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WOOD QUALITY OF MISSISSIPPI'S PINE RESOURCES

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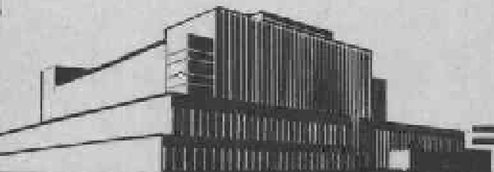

FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

This is the first of a series of technical publications resulting from a continuing cooperative study between the Southern Forest Experiment Station, New Orleans, La., and the Forest Products Laboratory, Madison, Wis. The State of Mississippi and various industries helped with the field phases of the work here reported. Such cooperation amounted to over 35 percent of the total field job, and this assistance is hereby gratefully acknowledged.

WOOD QUALITY OF MISSISSIPPI'S PINE RESOURCES[1]

By

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This report presents some of the highlights of wood quality research carried on in connection with the recently completed third Forest Survey of Mississippi (1).[3] The State of Mississippi and various industries helped with the field work. Such cooperation amounted to over 35 percent of the total field job, and this assistance is hereby gratefully acknowledged.

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.

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[1] Based on illustrated report presented at the 1958 Southern Forestry Conference, Monroe, La., March 27 and 28, and published in part in Forest Farmer, Vol. 18, Nos. 4 and 5, 1959.

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

[3] Underlined numbers in parentheses refer to Literature Cited at the end of the article.

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 labeled and sent tothe 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.

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

Figure 1 shows the range of variation in increment core specific gravity found in the pine population of Mississippi. Basic data are summarized in table 1. Especially noteworthy is the magnitude of the differences -- from around 0.25 to about 0.85. 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 2. 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 (fig. 1), 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. To convert specific gravity to wood density, in terms of pounds (ovendry) per cubic foot (green), multiply by 62.4, the weight of a cubic foot of water. Thus, if a freshly cut pulp bolt has a bark-free volume of 1.5 cubic feet and a specific gravity of 0.45, it has a density of 28.08 pounds per cubic foot (0.45 x 62.4) and a dry weight of 42.12 pounds (1.5 x 28.08).

Relationship of Specific Gravity to Age

Figure 3 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 3 between slash and longleaf, and between shortleaf and loblolly, are significant at the extremes of age.

Even relatively small differences in specific gravity have considerable practical importance. A rule of thumb that will help orient one's thinking in this regard is as follows: An increase or decrease of only 0.01 in specific gravity is reflected in an increase or decrease of about 50 pounds in the dry weight of an average cord of southern pine pulpwood.

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 (6). 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 figure 4. There is a high degree of correlation in all cases, and the regression equations in figure 4 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. Sampling in the Wahlgren-Fassnacht study was largely concentrated in the ages and sizes that normally supply most of the pulpwood. Thus, trees under 20 and over 50 years of age are not in all cases well represented in the data on which the regressions in figure 4 are based. Consequently, caution should be used in predicting tree gravities from core gravities at the extremes of the core gravity.

Differences in Specific Gravity Between Species

The comparisons made in figure 5 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 cord has a solid-wood content of 74 cubic feet, the average found in Miller's (3) study of 100 truckloads of pulpwood; and (2) that a standard 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 value 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, which are about intermediate in density, are approximately 10 percent greater than those for spruce pine and 10 percent less than those for the longleaf-slash group.

If the dry weights used throughout this report are confusing to the reader, there is a convenient rule of thumb for converting them to approximate green weights. Simply double the dry weight to convert it to green weight, as the moisture content of pine in the freshly cut condition averages just over 100 percent (5).

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 cord, 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.

In interpreting the data shown in the various charts, it should be remembered that the values given are all averages based on a representative, equispaced, systematic sample of the pine population of the entire state. These values will not necessarily hold for any individual tree, stand, or area, because of the great variation within species shown in figure 1. Thus, although slash and longleaf average higher in specific gravity than any of the other species, some slash and longleaf have specific gravities of 0.30 or less. On the other hand, it is possible to find individual spruce pines that rank in the upper one-half of the wood density scale.

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 6. Only shortleaf and loblolly, 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 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 (5).

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 7.

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. 3), and also in tree density, its superiority in dry mass is 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.

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 8 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 characteristics. 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 8, 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.

Higher density southern pines must 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. Someone with a good nose 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. At best, they provide important new information that the forest manager should consider, along with other facts, in arriving at management decisions. Probably the chief value of the material here presented will be to focus attention on the need for a more adequate concept of wood quality and the factors that affect quality, 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.

Certainly no one should jump to the erroneous conclusion, on the basis of data presented in figures 6 and 7, that loblolly is a better species to plant or favor than shortleaf under any and all conditions -- or the equally absurd conclusion that all sites in southern Mississippi are superior to all sites in northern Mississippi.

Among things needed, of course, are more precise comparisons of the volume increment, wood density, and merchantable dry mass of loblolly and shortleaf pine growing together over a range of known site qualities. As will occur to most foresters, shortleaf may show up better on the poorer, drier sites that are about marginal for the more demanding loblolly. Some information on this subject will be obtained from fundamental research in progress at the

Crossett Research Center and from the current Arkansas Forest Survey, where soils on the sample plots are being evaluated according to Zahner's (7) soil-site classification.

The north-south variation in specific gravity and dry mass per tree shown in figures 6 and 7 is real and significant for the areas into which the State was divided. The overall picture, however, is not so simple as it appears. Statistical analysis of the data on the IBM 704 electronic computer, according to the program developed by Grosenbaugh (2), indicates that, although latitude alone is strongly correlated with the increase in specific gravity from North to South, there is also a longitudinal effect, almost as strong, of increasing specific gravity from West to East. The net result seems to be a broadly diagonal effect of increasing specific gravity from the northwestern to the southeastern part of Mississippi.

Longitude and latitude can affect growth or wood density only to the extent that they reflect differences in soil, rainfall, length of growing season, geographic race, or some other factors or combinations thereof that are more directly related to tree growth and wood density. The statistical study is continuing in an effort to learn more about the factors that affect specific gravity. The results will be published in subsequent reports.

Application to Forest Resource Surveys

The wood density data obtained in Mississippi have immediate practical application in 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 relationship expressed in figure 2, the dry mass 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 minimum 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.

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(6) Wahlgren, H. E., and Fassnacht, D. L.
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Table 1.--Summary of average core specific gravities and tree diameters, by age class and area, for southern yellow pines 5 inches d.b.h. and over as sampled in the Mississippi Forest Survey

Species	Median of age class	Southern area			Central area			Northern area			Entire state		
		Trees	Average diameter at breast height	Average specific gravity	Trees	Average diameter at breast height	Average specific gravity	Trees	Average diameter at breast height	Average specific gravity	Trees	Average diameter at breast height	Average specific gravity
	Yr.	No.	In.		No.	In.		No.	In.		No.	In.	
Slash pine	10	50	4.8	0.493									
	20	161	7.4	.546									
	30	156	9.1	.565									
	40	96	10.6	.572									
	50	48	11.3	.583									
	60+	65	13.5	.598									
	ALL	576	9.2	.560									
Longleaf pine[1]	10	60	5.2	.492									
	20	376	8.9	.540									
	30	316	10.1	.557									
	40	127	11.9	.570									
	50	22	13.1	.588									
	60+	91	13.7	.602									
	ALL	992	9.7	.553									
Shortleaf pine	10	75	5.0	.456	152	5.0	0.454	132	4.8	0.452	359	5.0	0.450
	20	115	7.1	.502	327	6.8	.491	335	6.5	.489	777	6.7	.492
	30	127	9.0	.528	284	8.4	.520	276	8.2	.519	687	8.5	.521
	40	81	11.7	.546	229	9.4	.534	144	9.2	.525	454	9.8	.533
	50	51	11.5	.548	103	10.7	.539	75	10.1	.543	229	10.7	.542
	60+	70	13.0	.565	123	12.1	.565	116	12.2	.556	309	12.3	.561
	ALL	519	9.2	.522	1,218	8.3	.513	1,078	8.0	.508	2,815	8.3	.512
Loblolly pine	10	451	6.0	.434	422	5.4	.428	114	5.9	.431	987	5.7	.433
	20	484	9.0	.489	509	8.4	.470	119	8.2	.479	1,112	8.7	.479
	30	352	12.4	.517	413	11.6	.511	64	11.8	.511	829	12.0	.513
	40	218	13.9	.538	174	13.2	.529	18	14.0	.511	410	13.6	.533
	50	112	14.2	.554	89	15.4	.532	10	14.9	.501	211	14.8	.542
	60+	98	17.3	.568	84	16.1	.541	21	14.5	.507	203	16.5	.550
	ALL	1,715	10.6	.496	1,691	9.7	.482	346	9.0	.473	3,752	9.9	.489
Spruce pine[1]	10	9	4.3	.421									
	20	39	9.5	.456									
	30	50	11.9	.455									
	40	48	13.1	.497									
	50	18	13.7	.471									
	60+	14	17.8	.513									
	ALL	178	11.9	.471									

[1] Includes occasional trees in central area.

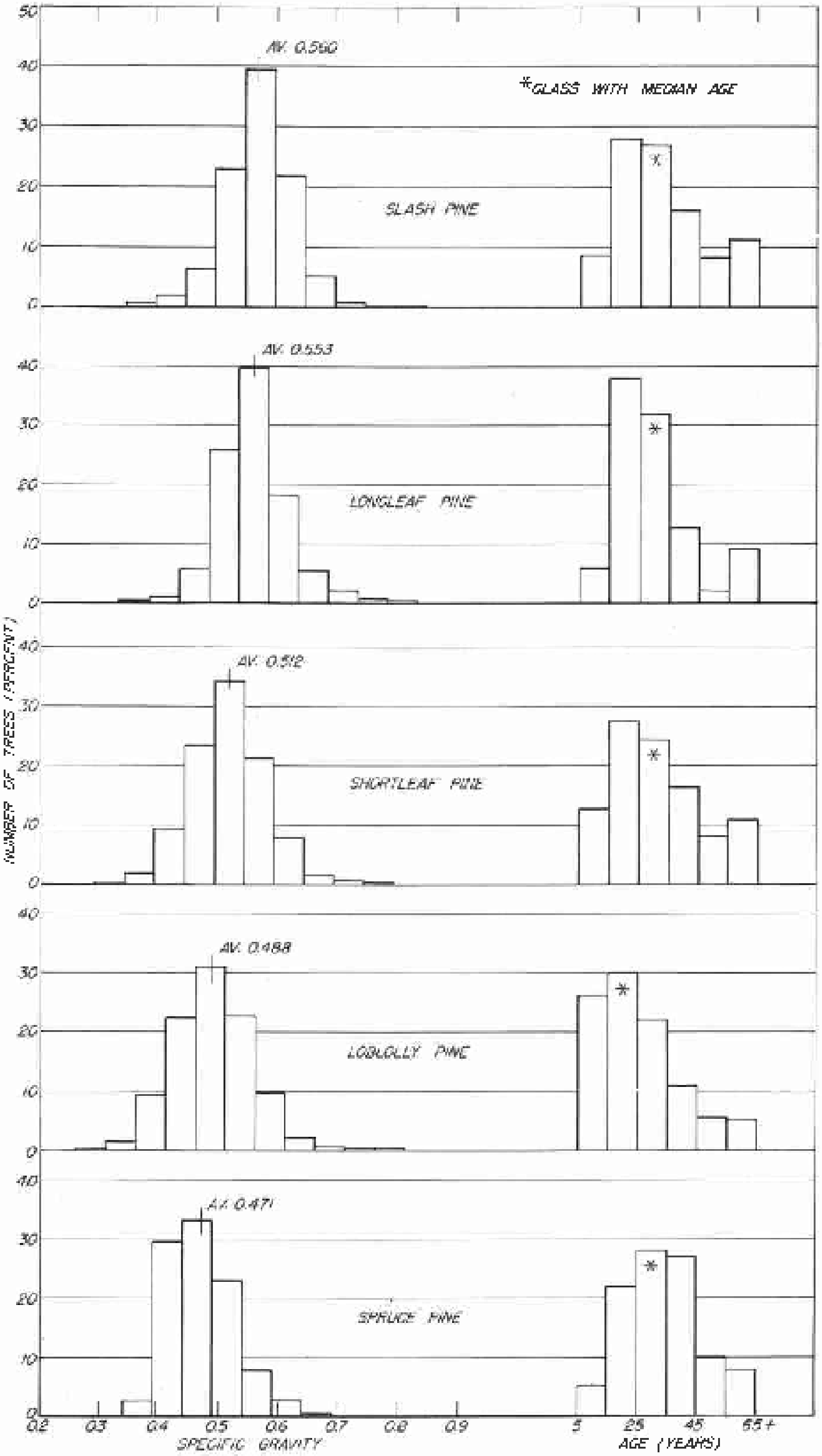

Figure 1. --Frequency distribution of age and core specific gravity at breast height (3 inches d. b. h. and over) for five species of pine in Mississippi. Number of trees in sample: slash, 576; longleaf, 992; shortleaf, 2,815; loblolly, 3,752; spruce pine, 178.

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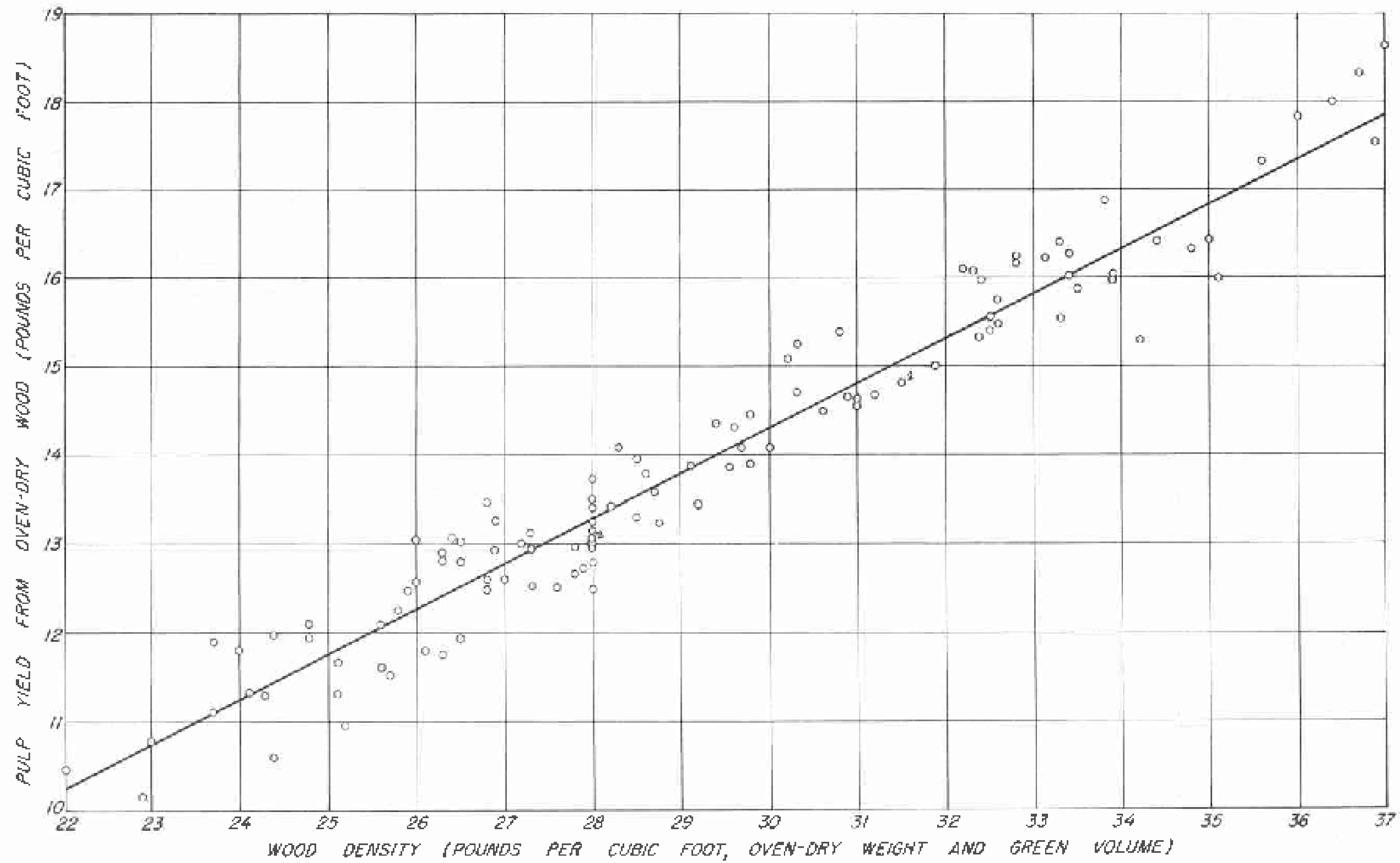

Figure 2. --Relationship between wood density and kraft pulp yields of southern pine pulpwood.

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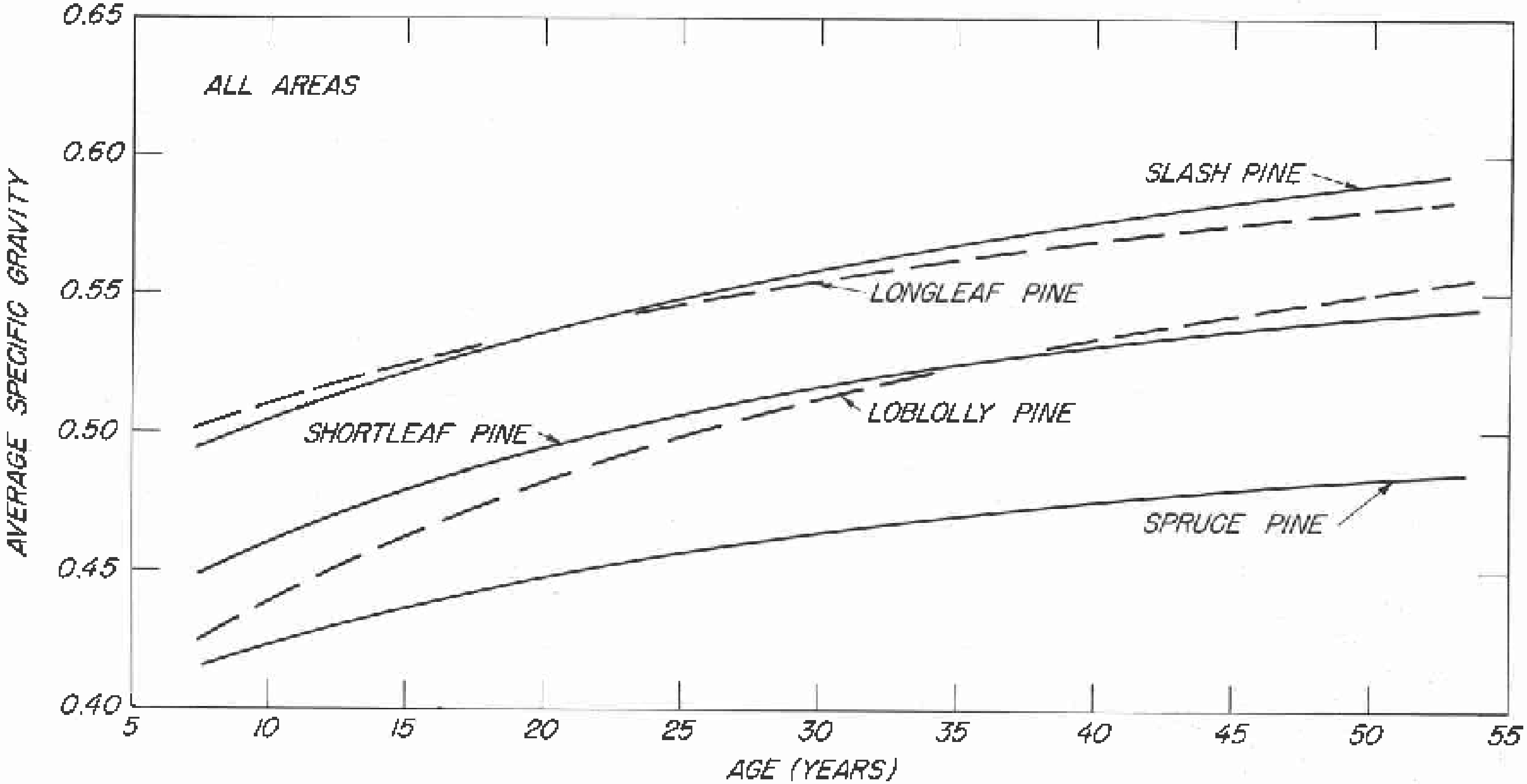

Figure 3. --Relationship between age and core specific gravity at breast height for five species of pine in Mississippi.

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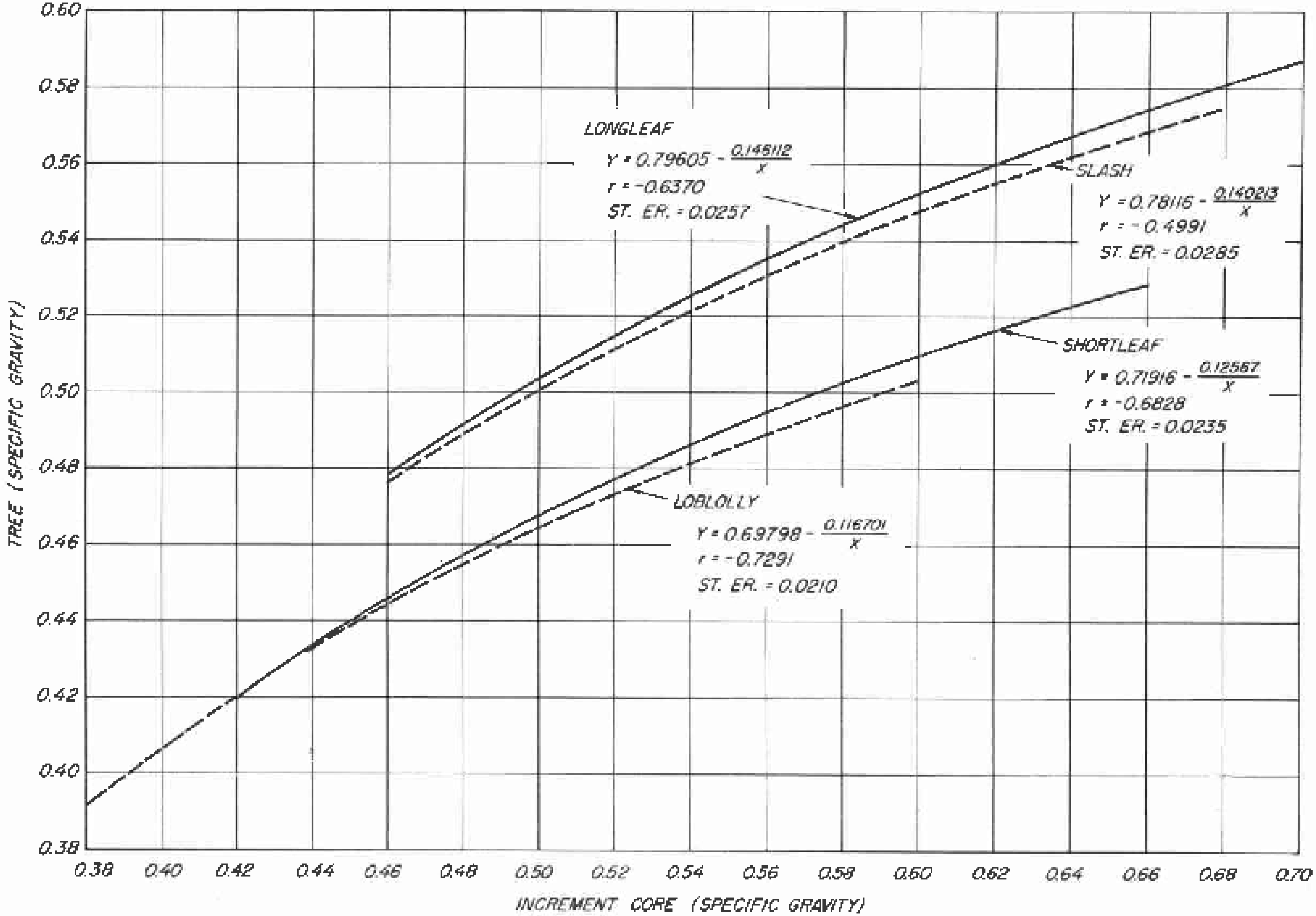

Figure 4. --Curves of relationship between specific gravity of increment core at breast height and weighted specific gravity of total merchantable volume of the tree for four species of pine in Mississippi. Based on data from 100 trees of each species.

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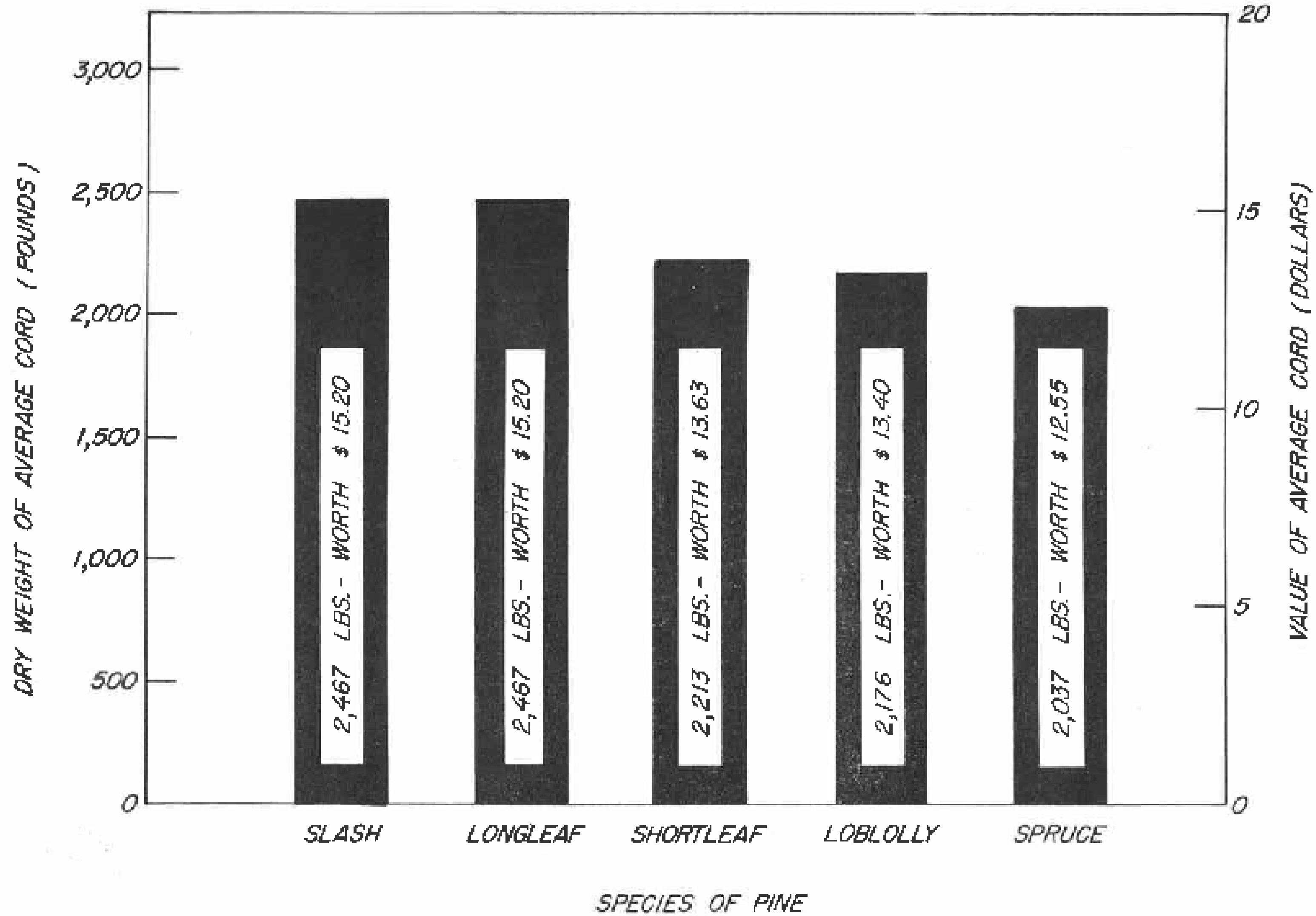

Figure 5. --Comparison of average dry weight and estimated value of standard cord of wood from different species of pine in Mississippi at age 30.

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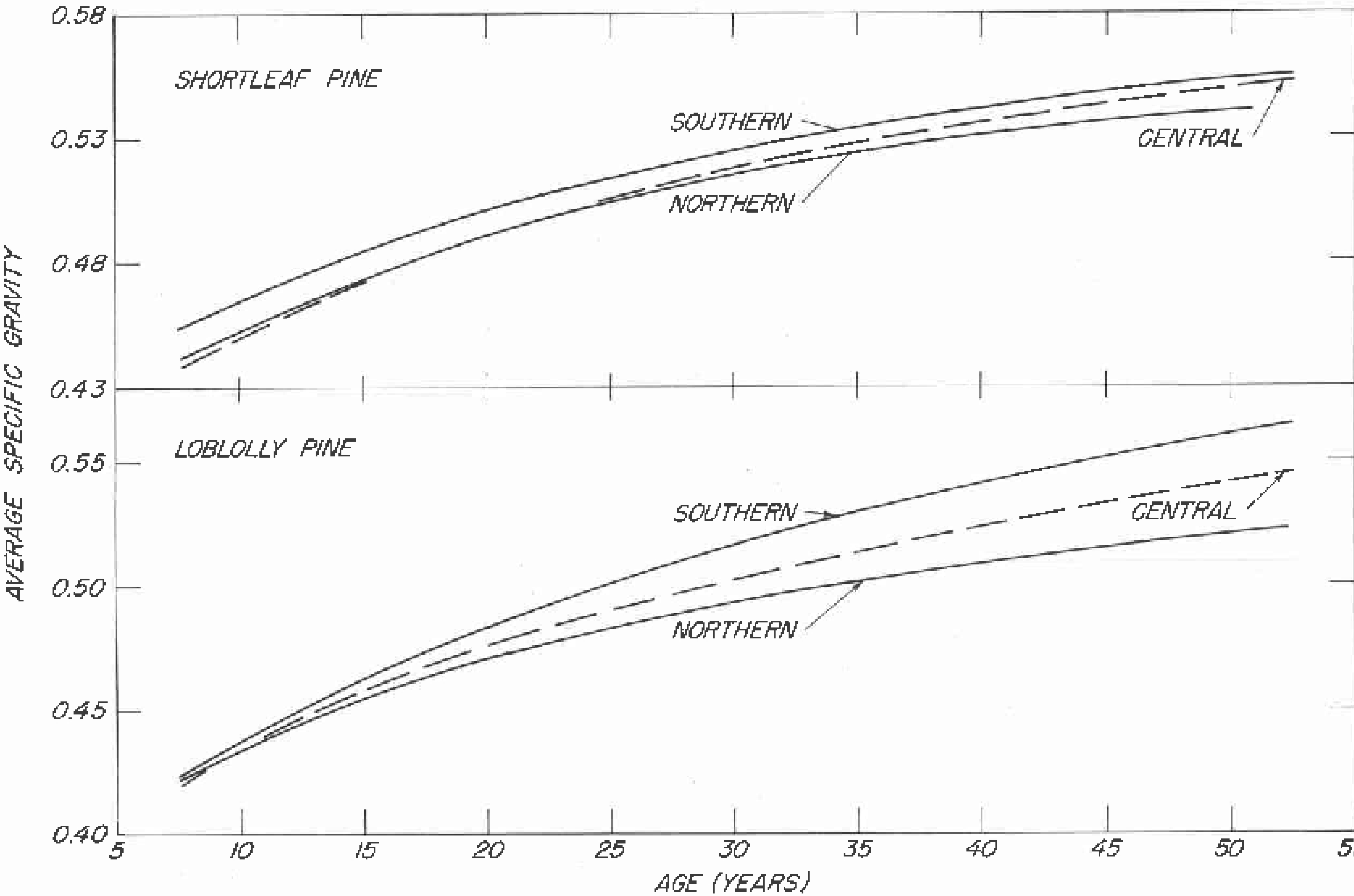

Figure 6. --Relationship between age and core specific gravity at breast height for loblolly and shortleaf pine in North, Central, and South Mississippi.

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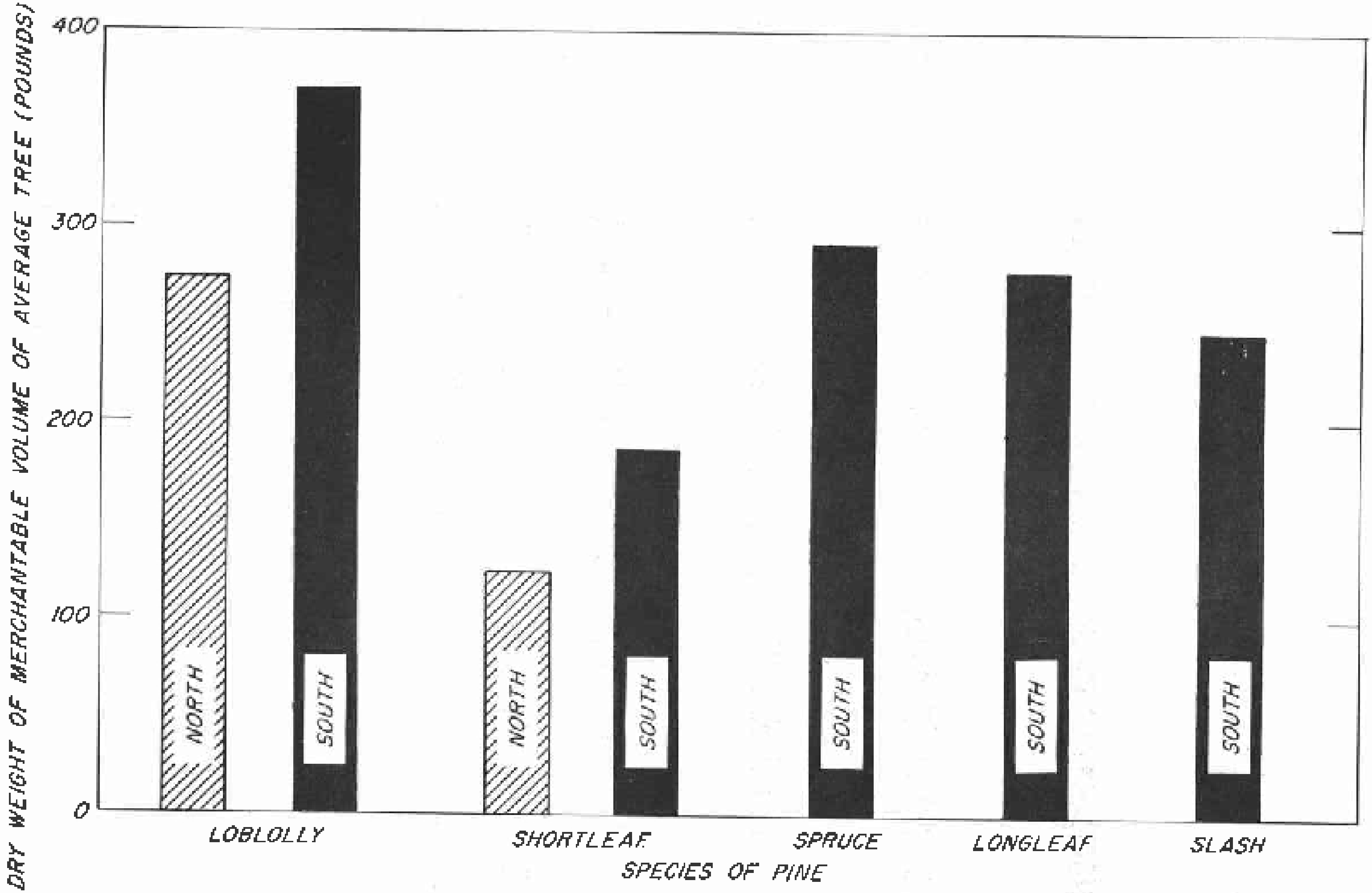

Figure 7. --Average merchantable dry weight per tree at age 30 for various species and areas in Mississippi.

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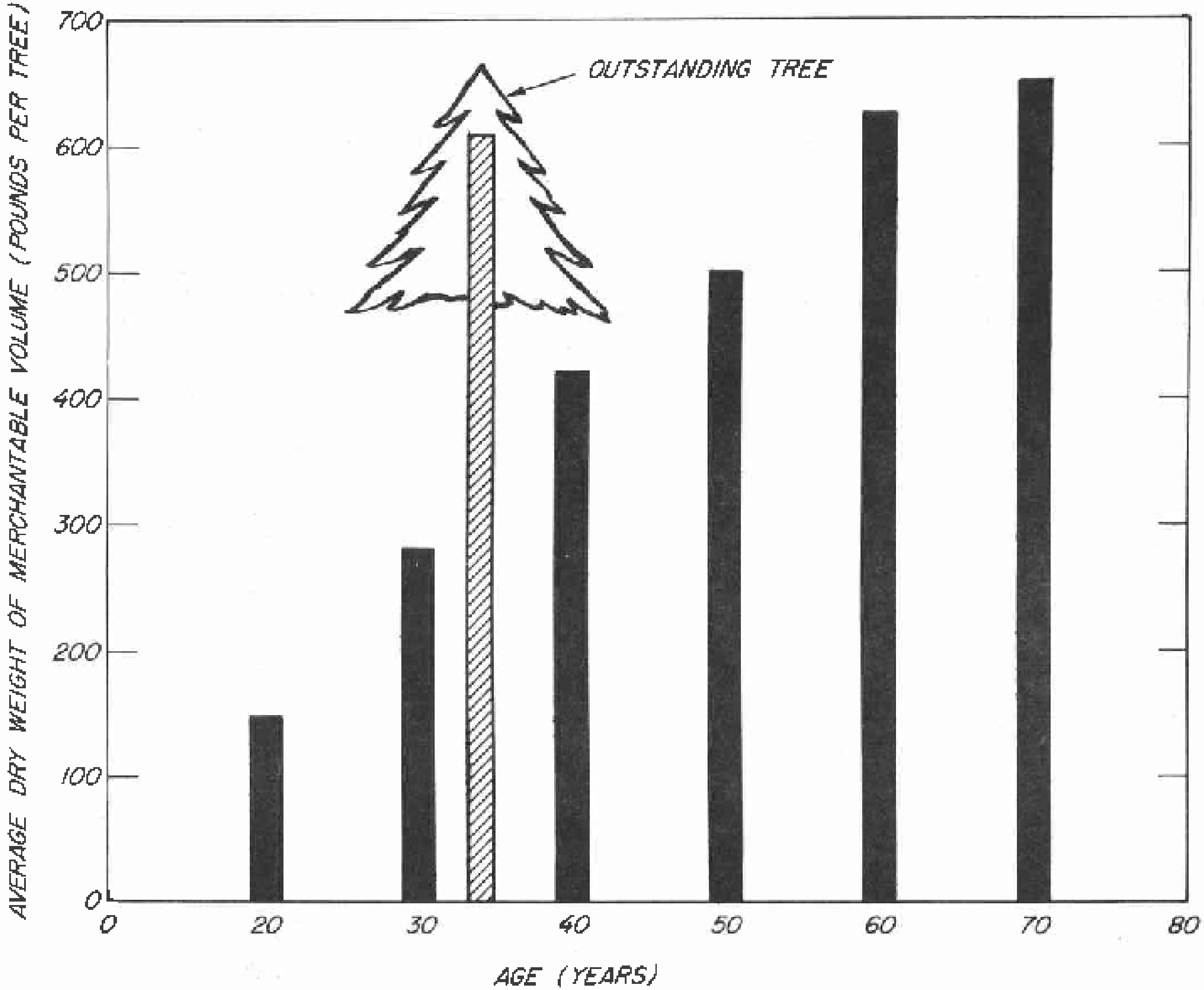

Figure 8.--Merchantable dry weight of outstanding longleaf tree 34 years of age compared with dry weights of average longleaf trees at various ages.

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