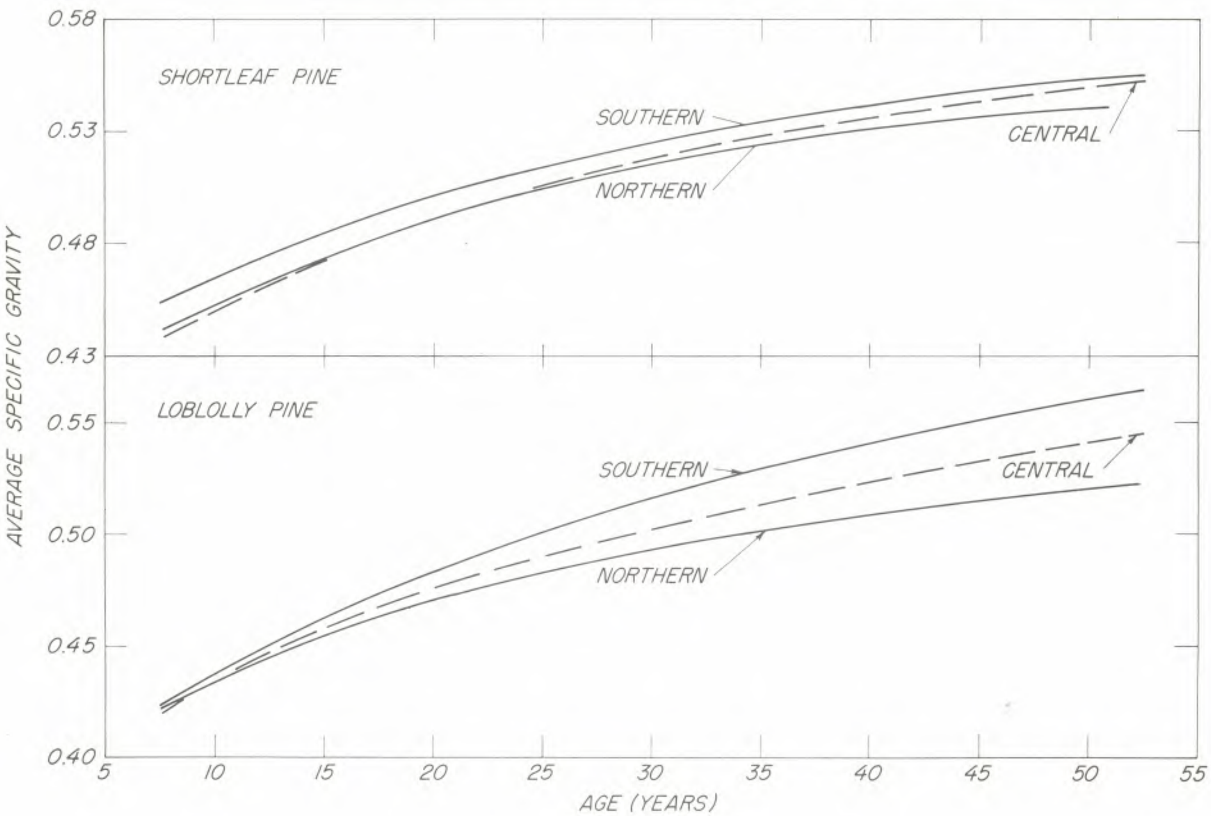


Figure 4.--Relationship between age and core specific gravity at breast height for loblolly and shortleaf pine in North, Central, and South Mississippi.



pulpwood is bought and sold on a weight basis. The seller obtains a higher price for the higher density wood, and the pulp mill benefits from the greater pulp yields produced by such wood. Other important advantages of buying wood on a weight basis are discussed in a recent publication by Taras (7).

Yield in Terms of Dry-Weight Per Tree

In view of developments in the last decade, it is evident that the time will soon come when all pine pulpwood throughout the South will be sold on a weight basis. Therefore, forest managers accustomed to thinking only in terms of cords and board-feet might profitably check their management practices for performance under conditions that will obtain when a large part of their product will of necessity be cruised, valued, and marketed by the pound or ton.

Through the years, foresters have accumulated a large amount of information on the volume of wood produced by various species at different ages over a range of site qualities. Now it becomes important to have similar information on weight. Data from the Mississippi Survey provide the first extensive information on this subject. Net tree volume in cubic feet multiplied by tree density gives the total dry weight of merchantable material in a tree. In this way the dry weight of wood produced by trees of the various species at different ages was determined for the major areas of the State. Some comparisons, based on average dry weight per tree at age 30 are shown in figure 5.

On this basis, loblolly is definitely superior to shortleaf in both the northern and southern parts of the State, and to the other species where they occur together in the South. Since loblolly ranks only fourth in increment core specific gravity at this age (fig. 2), and also in tree density, its superiority in dry mass in due largely to its greater volume increment in 30 years. Dry mass, or weight, as previously indicated, is the product of volume and density.

Perhaps the most surprising finding is the showing made by the lowly spruce pine, which ranks at the bottom of the wood density scale. However, its average volume increment per tree in 30 years, which is second only to loblolly, is sufficient to put it ahead of the other three species in terms of dry weight produced per tree at that age.

Spotting Exceptional Trees

One of the objectives of this research was to search out individual trees that are definitely superior in regard to wood quality. As the increment cores were processed at the Forest Products Laboratory, those having a specific gravity considerably higher than the average were flagged. In most cases, these cores were extracted to remove any resin present and then rerun to make certain that the specific gravity determination was correct. Data on these trees were sent promptly to the Southern Forest Experiment Station for additional on-the-ground checking by the staff of the Southern Institute of Forest Genetics.

Complete records on plot location and individual tree number made it possible to relocate the trees selected for further study. Two additional increment cores were taken from each of these trees, and specific gravities thereon were determined independently by the Southern Institute of Forest Genetics as a double check on wood density at breast height. In addition, the forest geneticists who inspected these trees made detailed observations on tree form, branching habit, size of limbs, freedom from insects and disease, and the like.

Figure 5.--Average merchantable dry weight per tree at age 30 for various species and areas in Mississippi.

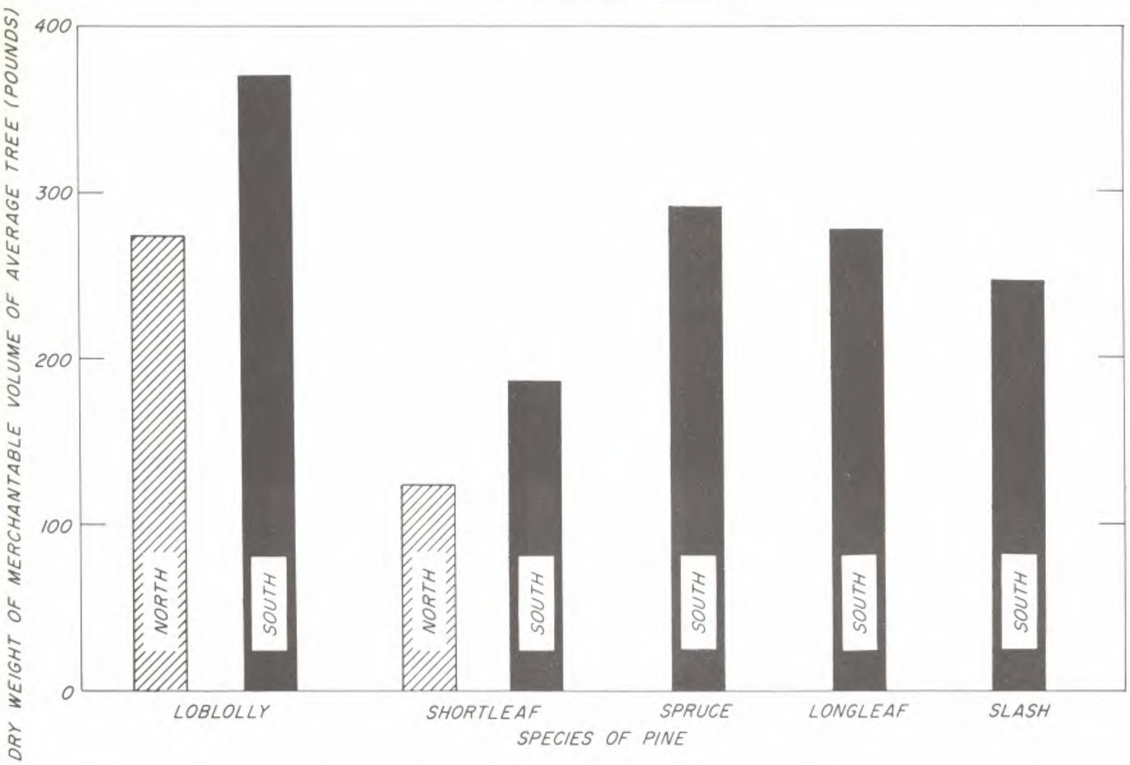
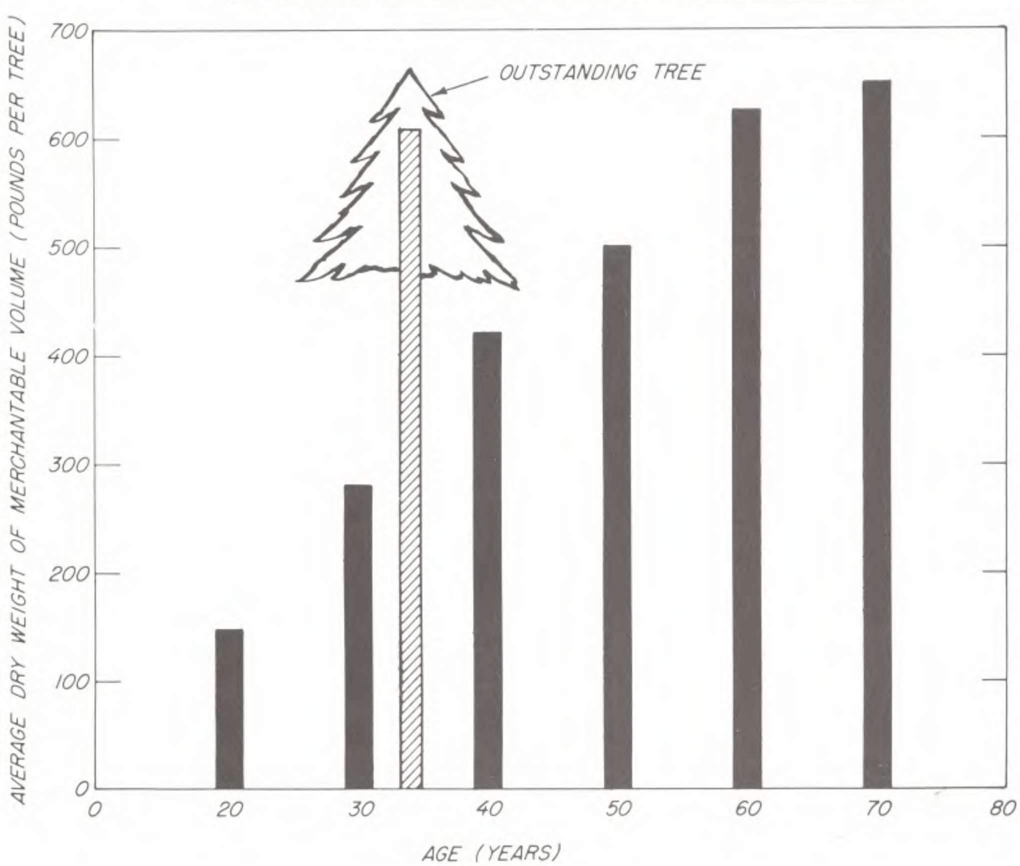


Figure 6.--Merchantable dry weight of outstanding longleaf tree 34 years of age compared with dry weights of average longleaf trees at various ages.



As might be expected, some of the trees with the highest specific gravity turned out to be relatively poor in form, growth rate, or some other important characteristic. Because of their exceptional specific gravity, however, many such trees will prove valuable in breeding research aimed at increasing wood density. For example, they can be crossed with trees of outstanding growth rate and good form but of average density with the hope of obtaining progeny that possess a superior combination of these desirable characteristics.

A few outstanding trees were located that combined exceptional wood density with average or better growth rate, form,branching, and other important characteristics. Data for the best longleaf are shown in figure 6 in comparison with average trees of the same species in southern Mississippi. This particular tree has a specific gravity of 0.748 at breast height and a net volume of 16.2 cubic feet at the age of 34. So far as can be ascertained, this is the highest specific gravity recorded for any living southern pine of the same age class that is also above average in growth rate and acceptable as to form, branching, and other important character istics. The tree attained an estimated dry weight of 607 pounds in 34 years, about double the dry mass of average trees of the same age, and almost equal to that of average trees twice its age. Incidentally, by connecting the bars shown in figure 6, it is possible to construct what is essentially a dry mass yield curve for longleaf pine in southern Mississippi. Such a curve provides the most realistic and useful standard of comparison thus far developed for rating plus trees according to their gross pulp yield potential. Similar dry mass yield curves are being developed for the other species, since they will have applications in forest management and resource surveys as well as genetics.

A number of outstanding trees of other species were also discovered in this manner during the Forest Survey of Mississippi. Scion material from the more promising individuals either has been or soon will be propagated, by vegetative means, and established at the Southern Institute of Forest Genetics, Gulfport, Miss., for use in breeding research and to stock experimental seed orchards. These plus trees will of course be artificially crossed, under controlled conditions, with other selected trees to determine the extent to which their apparent superiority is transmitted to the progeny.

An unexpected dividend developed from the systematic mass screening conducted as a part of the Forest Survey. The procedure followed served to pinpoint areas where it was highly profitable to look intensively for superior individuals. Although the higher density trees picked up on the survey plots did not always prove, upon further testing, to be particularly outstanding, additional "prospecting" in the immediate vicinity frequently did locate some really promising individuals. A majority of the best trees found were located in this way. These localized "high-density areas" may in some cases be due to the occurrence in the present population of a good sprinkling of descendants from some super tree that has long since been harvested and converted to lumber or paper. Who knows?

We do know that higher density southern pines occur in nature than any thus far located. This is evident from the records on thousands of wood samples tested at the Forest Products Laboratory over a period of 40 years. The problem is to identify them while they are still alive, so their choice germ plasm can be preserved and multiplied. The chief obstacle is that a high-density tree looks just like any other tree, and the only reliable way to determine density is to make a density measurement at some sampling point. Moreover, it appears that such super trees occur with a frequency of only about one in 10,000. Some one like Ernie Schreiner with a good nose for the finer things in life, and a lot of luck, might stumble onto one in the back 40 on the first try. The odds are, however, that when better southern pines are found they will be located by some sort of systematic mass screening similar to the cooperative Forest Survey of Mississippi here described. This year the search is being continued in Arkansas, Missouri, and Florida in connection with current Forest Surveys in these States.

Application to Forest Management

Some of the data included in this progress report are too new, and still too undigested, to justify hazarding any very specific recommendations regarding their application in forest management. For this reason, and because this is primarily a genetics meeting, I will limit my, comments on this subject to the following The data here presented provide important new information that the forest manager should consider, along with other facts, in arriving at management decisions. Probably their chief value at this time will be to focus attention on the need for a more adequate concept of wood quality and the factors that affect qual ity, to stimulate thought and activity in this long-neglected field, and to suggest the kinds of research needed to answer some of the questions that have been raised.

I might add that the mass of data accumulated during the Mississippi Survey is being subjected to thorough statistical analysis according to the new machine program by Grosenbaugh (8) for the IBM 704 electronic computer. Of major interest is the extent to which specific gravity is affected by various environmental factors. For example, is the observed trend of increasing specific gravity from North to South related to summer rainfall? The results of the statistical study will be published in subsequent reports.

Application to Southern Forest Resource Surveys

The wood density data obtained in Mississippi have immediate practical application in southern forest survey work. From the information available it will soon be possible to present the resource data in terms of tons of merchantable material available for pulp production classified by species, size class, and on an acre, county, survey unit, or some other unit-area basis. Or, using the experimentally established relationship between wood density and pulp yields, the dry mass data can be converted to tons of processed pulp.

For the lumberman, good estimates can be made of the proportion of the sawtimber volume by species, size class, log grade, or area -- that will meet mini mum Southern Pine Inspection Bureau specifications for dense and longleaf structural lumber, timbers, and heavy dimension. Similar information should also be of value to those interested in high-strength piling and transmission poles.

Applicability of These Techniques in the Northeast

I believe that the techniques developed to evaluate wood quality of southern yellow pines in Mississippi could be used to advantage, with little or no modification, on northeastern species that are normally used chiefly for pulp, some form of chemical utilization, such as charcoal, structural lumber, or certain other uses, such as tool handles and athletic equipment, where high mechanical strength is a major requirement. Probably the most promising place to start would be the sprucefir type. Next in order, from the standpoint of applicability, might be the hard pine areas of the southern part of the region. With some modifications in present methods and equipment, these methods might also be used to advantage on low-quality hardwoods. That is, stands that are so poor in species composition or lumber and veneer grade yield potential that most of the volume will likely be used for pulp or chemical wood.

Specific gravity is not a very good index to the machining and finishing properties of wood, dimensional stability, paintability, appearance, or figure. Hence the methods here discussed would be of little value in determining intrinsic wood quality of the cabinet hardwoods, or such softwoods as white pine, in terms of suitability for their normal uses. Wood-quality evaluation of these species will require a different approach (9), and possibly some destructive sampling when applied to resource surveys.

Literature Cited

(1) Anonymous 1958. Mississippi forests, Southern Forest Experiment Station Forest Survey Release No. 81.

(2) Mitchell, H. L., and Wheeler, P. R. 1959. The search for wood quality. Forest Farmer, Vol. 18. Nos. 4 and 5.

(3) ---------------------------1959. Wood quality of Mississippi's pine resources. Forest Products Lab. Report No. 2143.

(4) Mitchell, H. L. 1958. Wood quality evaluation from increment cores. Tappi, Vol. 41, Nov 4. pp. 150-156.

(5) Wahlgren, H. E., and Fassnacht, D. L. (1959) Estimated tree specific gravity from a single increment core. Manuscript in preparation as Forest Products Laboratory Report.

(6) Miller, R. H. 1941. Measuring green southern pine pulpwood by weight. Paper Trade Journal Vol. 113, July.

(7) Taras, M. A. 1956. Buying pulpwood by weight as compared with volume measure. Southeastern Forest Experiment Station Paper-No. 74.

(8) Grosenbaugh, L. R. 1958. The elusive formula of best fit: A comprehensive new machine program. Southern Forest Experiment Station Occasional Paper No. 158.

(9) Mitchell, H. L. 1957. Applying forest tree improvement practices in the Lake States. Production of quality wood. Forest Products Laboratory Report No. 2103.

DISCUSSION

TABER. I'd like to ask how much resin was in that exceptional pine?

MITCHELL. All resin was extracted from the increment cores from this tree before the specific gravity determinations were made.

BEERS. This relationship you found with the dry weight of managed loblolly pine being approximately two times greater than slash pine at age 30, is of course, specific for Mississippi and that region. It should be pointed out that this would not necessarily hold for, say, Florida.

MITCHELL. What you say is true, At the present time we do not know the extent to which the relationships found in Mississippi will hold for Florida or any other Southern States. However, we are now working in Florida, Arkansas, and Missouri, and should soon have comparable data for these states. Eventually, we hope to cover the entire South.

GERHOLD. Do you have an approximate cost figure pertaining to the state survey of the pine species in Mississippi?

MITCHELL. Probably your question is best answered in this ways From our experi ence in Mississippi we believe that, when done on a routine basis primarily to meet Forest Survey objectives and standards of accuracy, the taking and processing of increment cores should not increase normal Survey costs by more than around 5 percent. The Mississippi study costs were of course considerably higher than this because of the time spent checking and working the bugs out of our techniques, the elaborate statistical analyses required to meet various supplementary research objectives, and the fact that sampling intensity was greater than needed for resource survey purposes.

SMITH. Would you care to comment how this might be translated to forest management, other than wood purposes I mean the findings on specific gravity of southern pines.

MITCHELL. The most prudent comment at this stage is that the study here reported provides important new technical information that the forest manager should consider, along with other facts, in arriving at management decisions.

Would you care to comment on this point, Bruce? I know you have given a lot of thought to the general subject of wood quality of southern pines.

ZOBEL. No, but I did want to comment on one thing though that might lead to false ideas about this growth-rate business. You were talking about the whole state, a large group of trees on different sites. If we take a bunch of trees on the same site we won't find this relationship between specific gravity and growth rate. It's very hard to find, especially in dominant and co-dominant trees where you have good growth rates.

MITCHELL. In our analysis of the Mississippi data we did not find a strong cr consistent relationship between growth rate and specific gravity. Multiple regression analysis showed that growth rate did not account for much of the variation. The effects of age, diameter, and several other variables were much stronger, as might be expected in a sample of this kind. In more detailed and carefully controlled studies, however, we frequently do find a significant correlation with growth rate, as in Yandle's statistical study of loblolly pine published in FPL Report No. 2049.

EYRES. Can you relate the external appearance of trees to their specific gravity?

MITCHELL. I'm glad you asked that question, After a thorough statistical analysis of the effects of nine different independent variables -- diameter, volume, height, etc. -- on the 704 electronic computer, and checking the 511 possible regressions, we concluded that the only way to determine specific gravity with acceptable accuracy was to make an actual determination at some sampling point.

SHOPMEYER. I'd like to ask Dr. Enright how old the pine trees were from which he got the cuttings?

ENRIGHT. If I remember correctly, the pines were 25 to 30 years old. The spruce was about 40 years old.

EYRES. What survival did you get on your outplanted conifers after they had rooted, or did you do any outplanting?

ENRIGHT. They've been out more than a year now. The last report was that we have lost one spruce. I will have to qualify that and say that in a previous planting all were lost. We had a new man operating a power mower who now knows all about trimming spruces.

BEERS. Do you find that light intensity or duration has any effect on rooting?

ENRIGHT. I'm convinced that it does, but I can't say that I've found anything definite along that line.

TABER. I came in late. In your coniferous studies did you use softwood or hardwood cuttings?

ENRIGHT. Two-year wood.

TABER. What I meant is, did you have hardened one year wood or did you use springwood?

ENRIGHT. It is a matter of interpretation. To answer your question directly - it was hardened one-year wood; taken later would have been considered 2-year wood.