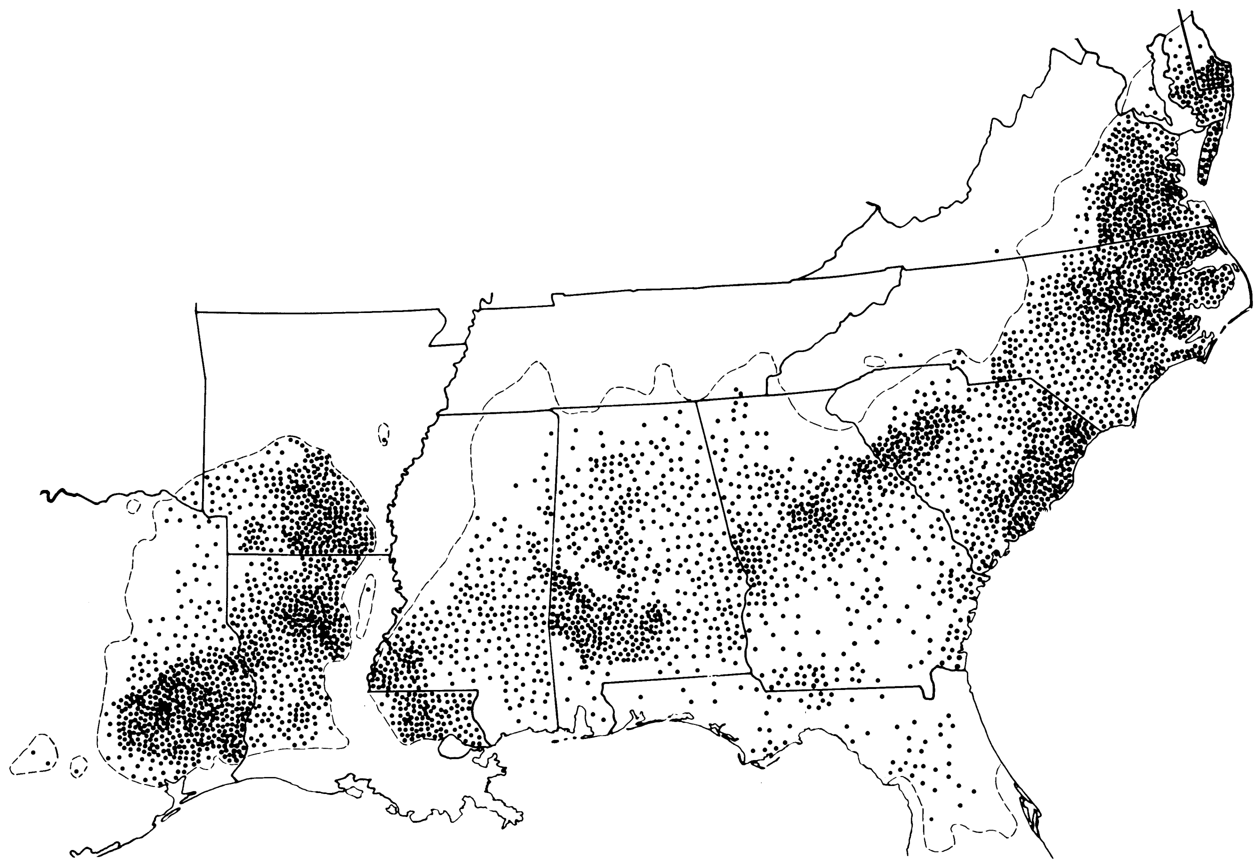
CHAPTER 5

GEOGRAPHIC VARIATION—TREES IN PLACE

LOBLOLLY PINE

Wood Volume

As described in chapter 1, loblolly pine has the largest total volume of all southern pines and is exceeded only by shortleaf pine in area of natural range. However, timber volume is concentrated in well-defined population centers rather than spread uniformly over areas of similar soil, rainfall, and temperature (fig. 46). In the northern part of the Atlantic Coastal Plain, an area of large wood volume, high temperature and rainfall coincide, but in Texas, another center of concentrated wood volume, high temperature occurs during a period of low rainfall (fig. 11). In the East, volume is high along the Atlantic Coast in South Carolina, North Carolina, and Virginia. Mohr (1897) noted the large volume of loblolly pine in the Carolinas. In Georgia, Alabama, and Mississippi, volumes are lower than in the East, but they are high locally. In the West, volume is highest in a broad area extending from the Gulf Coast in southeast Texas northeastward through north-central Louisiana and southeast Arkansas. The occurrence of high volume does not seem to coincide with the presence of highly vigorous races, according to results of certain racial variation studies made to date and reviewed in the next chapter. Loblolly pine, which grows faster than shortleaf, hybridizes with shortleaf in Texas and Louisiana (Hare and Switzer 1969), but the effect on growth rate is difficult to estimate. Results of



Each dot represents an average of 5,000,000 cubic feet.

Figure 46.—Geographic variation in loblolly pine wood volume. Population centers occur in most states, but vary in size. Louisiana has two centers, but on opposite sides of the Mississippi River. South Carolina has one population center on the coast and one in the Piedmont. (Sternitzke and Nelson 1970)

racial variation studies are showing loblolly pine from west of the Mississippi to be more fusiform-rust resistant than trees from certain other locations in the range, and this in turn influences wood volume and tree quality (Wells and Wakeley 1966; Kraus 1967b). Severity of fusiform rust attack on loblolly pine is not uniform throughout the range of loblolly pine (Wakeley 1954a).

Site Index

In northeastern Louisiana and southeastern Arkansas, site index for loblolly pine declined northwards at similar rates on all soils (Bassett and Beene 1967). In their study, latitude accounted for half the site-index variation. Site index differed significantly between soils. It was concluded that for each soil, mean site index could be estimated by township reasonably accurately, but site quality of individual plots might vary greatly from estimated values. For the loblolly pine type in the Atlantic Coastal Plain, average site index at 50 years decreased from 80 feet in Florida and Georgia to 76 feet in South Carolina, 71 feet in North Carolina, to 70 feet in Virginia, but the trend was weaker in the Piedmont (Cruikshank 1954). A relationship between site and latitude was not evident for other pine types.

Wood Characteristics

The southern wood density survey conducted by the Forest Products Laboratory in cooperation with the Forest Survey showed there is a trend toward increasing specific gravity from northwest to southwest (Mitchell 1964; USDA Forest Products Laboratory 1965). The pattern is well correlated with warm-season rainfall. There is an indication of a clinal trend with longitude, but, as with latitude, the differences are very small in comparison to those due to tree size and differences among trees of the same size (fig. 47). Early work with the wood characteristics of loblolly pine showed also that density decreased in a northerly direction from the Gulf Coast (Johnson and Roth 1896). Average increment core specific gravity and number of sample trees by survey units and diameter classes are given. Estimates for sawtimber-size trees can be prepared by averaging values for trees over 9 inches. Regional gradients occurred also in specific gravity of trees selected for National Forest seed orchards (Saucier and Taras 1969).

Within the State of Mississippi the Forest Survey shows that wood specific gravity of loblolly pine increases slightly from north to south (Mitchell and Wheeler 1959b). As in other regions the differences were very small, with a total range of only about 0.04.

Einspahr, Peckham, and Mathes (1964) examined the wood of 65 loblolly pines from the Coastal Plain area of South Carolina and Piedmont of North Carolina, to establish base lines for judging wood quality. Because there were significant differences between the two geographical areas, separate base lines were set up for specific gravity, percent summerwood, alcohol-benzene extractives, pulp yield, and zero-span tensile strength (table 4 and fig. 48). For these characteristics, the values for trees from the Coastal Plain were higher than those from the Piedmont. For wood specific gravity, the relationship with age of tree seemed very similar between the Coastal Plain and Piedmont. For summerwood percent, there was a slight difference in the age relationship between the two areas, but for fiber strength the difference was quite marked. Fiber strength increased much faster with tree age in the Piedmont trees than in the Coastal Plain trees. Differences in specific gravity were high (0.13) among trees of the same age, low (0.03) for the average tree of different ages, and low (0.04) for the average tree on different areas.

From a study of specific gravity and tracheid length of loblolly pine in Maryland and Delaware, Whitesell *et al.* (1966) concluded that these characteristics of the wood fell in the usual pattern of geographic variation. Previous studies had indicated a decrease in these trait values from south to north. The results reported by Whitesell and others fall within the general pattern within the four zones sampled except that one plot in Westmoreland County, Virginia, had very low specific gravity and short tracheids. As in the earlier studies of loblolly pine wood, multiple regression of site, growth, and age accounted for only a minor proportion of the variation in tracheid length and specific gravity so that the observed differences were attributed to geographic variation. Most variance was accounted for by tree-to-tree and within-tree differences. Even at the edge of its northern range loblolly pine produces wood with desirable qualities similar to those of trees farther south.

In southern Illinois, several hundred miles north of the natural range of loblolly pine, where fast-growing softwoods must be planted if needed, wood specific gravity in planted stands is low (Gilmore *et al.* 1961). These conclusions were based on examination of increment cores from 39 loblolly pine trees selected from 86 plantations in 12 counties. Average age, d.b.h., and total height were 14 years, 6.1 inches, and 36 feet, respectively. Specific gravity of loblolly pine was slightly lower (0.416) than that of shortleaf pine (0.435), although shortleaf pine trees averaged 3 years older in age. Specific gravities were much lower for trees growing in Illinois than in Mississippi. The maximum specific gravity for loblolly and shortleaf pines growing in Illinois

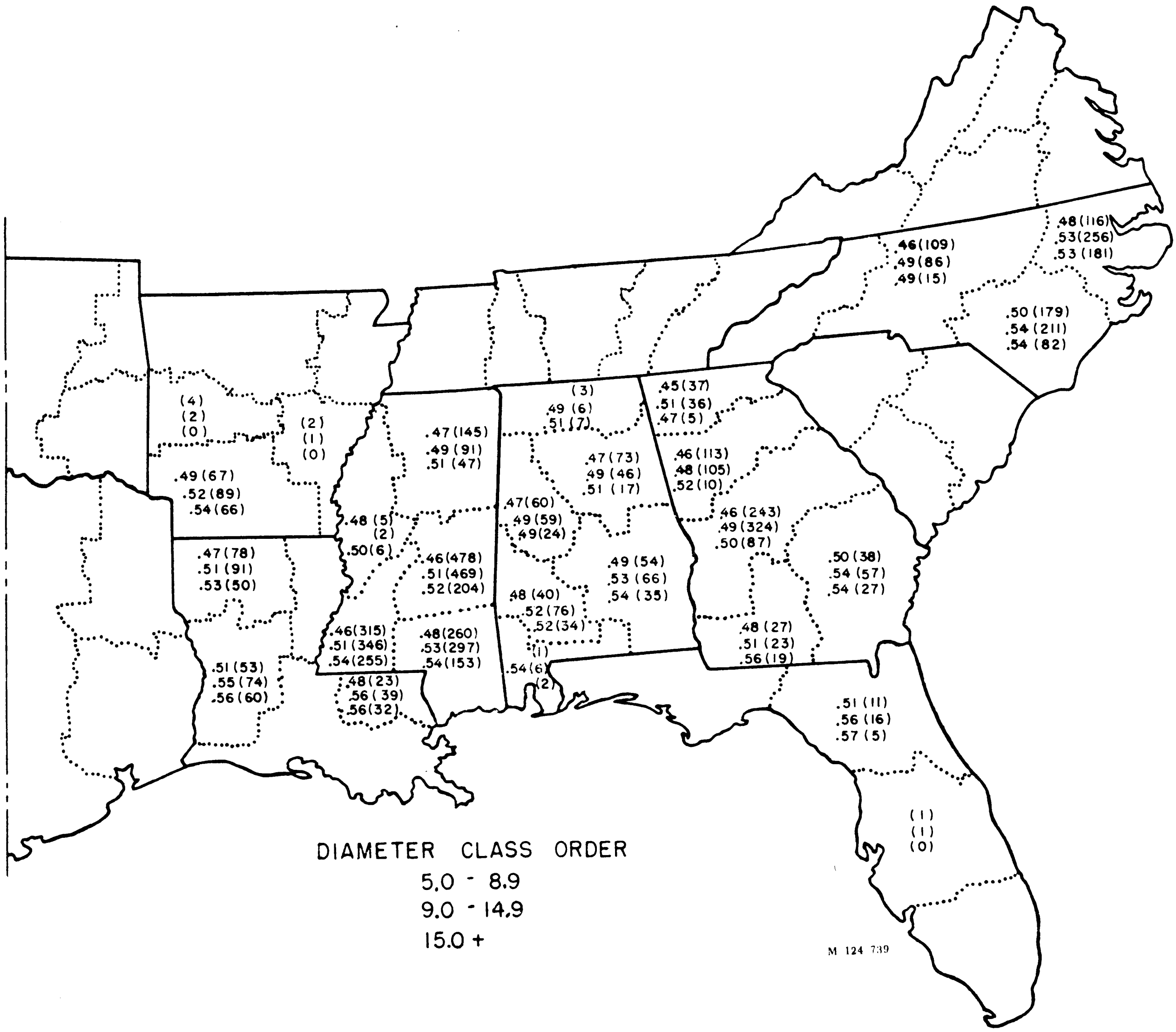


Figure 47.—Average increment core specific gravity for loblolly pine and, in parentheses, number of sample trees by Forest Survey units and diameter classes. Specific gravity varies more by tree diameter class than by geographic location, but both are important in affecting yields of pulp and strength of timbers. (USDA Forest Products Laboratory 1965)

barely exceeded the mean of the Mississippi trees. Pulp yield per unit volume for the two tree species is considerably lower in Illinois than in Mississippi. The larger yield of loblolly pine per cord in Mississippi—216 pounds—amounts to a considerable quantity of pulp. On this basis, assuming that a cord per acre per year is produced in both states, approximately 2⅛ tons less wood per acre is produced at pulpwood age of 20 years in Illinois than on a comparable acre in Mississippi. In a study of the effect of spacing on wood specific gravity in loblolly pine in southern Illinois, Geyer and Gilmore (1965) concluded that spacing intervals of 4 to 10 feet had little effect on wood density at 14 years of age. The difference between the highest and lowest specific gravity (0.397 to 0.414) was too minor to be of practical importance. They concluded also that little of the variation in specific gravity can be attributed to rate of growth alone. Thus, specific gravity cannot be increased by planting trees at close spacing.

Regression equations of breast height wood specific gravity to total tree specific gravity were prepared for loblolly pine in the Coastal Plain of South Carolina (Zobel *et al.* 1965). They found that site index values for various natural stands at 21 locations ranging in ages from 13 to 50 years had very little effect on average tree specific gravity or percent of corewood. Neither was there an effect of stand density on specific gravity of wood produced on trees of all ages and all sites encountered. Most of the differences in dry-weight yields were associated with differences in age of stand. However, the regression equation of breast height to total tree specific gravity differed from the one developed by Wahlgren and Fassnacht (1959) for lob-

Table 4.—*Summary of age-wood characteristic regression equation and correlation coefficient calculations for loblolly pine stands in Coastal Plain South Carolina and Piedmont North Carolina (Einspahr, Peckham, and Mathes 1964)*

Wood characteristic	Geographic area	Ave. of trees (yrs)[1]	Ave. value for trees[1]	Correlation coefficient	Regression equation[2]
Specific gravity (g/cc)	I	32.2	0.518	0.426[3]	$\hat{Y} = 0.463 + 0.0017X$
	II	29.7	0.480	0.415[3]	$\hat{Y} = 0.431 + 0.0016X$
Summerwood (%)	I	32.2	45.1	0.417[3]	$\hat{Y} = 0.359 + 0.0028X$
	II	29.7	39.1	0.318[3]	$\hat{Y} = 0.335 + 0.0019X$
Juvenile wood (%)	I & II	30.5	24.5	−0.714[3]	$\hat{Y} = 0.544 - 0.0100X$
Zero-span tensile strength	I	32.2	45.9	0.387[3]	$\hat{Y} = 38.98 + 0.214X$
(lbs/in)	II	29.7	48.9	0.626[3]	$\hat{Y} = 34.03 + 0.498X$
Fiber length (mm)	I & II	31.1	2.41	0.561[3]	$\hat{Y} = 1.76 + 0.021X$
Fiber width (μ)	I & II	30.5	41.23	−0.280[NS]	$\hat{Y} = 45.23 - 0.131X$
Cell wall thickness (μ)	I & II	30.5	3.09	−0.500[3]	$\hat{Y} = 1.90 + 0.039X$
Lignin (%)	I & II	31.4	28.4	−0.415[3]	$\hat{Y} = 29.66 - 0.40X$
Extractives (%)	I	32.2	7.4	−0.345[3]	$\hat{Y} = 10.73 - 0.103X$
	II	29.7	6.4	0.147[NS]	$\hat{Y} = 4.06 + 0.046X$
Pulp yield (%)	I	32.3	40.2	0.448[3]	$\hat{Y} = 37.65 + 0.083X$
	II	29.4	38.6	0.350[3]	$\hat{Y} = 36.15 + 0.080X$

[1] Average value for trees used in calculations. [2] $\hat{Y}$ = Predicted value and X = tree age. [3] Significant at 1% level of probability except as indicated by NS (not significant) notations.

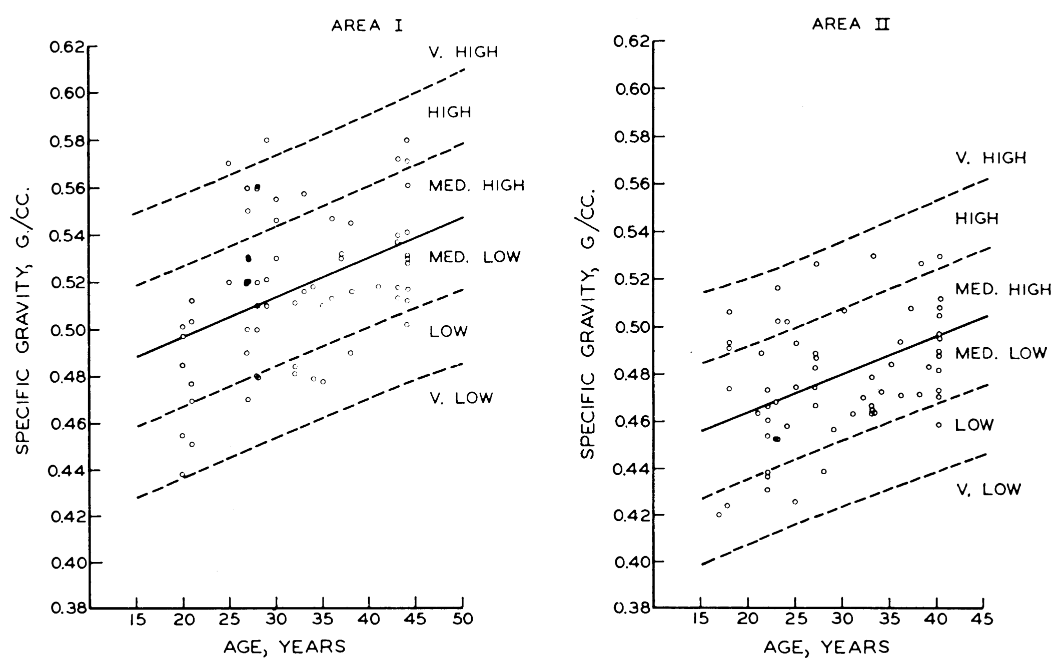


Figure 48.—Wood specific gravity base-line values for Area I (Coastal Plain South Carolina) and Area II (Piedmont North Carolina). The solid line is the regression equation line, the dashed lines are one and two standard deviations above and below the regression line. The effect of geographic location on specific gravity is small, also that due to age, but the range among individual trees of the same age is large. (Einspahr, Peckham, and Mathes 1964)

lolly pine trees in Mississippi. If the Mississippi regression equation had been used on South Carolina loblolly pines, the whole-tree specific gravities would have been considerably overestimated for low breast-height values and considerably underestimated for the high breast-height values. In the South Carolina data the regression equation for corewood was different from that for outerwood.

A loblolly pine study to determine the cellulose variation by trees, sites, and geographic regions shows much greater variation among trees than among sites or regions (Zobel and McElwee 1958b). In four of the five areas sampled, the juvenile and mature cellulose yields, either water-resistant carbohydrate or alpha-cellulose, were different but were highly correlated. The relationship was generally high and significant at the 1-percent level. However, in one area no relationship existed. No explanation was apparent, but it was thought that early heartwood formation which was beginning to take place may have caused greater variability in cellulose yields.

In a study of natural variation in wood specific gravity of loblolly pine, Zobel and McElwee (1958a) found there was a broad geographic trend in which average specific gravity decreased in a westward direction in the six-state area (Alabama to Virginia). Variation was always much greater between trees on any one site than between sites or geographic areas. For wood of the same age there was little relationship between growth rate and specific gravity.

Zobel, Thorbjornsen, and Henson (1960) studied wood specific gravity, tracheid length at 15 and 30 years, percentage of water-soluble carbohydrates (similar to holocellulose), percentage of alpha-cellulose, and percentage of compression wood over a seven-state area in southeastern United States to determine site-to-site, geographic-area, and individual-tree variation. Highly significant differences were found between sites for all wood characteristics. Wood specific gravity and, to a lesser extent, tracheid length followed a geographic pattern. Specific gravity was low in the north and northeast part of the species range, intermediate in the Piedmont, and highest in the Coastal Plain of the Carolinas and Georgia. Cellulose yields based on dry weight of wood did not appear to follow any geographic pattern. Variation among trees within plots was highly significant for specific gravity and tracheid length, but not for alpha-cellulose yield and compression wood. Tracheid lengths at 30 and 15 years were closely related as were water-resistant carbohydrates and alpha-cellulose. Compression wood had high negative correlation with cellulose yields.

Moisture content of loblolly pine trees in the mountainous area of Tennessee and in some areas of the Georgia Coastal Plain was higher than for trees in the adjoining Piedmont areas, regardless of age class (fig. 49) (Zobel, Matthias, Roberds, and Kellison 1967). For trees 36 to 45 years of age, moisture content was 92 to 100 percent for trees from South Carolina and Texas, 100 to 105 percent for trees from Virginia and North Carolina, and 110 to nearly 120 percent for those from Georgia and Tennessee.

Fusiform and Comandra Rust Infection

Percentage of planted trees 5 to 12 years old infected by fusiform rust varied widely among broad geographic areas throughout the loblolly pine range. Infection of over 75 percent was observed in a broad band through central Georgia and westward—State forestry agencies cooperating with the USDA Forest Service in this survey (Phelps 1973). Comandra rust is considered an important factor in loblolly pine plantation management in east Tennessee (Cordell and Knighten 1969). Shortleaf pine is also susceptible, but Virginia and pitch pines and pitch × loblolly are only lightly infected (Powers 1972).

Cones, Seed, and Needles

An extensive study of cones and twig material of loblolly pine showed extensive geographic variation in several traits (Thorbjornsen 1961). In his study approximately 20 sound cones and 5 twigs were collected from 15 different trees within 18 areas distributed throughout the range of loblolly pine. Of the 13 morphological characteristics which showed highly significant differences among areas in the analysis of variance, the majority did not show regional trends. These traits were seed wing length, seed length, cone length, needle length, and frequency of serrations on the needle margin. Morphological traits that did show regional trends were seed form, seedcoat thickness, cone weight, cotyledon numbers, and stomatal frequency (fig. 50). All plots from the northern and eastern portion of the natural range had trees with rounded seeds; all from southern and western areas had narrow seeds. Seedcoats were extremely thin on 4 plots in the western part of the range, while they were thick on 10 plots in the eastern part of the range, but there was no evidence of discontinuity, which suggests a clinal pattern. Small cones were found on trees in the extreme southwest and southeast of the species range, large cones in the central areas, and intermediate cones in the northeastern part. Plots representing the extreme northeast, southeast, and west had seed with fewer cotyledons than plots from the central portion of the species range. It is

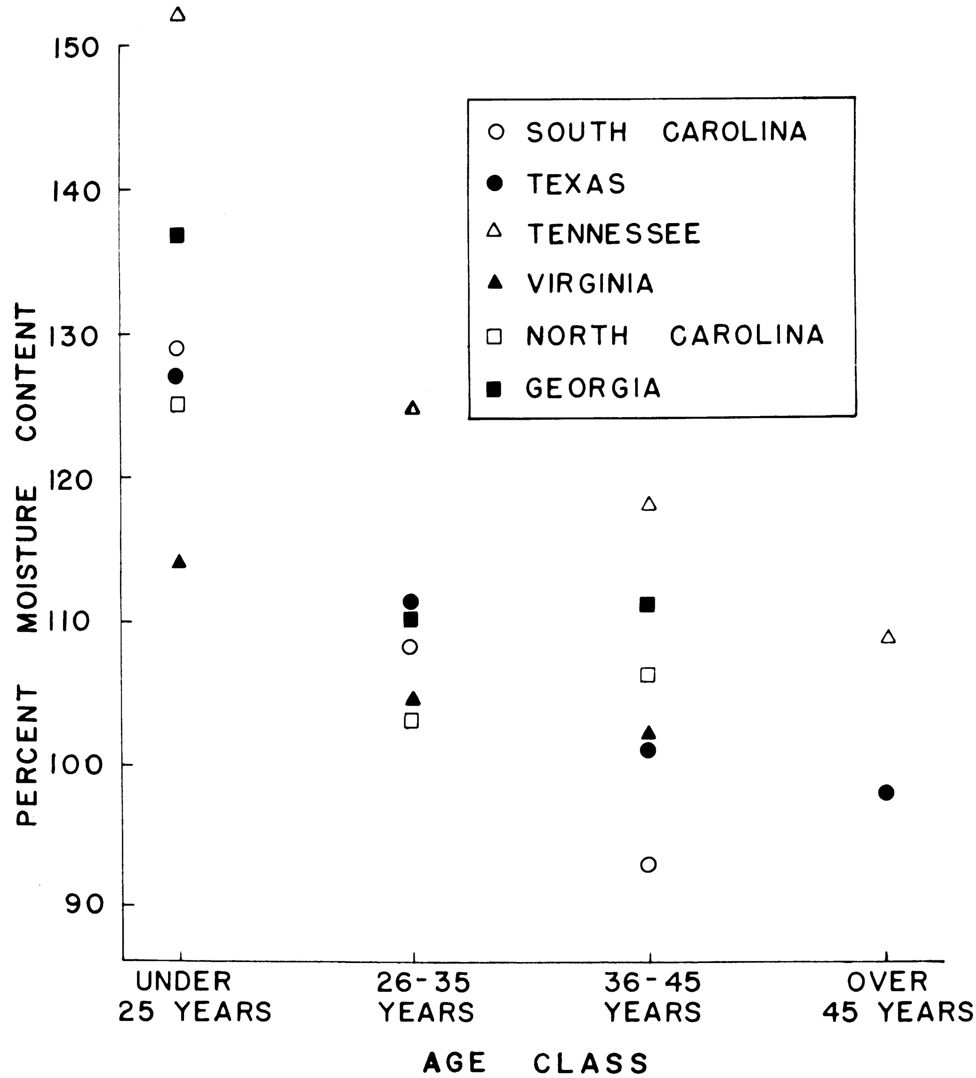


Figure 49.—Moisture content of loblolly pine from stands of different ages growing at different locations. Values are consistently high for Tennessee, but those for North Carolina and Texas are not very different. (Zobel, Matthias, Roberds, and Kellison 1967)

also possible that all trees of the extreme south produce seeds with few cotyledons, since the four southernmost locations studied had low cotyledon numbers. With one exception, stomatal frequencies of the plot material fell into two groups divided by the Mississippi River: stomatal frequency was low for plots west of the Mississippi and high east of the river except in coastal South Carolina. Also, there was an increase in stomatal frequency in the west-to-east direction. A drought index was constructed for each plot by using the precipitation-temperature ratio. When the ratio of May-to-August precipitation over the average summer temperature was correlated with stomatal frequency, the r-value was 0.666, highly significant. Therefore, some evidence shows that the number of stomates may have developed as an adaptive cline to a gradual change in moisture supply.

Electrophoretic patterns of seed proteins varied among loblolly pine seed from eight eastern locations (in Virginia, Maryland, Florida, and Georgia) and four western (in Oklahoma and Texas) but not in shortleaf pine seed from three locations in Mississippi (Hare and Switzer 1969). Comparison of patterns indicated introgression between western loblolly pine and shortleaf pine.

Monoterpene Content of Oleoresin

The percentage of various terpenes in the wood of loblolly pine varied in a clinal pattern based on samples from 30 geographic locations (fig. 51)

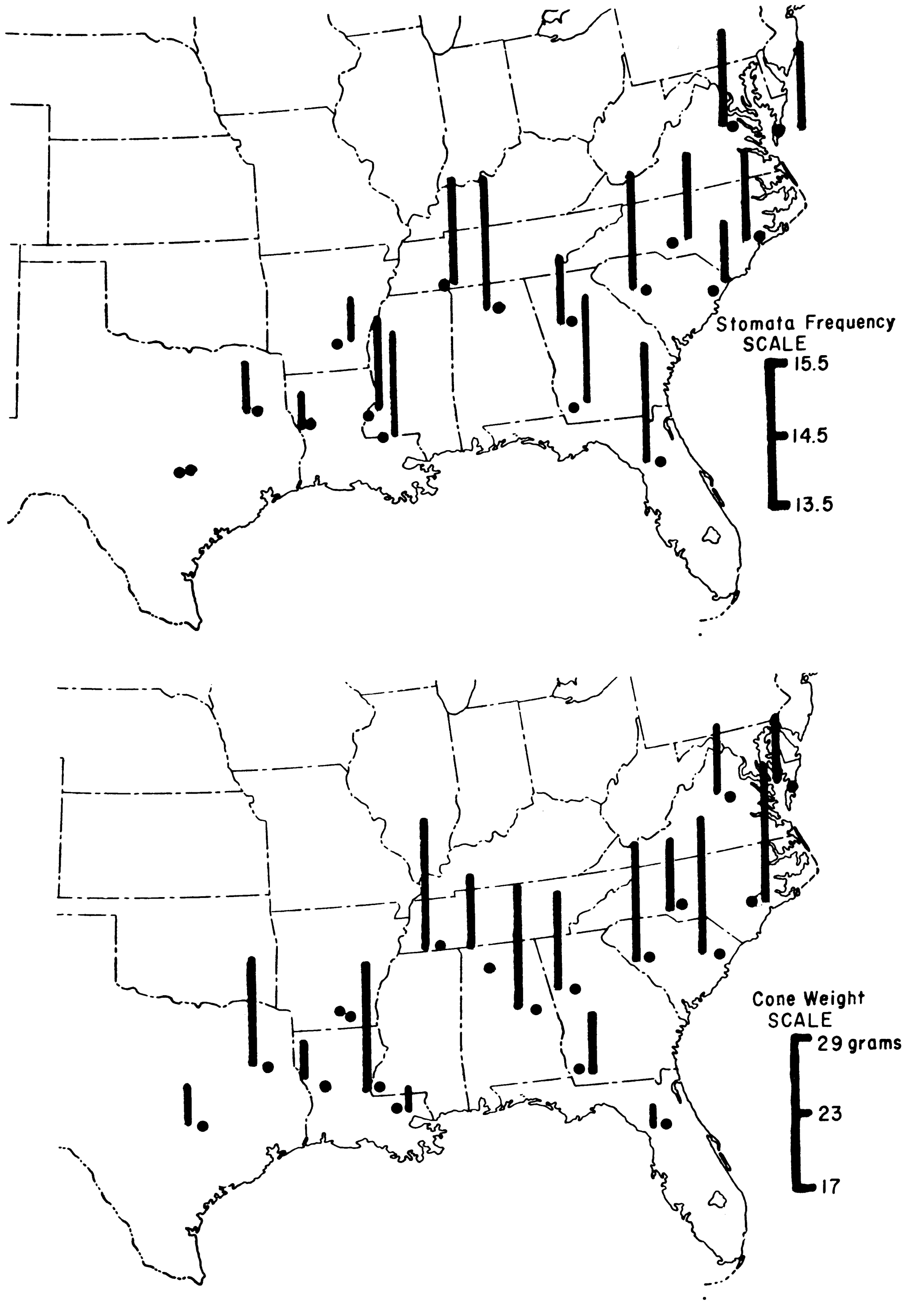


Figure 50.—Geographic variation in loblolly pine. (Top) Stomata frequency decreases from east to west but there are significant differences between certain areas within regions. (Bottom) Cone weight decreases from east to west as does stomata frequency but the differences between local areas are more frequent. (Thorbjornsen 1961)

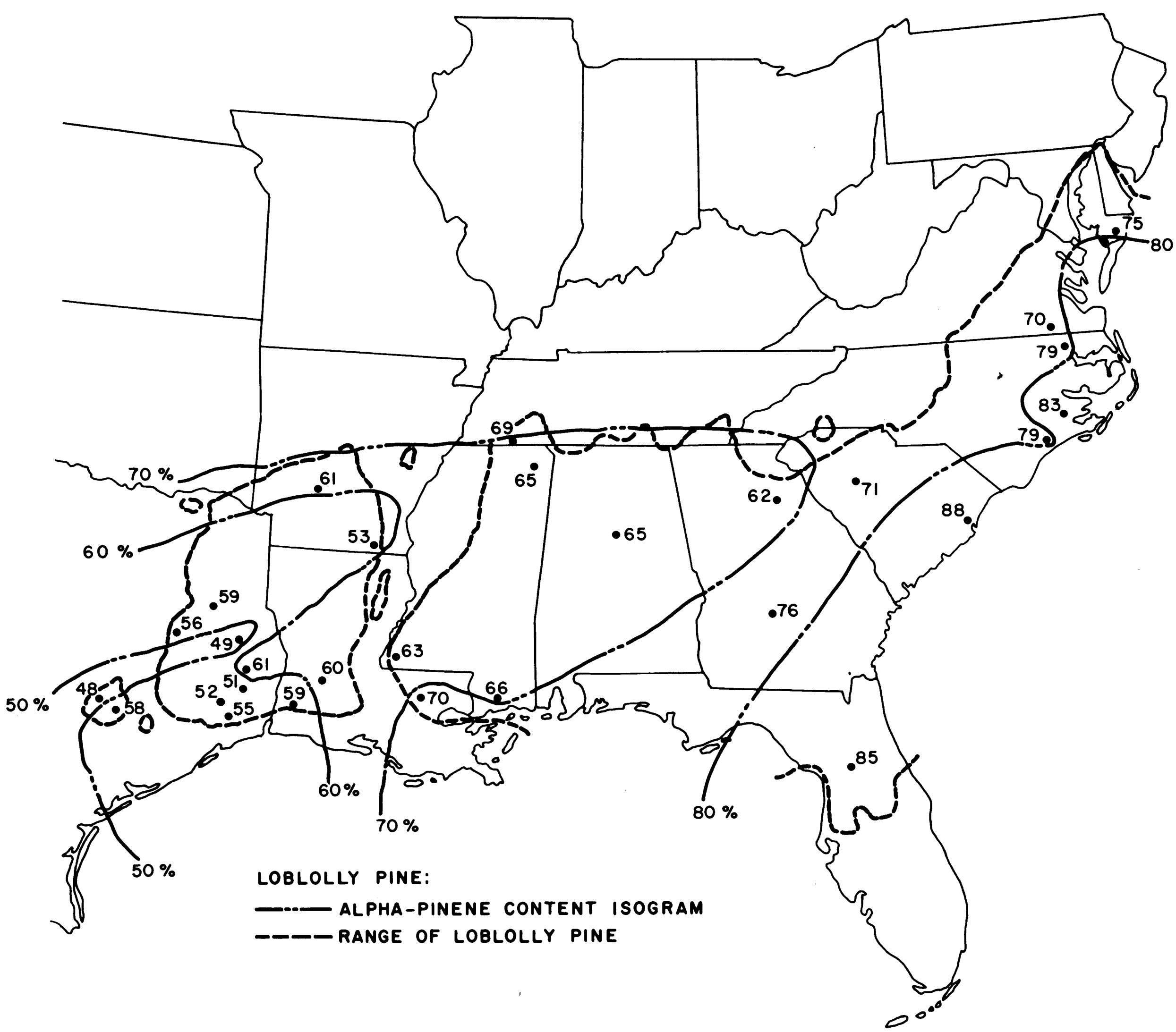
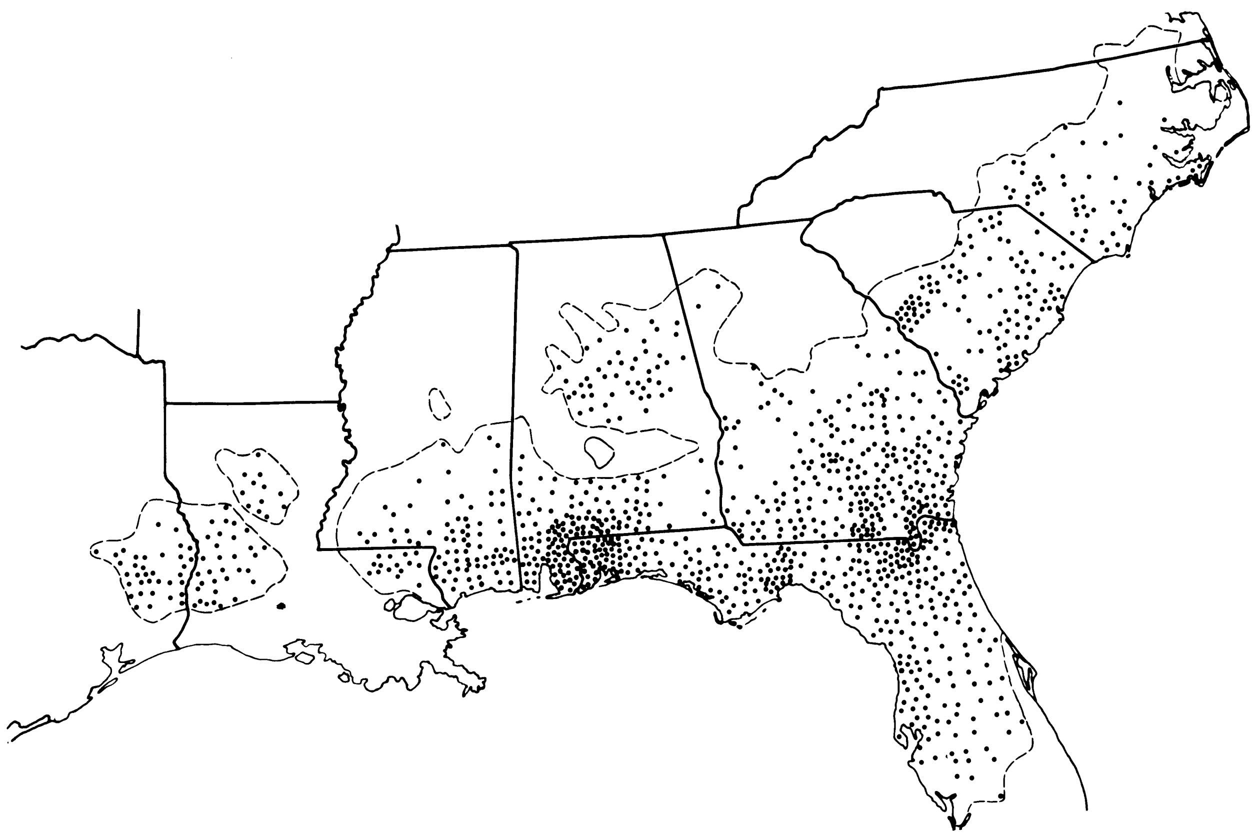


Figure 51.—Variation in alpha-pinene content of loblolly pine wood through the range of the species. (Coyne and Keith 1972)

(Coyne and Keith 1972). Trees at eastern locations along the Atlantic Coastal Plain were highest in alpha-pinene content, those at northern locations had less, and those at western and central locations had the least. Variation among trees in stands west of the Mississippi River was less than at locations east of the river. The average content of limonene and beta-phellandrene was higher in stands west than east of the Mississippi Delta. There were no outstanding qualitative or quantitative monoterpene differences between trees in stands inside or outside documented southern pine beetle epidemic areas. Variation among trees in relation to stands at different locations is discussed in the chapter on variation among trees.

LONGLEAF PINE

The range of longleaf is smaller than that of either loblolly or shortleaf pines but larger than slash pine. Longleaf pine is important to industry, but the species is difficult to plant. Timber volume is evenly distributed over the range, but there are areas of higher stocking in northeast Florida and extreme west Florida and southwest Alabama (fig. 52). A distribution map of virgin longleaf pine stands in 1912 shows a population center similar to present-day stands in southern Alabama (Wahlenberg 1946). It is not definitely known if highly vigorous races are associated with these locations, but early results of a southwide study indicate this



Each dot represents an average of 5,000,000 cubic feet.

Figure 52.—Geographic distribution of longleaf pine wood volume. One population center lies in northeast Florida and the adjacent area in Georgia, and the other lies in the extreme western tip of Florida and the adjacent area in Alabama. (Sternitzke and Nelson 1970)

might be true (Wells and Wakeley 1970a).

In the Atlantic Coastal Plain of Florida and northward through the Carolinas, site index of longleaf pine on well-drained soils is influenced by moisture equivalent and latitudinal distribution (Ralston 1951). Better growth in the South is attributed to a longer frost-free period of growth and increased precipitation during the growing season.

Wood specific gravity variation apparently follows the same variation pattern as in loblolly pine; average specific gravity values increase from north to south along the Atlantic Coast and west to east along the Gulf Coast, but the differences are small (USDA Forest Products Laboratory 1965; Saucier and Taras 1969).

On the basis of only 11 collection points throughout the longleaf pine range, no geographic variation was evident in pollen grain size (Cain and Cain 1944). However, pollen grains were so small in a collection from Georgia that the identification of the species was questioned, although it was admitted that longleaf pine has rather distinctive species characteristics.

The most damaging disease of longleaf pine is brown spot [*Scirrhia acicola* (Dearn.) Sigg.] and it varies in severity throughout the range. The disease kills seedlings in the field and nursery. The most heavily infected areas are in parts of southern Alabama, Mississippi, Louisiana, and Texas (Wakeley 1954a). In southern Alabama, only 12 percent of the seedlings in natural stands had less than 10 percent infection, and the two lightly infected classes (low plus moderate infection) ranged from 12 to 28 percent among stands. In northern Alabama, 5 percent of the seedlings had less than 10 percent infection (Boyer 1972). In Louisiana, 227 families of longleaf pine seedlings had means ranging from 4 to 59 percent of diseased needle tissue (Derr 1971). A map of brown-spot infection zones in relation to important diseases of other major southern pine is given in the chapter on variation among trees in longleaf pine.

PITCH PINE

Pitch pine is a minor species with a natural range from the southern Appalachian Mountains in north Georgia northeastward to coastal areas in Maine and inland to southeast Ontario.

Pitch pine has not been widely studied in tree breeding research, but information on geographic variation in wood specific gravity has been obtained. Average unextracted increment core specific gravity of pitch pine in New England and New York was 11.1 percent less than unextracted increment core specific gravity in North Carolina, South Carolina, and Tennessee (Saucier and Clark 1970). Extracted increment core specific gravity was also lower in New England than in all other regions. Thus, specific gravity variation seems to follow the pattern established for some other species in that it decreases from south to north.

Length of needles in pond and pitch pines formed a gradient, increasing from north to south in a study by Clausen (1939). Two to 13 collections at 10 locations from Massachusetts to Florida showed an average length of 7.9 cm for the northernmost collection, 13.9 cm for North Carolina or the central Atlantic States, and 17.6 cm for Florida. The author suggests that inasmuch as from southern New Jersey southward, there are trees with leaves 15 cm or more long, and since this length previously has been used as the dividing line between the two species, this length might be considered as the arbitrary median between the two populations.

Also, Smouse (1970) found that buds, seeds, cones, serotiny, and oleoresin composition varied clinally within pitch and pond pines, and the clinal patterns converged toward the transition zone in the southern New Jersey region. The natural populations in the transition zone were morphologically intermediate between nearby populations of the two species.

Natural hybrids have been observed between pitch pine and shortleaf (Illick and Aughanbaugh 1930), loblolly, and pond (Little *et al.* 1967), and Table-Mountain pines (Zobel 1969). Thus, traits of the species with which pitch pine hybridizes may be found in certain pitch pine stands.

POND PINE

Pond pine, relatively minor in total wood volume, is utilized with other southern pines. As with pitch, sand, spruce, and Virginia pines, it has not been studied as thoroughly in forest genetics research as the major southern pines. In fact, it was until recently considered a variety of pitch pine.

The natural range is limited to the east Gulf Coast and the Atlantic Coast from mid-Florida to Maryland. The volume of pond pine increases northeastward from Florida through Georgia and South Carolina, reaching its highest concentration in coastal North Carolina (fig. 53) (Janssen and Weiland 1960).

In pond pine, there was no definite pattern of variation in wood specific gravity or tracheid length between geographic area or depth of organic material in the coastal area of North Carolina (McElwee and Zobel 1962). The range in latitude was small (34°30′ N. to 36°30′ N.). However, there were differences in both traits among the individual plots as well as among trees.

Kang (1966) studied 30 traits of pond and loblolly pines and their hybrids in the North Carolina Piedmont and Coastal Plain, concluding that, although trees in the coastal areas were slightly different in some traits from those in the drier inland areas, a surprising uniformity existed among locations for both species.

From a study of several traits, Smouse (1970) concluded clinal variation occurred from south to north. Further facts are included in the preceding discussion of pitch pine.

SAND PINE

Sand pine is confined, almost entirely, within the State of Florida but exhibits geographic variation in several traits. The largest concentration of wood volume is in north-central Florida (Janssen and Weiland 1960). Cone characteristics were used by Little and Dorman (1952a) as the basis for distinguishing two races. In central Florida, the Ocala race is characterized by being largely closed-coned. To the west in Florida, the Choctawhatchee race is largely open-coned. No morphological differences between trees and needle specimens of sand pine of the two races were found. Barnett and McLemore (1965) reported additional differences between the two races in cone and seed characteristics. Trees of the Choctawhatchee race produced cones averaging 1,010 per bushel and 56,100 seeds per pound. The Ocala race of peninsular Florida had cones averaging 830 per bushel, with 47,200 seeds per pound. Choctawhatchee cones opened readily at 105° F, while Ocala cones open only if dipped in boiling water and dried. Seed from both races are easily stored at 10 percent moisture and 25° F. Choctawhatchee seed requires stratification for 14 days for good germination. Ocala seed from new and 1-year-old cones are nondormant. Ocala cones 2 or more years old yield seed of decreased viability.

In west Florida, sand pine stands are largely uneven-aged because the cones of the Choctawhatchee race open more readily than do those of the Ocala race, in which stands are even-aged (Cooper *et al.* 1959; Burns 1968).

Wood specific gravity at breast height, as indicated by both extracted and unextracted increment

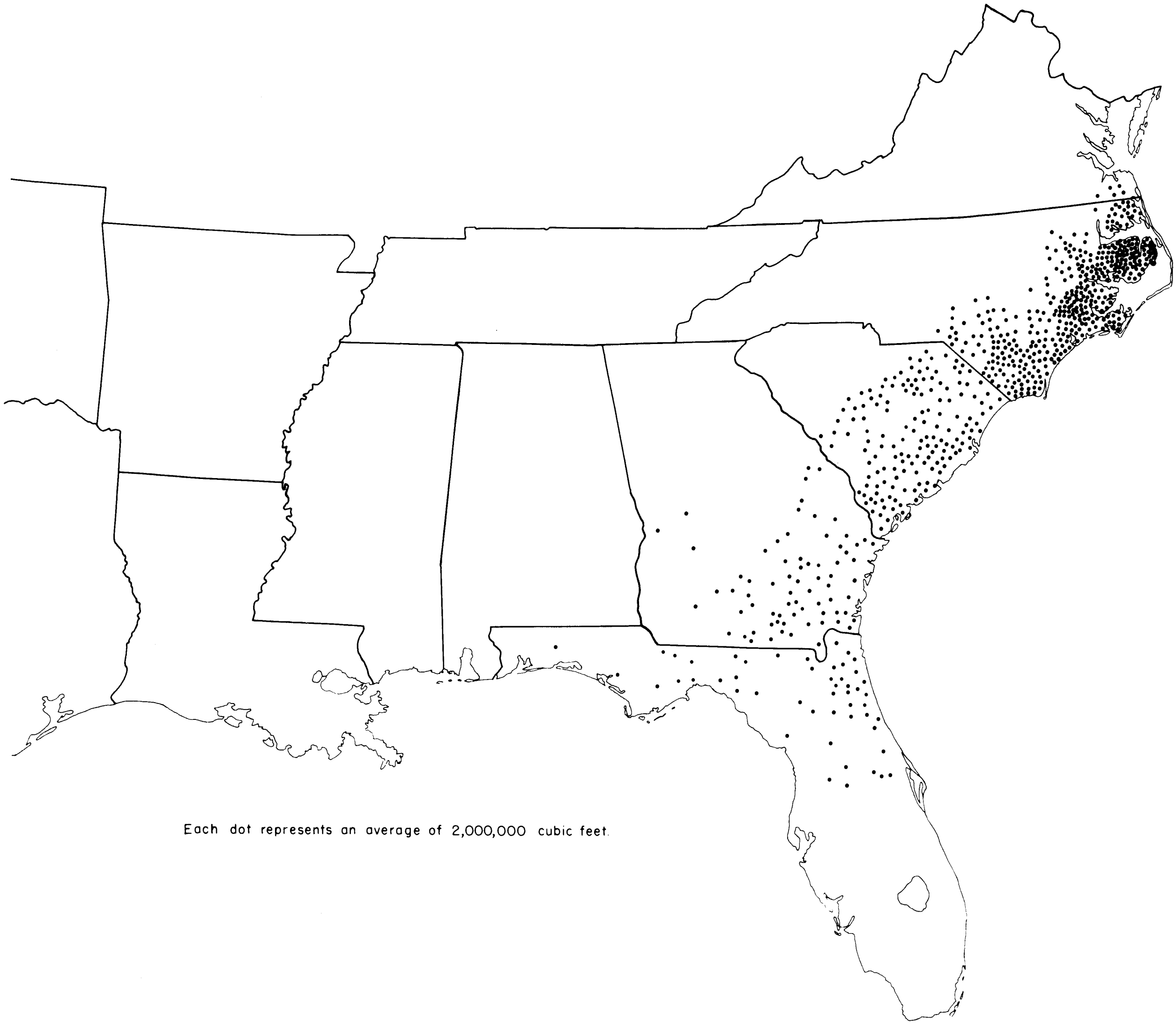


Figure 53.—The volume of pond pine increases from northern Florida through Georgia and South Carolina, reaching its highest concentration in coastal North Carolina. (Janssen and Weiland 1960).

cores, is lower for Ocala sand pine than for Choctawhatchee sand pine (Clark and Taras 1969). The average specific gravity of extracted increment cores from Ocala sand pine was 0.407, and from Choctawhatchee sand pine it was 0.442. The amounts of benzene-alcohol extractives were greater for Choctawhatchee than for Ocala sand pine. However, the differences in wood specific gravity might be partly an age effect, as the Ocala sand pine averaged 25 years and the Choctawhatchee sand pine 34 years. No continuous variation in specific gravity from north to south or east to west was indicated by the data, except for the racial means, but there were differences among the sample plots, disregarding average age, which, for Ocala sand pine, ranged from 14 to 42 years.

SHORTLEAF PINE

Wood Volume

Shortleaf pine, as shown in figure 6, has the most extensive range of any southern pine. The total wood volume is much less than that of loblolly pine and is not evenly distributed over the species range (Janssen and Weiland 1960). As in loblolly pine, there is a concentration of high volume in the northeast and the western part of the range (fig. 54). However, the areas of high volume do not coincide for the two species. In the East, shortleaf population centers are in the Piedmont of the Carolinas and Virginia, and large loblolly population centers are in the Coastal Plain. In the West