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Pine Growth Reductions in the Southeast

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EXECUTIVE SUMMARY

Periodic timber inventories in the Southeastern United States indicate that net annual growth of softwood timber there has peaked and turned downward after a long upward trend. The most pronounced declines have been measured in the growth of yellow pines on non-industrial private forest land, which accounts for about 69 percent of the timberland in this five-State region (Florida, Georgia, North Carolina, South Carolina, and Virginia). These declines are important because trends in net volume growth strongly influence amounts of timber available for future harvest. This report documents some early investigations into the pattern of the growth reduction conducted by the Forest Inventory and Analysis (FIA) Research Work Unit at the Southeastern Forest Experiment Station.

Net growth of softwood volume in the region is affected by (1) changes in the area of timberland, (2) ingrowth rates of sapling-size trees across the minimum threshold for volume computation, (3) volume lost to mortality, and (4) the volume increment on survivor trees. Area of timberland in the Southeast peaked at 91 million acres in 1963 and has since declined to 85 million acres. Since the early 1970's, ingrowth of yellow pine saplings has decreased and the effects are now showing up as declines in numbers of trees and volumes in the 6- to 10-inch diameter classes. In 1982, FIA resource analysts discovered that the average annual radial growth of surviving yellow pines in the Piedmont and Mountains of Georgia was 20 to 30 percent less between 1972 and 1982 than between 1961 and 1972.

The investigation was expanded because of the importance of the finding and because the FIA data set is uniquely suited for such study. FIA surveys are the only ones designed to measure the entire timber population of the Southeast, and the recurring measurements permit reliable estimates of change. It should be recognized, however, that FIA data are not ideally suited for determination of the causes of the growth reductions that were discovered.

Further study of existing and newly collected FIA timber inventory data revealed that the average annual radial growth rate of most yellow pines under 16 inches in diameter has declined by 30 to 50 percent throughout the Piedmont and Mountain areas of the Southeast since the permanent FIA inventory sample locations were measured during the third survey cycle (1957-1966). Remeasurement data taken during the fourth (1966-1977) and fifth (1977-1985) survey cycles show that the reductions in the Piedmont and Mountains were gradual. About half of the reduction occurred before and half after the fourth survey growth period.

Comparison of radial growth rates over the same three time periods for the Coastal Plain of Georgia, South Carolina, and North Carolina revealed a reduction of similar magnitude. A difference in the Coastal Plain, however, was that 80 to 90 percent of the reductions occurred between the third and fourth survey cycles. The reduction between the fourth and fifth growth periods was much less dramatic. While the actual reduction in average annual radial growth varies substantially among diameter classes, species, and subregional areas, the majority of the differences are statistically significant at one standard error, 67 percent probability. Most differences are statistically significant at higher levels of probability for comparisons of third survey growth with that from the latest survey growth period.

The measured declines in the average radial growth rates of pines in diameter classes below 16 inches are worrisome, but their meaning is difficult to interpret because they were possibly caused in part by increases in stand age and stand density that are known to have occurred. The FIA data, therefore, were reanalyzed to determine whether the reductions in radial growth could be explained by changes in stand age or density over time. When softwood growth was

expressed in terms of basal area increment, reductions of similar magnitude to those in average annual radial increment were discovered even when the data were stratified by initial stand basal area. That is, basal area growth of survivor trees was less in the fifth survey data than in third survey data even for stands of the same initial densities in each period. Just as in the radial growth comparisons, the basal area growth differences varied by initial basal area classes, species, and subregional areas, but the majority of the differences were statistically significant at one standard error.

A further stratification of the basal area growth data for the fourth and fifth survey cycles, by both stand age and initial stand basal area, was hampered by small sample size. Even though there was a general trend of reductions in the basal area growth of survivor trees between the fourth and fifth surveys, the differences were often not statistically significant at one standard error.

Reductions in the growth of yellow pine trees in the Southeast are apparent in these findings, but there is not sufficient evidence to determine what might be causing the growth reductions. A number of hypotheses about the causes of the growth reduction are forwarded to guide further analyses, including (1) atmospheric deposition, (2) increased stand density, (3) increasing stand age, (4) increasing competition from hardwoods, (5) drought, (6) reductions in the water table, (7) loss of old field conditions, and (8) increased impacts of diseases. The most likely hypothesis is that a combination of these causes is affecting growth rates to varying degrees and perhaps interacting differently on different sites at different points in time. Because of the unique population character of the FIA data set, FIA data, especially when augmented by special data-collection efforts, provide an opportunity to contribute to tests of these hypotheses.

INTRODUCTION

Recent Forest Surveys in the Southeast--Florida, Georgia, North Carolina, South Carolina, and Virginia--have measured reductions in rates of pine timber growth across much of the region. The reductions are apparent in several measures of growth rates: (1) Actual volume of net annual growth has declined over large areas, (2) average rates of diameter growth of individual trees by diameter class, have slowed, and (3) stand growth, expressed in basal area per acre, appears to be down more than one might expect from changes in stand age and stand density.

The Forest Inventory and Analysis (FIA) Research Work Unit of the Southeastern Forest Experiment Station bases these conclusions on comparisons of the most recent statewide inventory results with those from earlier surveys. FIA inventories the forests of each State at intervals that have averaged approximately 10 years. It has completed the fifth such cycle through the Southeast and started the sixth. Where special problems have been identified, FIA has also conducted interim surveys of the timber resource in some States.

This Bulletin describes FIA's present knowledge about the growth reductions. The primary purpose is to describe the situation in sufficient detail to aid future analysis. The causes for these reductions are not yet known, but several possible causes are discussed. Key inventory procedures and definitions must be understood to interpret the data and are presented where needed.

FIA divides the five Southeastern States into 21 Survey Units for its inventories and analyses, but for the purposes of this report it was desirable to combine Survey Units. Thus, many of the trend data are presented by State and physiographic region in this Bulletin. In addition, special groupings of Survey Units, called study areas, are used here.

The complete story of reductions in pine growth in the Southeast involves massive quantities of data, which are best presented in tables. In this report, tables essential to an understanding of the general descriptions in the text are presented with the text and assigned Roman numerals. Detailed tables that can be used in future analyses are presented in the appendix and assigned Arabic numerals.

The first major section of this Bulletin examines trends in volumes of pine measured in the most recent surveys of the region. This section provides strong evidence that growth of pine timber volume has slowed over extensive areas of the Southeast. The major factors known to have contributed to the slowdown in volume growth are described in the next section. A slowdown in growth of individual pine trees is one of these factors. Special analyses, described in the next section, document a decline in radial growth of all but the largest pines over large areas. Next, changes in stand basal area are examined to determine whether increasing stand density and age are the primary causes for the reduction in radial growth. Although this work is not complete, early results indicate that stand growth expressed in basal area per acre has slowed. The closing sections of the text briefly outline hypothetical causes for the growth reductions. Finally, detailed tables are presented in the appendix.

Much of the information in this Bulletin is presented in the order in which it was discovered. The objective is to fully describe a situation that FIA is still analyzing. Readers are invited to share their interpretations of the situation and to suggest approaches to future analysis of this important situation.

REGIONAL TRENDS IN PINE VOLUME

Recent Forest Surveys have measured significant reductions in the net annual growth of yellow pine timber in the Southeast. These reductions reverse a long, upward trend in the growth of pine in this important softwood region. This change has occurred some 20 years earlier than projected in the 1980 Resources Planning Act (RPA) Assessment (USDA Forest Service 1979, 1982). The largest reductions have been measured on nonindustrial private forest (NIPF) land in the Piedmont and Mountain regions, where the net annual growth of yellow pine growing stock is down 26 percent.

TRENDS IN PINE VOLUME GROWTH

Volume growth is the net annual increment of merchantable timber volume in the absence of man-caused removals. Net growth of timber volume should not be confused with the annual change in inventory volume. Annual change is net growth minus removals. The components of net annual growth of timber volume are (1) survivor growth, the increment in merchantable volume in trees 5.0 inches d.b.h. and larger which survive from the beginning of the year through the end of the year, (2) ingrowth, the merchantable volume in trees that reach 5.0 inches d.b.h. during the year at the time they reach 5.0 inches d.b.h., (3) growth on ingrowth, the volume increment of these ingrowth trees for the remainder of the year, (4) growth on removals, the annual volume increment of trees 5.0 inches d.b.h. and larger prior to their removal, and (5) growth on mortality, the annual volume increment of trees 5.0 inches d.b.h. and larger prior to their death.

The fifth inventory cycle through the Southeast was begun in South Carolina in April 1977. The surveys continued to measure increases in net annual growth of pine through Florida and the Coastal Plain of Georgia. Reductions in pine growth began to show up in the Piedmont and Mountains of Georgia over the remeasurement period between 1972 and 1982 (appendix A, table 1). Forest Survey has continued to measure reductions throughout South Carolina, the Piedmont and Mountains of North Carolina, and

Coastal Plain of Virginia. Even in the Coastal Plain of North Carolina, where some net increase was measured, growth of pine on NIPF land declined. In fact, Forest Survey has measured declines in net annual growth of yellow pine on NIPF land across 11 consecutive Survey Units extending from Central Georgia through the Coastal Plain of Virginia.

The most recent statistics for South Carolina were developed from an interim survey of the pine resource conducted in 1983 (Tansey 1984). The interim survey measured a 24-percent increase in annual removals of pine over the 5- to 6-year remeasurement period. More important, the interim survey measured a 28-percent decrease in net annual growth of pine.

Although most of the growth reduction has occurred on NIPF land in the Piedmont and Mountains of the Southeast, growth was also down on public land in the same regions (appendix A, table 2). Growth of pine on industry holdings in these regions did little better than hold its own. Large increases in pine growth were measured on industry land in the Coastal Plain, where trees on extensive acreages of pine plantations are reaching merchantable size.

Generally, reductions in the Piedmont and Mountains have occurred in all pine species (appendix A, table 3). Reductions in growth of shortleaf pine have been particularly severe. Timber management has favored loblolly pine, and the inventories of shortleaf pine are declining rapidly. A large part of the increase in pine growth in the Coastal Plain can be attributed to maturing slash pine plantations in Florida and southern Georgia. Longleaf pine and pond pine are the other major yellow pines in the Coastal Plain. Virginia pine is the other major yellow pine in the Piedmont and Mountains.

TRENDS IN PINE REMOVALS

In contrast to the decline in net annual growth, annual removals of pine continue to increase, bringing about a very tight growth-removal situation throughout most of the Southeast. In the fourth inventory cycle, net annual growth exceeded annual removals of pine by 39 percent. In the latest surveys, growth exceeded removals by only 10 percent for the region as a whole, and many areas showed deficits. Extrapolations of these trends suggest that pine growth and removals are probably very close to a balance at this time.

The most recent surveys have measured sharp increases in annual removals in Florida, Georgia, and South Carolina but very little change in North Carolina and Virginia (appendix A, table 4). By ownership, the largest percentage increases in pine removals have been on industry land in the Piedmont and on NIPF land in the Coastal Plain (appendix A, table 5). By species, the largest increase has been in slash pine (appendix A, table 6).

Natural stands of slash pine are rapidly being harvested in the Coastal Plain, and much of the harvest of plantation wood is of this species. Many of the older pine plantations where trees are reaching merchantable size are slash pine. In the 1950's and 1960's, slash pine accounted for a large share of the planting throughout the region's southern Coastal Plain and up into the Piedmont of Georgia and South Carolina.

TRENDS IN PINE INVENTORIES

As the growth-removal situation for pine has tightened, the inventory volume has leveled off. Over the most recent remeasurement periods, the inventory volume of yellow pine increased only 6 percent in the Southeast as a whole, and even less in the Piedmont and Mountains. Most of the increase shows up in Florida, the Coastal Plain of Georgia, and the Piedmont and Mountains of Virginia (appendix A, table 7), the areas with the oldest data. By ownership, most of the recent increase in pine volume has occurred on public and forest industry land in the Coastal Plain (appendix A, table 8). The inventory volume on NIPF land appears to have peaked throughout the region. By species, slash pine and loblolly pine volumes in the Coastal Plain are still increasing. The inventory of shortleaf pine is declining rapidly throughout the Southeast. Longleaf pine accounts for most of a decline in volume of other yellow pines in the Coastal Plain, and Virginia pine accounts for most of an increase in volume in this class in the Piedmont and Mountains (appendix A, table 9).

FACTORS CAUSING REDUCTIONS IN NET GROWTH

At least four major factors are causing the reductions of net annual growth of pine in the Southeast: (1) a continuing decline in area of timberland, (2) inadequate regeneration on NIPF land after harvesting, (3) a sharp increase in the annual mortality of pines, and (4) a slowdown in the rates of individual-tree diameter growth in parts of the region.

DECLINE IN AREA OF TIMBERLAND

Past land-use changes in the Southeast have significantly affected timber volume growth in the region (Boyce and Knight 1980). Major shifts in land use since 1945 are particularly relevant to the recent reduction in pine timber growth. Between 1945 and 1969, area of cropland harvested in the Southeast declined by more than 10 million acres according to statistics from the U.S. Census of Agriculture. Much of the former cropland seeded to trees, and area of timberland in the region increased by 4.4 million acres.

During this period, planting and natural seeding of pine trees on old fields more than compensated for the failure to regenerate pine stands after harvests. The age distribution of pine and mixed pine-hardwood stands on NIPF land in the Southeast today reflects the high rate of pine establishment between 1945 and 1965. More than 40 percent of all pine and oak-pine stands on NIPF land are between 20 and 40 years old (appendix A, table 10).

In the 1960's the acreage of cropland harvested bottomed out, and since 1969 the region has experienced an increase in cropland caused by a sharp rise in the production of soybeans. Area of cropland harvested has increased by 3.6 million acres. Many acres of timberland have been cleared for agriculture. In addition, urban development continues to consume timberland at the rate of 170,000 acres annually. The net result has been a 5.9-million-acre decrease in the area of timberland since 1963.

Because of this turnabout in cropland acreage, a major source of new pine stands on NIPF land has dried up. Since many NIPF owners in the region fail to regenerate their pine stands after harvest, many of the acres retained in timberland have reverted to hardwoods. In the absence of any large-scale establishment of pine on nonforest, the area of young pine stands on NIPF land plummeted. As a result, there are 30 percent fewer pine and oak-pine stands 20 years old and younger than similar stands between 20 and 40 years old.

Based on 1982 statistics from the Census of Agriculture, the increase in area of cropland harvested in the Southeast has almost halted. Timberland is still being rapidly diverted to urban and related uses, however. The pine and oak-pine forest types have experienced a 3.2-million-acre net decrease between the fourth and fifth Forest Surveys. The fastest rate of decrease in these types was measured in the Piedmont and Mountain Units of Georgia (appendix A, table 11).

Small increases were measured in these types on both public and industry holdings, but the recent declines on NIPF land total 3.7 million acres (appendix A, table 12). Of the major softwood types, shortleaf pine and longleaf pine have experienced the largest loss (appendix A, table 13).

INADEQUATE REGENERATION ON NIPF LANDS

Another factor causing the reduction in pine net growth is adequate regeneration on NIPF land after harvesting.

Although recent Forest Surveys show some improvement in the regeneration of pine on such land, the record during the 1960's and 1970's was not good. Many NIPF owners accept whatever regeneration nature provides after timber harvests. In many cases, hardwoods or mixed stands of pine and hardwood replace pine without some intervention on the part of the landowner. Changes on NIPF land are especially important because these owners account for more than two-thirds of the timberland in the Southeast.

Over the past 10 years, the area of NIPF land harvested and kept in timber has averaged about 950,000 acres each year. This figure includes both final harvesting and high-grading but excludes thinning and other intermediate cutting. Of these 950,000 acres harvested, 610,000 acres supported pine or oak-pine stands prior to harvest. On NIPF land, the total area successfully regenerated to pine or oak-pine averaged about 330,000 acres, or 54 percent of the pine and oak-pine harvested. The area artificially regenerated to pine averaged less than 20 percent of the acreage of pine and oak-pine harvested. USDA Forest Service statistics indicate that the annual rate of planting on NIPF land in the Southeast has increased significantly in recent years, exceeding 280,000 acres in both 1982 and 1983. The latest rate of planting is still well below the rate of harvest, however.

About 1970, the consequences of inadequate regeneration on NIPF land and the absence of pine seeding onto old fields began to show up in the Forest Survey statistics as reductions in the numbers of pine saplings (Boyce and Knight 1979). The latest cycle of surveys shows 40- to 50-percent declines in the numbers of pine saplings on NIPF land. More important, these declines in tree numbers have now progressed up into the 6- and 8-inch diameter classes, where they are affecting ingrowth and inventory volumes. Since some of the sharp decrease in numbers of pines can be attributed to the shift from dense natural stands to plantations, prospective declines in the larger diameter classes are somewhat smaller than those experienced in saplings.

In the latest Forest Surveys of Florida, Georgia, North Carolina, South Carolina, and coastal Virginia, the number of 6-inch pine trees on NIPF land was down 27 percent from the fourth survey. A 60-percent increase in the number of 6-inch pines on forest industry land only partially compensated for the loss on NIPF land. Overall, there was a 4-percent decrease (appendix A, table 14).

INCREASE IN PINE MORTALITY

A third factor affecting the reduction in net growth is a sharp increase in the mortality of pine. The statistics indicate 15 percent of the gross annual growth of yellow pine is now lost to mortality, compared with 9 percent 10 years ago. Overall, statistics in this report show a 77-percent increase in the annual mortality of pine growing stock. Larger increases have occurred in Florida, Georgia, and parts of Virginia. Smaller increases have occurred in North Carolina, South Carolina, and coastal Virginia. For South Carolina, where the interim survey figures are compared with those from the fifth survey, the changes are for a 5- to 6-year remeasurement period (appendix A, table 15).

By ownership, the largest percentage increases in pine mortality have been on public land, where stands are generally carried over longer rotations (appendix A, table 16). Within each ownership class, the largest increases in mortality have occurred in the Piedmont and Mountains. Of the major pine species, slash pine has experienced the largest percentage increase (appendix A, table 17). Slash pine planted off site and north of its natural range has been particularly susceptible to a number of damaging agents.

Much of the increase in mortality can be attributed to periodic outbreaks of pine bark beetles over fairly extensive areas. Forest Survey statistics suggest that insects account for 35 to 40 percent of the softwood mortality in the Southeast each year. Suppression is the second leading identifiable cause of death, followed closely by disease. Fusiform rust, littleleaf disease, and root rot are the three leading diseases affecting pines in the region.

SLOWDOWN IN INDIVIDUAL-TREE GROWTH

Of all the factors known to be causing reductions in pine growth, measured declines in rates of individual-tree diameter growth in much of the region have attracted the most attention. The remainder of this report will deal with these findings. It is important to remember, however, that reductions in net growth of yellow pine would have occurred because of the area reductions, regeneration reductions, and mortality increases even if diameter growth rates had remained stable. Although it is difficult to quantify how much of the overall reduction in net growth of pine volume is caused by each factor, the results from the interim survey of pine timber in South Carolina provide one crude measure of the relative amount attributable to diameter growth reduction. In interim surveys, the average annual radial increments developed over the most recent complete remeasurement period usually are used to process the interim data. In the case of South Carolina, evidence of a slowdown in tree growth had already been turned up in parts of Georgia. Therefore, a decision was made to remeasure the diameters in South Carolina in the interim survey. When the interim survey data were processed, results using the old diameter growth rates were compared with those using the new diameter growth rates. With the old rates, the decline in net growth averaged 18 percent; with the new rates, the decline averaged 28 percent. Thus, about two-thirds of the measured decline in volume growth across the State would have occurred even if no reduction in individual-tree diameter growth had surfaced.

SETTING THE STAGE

The remainder of this report deals specifically with the reduction in individual-pine-tree diameter growth, its effect on stand-level growth, potential causes of the declines, and areas of investigation that may shed more light on this phenomenon. Before presenting the quantitative evidence we shall (1) present the basic geographic unit used for analysis and reporting, (2) describe past and present FIA sampling procedures, (3) discuss the limitations inherent within the Survey data, and (4) show how the FIA data are representative of the population of trees and stands by using examples of common changes in tree tally at sampling points.

STUDY AREAS

For analytical and reporting purposes, 12 study areas were identified (fig. 1). We pooled separate Survey Units to form areas with similar physiography, species, and general forest conditions. The study areas do not overlap States. Remeasurement years, and thus the periods over which growth is measured, are different in adjacent States.

FIA SAMPLING PROCEDURES

The FIA inventory design is based on a well-distributed, systematic sample with proportionate sampling of all forest types, sites, and ownerships. Currently, about 25,000 permanent plots are installed in the Southeast; each plot represents an average of 3,400 acres. Forest Survey has now completed the fifth periodic inventory of the forest resources of the region. A number of inventory methods and designs have been used over the years.

In 1933, the first inventory of the forest resources in the Southeast began (table I). Crews followed compass lines spaced 10 miles apart and installed 1/4-acre plots at intervals of 660 feet along these lines. Certain tally trees were bored to determine diameter growth rates. The second survey covered the

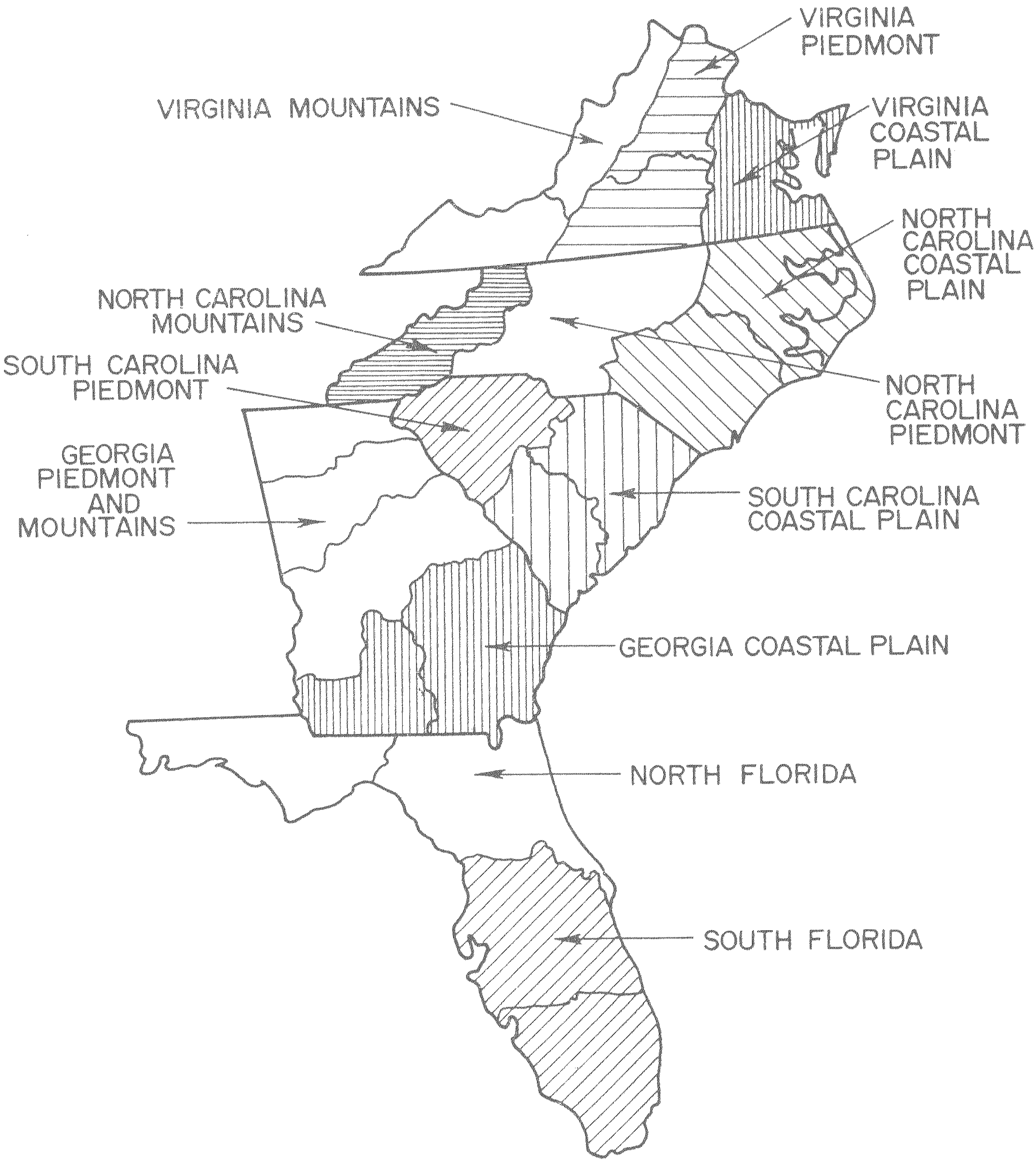


Figure 1.--Forest Survey delineations of growth-loss study areas in the Southeast.

Table I.--Forest Survey field completion dates (month/year) in the Southeast, by State, study area, and survey cycle

State and study area	Survey cycle				
	First	Second	Third	Fourth	Fifth
South Carolina:					
Coastal Plain	6/34-12/36	11/46-11/47	11/57- 8/58	2/67- 7/68	8/77- 8/78
Piedmont	9/36-12/36	11/47- 3/48	7/57-11/57	8/66- 2/67	4/77- 8/77
State	6/34-12/36	11/46- 3/48	7/57- 8/58	8/66- 7/68	4/77- 8/78
Florida:					
North Florida	11/33-11/35	6/48- 3/49	8/58- 2/59	7/68-11/69	9/78-12/79
South Florida	12/35- 4/36	3/49- 8/49	2/59- 8/59	11/69- 6/70	12/79- 5/80
State	11/33- 4/36	6/48- 8/49	8/58- 8/59	7/68- 6/70	9/78- 5/80
Georgia:					
Coastal Plain	12/33- 6/34	7/50- 3/52	8/59- 9/60	6/70- 8/71	5/80-10/81
Piedmont & Mtns.	9/35- 3/36	4/52-11/53	9/60- 8/61	7/71-11/72	10/81- 1/83
State	12/33- 3/36	7/50-11/53	8/59- 8/61	6/70-11/72	5/80- 1/83
North Carolina:					
Coastal Plain	2/37-12/37	12/51- 2/55	8/61- 6/63	11/72- 5/74	11/82-12/83
Piedmont	4/37- 6/37	7/55- 1/56	6/63- 9/64	5/74- 1/75	12/83- 8/84
Mountains	1/38- 8/38	3/55- 7/55	7/63-11/64	5/74- 9/74	4/84- 9/84
State	2/37- 8/38	12/51- 1/56	8/61-11/64	11/72- 1/75	11/82- 9/84
Virginia:					
Coastal Plain	3/40- 7/40	6/56-10/56	11/65- 5/66	2/75-11/75	9/84- 2/85
Piedmont	7/40- 9/40	10/56- 2/57	11/64- 7/65	11/75- 8/76	3/85- 8/85
Mountains	9/40-11/40	2/57- 6/57	7/65- 8/66	8/76- 3/77	5/85-10/85
State	3/40-11/40	6/56- 6/57	11/64- 8/66	2/75- 3/77	9/84-10/85
Southeast	11/33-11/40	11/46- 6/57	7/57- 8/66	8/66- 3/77	4/77-10/85

period from 1946 to 1957; a 1/5-acre circle was the basic sample plot. These plots were randomly selected and systematically distributed by using grids printed on aerial photographs. Again, trees were bored to determine growth rates. The second survey marked the initial use of permanent sample plots in the Southeast as plot locations were documented so they could be remeasured.

Point sampling was introduced into Forest Survey plot design during the third inventory cycle between 1957 and 1966. Two versions of the new sampling technique were used during the third survey. A single BA-10 variable plot was superimposed on the old 1/5-acre sample plots in South Carolina, Florida, Georgia, and the Coastal Plain of North Carolina. In the remainder of North Carolina and in Virginia, a 10-point cluster of BA-37.5 plots was established at each sample location. This plot design is still in use.

During the third survey cycle, methods of growth determination were in transition. Trees were still bored to obtain diameter growth information while the switch to diameter remeasurements was tested and gradually implemented. The changeover from increment core to remeasurements on permanent plots was complete by the time the fourth survey began in 1966. Fourth survey methodology consisted of relocating the BA-10 or BA-37.5 plot, remeasuring surviving trees, and establishing a new inventory suitable for future remeasurement. The fifth survey cycle began in 1977 and was completed in late 1985. Procedures were much the same as those of the fourth inventory cycle. Three of the 10 sample points at each location are currently remeasured.

Detailed descriptions of FIA plot inventory and remeasurement procedures are provided in field manuals for each State and survey cycle.[1] Recent Resource Bulletins also provide definitions of all terms commonly used in the inventories (Sheffield and Knight 1984).

[1]Available from the Southeastern Forest Experiment Station, Forest Inventory and Analysis.

DATA LIMITATIONS

Because of the changes in basic inventory design over the years, it is difficult to develop comparable estimates of individual-tree growth rates over time. Tree growth data from the earlier surveys are limited. No published records of individual-tree growth rates exist for the first survey period, and field forms from that survey were destroyed years ago. Similar problems exist for the second survey, but the field forms containing measurements of tree core increment have been salvaged for Virginia. These data will eventually establish tree growth rates in this State for the 1947 to 1957 period, the oldest information extractable from the FIA data base. Data available from the third survey period are mostly in the form of increment core measurements recorded on the field forms. Some of that third survey data have been coded for computer analysis. Eventually all of it will be converted into a form suitable for computer storage and analysis. Tree growth-rate data for the fourth and fifth survey periods are based entirely on diameter remeasurement data. The initial discovery of diameter growth reduction came from comparisons of average growth rates from these diameter remeasurements. In South Carolina, the interim survey diameter remeasurement in 1983 provided another period for comparison beyond the fifth inventory.

Analyses of available data and investigations into possible causes of tree growth reduction are more difficult and limited than would be the case if the FIA inventories were designed for such uses. Certain key tree, stand, and site parameters either have not been collected or have been collected in a variable manner over time. These survey design and data limitation problems limit analyses of possible causes of the growth reduction.

UNDERSTANDING THE NATURE OF THE FIA DATA

FIA remeasurement data are unique in that they are drawn from the entire population of trees and stands across the Southeast. Procedures are designed to accurately sample the population at each point in time and to measure basic changes in the population from inventory to inventory. The broad-based and dynamic nature of the population of trees and stands is difficult to fully comprehend, even for someone with experience in forest inventory. For this reason, three examples of changes in stands and associated tally of trees over time in hypothetical point samples (variable-radius plots) are provided to put into focus the source and nature of the data used in subsequent sections.

In the first example (fig. 2), four trees are included in the inventory at the hypothetical sampling point in the third survey. Remember that other trees are also in the vicinity of those shown, but they are not large enough to be included in the tally for this inventory period. When remeasured in the fourth survey, tree 1 has died. Trees 2, 3, and 4 have survived and are remeasured. These three trees would be included in the computation of average diameter growth; the averages are usually assigned to the tree's diameter class in the third survey, the beginning of this growth period. The same three remeasured trees are expanded to per acre levels and the diameter growth is converted to stand basal area growth (survivor growth) by methods and concepts documented by Beers and Miller (1964).

A new inventory is now established at the same plot center (PC) to measure the current inventory and set a new base for the next remeasurement. Remeasured trees 2, 3, and 4 become part of the new inventory, but an additional tree (#5) is also included because it is now large enough to be within the limiting distance determined by the basal area factor of the point sample. During the next plot remeasurement (fifth survey), this new tree is remeasured along with trees 2 and 4. Tree 3 has been cut in this example. Diameter growth rates for individual trees would be based on trees 2, 4, and 5 and assigned to the diameter class of the respective trees in the fourth inventory. Survivor growth for the stand would be calculated using the same trees.

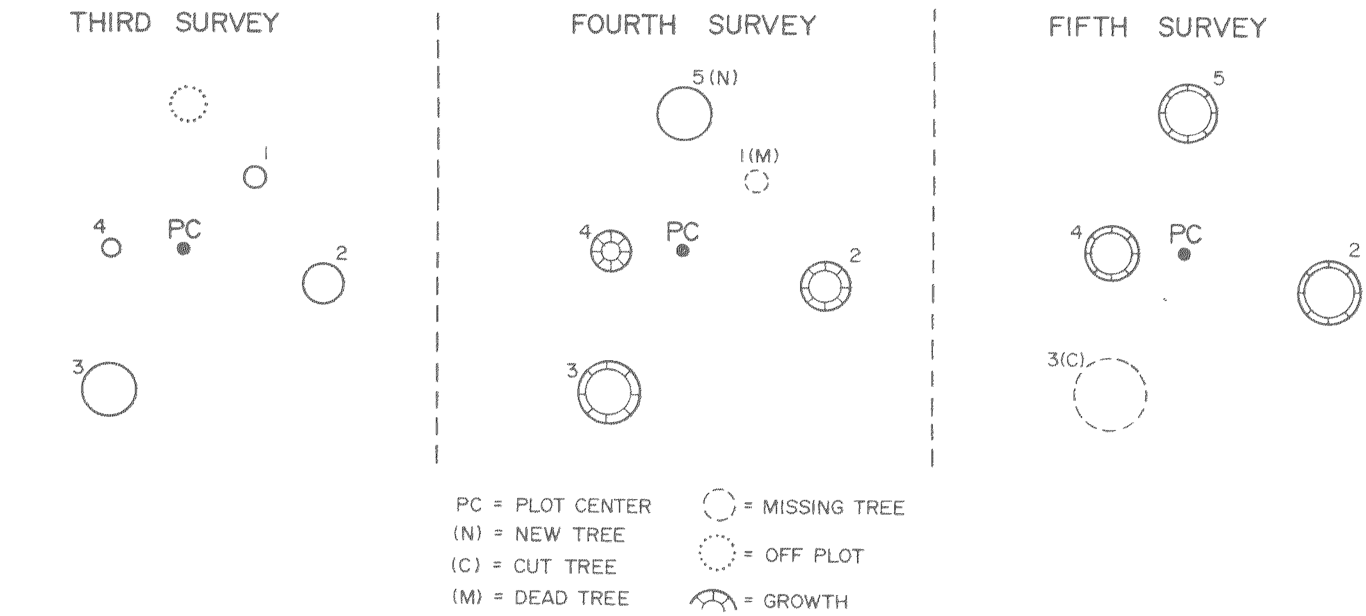


Figure 2.--Tree tally and remeasurement trees at a hypothetical sampling point in three successive inventories--some cutting, mortality, and new trees.

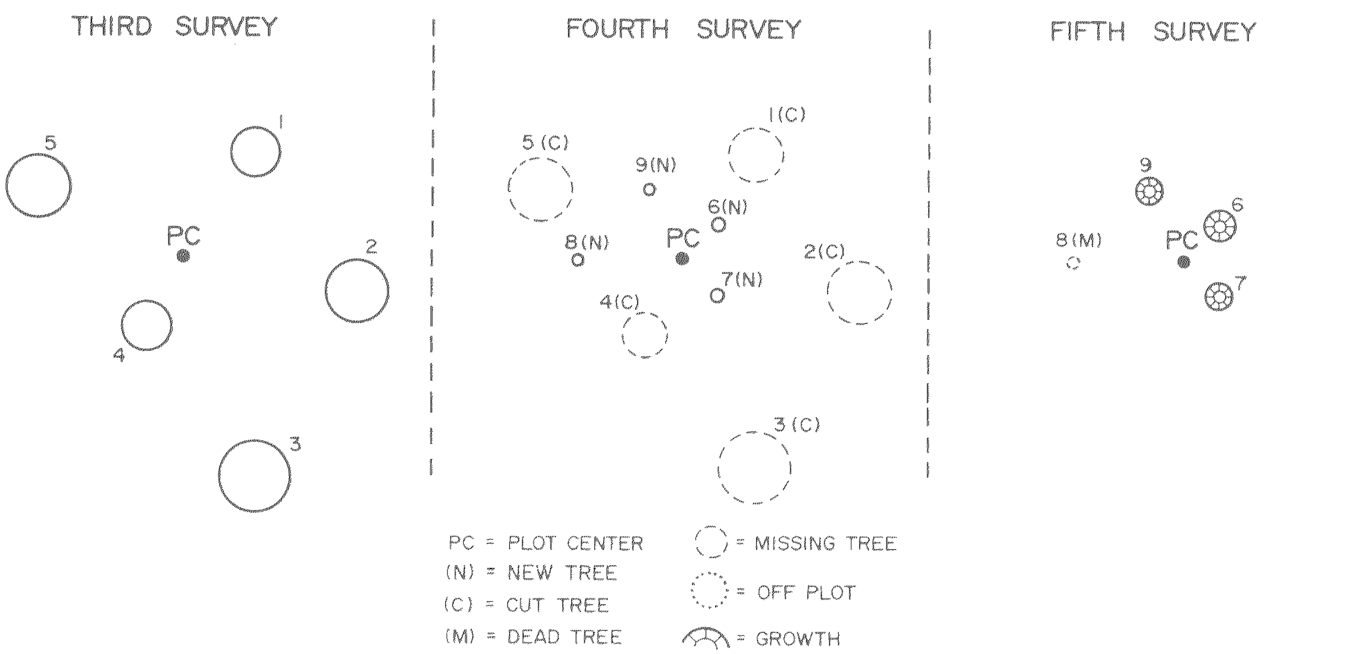


Figure 3.--Tree tally and remeasurement trees at a hypothetical sampling point in three successive inventories--timber harvest and regeneration.

It is important to note that if only undisturbed plots were included in the computation of average growth, this hypothetical plot would be included for the third-fourth growth period. Because timber cutting occurred between the fourth and fifth surveys, this plot would be excluded from the computation of average growth for this period.

In another typical example of changes on a plot (fig. 3), the initial inventory consists primarily of sawtimber trees. These trees are cut before the fourth survey remeasurement; no trees remain on which to compute average tree diameter growth or survivor growth for the stand. However, a number of small saplings have become established and are

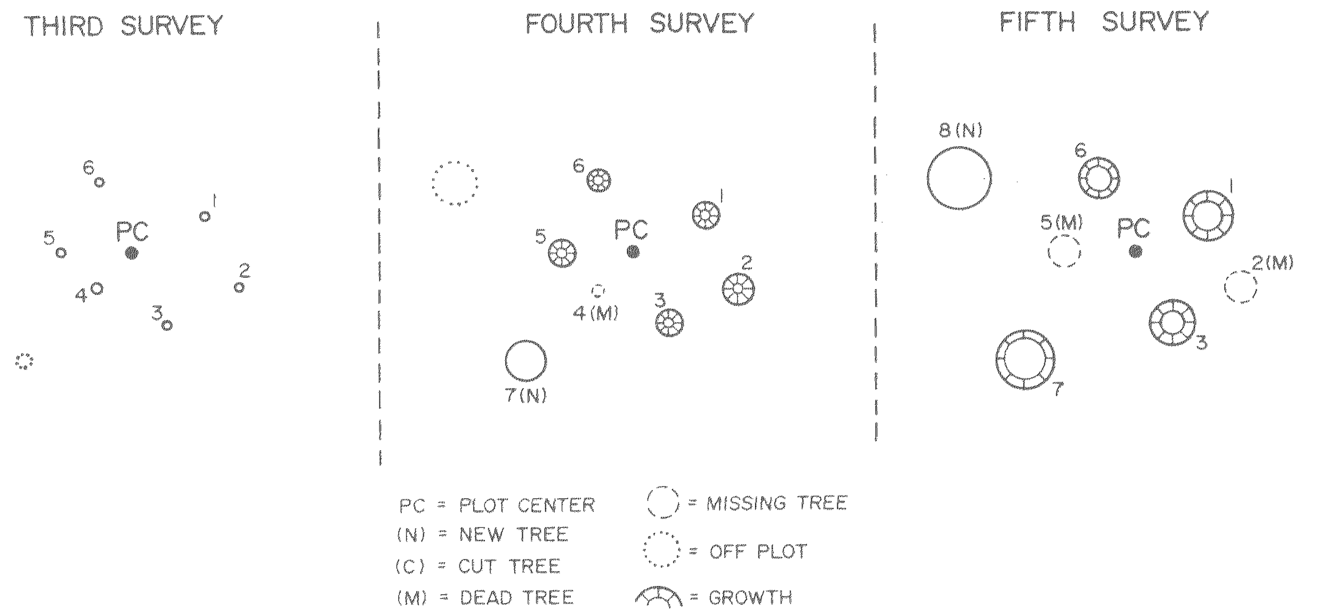


Figure 4.--Tree tally and remeasurement trees at a hypothetical sampling point in three successive inventories--no major disturbance.

part of the new inventory on this plot in the fourth survey (trees 6, 7, 8, 9). Those surviving until the fifth survey remeasurement (trees 6, 7, 9) are remeasured and constitute the source of growth information for this plot during the latest growth period.

The third survey inventory in a third example (fig. 4) consists of saplings (trees 1-6). The stand is undisturbed between the third and fourth and again between the fourth and fifth surveys. A number of the trees grow larger and are remeasured, while others die. Again, new trees are added in subsequent inventories as their size increases, providing new remeasurement opportunities in the next remeasurement. Even though the trees in this example are obviously older in the last inventory and may be growing slower as a result, it is important to realize that growth that occurs on the same trees in consecutive periods is assigned to a different diameter class for each period. Similarly, stand growth is assigned to higher stand age and/or density classes for each period.

Many more examples would be needed to exhaust all possible combinations of stand and tree history for the different growth periods. Two points should be remembered: (1) Tremendous diversity exists in the population of trees and stands over large geographic areas, and (2) sampling procedures employed by FIA are designed to capture and measure the changes in the population from one inventory to the next. Changes in tree and stand growth presented here are not based on a single sample of trees selected during the third survey and tracked over succeeding remeasurement periods. The population of trees and stands is resampled at each inventory to establish a new base for the next remeasurement.

INDIVIDUAL-TREE GROWTH REDUCTION

Reductions in survivor growth of pines were first observed at the individual-tree level. The measure of tree growth used in the individual-tree analysis was average annual radial increment (AARI). Tree volume growth would have been more desirable, but tree heights were not measured with the same precision as tree d.b.h. In some cases, heights of individual remeasured trees were not available for use. Because AARI's (and tree volume growth) do not adequately describe stand productivity, more detailed analysis of the data was deemed necessary. In the meantime, AARI's could be computed rather quickly from the latest remeasurement data to provide an initial examination of growth trends.

AARI COMPUTATION

Declines in AARI's in natural stands of loblolly pine in the Georgia Piedmont and Mountains are shown in plottings of radial growth by initial diameter class for the two most recent remeasurement periods (fig. 5). Reductions in this particular example range from 11 percent for the 14-inch diameter class to 37 percent for the 2-inch class.

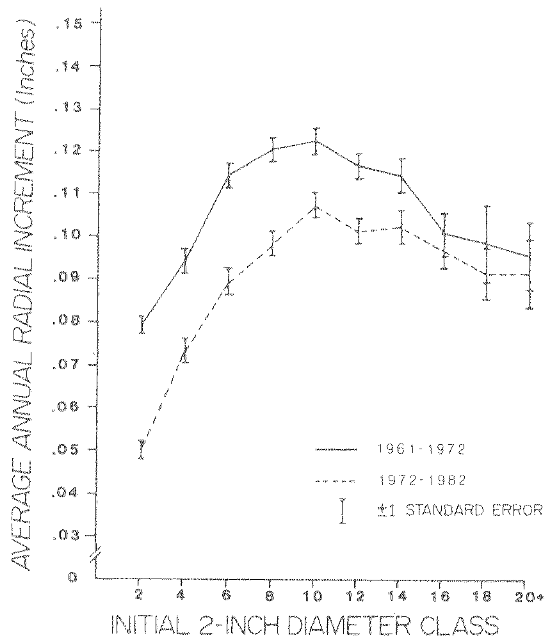


Figure 5.--Average annual radial increment (AARI), by diameter class, for loblolly pine growing in natural stands during the two latest remeasurement periods, Georgia Piedmont and Mountains.

In this and subsequent presentations of AARI, mean growth values are shown for each diameter class. Pine trees that were measured at the beginning of either remeasurement period and survived to be remeasured at the end of the period form the basis for the growth computation. For each remeasurement period, the steps involved were as follows:

1. Surviving pine trees were assigned to a diameter class based on the diameter of the tree at the beginning of the growth period.
2. Annual diameter growth for each surviving tree was computed by dividing the change in d.b.h. by the number of years between remeasurements.
3. AARI for each tree was computed by dividing annual diameter growth by 2.
4. Mean AARI's for each diameter class and species were calculated by summing individual-tree AARI's and dividing by the number of individuals.

Since the AARI's were computed independently for each period, the means do not reflect declining growth for the same trees tracked across both remeasurement periods, but simply reflect how trees of the same diameter class are growing in successive time periods. The dynamics of the tree population ensure a continuous turnover of individuals within a size class. During any one growth period many trees are cut, others die, new trees grow large enough to be included in the inventory, and most survivor trees grow into a larger diameter class. Therefore, the averages reflect naturally occurring changes in overall forest structure over time.

Standard errors are indicated around the means in the example plotting of AARI (fig. 5) but are omitted from subsequent illustrations of AARI. Means, sample sizes (number of trees), and standard errors for all the AARI data are available in tables in appendix A. Tests of significance beyond providing means, sample size, and standard errors are omitted. Readers may wish to make their own interpretations of significance based on these statistics. Some interpretation of statistical significance is provided in the text.

The shapes of the growth curves do not resemble those in traditional growth and yield studies of managed stands. Most of the natural stands in the FIA remeasurements are not managed, and trees of all crown classes are included in the averages. Relatively high proportions of intermediate and overtopped trees in the smaller diameter classes suppress the growth values.

AARI COMPARISONS

AARI data for the latest inventories (those with diameter remeasurements) were assembled for each of the study areas for which there were two or more available remeasurements. The data are presented in appendix A for the major pine species growing in natural stands within each study area and for planted stands where the sample is large enough (table II; appendix A, tables 18-47). Since AARI trends in the Coastal Plain differ from those in the Piedmont and Mountains, the important findings are summarized for each region.

Piedmont and Mountains

A pattern of reduced AARI is evident for all major pine species growing in natural stands throughout the upland areas of the Southeast between the two most recent remeasurement periods. For most study areas, the growth slowdown apparently occurred between the fourth and fifth surveys--sometime in the 1970's or early 1980's. In South Carolina, pine diameter growth changed little between the fourth and fifth surveys but did decline thereafter based on AARI's determined for the interim survey remeasurement period. Reductions during this 5-year period (1978 to 1983) were as severe as for 10-year periods in adjacent States.

Reductions in diameter growth of pines in natural stands are evident for all but the largest pine trees in the Piedmont and Mountain regions. The

Table II.--A summary of appendix A tables showing AARI comparisons for growth-loss study areas

Study area	Survey period			Stand type	Pine species	Table
Georgia Piedmont and Mountains	1961-1972,	1972-1982	--	Natural	Loblolly	18
				Natural	Shortleaf	19
Georgia Coastal Plain	1961-1972,	1972-1982	--	Natural	Slash	20
				Natural	Longleaf	21
				Natural	Loblolly	22
				Planted	Slash	23
South Carolina Piedmont	1958-1968,	1968-1978,	1978-1983	Natural	Loblolly	24
				Natural	Shortleaf	25
				Planted	Loblolly	26
South Carolina Coastal Plain	1958-1968,	1968-1978,	1978-1983	Natural	Loblolly	27
				Natural	Pond	28
				Natural	Longleaf	29
	--	1968-1978,	1978-1983	Planted	Loblolly	30
				Planted	Slash	31
North Carolina Piedmont	1964-1974,	1974-1984	--	Natural	Loblolly	32
				Natural	Shortleaf	33
				Natural	Virginia	34
North Carolina Coastal Plain	1964-1974,	1974-1984	--	Natural	Loblolly	35
				Natural	Pond	36
				Natural	Longleaf	37
North Carolina Mountains	1964-1974,	1974-1984	--	Natural	Virginia	38
				Natural	White	39
Virginia Piedmont	1966-1976,	1976-1985	--	Natural	Virginia	40
				Natural	Shortleaf	41
Virginia Coastal Plain	1966-1976,	1976-1985	--	Natural	Loblolly	42
				Natural	Virginia	43
Virginia Mountains	(Not available at present time)					
North Florida	1959-1970,	1970-1980	--	Natural	Slash	44
				Natural	Longleaf	45
				Planted	Slash	46
South Florida	1959-1970,	1970-1980	--	Natural	Slash	47

magnitude of the reduction varies by species and diameter class but averages 20 to 30 percent; the majority of differences in AARI's are statistically significant at one standard error or higher probability. These changes are based on a relatively large number of remeasured trees, with several hundred samples in many combinations of species and diameter class.

A comparison of pine diameter growth trends for plantations in the Piedmont and Mountains was possible only in South Carolina (appendix A, table 26). Again, reductions show up for loblolly pine in the interim survey data (1983), compared with data from the two previous remeasurements. Differences between diameter classes often were not statistically significant at one standard error. The sample size for plantation loblolly pine in this study area is not particularly large, especially in the fifth survey where most diameter classes have fewer than 30 samples.

Coastal Plain

The AARI values for the latest surveys in the Coastal Plain show little evidence of general growth reductions in natural stands. Trends in diameter growth vary by study area, species, and size class. Loblolly pine, the most widespread species in the Coastal Plain, grew as well in the fifth survey period as in the fourth in Coastal Plain study areas in Virginia and North Carolina. Some reduction in diameter growth of natural loblolly is evident in the Georgia and South Carolina Coastal Plain areas, primarily in the smallest diameter classes. The reduction in South Carolina apparently occurred between the fifth and interim surveys.

For other pine species in natural stands, there are similar inconsistencies in diameter growth trends. In the Coastal Plain regions of Georgia and North Carolina, radial growth rates for longleaf pine were down for the smaller diameter classes (generally the 2- through the 10-inch class) between the fourth and fifth surveys. In North Florida and South Carolina, the most recent diameter remeasurement data indicate relatively stable growth for longleaf pine. Slash pine diameter growth for natural stands in the Georgia Coastal Plain is relatively stable in all but the smallest diameter classes. Natural slash in North Florida has slowed somewhat more in diameter growth, while no general trend is evident in South Florida.

Comparisons of diameter growth rates were possible for planted slash pine and loblolly pine in certain study areas where the sample size was large for two or more remeasurement periods. Growth trends for these types also vary geographically. Diameter growth of planted slash pine is relatively stable in the Georgia Coastal Plain, generally up in North Florida, and generally down for the smaller trees in South Carolina. The reduction in South Carolina may be attributable to the decrease in planting of this species this far north in the last 10 to 15 years. Without recent plantings, average growth rates in small diameter classes are expected to decline because they represent increasing proportions of suppressed trees as the stands age. Growth of loblolly pine in plantations is compared only in the South Carolina Coastal Plain, where relatively stable growth rates are indicated. Management factors such as changes in tree spacing over time, drainage, bedding, use of genetically improved stock, etc., complicate the evaluation of diameter growth trends in plantations more than for natural stands.

THIRD SURVEY INCREMENT CORE MEASUREMENTS

A logical conclusion based on data available from the fourth, fifth, and interim surveys was that any diameter growth decline was probably restricted to yellow pines in the Piedmont and Mountain areas of the Southeast. The FIA staff decided that growth information from the third survey should be examined. The effort to code third survey data for computer storage and analysis began with the Piedmont and

Mountains of Georgia, continued with the South Carolina Piedmont, and was eventually extended into the Coastal Plain. These efforts are continuing.

Few diameter remeasurement data are available for the third survey. Tree growth data gathered during that survey came from tree cores extracted from inventory trees. In order to compare growth rates for this period with more recent ones, tree core measurements had to be converted to AARI's.

Conversion to Equivalent AARI's

During the third survey of South Carolina, all sample trees 3.0 inches d.b.h. and larger were bored on the plot center side of the tree and the last full 5 years of radial growth was measured and recorded to the nearest 1/20 inch. In Georgia, the minimum size of tree bored for radial growth was 4.0 inches d.b.h. Trees of any size with abnormalities or defects at breast height were not bored.

Bark measurements at breast height on more than 40,000 trees provided the data necessary to develop equations to predict bark thickness, by species and d.b.h. The procedure developed to compute radial growth (including bark) from the third-survey tree core measurements (excluding bark) required computing regression coefficients for bark thickness prediction equations for each species. Separate sets of equation coefficients were solved for saplings (trees under 5.0 inches d.b.h.) and larger trees. Three different calculating procedures were tested, and their results were compared over a wide range of diameters and radial growth rates. The three mathematical procedures were further tested using the actual third survey sample trees for both study areas in Georgia. All three methods produced essentially the same estimates of AARI on a tree-by-tree basis and at the summary level. The procedure selected for use in this study produced the lowest estimate of AARI's. The prediction equations and a more detailed explanation of the procedure are presented in appendix B. All trees whose radial growth rates were unknown were assigned an average radial growth value by species and diameter class within each study area. Sample trees assigned an average growth were not used in making AARI comparisons but were used in estimating initial basal area per acre and basal area growth per acre.

D.b.h. 5 years prior to the third survey was calculated for each tree from the computed AARI. Trees were then sorted and averages developed by the same procedures as for the fourth and fifth surveys.

Limitations of Third Survey Data

During the recovery and analysis of third survey data for Georgia and South Carolina, several limiting factors were identified. The first and perhaps most serious limitation of the third survey data was that it was impossible to account for all the major components of change during the 5-year growth period. Third survey inventory trees were processed backward, so only surviving trees and ingrowth trees could be accounted for during the period. There was no record of trees that died or were cut during the growth period. This limitation prevents the complete reconstruction of stand conditions at the beginning of the growth period. Another limitation of the third survey data was the lack of stand history information for the 5-year period. Past disturbance and cutting history coding only recognized the 3 years preceding the time of the inventory, leaving 2 years of possible unaccounted disturbances during the growth period and no record of stand history prior to the period.

The date and nature of stand origin (planted or natural) would have been useful for this study. During the 20 years prior to the third survey, many pine stands in the Piedmont of Georgia and South Carolina originated on abandoned agricultural land either by planting or by natural regeneration. A distinction between planted and natural stands was made in the Piedmont and Mountains of Georgia but not in the Coastal Plain of Georgia or in South

Carolina. Stands originating on old-field sites were not identified in either State. Also, stand age was not determined.

Piedmont and Mountains

Results for the Georgia Piedmont and Mountains indicate that diameter growth of natural loblolly and shortleaf pine has declined over a longer period than first thought (fig. 6). For loblolly pine, reductions averaging 30 to 40 percent over most diameter classes are apparent in comparing the latest growth rates (1972 to 1982) with those of the earliest period (1956 to 1961). The decline for loblolly is greater between the third and fourth survey than between the fourth and fifth. Shortleaf pine growth has slowed more dramatically over the entire period; 40- to 50-percent drops in growth rates have occurred for this species. About half of the loss took place before the fourth survey and half in the latest growth period. For both loblolly and shortleaf pine in this study area, reductions in mean AARI between the third and fifth surveys are statistically significant at least at one standard error; most means within diameter classes differ at much higher levels of significance. The sample size is large for these two species; well over 100 samples were present in most diameter classes in all three surveys (appendix A, tables 48-49).

AARI's for the third survey are not presented for the 2-inch diameter class. Trees of this size were not bored. Averages were computed for this diameter class but were based on larger trees that were growing fast enough to have been in the 2-inch class at the beginning of the growth period (5 years earlier). Thus, AARI's for this diameter class are biased, compared with later diameter remeasurements of all trees.

In the South Carolina Piedmont, major reductions in diameter growth for natural loblolly and shortleaf pines occurred between the third and interim survey periods. For most diameter classes the declines are statistically significant at the 95-percent probability level, given the large sample size and standard error values (appendix A, tables 53-54). In South Carolina the data span 3 decades (1953-1983). The growth decline does not appear to have occurred continuously throughout the period. Declines occurred between the third and fourth surveys and between the fifth and interim surveys. The fourth and fifth survey AARI's are essentially the same.

Coastal Plain

The completed analyses of third survey data for Coastal Plain areas have been quite surprising--current diameter growth rates for yellow pines are considerably lower than those of 2 to 3 decades ago. For instance, natural slash pine growth rates have declined by approximately 40 percent in the Georgia Coastal Plain (fig. 7). Almost all of this drop occurred in the third and fourth survey periods, and the differences in AARI's are statistically significant at one standard error or more. Declines of somewhat smaller magnitude are apparent for loblolly pine in this region. The same trends exist in the Coastal Plain areas of North and South Carolina (figs. 7 and 8). In each area and for each major pine species, an overall diameter growth reduction is apparent, and most of the loss took place between the third and fourth surveys. The reductions between the third and latest surveys are significant at the 95-percent probability level for most combinations of species and diameter class (appendix A, tables 50-52, 55-60).

STAND GROWTH REDUCTIONS

Over the past 3 decades in the Southeast, the average age and density of pine stands have changed dramatically. The average pine stand today is generally older and more densely stocked than the pine stand of 30 years ago. Of the factors contributing to overall net growth reductions at the regional level,

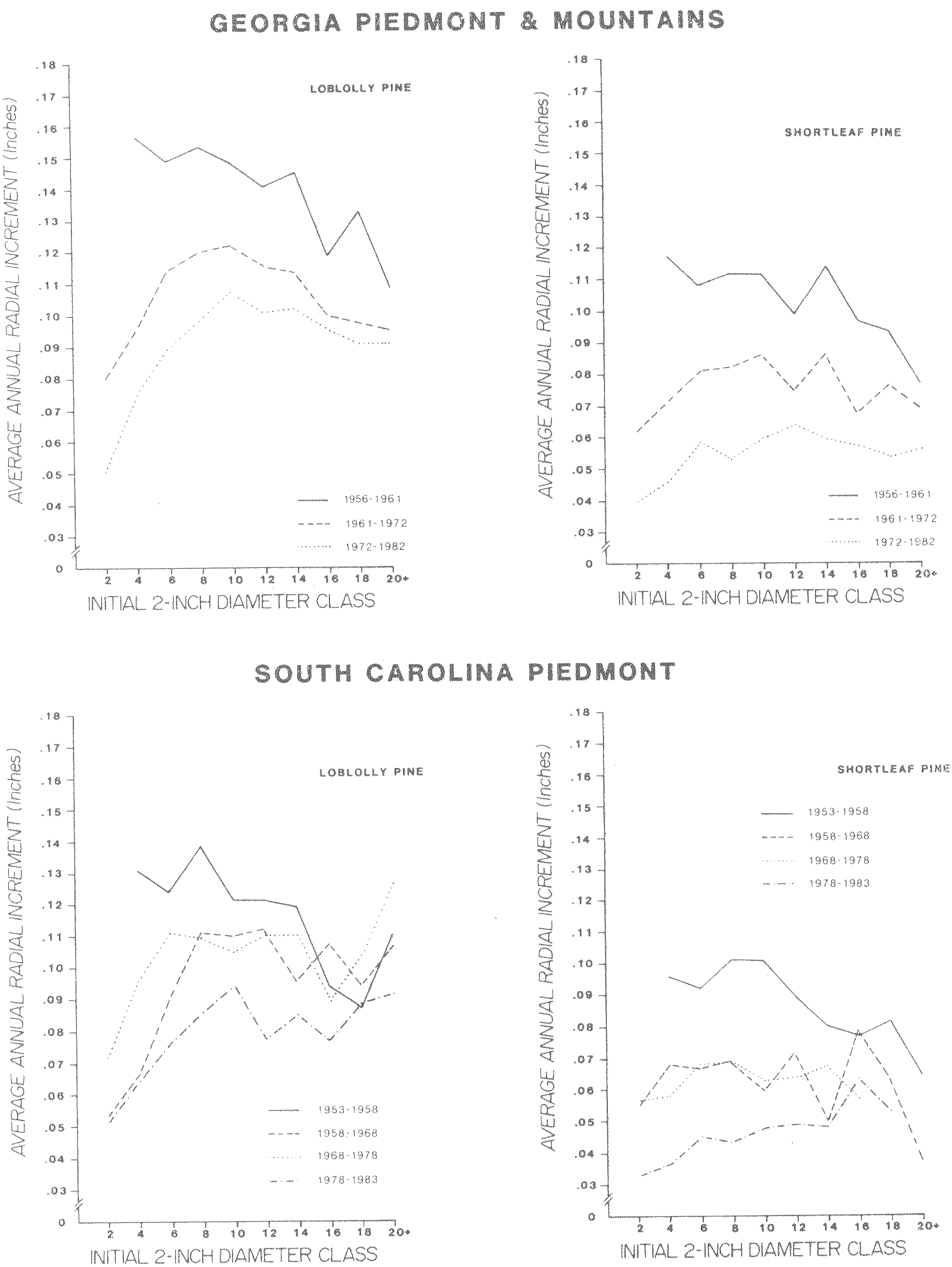


Figure 6.--Average annual radial increment (AARI), by diameter class, for the major pine species growing in natural stands, by growth period and study area.

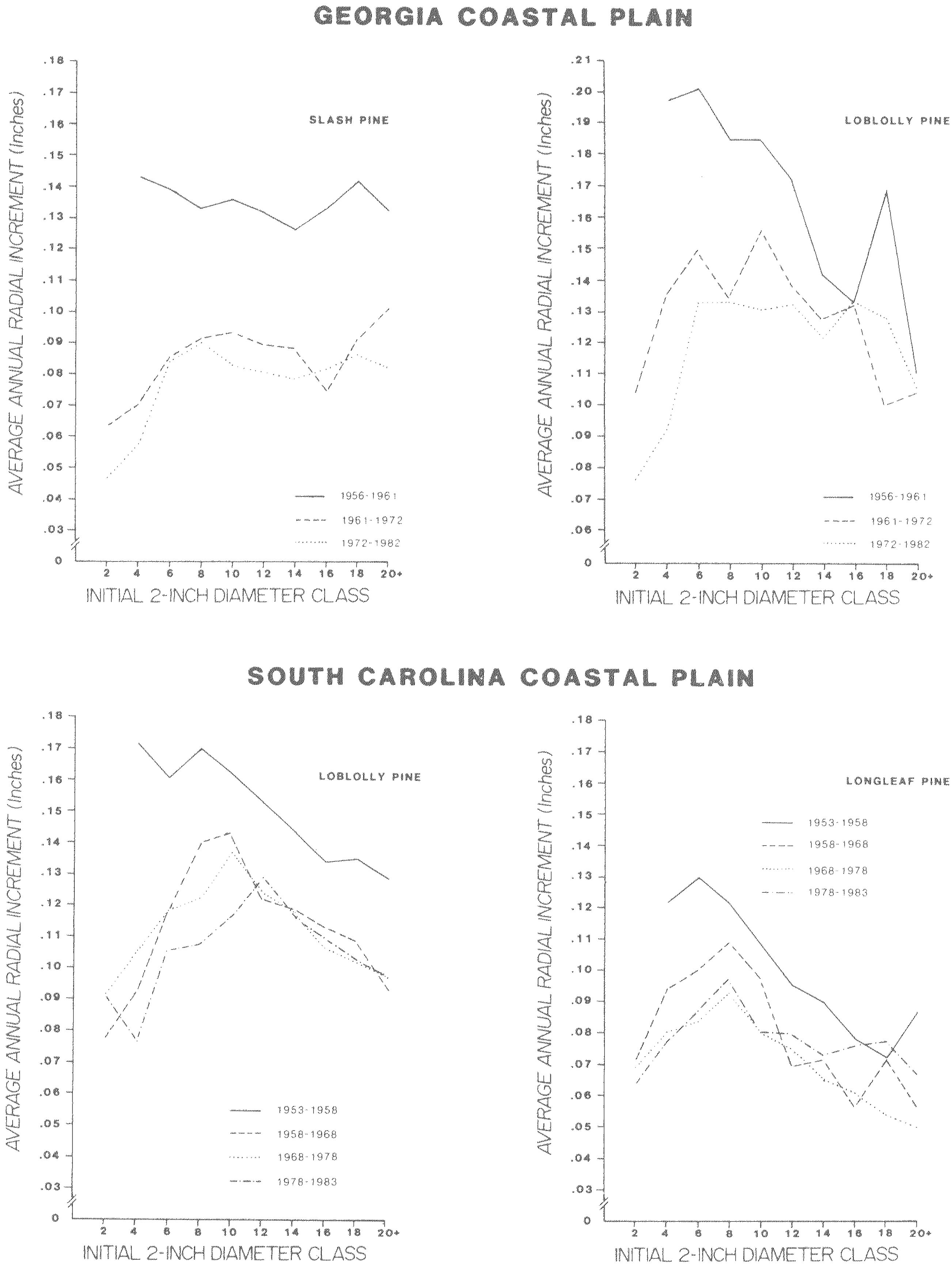


Figure 7.--Average annual radial increment (AARI), by diameter class, for the major pine species growing in natural stands, by growth period and study area.

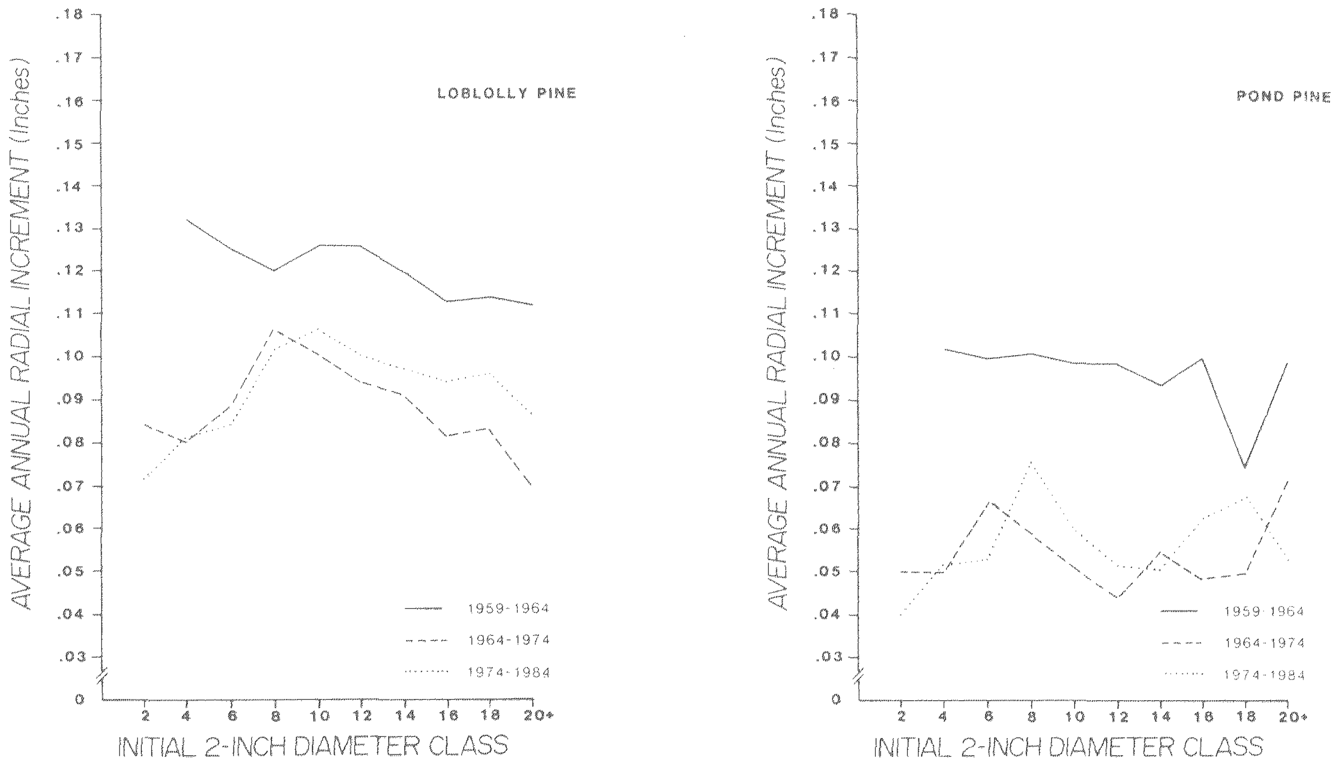


Figure 8.--Average annual radial increment (AARI), by diameter class, for the major pine species growing in natural stands, by growth period, North Carolina Coastal Plain.

slowdowns in the growth rates of individual trees, increased mortality, and declining ingrowth are the most disturbing. This section focuses on these factors to investigate growth at the stand level and explores the possibility that regional changes in stand structure may be responsible for the observed growth reductions.

The analysis was accomplished by comparing rates of average annual basal area growth per acre for three separate growth periods in two study areas of Georgia. Natural loblolly and shortleaf pine stands in the Piedmont and Mountains and natural slash pine stands in the Coastal Plain were chosen for analysis. These combinations afforded the largest and most current data base available at the time this study was begun. Similar analyses involving other forest types and study areas are incomplete.

STAND LEVEL DATA

Special summary records were generated from the third, fourth, and fifth inventories of Georgia to examine stand basal area growth trends. To be included in the data set for a given survey period, samples were required to have at least 1 square foot of basal area per acre in trees 1.0 inch d.b.h. and larger at both the initial and terminal inventories. Any plots showing evidence of planting or timber cutting during the remeasurement period were excluded. Other treatments and disturbances, or cutting prior to a given remeasurement period, were not taken into account. Key stand variables retained on the summary records include forest type, stand age, initial inventory, survivor growth, ingrowth, and mortality. Because of changes in collection procedures, many of these variables were computed differently for each survey. Variable definitions and computational methods are outlined below.

Forest Type

Forest type was assigned on the basis of the initial inventory of each sample. In order to qualify as one of the three forest types used in this analysis, samples were required to have at least 50 percent of all-live basal area in yellow pine species, and a plurality of the yellow pine basal area in the particular species appearing in the detailed forest type name.

Planting history was not collected in the 1961 survey of the Georgia Coastal Plain. The slash pine data presented here for the period between 1956 and 1961 include only a small number of planted stands. Most of these were rejected because the trees on them had not yet reached 1.0 inch d.b.h. by 1956. Plantation management was just becoming a common forestry practice at that time.

Stand Age

The stand age assigned by field crews is the average age of all trees representing the manageable stand. In the absence of a manageable stand, the assigned age is the average age of all trees in the primary overstory. Stand age was available only for the fifth survey terminal inventory. Stand ages used in this analysis apply to the initial inventory of each period. Fifth survey initial stand age was determined by subtracting the remeasurement period from the terminal stand age. Fourth survey initial stand age was computed by subtracting the fourth survey remeasurement period from the fifth survey initial age on all plots common to both surveys. Age was not regressed to any third survey samples or any fourth or fifth survey samples that experienced a major man-caused disturbance during the remeasurement period.

Initial Inventory

For the fourth and fifth surveys, initial inventory is defined as the total basal area per acre of all live trees at least 1.0 inch d.b.h. at the beginning of the remeasurement period. In the case of the fifth survey, initial inventory was calculated from trees tallied on the BA-37.5 3-point subsample established during the fourth survey in 1972. The fourth survey initial inventory was obtained from the BA-10 sample installed during the third survey in 1961.

Because no second survey plots were directly remeasured, it was not possible to completely reconstruct the third survey initial inventory. However, the 5-year growth measurements collected from tally trees during the third survey made it possible to estimate the d.b.h. of those trees in 1956. The estimates of old d.b.h. were subsequently used to approximate the stand basal area existing in 1956. The 1956 basal area values do not include trees that died between 1956 and 1961, so the 1956 initial inventory estimate is actually the survivor-tree initial inventory, and therefore underestimates the actual 1956 basal area.

Survivor Growth, Ingrowth, and Mortality

Net growth between two timber inventories can be divided into three separate components: survivor growth, ingrowth, and mortality. Survivor growth is the basal area growth per acre accrued on all live trees 1.0 inch d.b.h. and larger at the time of initial inventory that survived to the end of the remeasurement period. Ingrowth is the terminal inventory basal area per acre assigned to all live trees which grew across the 1.0-inch diameter threshold during the remeasurement period. Mortality is the initial basal area of trees 1.0 inch d.b.h. and larger at the initial inventory that died from natural causes during the remeasurement period. Fifth survey survivor growth, ingrowth, and mortality were determined from the 1982 remeasurement of tally trees originally recorded on the 1972 3-point subsample. The fourth survey components of growth were obtained from the 1972 remeasurement of tally trees recorded on the 1961 BA-10 plots.

The absence of a third survey remeasurement sample made reconstruction of ingrowth and mortality estimates between 1956 and 1961 impractical. Survivor growth for this period was calculated from the 5-year increment core measurements.

The basal area growth occurring on each sample during each remeasurement period was calculated according to methods outlined by Beers and Miller

(1964) for variable-plot samples. In order to maintain a valid estimate of population growth for all three periods, "nongrowth" (variable-plot ongrowth) trees were counted as part of the new initial inventory following remeasurement of the old inventory at each sample. Nongrowth trees are used only to establish a new inventory base for future remeasurement and do not figure into growth calculations until the next growth period.

METHODS

In order to determine if regional changes in the average density or age of pine stands in these two study areas are responsible for changes in overall growth rates, stands were stratified by the conditions existing at the initial inventory of each remeasurement period. Samples were grouped into 10-year initial age classes and 20-square-foot initial basal area classes. The subsequent growth occurring in these stands, grouped by initial age and basal area classes, was then compared for the three growth periods to determine if changes in stand growth rates were still evident when these factors were held constant.

It must be emphasized that the samples used for any one of the three growth periods constitute a random draw of the population of undisturbed natural stands present during that period. In other words, the same set of samples has not been tracked over three periods in time. Plots that met the qualifications to be counted for one period may not have been used for another period for several reasons. Foremost among these reasons are:

1. Changes in the forest land base. Some samples were cleared to a nonforest condition, whereas others reverted to forest from nonforest.

2. Cutting history. Some samples experienced some type of timber cutting during one remeasurement period but not during another. Samples falling in this category were used only for the periods during which they were undisturbed.

3. Changing forest type. Based on the criteria for determining forest type, a given sample may have qualified as a loblolly, shortleaf, or slash pine type during one period but not during another.

Some sample locations may have been used for more than one of the three growth periods. Reuse is not perceived as having any serious implications. Although exactly the same trees were remeasured at each sample within each growth period, differences in sample design resulted in the measurement of different trees between the periods. To elaborate, stand growth between 1961-1972 was derived from the remeasurement of the single-point BA-10 plots. Stand growth between 1972-1982 was estimated from the remeasurement of three BA-37.5 points installed at each plot location. Even though some of the same trees may have been included in growth estimates used for both periods, they carried different per-acre expansion factors. Also, the stands they occurred in would most likely have been assigned to different combinations of initial age and density.

FOURTH AND FIFTH SURVEY COMPARISONS

Changes involving net growth, survivor growth, ingrowth, and mortality of natural loblolly pine stands in the Piedmont and Mountains of Georgia between 1961-1972 and 1972-1982 are depicted in figure 9. Initial stand densities, net annual growth, and the components of net growth include all species present in the stand. Data used to produce these graphs are provided in appendix A, table 61. The effect of initial stand density is held constant along the x-axis of each graph.

Net growth declined substantially over the entire range of initial stand densities, as compared with the former

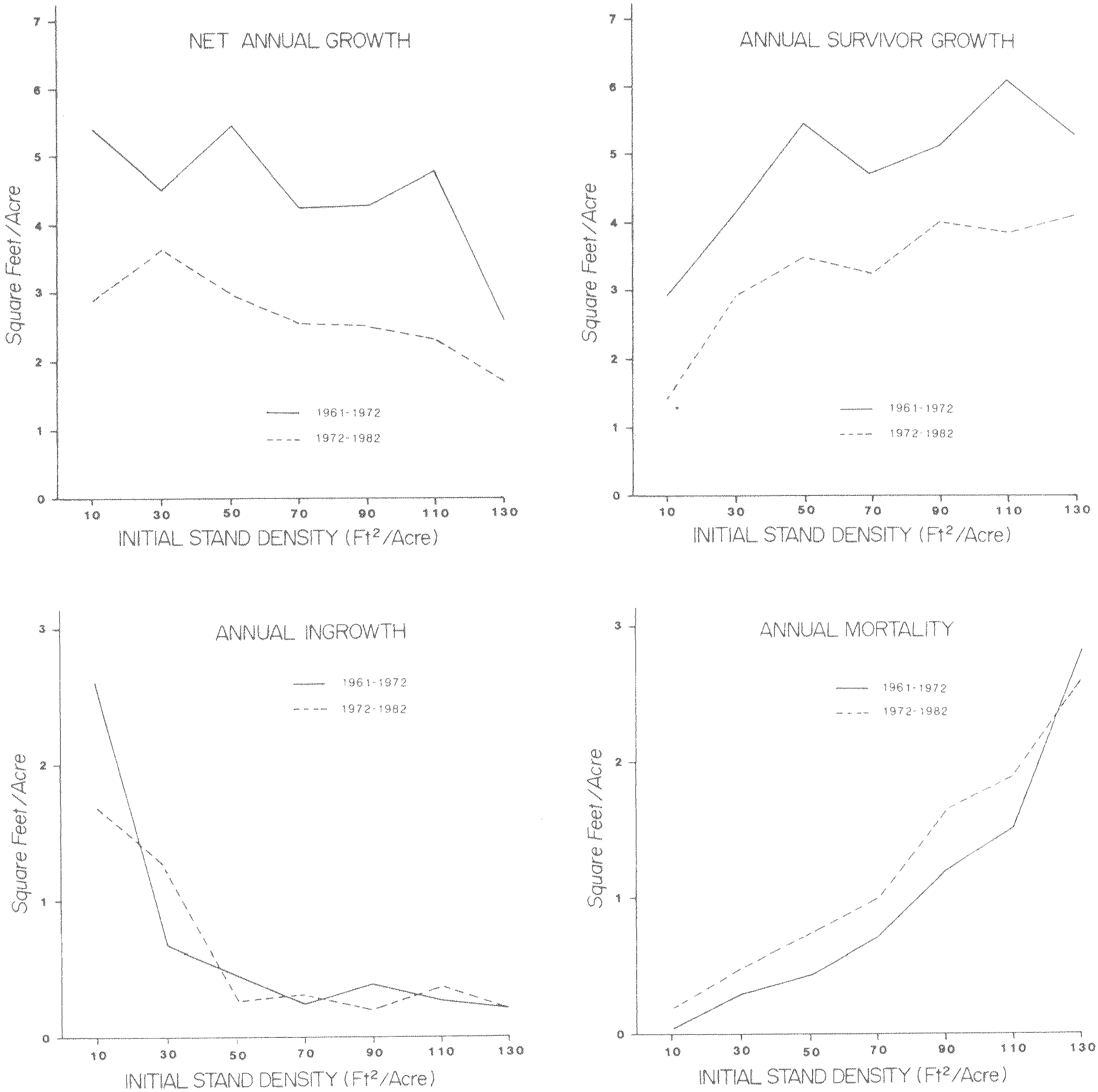


Figure 9.--Net annual basal area growth and the components of net annual growth for natural loblolly pine stands, by initial stand basal area and remeasurement period, Georgia Piedmont and Mountains.

remeasurement period. It is evident that declining survivor growth across the range of initial densities is the major cause of the overall reduction in net growth. Increased mortality is a contributing factor. Ingrowth has remained fairly stable but is down in the most sparsely stocked stands.

Figure 10 shows differences in growth between the two periods when initial stand age is used as the control variable. Data used to draft these figures are provided in appendix A, table 62. Fewer samples were available for the stand age analyses because of restrictions imposed on the methods used to regress stand age from the fifth survey. Although net growth has declined across the range of initial ages, older loblolly stands do not seem to have been affected as severely. Survivor growth has fallen in stands less than 35 years old but gained slightly in older stands. Mortality has risen in all age classes. Increased mortality in stands 35 years and older has offset increased survivor growth in these stands. Ingrowth is down in the youngest stands, where it counts the most.

Table III is a matrix designed to isolate the combined effects of initial stand age and density on net annual growth for each period. Unfortunately, the samples are too small in individual cells of the matrix to draw any definite conclusions. Sample sizes range from a low of 0 to a high of 19. As a result, the standard errors of each cell are relatively high. About half the cells show a significant growth loss at one standard error when both initial stand density and age are held constant. More than half indicate a growth decline during the latter period, but the differences are not all significant.

Table IV highlights the relationships among the components of growth and initial stand conditions for the 1961-1972 growth period. Table V shows these same relationships for the 1972-1982 data. Two points apparent from a comparison of these tables are worth mentioning. First, no real changes have taken place in the relationships among these variables between the two periods. Second, mortality is not significantly correlated with survivor growth.

This last relationship may be evidence that the agent(s) causing increases in mortality is not necessarily responsible for reductions in survivor growth. If the same agent were responsible for both phenomena, one might expect mortality to be negatively correlated with survivor growth. This interpretation is by no means conclusive because the lack of correlation could also mean that possible declines in survivor growth on samples with high mortality are simply masked by increases in survivor growth due to more favorable conditions caused by the mortality. Whatever the case, there does not seem to be any evidence that one single agent or combination of agents is causing widespread mortality and declines in survivor growth on the same samples. If such agents are at work, their effects are subtle.

Virtually the same scenario portrayed for loblolly pine stands in the Piedmont and Mountains of Georgia also holds for natural shortleaf pine stands in the same region. Since only about half as many samples were available for shortleaf as for loblolly, the shortleaf data are more erratic. These data are presented in appendix A, tables 63-67. As with loblolly, net annual growth of shortleaf pine stands during the latest period has declined even when initial stand density and age are held constant. Again, older stands do not seem to have been affected as severely. The only notable difference between the two forest types is that shortleaf stand survivor growth seems to have remained relatively steady over the entire range of initial ages when stand age is held constant (appendix A, table 64). Thus, declines in the net annual growth of shortleaf stands over the latest remeasurement period have been more heavily influenced by increases in mortality and declines of ingrowth.

A somewhat different situation exists for natural slash pine stands in the

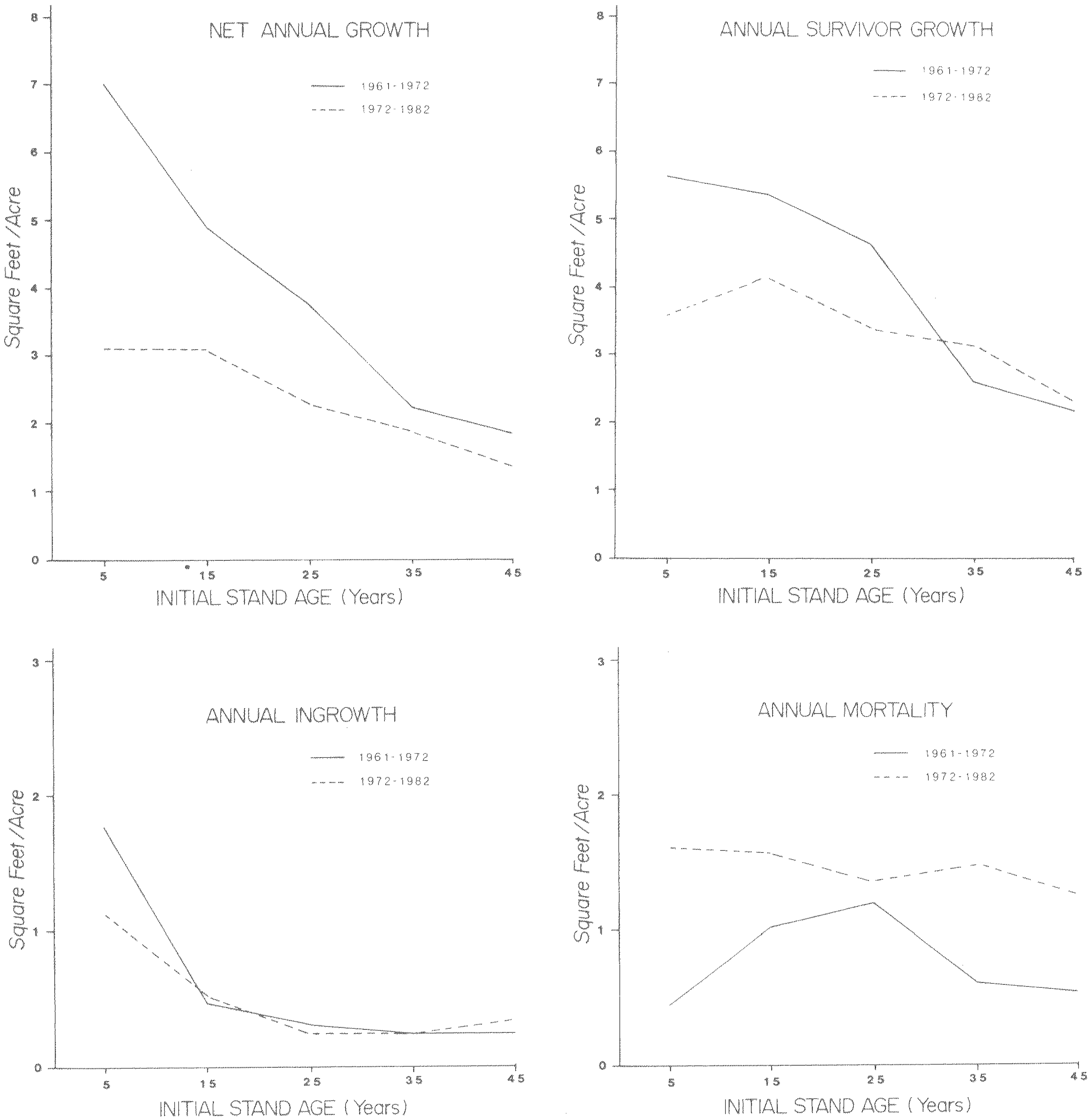


Figure 10.--Net annual basal area growth and the components of net annual growth for natural loblolly pine stands, by initial stand age and remeasurement period, Georgia Piedmont and Mountains.

Table III.--Sample sizes (N), means ($\bar{X}$), and standard errors ($S_{\bar{x}}$) of net annual basal area (BA) growth for natural loblolly pine stands in the Georgia Piedmont and Mountains, by initial stand age, initial stand density, and survey cycle

Initial stand-density class BA/acre (ft^2)	Survey cycle	Initial stand-age class (years)														
		1-9			10-19			20-29			30-39			40+		
		N	$\bar{X}$	$S_{\bar{x}}$	N	$\bar{X}$	$S_{\bar{x}}$	N	$\bar{X}$	$S_{\bar{x}}$	N	$\bar{X}$	$S_{\bar{x}}$	N	$\bar{X}$	$S_{\bar{x}}$
			ft^2			ft^2			ft^2			ft^2			ft^2	
1-19	4	16	6.96	0.82	7	4.22	0.78	1	0.65	--	1	0.74	--	--	--	--
	5	7	2.83	.48	5	3.03	.99	3	1.76	0.11	--	--	--	--	--	--
20-39	4	6	5.69	1.79	11	5.21	.72	3	3.57	1.32	3	.91	0.26	1	1.62	--
	5	4	6.07	.21	14	5.21	1.01	8	2.24	.66	2	.87	.99	4	.58	0.90
40-59	4	8	9.33	1.24	18	5.85	.84	4	4.83	1.08	2	2.08	.10	--	--	--
	5	5	5.70	1.05	18	3.45	.51	5	1.45	1.01	2	1.01	.55	7	1.54	.59
60-79	4	2	4.59	1.25	13	3.76	.71	2	3.83	.28	3	3.30	.58	3	1.58	.66
	5	3	2.24	.33	19	3.00	.72	26	2.43	.33	4	3.36	1.10	2	1.97	2.07
80-99	4	--	--	--	9	5.09	.94	5	6.25	.66	2	3.59	.19	1	1.06	--
	5	3	-1.81	1.66	12	4.20	.45	14	2.37	.68	8	2.39	1.05	2	.74	.43
100-119	4	2	5.81	.21	9	5.37	1.06	2	1.50	1.67	2	3.72	.45	--	--	--
	5	2	4.06	5.94	12	2.70	.96	18	2.17	.42	4	.47	1.88	8	2.67	.69
120+	4	1	3.81	--	4	3.15	2.97	5	2.14	1.81	1	-.54	--	1	4.09	--
	5	2	-.38	2.58	17	1.36	.97	24	2.44	.53	16	1.88	.68	7	.38	1.34

Table IV.--Correlation coefficients (upper) and associated probability values[a] (lower) for initial inventory and stand age, net annual growth, and components of net annual growth, natural loblolly pine stands in the Georgia Piedmont and Mountains, fourth survey

N=148	Initial inventory	Net annual growth	Survivor growth	Ingrowth	Mortality	Initial stand age
Initial inventory						
Net annual growth	-0.2203 .0071					
Survivor growth	.2293 .0051	0.7847 .0001				
Ingrowth	-.4089 .0001	.3381 .0001	-0.1680 .0412			
Mortality	.6310 .0001	-.4052 .0001	.0831 .3154	-0.1822 .0267		
Initial stand age	.3199 .0001	-.4382 .0001	-.3309 .0001	-.3261 .0001	0.0238 .7737	

[a]Probability > | R | under Ho:RHo=0.

Table V.--Correlation coefficients (upper) and associated probability values[a] (lower) for initial inventory and stand age, net annual growth, and components of net annual growth, natural loblolly pine stands in the Georgia Piedmont and Mountains, fifth survey

N=287	Initial inventory	Net annual growth	Survivor growth	Ingrowth	Mortality	Initial stand age
Initial inventory						
Net annual growth	-0.2222 .0001					
Survivor growth	.2646 .0001	0.6937 .0001				
Ingrowth	-.2697 .0001	.3225 .0001	-0.0437 .4608			
Mortality	.4964 .0001	-.6882 .0001	-.0630 .2872	-0.0505 .3943		
Initial stand age	.2831 .0001	-.2093 .0004	-.2531 .0001	-.2147 .0002	-0.0452 .4457	

[a]Probability > | R | under Ho:RHo=0.

Coastal Plain of Georgia. Figures 11 and 12 delineate changes in the net growth of slash pine stands between the latest two remeasurement periods. The data that accompany these figures are provided in appendix A, tables 68 and 69. General declines of net stand growth between the fourth and fifth surveys are still evident despite stratifications by initial age and density. However, these declines are not nearly as dramatic as those found in loblolly and shortleaf stands in the Piedmont and Mountains. Additional data enabling further comparison of slash pine stands with loblolly and shortleaf stands are included in appendix A, tables 70-72.

THIRD, FOURTH, AND FIFTH SURVEY COMPARISONS

As mentioned above, the relationship between survivor growth and the initial inventory of survivor trees was reconstructed from increment core measurements for the period between 1956 and 1961. Initial survivor-tree inventories and survivor-tree growth were also calculated from the 1961-1972 and 1972-1982 remeasurement data to permit a standard basis of comparison for three periods in time. These comparisons are presented in figure 13 and approximate the performance of survivor growth when initial stand density is used as the control variable. The data used to produce these figures and their associated standard errors can be found in appendix A, tables 73-75. The initial stand density classes are underestimates because mortality trees were not taken into account. These figures are roughly comparable to the survivor-growth graphs in figures 9 and 11. Equivalent comparisons by initial age are not available because age was not regressed to the third survey.

Survivor growth of loblolly stands in the Georgia Piedmont and Mountains dropped about the same amount between the third and fourth remeasurement periods as between the fourth and fifth, regardless of initial stand density. Although the data are more erratic, natural shortleaf stands in the same area have followed a similar pattern. The survivor growth of Coastal Plain slash pine stands between 1956 and 1982 plunged about the same total amount as loblolly and shortleaf stands in the Piedmont and Mountains. However, it is obvious that most of the decline in the Coastal Plain stands occurred prior to 1972. Assuming the same factors are responsible for survivor-growth declines

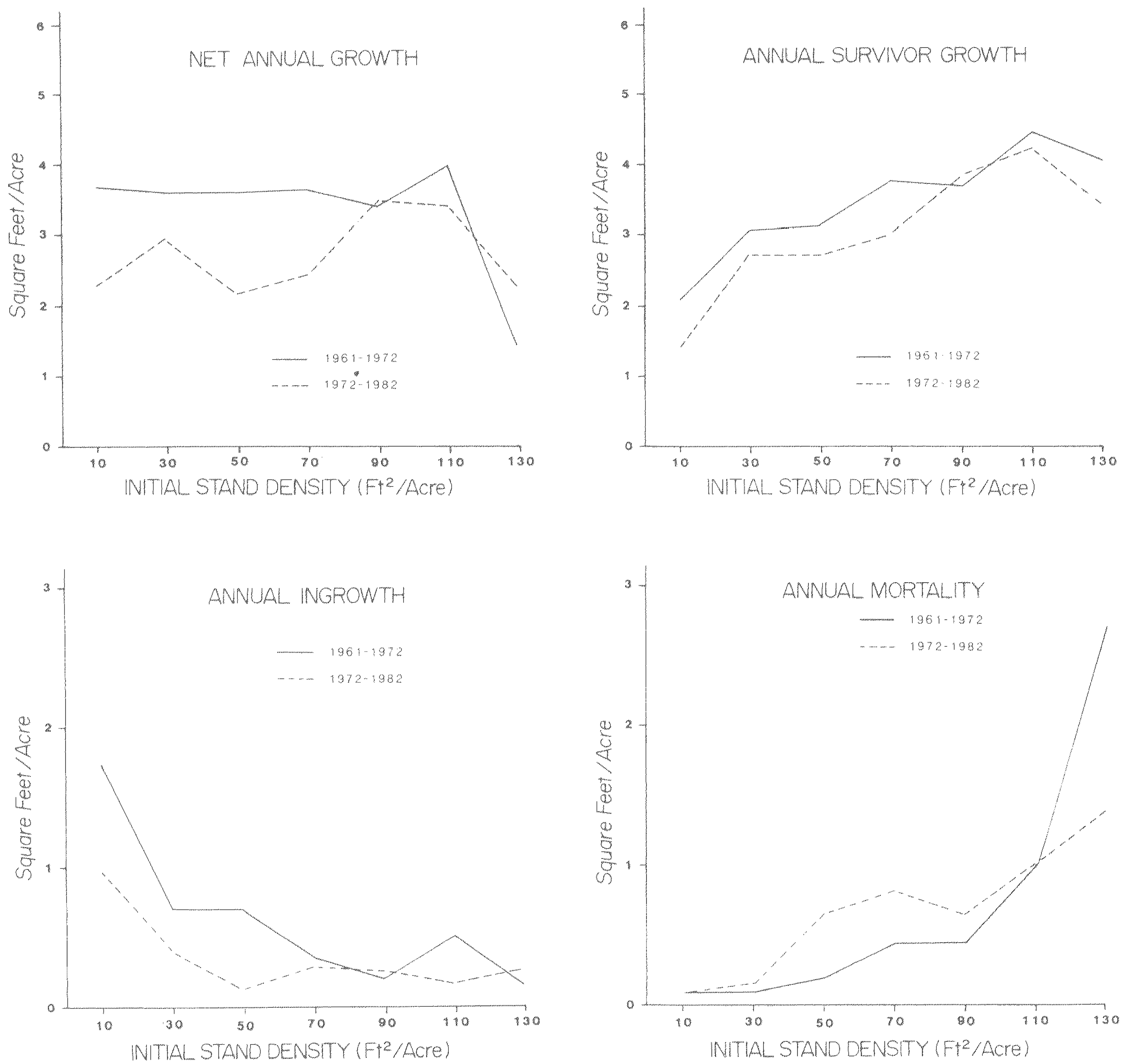


Figure 11.--Net annual basal area growth and the components of net annual growth for natural slash pine stands, by initial stand basal area and remeasurement period, Georgia Coastal Plain.

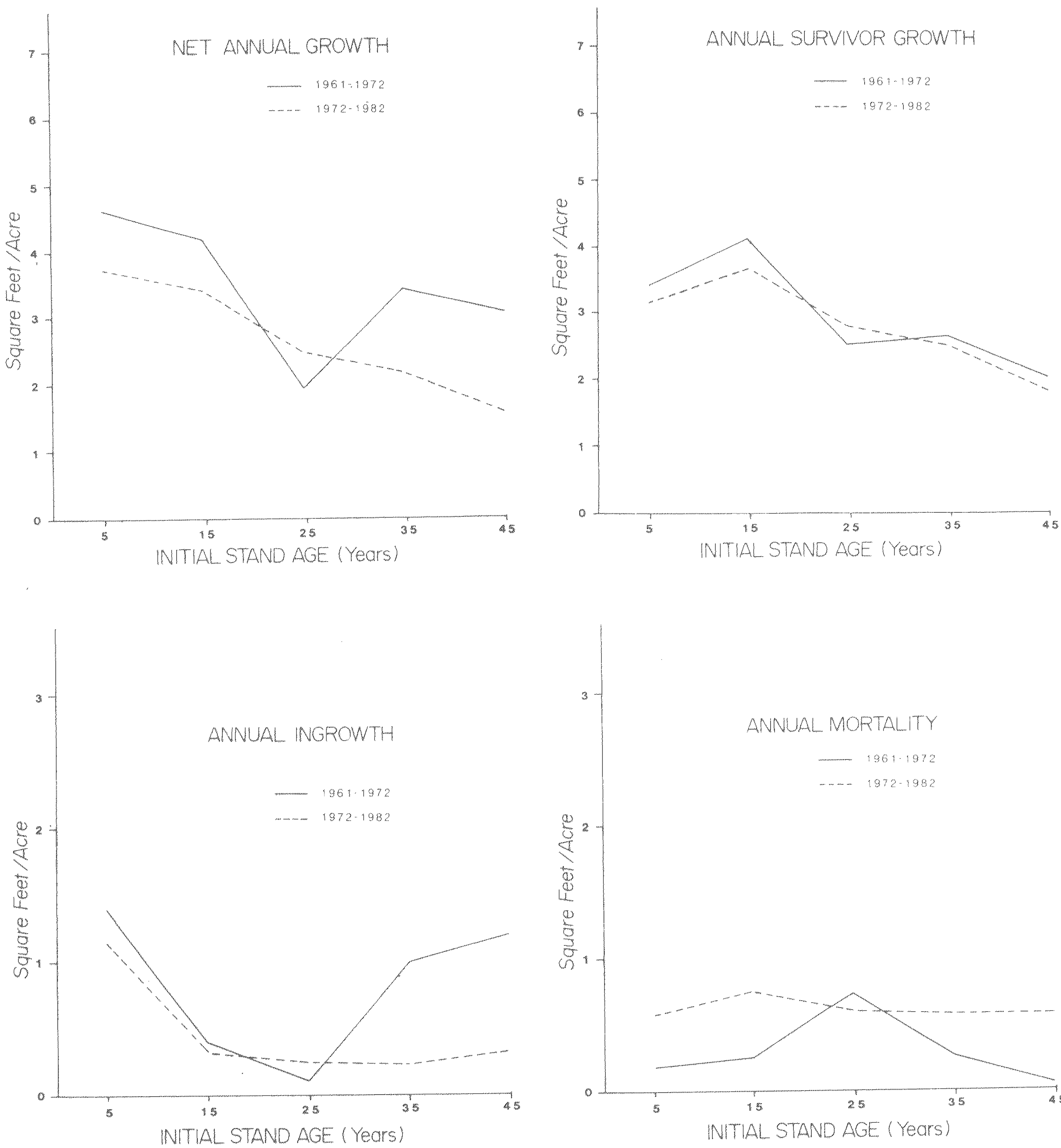
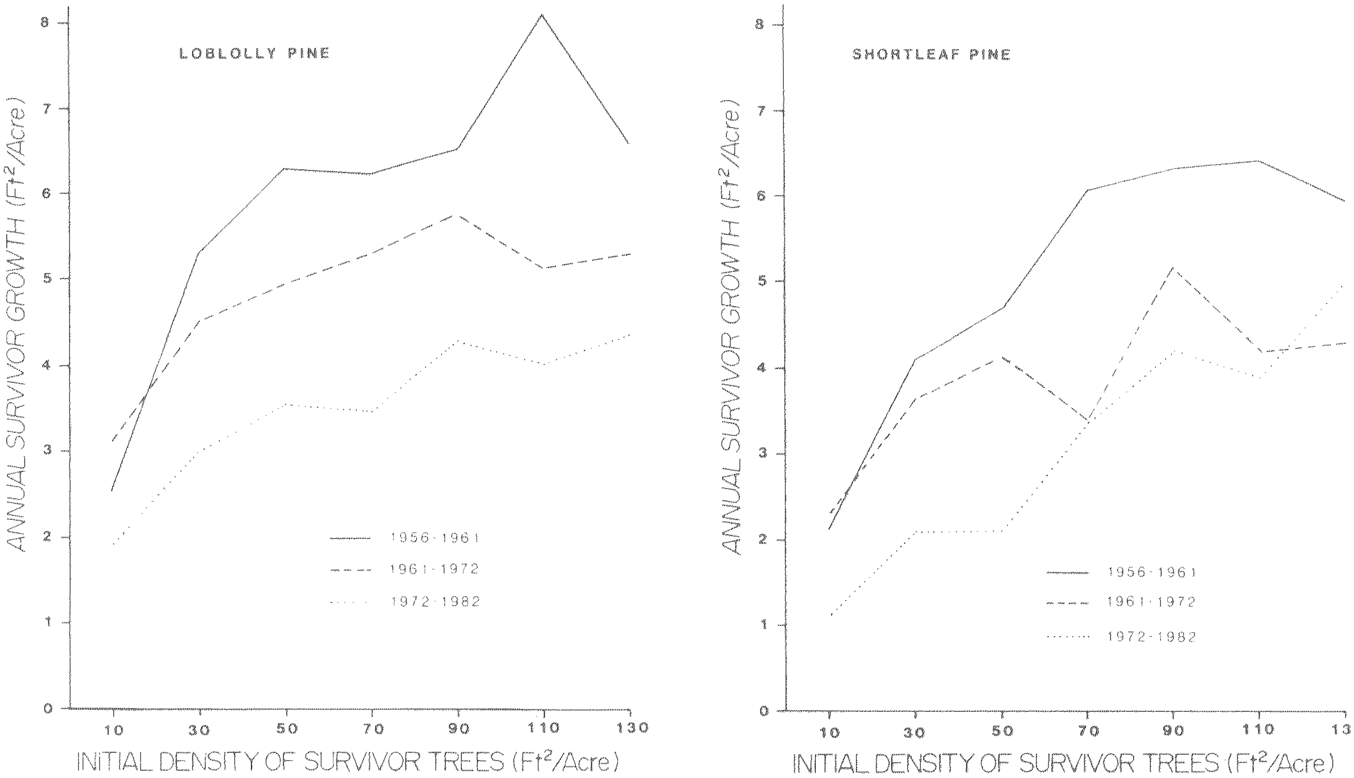


Figure 12.--Net annual basal area growth and the components of net annual growth for natural slash pine stands, by initial stand age and remeasurement period, Georgia Coastal Plain.

GEORGIA PIEDMONT & MOUNTAINS



GEORGIA COASTAL PLAIN

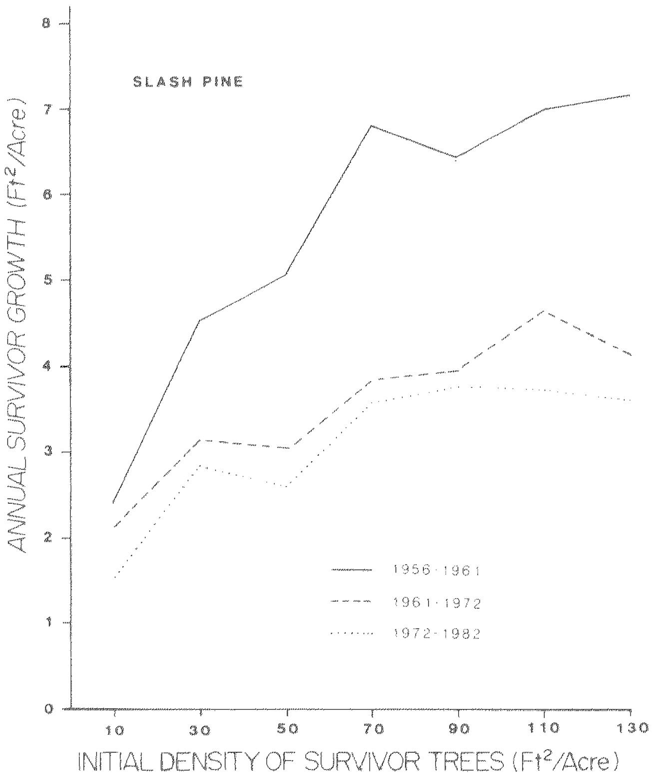


Figure 13.--Net annual basal area survivor growth by the initial basal area of survivor trees, by remeasurement period, forest type, and study area.

in both regions, it appears that Coastal Plain stands were impacted more suddenly and earlier than pine stands in the Piedmont and Mountains.

Although in some cases growth declines by initial density class are not statistically significant between the third and fourth and the fourth and fifth periods, differences between the third and fifth periods are significant at one standard error or higher probability in nearly all classes.

DISCUSSION

Net Growth

General declines in the net annual growth of the three forest types presented here are apparent when the latest remeasurement period is compared with the 1961-1972 period. During the last decade, stands in the Georgia Piedmont and Mountains have been affected more severely than stands in the Coastal Plain. Although regional increases in stand density and age can logically be expected to have a detrimental impact on net growth, they do not seem to explain the magnitude of decline observed. Regional changes in stand density, by themselves, do not account for the difference in growth between the two periods. Reductions are evident even when stands with the same initial densities are compared. Regional changes in stand age, by themselves, do not explain the declines in overall net growth. In most cases, reductions persist even when stands with the same initial ages are compared. The data sets are too small to effectively test the combined effects of age and density as presented in this analysis.

With some noted exceptions, survivor growth, ingrowth, and mortality have all been adversely affected and are contributing to the overall decline.

Survivor Growth

Of the three components, survivor growth has the most influence on net growth. Data indicate that survivor growth in the two Piedmont and Mountain forest types has been falling steadily during the latest 2 decades. Survivor growth in the Georgia Coastal Plain has dropped by a similar amount, but most of the reduction in these stands occurred sometime between 1961 and 1972. When stratified by initial stand density, results are reasonably consistent. Survivor growth declines are apparent for nearly every initial density class in all three forest types.

The picture becomes less distinct when age is held constant. Survivor growth in Coastal Plain slash pine stands is only slighty down. However, age comparisons were available only for the latest two remeasurement periods, and most of the Coastal Plain decline took place during the first of these periods. Survivor growth reductions in the Piedmont and Mountain loblolly stands are significant only in the younger age classes. Survivor growth in upland shortleaf stands does not seem to have suffered when viewed by stand age.

Ingrowth

Ingrowth is an important component of net growth only in sparsely stocked and young stands. In all cases, ingrowth has declined in the most sparsely stocked stands. In Coastal Plain slash pine stands, this decline also extends into medium-stocked stands. Likewise, ingrowth is down in all of the youngest age classes. In shortleaf pine stands, ingrowth reductions are apparent through the 35-year age class.

Mortality

Mortality is highly correlated with initial stand density. Increases have consistently occurred across the midrange of initial density classes in all three forest types. Mortality in the most densely and sparsely stocked stands has not increased noticeably, and in some cases has actually declined.

Mortality is not significantly correlated with stand age. FIA data indicate that annual mortality in basal area per acre is relatively constant regardless of stand age. Nonetheless, levels of mortality between the two periods, when examined by stand age, have increased in almost every age class for all three forest types during the latest period.

Additional Comments

The magnitude and timing of stand growth reductions in the two Georgia study areas are consistent with individual-tree growth slowdowns in the same regions. However, we caution that stand level findings for loblolly, shortleaf, and slash pine in the two Georgia study areas apply only to these forest types in these two study areas. Future analyses of other species and study areas may yield different results.

POSSIBLE CAUSES

What are the most likely causes for the reductions in pine tree and stand growth over the past 2 to 3 decades? Before the third survey results revealed reductions in the Coastal Plain and lengthened the period of change, possible explanations focused on factors that might explain growth changes in the Piedmont during the past decade. The growth decline is now known to be broader in scope and the identification of causal agents has been made more difficult.

The likelihood that any one agent could cause most of the decline throughout the entire region and across the timespan involved is small. There is, however, a set of agents that have the potential of accounting for some portion of the reductions.

ATMOSPHERIC DEPOSITION

One hypothesis is that atmospheric deposition of pollutants in various forms is adversely affecting the growth of trees across large areas in the Eastern United States. While popular articles have connected atmospheric pollution with slowing pine diameter growth, there is currently no scientific evidence either confirming or refuting this hypothesis for pine growth reductions in the Southeast. In Europe, visible symptoms such as defoliation and unexplained mortality are indicators of forest decline (Schutt and Cowling 1985). Forest conditions similar to those in Europe have also been documented in certain high-elevation forests in the Eastern United States (Bruck and Robarge 1984; Siccama and others 1982). In both areas, there is evidence of a link between forest decline and atmospheric deposition. Although the visible symptoms found in those areas are not apparent in pine forests in the Southeastern United States, there is some evidence that radial growth reductions occurred in Europe many years before visible symptoms were apparent (Schutt and Cowling 1985). Therefore, any possible link between atmospheric deposition and growth changes should be investigated. Atmospheric deposition, for example, may predispose forests to the effects of other factors that reduce tree growth.

AGING OF STANDS

Since diameter growth naturally declines as stands mature (Kramer and Kozlowski 1960), changes in age class distribution from one period to another could be a factor in explaining some portion of the growth decline. The current age structure of natural pine stands throughout the Southeast suggests a higher proportion of remeasured pines are in older stands now than in previous inventories. For example, nearly one-half of natural pine stands are currently between 20 and 40 years of age. Stands older than 40 years account for 32 percent, but stands 20 years or younger account for only 20 percent of the total. The FIA data set is less than ideal for quantifying the impact of changes in age structure. In the third survey, stand age was not measured. When stand age was added as a data-collection item, it was estimated in broad classes and many stands were assigned a mixed age. Thus, analyses of the true impact of changing age structure have been limited. Even though reductions in tree AARI and stand basal area growth are still apparent after accounting for shifts in age, changes in age structure may still account for part of the declines.

INCREASED STAND DENSITY

Over the past 2 to 3 decades, density of forest stands in the Southeast has been increasing most rapidly in the upland areas of the region. For example, in the Georgia Piedmont and Mountains, basal area of trees 1.0 inch d.b.h. and larger in natural pine stands increased by more than 50 percent between 1961 and 1982. As stand density increases, average growth of individual trees normally declines because of greater competition for moisture, nutrients, and light (Smith 1962). FIA remeasurement data from any survey period show that individual-tree growth rates decline with increasing stand density, but growth rates for trees or stands within any stand density class are lower in the more recent than in earlier Surveys. These data suggest increased stand density alone does not account for most part of the observed tree and stand growth reductions.

INCREASED HARDWOOD COMPETITION

Improved fire protection and the infrequent use of prescribed fire over the past few decades have favored the survival and development of hardwoods and shrubs in natural pine stands in the Southeast. Although most of this vegetation is in the understory of these stands, a significant amount is also accumulating in the midstory and overstory. This vegetation competes for nutrients and moisture; when these items are limiting, the growth of pine trees will suffer (Cain and Yaussy 1984; Carter and others 1984; Clason 1984). The hardwood component of pine stands is increasing in both the Piedmont and Coastal Plain of the Southeast. In the Georgia Piedmont and Mountains, hardwoods accounted for one-fourth of the basal area (1.0 inch d.b.h. and larger) in natural pine stands in 1982, compared with 17 percent in 1961. Number of hardwood stems per acre increased from 240 to 390 over the same period. The percentage increase was even greater in the Georgia Coastal Plain. The contribution of these changes in hardwood competition to the observed pine growth decline has been difficult to determine from available FIA data. This possibility, however, is worthy of additional study.

DROUGHT

Trends in rainfall and general drought indices show that moisture stresses were probably higher in the late 1970's and early 1980's than in the 1960's and early 1970's (Karl and others 1983). Piedmont areas were probably affected to a greater degree than the Coastal Plain. The recent growth declines in the Piedmont can be more readily attributed to drought than the declines indicated by the third survey data. Available data, however, do not permit a quantitative assessment of the impact. We do not know all the specific effects of moisture stresses on forest growth, and we do not know what the stress values are at specific locations. Another problem is that Forest Survey data show average rates of growth over a period of several years rather than for individual years. Thus, it is difficult to correlate annual or monthly rainfall and drought index values with periodic growth rates for large areas. While drought may account for a significant portion of the most recent growth reductions in the Piedmont, the results indicated by the third survey data in both the Coastal Plain and Piedmont do not correlate with recurring drought periods. Studies currently underway (see next section) should shed additional light on the impact of drought on the growth reduction.

LOWER WATER TABLES

A potential causal agent on the Coastal Plain is a drop in water tables.

Moisture stress may well have increased in many Coastal Plain areas as a result of surface drainage and increased groundwater use, especially for irrigation. The extent to which this factor may have influenced tree growth, if at all, is not known. It is reasonable to postulate, however, that extended periods of drought combined with lower water tables would increase moisture stress.

LOSS OF OLD-FIELD SITES

An important potential factor in pine growth reduction, particularly in the Piedmont, is the land use history of many of the pine stands. A huge area of cropland was abandoned between 1945 and 1965. This area was concentrated in the Piedmont (Boyce and others 1975). Natural pine stands developing on these old fields may have benefited from previous cultivation and residual fertilizers and definitely benefited from the lack of competing woody vegetation. Over the past 20 years, relatively little farmland has been abandoned and the majority of new natural stands have been established on cutover forest land. Pines in these stands do not have the initial growth advantage of trees in old fields.

On the other hand, many of the abandoned fields were badly eroded. Pine tree growth was initially quite good on these areas but suffered as the competition for water, nutrients, light, and space intensified.

DISEASES

The impact of diseases such as fusiform rust, littleleaf disease, and annosus root rot on tree diameter growth is not precisely known. Less is known about broader scale effects on the growth of a species over a large area. We do know that the incidence of these diseases is high in some areas (Anderson and Mistretta 1982). Fusiform-rust infection of loblolly and slash pines is especially high and has increased over the past 2 to 3 decades (Dinus and Schmidt 1977). The occurrence of littleleaf disease on shortleaf pine is well documented, but it is also quite common on loblolly pine, especially on poor, eroded sites (Campbell and Copeland 1954).

Since some species exhibiting growth reductions are not affected by all these diseases, no one disease can account for the observed growth declines. Together, however, diseases could be causing some portion of the growth decline of several species. In some cases the presence of a disease may indicate a stressed condition resulting from one or a combination of other causal agents.

COMBINED EFFECTS

Given the scope of the reduction, it seems improbable that any one agent is the major driving force behind the changes. Several of the agents listed, and possibly others, have probably contributed to the decline in pine growth. Efforts to ascertain how much of the reduction is attributable to any one cause will be extremely difficult because of the interrelationships among them.

Obviously a great deal remains to be learned about the pine growth reductions and causes. A possibility to consider in future research is centered on the definition of normal growth. Regional tree growth rates may be cyclic. Since a regional average has never been established, the argument that third survey growth rates were abnormally high is just as valid as the argument that fifth survey rates are low.

FURTHER STUDY AND ANALYSES

Considerable progress has been made in recovering old FIA data and in preliminary analyses to define the geographic scope and timing of AARI declines in the Southeast. However, a great deal of research must be done before any conclusive statement can be made about the causes of this phenomenon. FIA can continue to contribute to a better understanding of the extent and severity of the regional growth decline.

During fiscal year 1985 four new efforts were initiated:

- Recovery of third survey data in all regions of the Southeast.

- Identification of permanent FIA plots in the Southeast that have been continually remeasured since the third survey. Trees on undisturbed plots will be remeasured and cores will be extracted to provide an independent verification of the periodic diameter measurements and to help explain the pattern of growth over the past 30 to 40 years.

- Development of a computerized drought index more appropriate to forest conditions than the Palmer drought index developed for agricultural purposes. A forest drought index, in combination with tree cores from undisturbed plots, will permit testing of moisture stress effects.

- Acquisition of old aerial photographs of sample locations to identify and separate stands established on old fields prior to the third survey. Growth trends for old-field pine can then be compared with those from other conditions to measure the possible influence of changes in the relative abundance of these stands.

Finally, there are additional steps that can be taken to provide additional data and insight:

- Reformat all FIA data to make them more suitable for use with standard statistical programs to enhance statistical testing and investigation into possible causal agents.

- Conduct more elaborate analyses of stand structure to obtain better measures of the combined effects of age, density, hardwood competition, and other causes. Such studies will include analyses of variance and fitting of data from different remeasurement periods to growth and yield models.

- Explore the possibility of combining data sets. Screening by several combinations of variables rapidly dilutes the resulting data set. Differences in the timing of inventories limit the feasibility of combining data sets across similar study areas. Growth trends should be evaluated for similar study areas and the data sets combined whenever possible.

- Identify long-term data sets for the Southeast Coastal Plain that show average water table depths and determine if those data aid in explaining the growth reductions in this region.

- Achieve and maintain a 5-year remeasurement period to monitor future growth trends and provide more timely forest resource information for the Southeast.

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Appendix

APPENDIX A: DETAILED TABLES

Table 1.--Changes in net annual growth of yellow pine growing stock on timberland in the Southeast, by State, by physiographic region, and remeasurement periods

State	Physiographic region	Remeasurement period	Net annual growth		
			From	To	Change
			- - Million cubic feet - -		
Florida	Coastal Plain	1970-1980	371	544	+173
Georgia	Coastal Plain	1971-1981	456	590	+134
	Piedmont & Mts.	1972-1982	672	565	-107
	Total	--	1,128	1,155	+27
South Carolina	Coastal Plain	1978-1983	357	308	-49
	Piedmont & Mts.	1977-1983	243	127	-116
	Total	--	600	435	-165
North Carolina	Coastal Plain	1973-1983	262	310	+48
	Piedmont & Mts.	1974-1984	228	149	-79
	Total	--	490	459	-31
Virginia	Coastal Plain	1976-1985	102	100	-2
	Piedmont & Mts.	1966-1977	76	119	+43
	Total	--	178	219	+41
Southeast	Coastal Plain	1970-1985	1,548	1,852	+304
	Piedmont & Mts.	1966-1984	1,219	960	-259
	Total	--	2,767	2,812	+45

Table 2.--Changes in net annual growth of yellow pine growing stock on timberland in the Southeast, by ownership class, by physiographic region, over the most recent remeasurement periods[a]

Ownership class	Physiographic region	Net annual growth		
		From	To	Change
		- - Million cubic feet - -		
Public	Coastal Plain	146	177	+31
	Piedmont & Mountains	89	70	-19
	Total	235	247	+12
Forest industry (includes leased)	Coastal Plain	446	683	+237
	Piedmont & Mountains	176	182	+6
	Total	622	865	+243
Other private	Coastal Plain	956	992	+36
	Piedmont & Mountains	954	708	-246
	Total	1,910	1,700	-210
All owners	Coastal Plain	1,548	1,852	+304
	Piedmont & Mountains	1,219	960	-259
	Total	2,767	2,812	+45

[a]See table 1 for remeasurement periods.

Table 3.--Changes in net annual growth of yellow pine growing stock on timberland in the Southeast, by species, by physiographic region, over the most recent remeasurement periods[a]

Species	Physiographic region	Net annual growth		
		From	To	Change
		- - Million cubic feet - -		
Loblolly pine	Coastal Plain	615	719	+104
	Piedmont & Mountains	684	567	-117
	Total	1,299	1,286	-13
Slash pine	Coastal Plain	568	846	+278
	Piedmont & Mountains	56	36	-20
	Total	624	882	+258
Shortleaf pine	Coastal Plain	19	16	-3
	Piedmont & Mountains	273	156	-117
	Total	292	172	-120
Other yellow pines	Coastal Plain	346	271	-75
	Piedmont & Mountains	206	201	-5
	Total	552	472	-80
All species	Coastal Plain	1,548	1,852	+304
	Piedmont & Mountains	1,219	960	-259
	Total	2,767	2,812	+45

[a]See table 1 for remeasurement periods.

Table 4.--Changes in annual removals of yellow pine growing stock on timberland in the Southeast, by State, by physiographic region, over the most recent remeasurement periods[a]

State	Physiographic region	Annual removals		
		From	To	Change
		- - Million cubic feet - -		
Florida	Coastal Plain	260	427	+167
Georgia	Coastal Plain	399	544	+145
	Piedmont & Mountains	379	535	+156
	Total	778	1,079	+301
South Carolina	Coastal Plain	227	271	+44
	Piedmont & Mountains	127	168	+41
	Total	354	439	+85
North Carolina	Coastal Plain	267	265	-2
	Piedmont & Mountains	147	139	-8
	Total	414	404	-10
Virginia	Coastal Plain	110	114	+4
	Piedmont & Mountains	80	86	+6
	Total	190	200	+10
Southeast	Coastal Plain	1,263	1,621	+358
	Piedmont & Mountains	733	928	+195
	Total	1,996	2,549	+553

[a]See table 1 for remeasurement periods.

Table 5.--Changes in annual removals of yellow pine growing stock on timberland in the Southeast, by ownership class, by physiographic region, over the most recent remeasurement periods[a]

Ownership class	Physiographic region	Annual removals		
		From	To	Change
		- - *Million cubic feet* - -		
Public	Coastal Plain	79	93	+14
	Piedmont & Mountains	58	75	+17
	Total	137	168	+31
Forest industry (includes leased)	Coastal Plain	460	575	+115
	Piedmont & Mountains	125	200	+75
	Total	585	775	+190
Other private	Coastal Plain	724	953	+229
	Piedmont & Mountains	550	653	+103
	Total	1,274	1,606	+332
All owners	Coastal Plain	1,263	1,621	+358
	Piedmont & Mountains	733	928	+195
	Total	1,996	2,549	+553

[a]See table 1 for remeasurement periods.

Table 6.--Changes in annual removals of yellow pine growing stock on timberland in the Southeast, by species, by physiographic region, over the most recent remeasurement periods[a]

Species	Physiographic region	Annual removals		
		From	To	Change
		- - Million cubic feet - -		
Loblolly pine	Coastal Plain	522	608	+86
	Piedmont & Mountains	360	530	+170
	Total	882	1,138	+256
Slash pine	Coastal Plain	344	623	+279
	Piedmont & Mountains	6	40	+34
	Total	350	663	+313
Shortleaf pine	Coastal Plain	19	23	+4
	Piedmont & Mountains	252	241	-11
	Total	271	264	-7
Other yellow pine	Coastal Plain	378	367	-11
	Piedmont & Mountains	115	117	+2
	Total	493	484	-9
All species	Coastal Plain	1,263	1,621	+358
	Piedmont & Mountains	733	928	+195
	Total	1,996	2,549	+553

[a]See table 1 for remeasurement periods.

Table 7.--Changes in inventory volume of yellow pine growing stock on timberland in the Southeast, by State, by physiographic region, over the most recent remeasurement periods[a]

State	Physiographic region	Inventory volume		
		From	To	Change
		- - - Million cubic feet - - -		
Florida	Coastal Plain	5,270	6,324	+1,054
Georgia	Coastal Plain	5,962	6,538	+576
	Piedmont & Mountains	8,202	8,313	+111
	Total	14,164	14,851	+687
South Carolina	Coastal Plain	5,066	5,276	+210
	Piedmont & Mountains	3,288	3,057	-231
	Total	8,354	8,333	-21
North Carolina	Coastal Plain	5,406	5,758	+352
	Piedmont & Mountains	4,073	4,130	+57
	Total	9,479	9,888	+409
Virginia	Coastal Plain	2,341	2,275	-66
	Piedmont & Mountains	2,102	2,589	+487
	Total	4,443	4,864	+421
Southeast	Coastal Plain	24,045	26,171	+2,126
	Piedmont & Mountains	17,665	18,089	+424
	Total	41,710	44,260	+2,550

[a]See table 1 for remeasurement periods.

Table 8.--Changes in inventory volume of yellow pine growing stock on timberland in the Southeast, by ownership class, by physiographic region, over the most recent remeasurement periods[a]

Ownership class	Physiographic region	Inventory volume		
		From	To	Change
		- - Million cubic feet - -		
Public	Coastal Plain	2,560	3,168	+608
	Piedmont & Mountains	1,816	1,935	+119
	Total	4,376	5,103	+727
Forest industry (includes leased)	Coastal Plain	5,843	6,986	+1,143
	Piedmont & Mountains	2,161	2,381	+220
	Total	8,004	9,367	+1,363
Other private	Coastal Plain	15,642	16,017	+375
	Piedmont & Mountains	13,688	13,773	+85
	Total	29,330	29,790	+460
All owners	Coastal Plain	24,045	26,171	+2,126
	Piedmont & Mountains	17,665	18,089	+424
	Total	41,710	44,260	+2,550

[a]See table 1 for remeasurement periods.

Table 9.--Changes in inventory volume of yellow pine growing stock on timberland in the Southeast, by species, by physiographic region, over the most recent remeasurement periods[a]

Species	Physiographic region	Inventory volume		
		From	To	Change
		- - - Million cubic feet - - -		
Loblolly pine	Coastal Plain	10,569	11,631	+1,062
	Piedmont & Mountains	8,674	9,171	+497
	Total	19,243	20,802	1,559
Slash pine	Coastal Plain	6,872	8,476	+1,604
	Piedmont & Mountains	341	320	-21
	Total	7,213	8,796	+1,583
Shortleaf pine	Coastal Plain	450	394	-56
	Piedmont & Mountains	5,018	4,189	-829
	Total	5,468	4,583	-885
Other yellow pines	Coastal Plain	6,154	5,670	-484
	Piedmont & Mountains	3,632	4,409	+777
	Total	9,786	10,079	+293
All species	Coastal Plain	24,045	26,171	+2,126
	Piedmont & Mountains	17,665	18,089	+424
	Total	41,710	44,260	+2,550

[a]See table 1 for remeasurement periods.

Table 10.--Stand-age distribution of pine[a] and oak-pine stands in the Southeast, by broad ownership class, as of the most recent Forest Surveys[b]

Stand-age	Broad ownership class			Total all ownerships
	Public	Forest industry	Other private	
	Thousand acres			
00-10	515	3,685	3,902	8,102
11-20	599	3,372	4,358	8,329
21-30	464	2,433	6,320	9,217
31-40	655	1,245	5,902	7,802
41-50	892	627	3,897	5,416
51+	1,290	619	3,876	5,785
Total	4,415	11,981	28,255	44,651

[a]Includes all softwood types.

[b]See table 1.

Table 11.--Changes in area of timberland in the Southeast with pine[a] and oak-pine forest types, by State, by physiographic region, over the most recent remeasurement periods[b]

State	Physiographic region	Area of pine and oak-pine type		
		From	To	Change
		Thousand acres		
Florida	Coastal Plain	9,568	9,194	-374
Georgia	Coastal Plain	6,945	6,328	-617
	Piedmont & Mountains	9,185	8,070	-1,115
	Total	16,130	14,398	-1,732
South Carolina	Coastal Plain	4,360	4,280	-80
	Piedmont & Mountains	2,929	2,895	-34
	Total	7,289	7,175	-114
North Carolina	Coastal Plain	5,659	5,184	-475
	Piedmont & Mountains	3,729	3,438	-291
	Total	9,388	8,622	-766
Virginia	Coastal Plain	2,024	1,917	-107
	Piedmont & Mountains	3,498	3,345	-153
	Total	5,522	5,262	-260
Southeast	Coastal Plain	28,556	26,903	-1,653
	Piedmont & Mountains	19,341	17,748	-1,593
	Total	47,897	44,651	-3,246

[a]Includes all softwood types.

[b]See table 1 for remeasurement periods.

Table 12.--Changes in area of timberland in the Southeast with pine[a] and oak-pine forest types, by ownership class, by physiographic region, over the most recent remeasurement periods[b]

Ownership class	Physiographic region	Area of pine and oak-pine type		
		From	To	Change
		- - - Thousand acres - - -		
Public	Coastal Plain	2,934	2,907	-27
	Piedmont & Mountains	1,432	1,508	+76
	Total	4,366	4,415	+49
Forest industry (includes leased)	Coastal Plain	9,059	9,047	-12
	Piedmont & Mountains	2,519	2,934	+415
	Total	11,578	11,981	+403
Other private	Coastal Plain	16,563	14,949	-1,614
	Piedmont & Mountains	15,390	13,306	-2,084
	Total	31,953	28,255	-3,698
All owners	Coastal Plain	28,556	26,903	-1,653
	Piedmont & Mountains	19,341	17,748	-1,593
	Total	47,897	44,651	-3,246

[a]Includes all softwood types.

[b]See table 1 for remeasurement periods.

Table 13.--Changes in area of timberland in the Southeast with pine[a] and oak-pine forest types, by type, by physiographic region, over the most recent remeasurement periods[b]

Type	Physiographic region	Area of pine and oak-pine type		
		From	To	Change
		- - - Thousand acres - - -		
Loblolly pine	Coastal Plain	6,628	7,040	+412
	Piedmont & Mountains	6,823	6,825	+2
	Total	13,451	13,865	+414
Slash pine	Coastal Plain	9,940	9,670	-270
	Piedmont & Mountains	498	386	-112
	Total	10,438	10,056	-382
Shortleaf pine	Coastal Plain	184	148	-36
	Piedmont & Mountains	3,005	2,238	-767
	Total	3,189	2,386	-803
Oak-pine	Coastal Plain	5,921	5,297	-624
	Piedmont & Mountains	5,316	4,910	-406
	Total	11,237	10,207	-1,030
Other	Coastal Plain	5,883	4,748	-1,135
	Piedmont & Mountains	3,699	3,389	-310
	Total	9,582	8,137	-1,445
All types	Coastal Plain	28,556	26,903	-1,653
	Piedmont & Mountains	19,341	17,748	-1,593
	Total	47,897	44,651	-3,246

[a]Includes all softwood types.

[b]See table 1 for remeasurement periods.

Table 14.--Change in numbers of yellow pine trees on timberland in Florida, Georgia, North Carolina, South Carolina,[a] and coastal Virginia between the fourth and fifth surveys

Ownership	D.b.h.	Million trees	Percent
Forest industry	2	-536	-29
	4	+92	+8
	6	+314	+60
	8	+144	+59
	10	+25	+20
	12+	-3	-3
Other private	2	-2,200	-47
	4	-1,031	-38
	6	-409	-27
	8	-20	-2
	10	+37	+9
	12+	+72	+16
All owners[b]	2	-2,758	-40
	4	-961	-23
	6	-95	-4
	8	+123	+11
	10	+66	+11
	12+	+90	+14

[a]Changes for South Carolina are between the fourth Survey and the Interim Survey.

[b]Includes public lands.

Table 15.--Changes in annual mortality of yellow pine growing stock on timberland in the Southeast, by State, by physiographic region, over the most recent remeasurement periods[a]

State	Physiographic region	Annual mortality		
		From	To	Change
		- - Million cubic feet - -		
Florida	Coastal Plain	24	52	+28
Georgia	Coastal Plain	30	62	+32
	Piedmont & Mountains	52	142	+90
	Total	82	204	+122
South Carolina	Coastal Plain	39	32	-7
	Piedmont & Mountains	29	46	+17
	Total	68	78	+10
North Carolina	Coastal Plain	37	50	+13
	Piedmont & Mountains	37	58	+21
	Total	74	108	+34
Virginia	Coastal Plain	25	30	+5
	Piedmont & Mountains	13	35	+22
	Total	38	65	+27
Southeast	Coastal Plain	155	226	+71
	Piedmont & Mountains	131	281	+150
	Total	286	507	+221

[a]See table 1 for remeasurement periods.

Table 16.--Changes in annual mortality of yellow pine growing stock on timberland in the Southeast, by ownership class, by physiographic region, over the most recent remeasurement periods[a]

Ownership class	Physiographic region	Annual mortality		
		From	To	Change
		- - Million cubic feet - -		
Public	Coastal Plain	15	25	+10
	Piedmont & Mountains	13	33	+20
	Total	28	58	+30
Forest industry (includes leased)	Coastal Plain	33	48	+15
	Piedmont & Mountains	17	32	+15
	Total	50	80	+30
Other private	Coastal Plain	107	153	+46
	Piedmont & Mountains	101	216	+115
	Total	208	369	+161
All owners	Coastal Plain	155	226	+71
	Piedmont & Mountains	131	281	+150
	Total	286	507	+221

[a]See table 1 for remeasurement period.

Table 17.--Changes in annual mortality of yellow pine growing stock on timberland in the Southeast, by species, by physiographic region, over the most recent remeasurement periods[a]

Species	Physiographic region	Annual mortality		
		From	To	Change
		- - Million cubic feet - -		
Loblolly pine	Coastal Plain	77	102	+25
	Piedmont & Mountains	47	114	+67
	Total	124	216	+92
Slash pine	Coastal Plain	37	71	+34
	Piedmont & Mountains	2	9	+7
	Total	39	80	+41
Shortleaf pine	Coastal Plain	5	6	+1
	Piedmont & Mountains	58	101	+43
	Total	63	107	+44
Other yellow pine	Coastal Plain	36	47	+11
	Piedmont & Mountains	24	57	+33
	Total	60	104	+44
All species	Coastal Plain	155	226	+71
	Piedmont & Mountains	131	281	+150
	Total	286	507	+221

[a]See table 1 for remeasurement periods.

Table 18.--Average annual radial increment of loblolly pine growing in natural stands, by initial diameter class and survey period, Georgia Piedmont and Mountains

Initial diameter class (inches)	Survey period 1961-1972			Survey period 1972-1982		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	895	0.079	0.0022	695	0.050	0.0018
3.0-4.9	491	.094	.0029	464	.073	.0027
5.0-6.9	487	.114	.0031	420	.089	.0028
7.0-8.9	462	.120	.0032	470	.098	.0025
9.0-10.9	426	.122	.0028	421	.107	.0026
11.0-12.9	293	.116	.0033	344	.101	.0028
13.0-14.9	172	.114	.0044	237	.102	.0035
15.0-16.9	103	.100	.0050	134	.096	.0043
17.0-18.9	56	.098	.0089	65	.091	.0066
19.0 and larger	45	.095	.0078	50	.091	.0079

Table 19.--Average annual radial increment of shortleaf pine growing in natural stands, by initial diameter class and survey period, Georgia Piedmont and Mountains

Initial diameter class (inches)	Survey period 1961-1972			Survey period 1972-1982		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	677	0.061	0.0019	329	0.039	0.0018
3.0-4.9	304	.071	.0031	246	.045	.0027
5.0-6.9	363	.080	.0027	255	.058	.0028
7.0-8.9	295	.082	.0030	248	.053	.0023
9.0-10.9	233	.086	.0029	196	.059	.0026
11.0-12.9	131	.074	.0034	123	.063	.0033
13.0-14.9	61	.086	.0049	44	.059	.0059
15.0-16.9	25	.067	.0078	24	.057	.0072
17.0-18.9	9	.076	.0123	7	.054	.0040
19.0 and larger	4	.069	.0086	8	.056	.0075

Table 20.--Average annual radial increment of slash pine growing in natural stands, by initial diameter class and survey period, Georgia Coastal Plain

Initial diameter class (inches)	Survey period 1961-1972 Sample trees			1972-1982 Sample trees		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	691	0.063	0.0021	628	0.046	0.0017
3.0-4.9	347	.070	.0032	493	.057	.0023
5.0-6.9	421	.086	.0027	320	.084	.0032
7.0-8.9	439	.092	.0025	339	.090	.0031
9.0-10.9	351	.094	.0025	247	.083	.0030
11.0-12.9	218	.090	.0033	174	.081	.0037
13.0-14.9	125	.089	.0046	87	.079	.0052
15.0-16.9	62	.075	.0058	57	.082	.0056
17.0-18.9	22	.092	.0096	22	.087	.0111
19.0 and larger	29	.102	.0172	9	.083	.0206

Table 21.--Average annual radial increment of longleaf pine growing in natural stands, by initial diameter class and survey period, Georgia Coastal Plain

Initial diameter class (inches)	Survey period					
	1961-1972			1972-1982		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	100	0.094	0.0057	42	0.054	0.0066
3.0-4.9	44	.113	.0090	44	.094	.0098
5.0-6.9	85	.134	.0054	55	.105	.0076
7.0-8.9	122	.110	.0047	77	.088	.0045
9.0-10.9	139	.099	.0038	109	.085	.0038
11.0-12.9	79	.079	.0048	85	.074	.0040
13.0-14.9	49	.083	.0056	53	.077	.0045
15.0-16.9	17	.064	.0069	19	.074	.0055
17.0-18.9	7	.087	.0336	4	.091	.0134
19.0 and larger	12	.066	.0058	6	.065	.0086

Table 22.--Average annual radial increment of loblolly pine growing in natural stands, by initial diameter class and survey period, Georgia Coastal Plain

Initial diameter class (inches)	Survey period					
	1961-1972			1972-1982		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	124	0.103	0.0078	90	0.076	0.0066
3.0-4.9	76	.135	.0107	81	.092	.0073
5.0-6.9	76	.149	.0123	57	.133	.0106
7.0-8.9	67	.134	.0089	78	.133	.0089
9.0-10.9	69	.156	.0092	99	.131	.0068
11.0-12.9	72	.139	.0070	66	.132	.0095
13.0-14.9	40	.127	.0106	58	.121	.0086
15.0-16.9	39	.132	.0102	38	.133	.0112
17.0-18.9	22	.100	.0103	25	.128	.0094
19.0 and larger	30	.104	.0150	30	.106	.0093

Table 23.--Average annual radial increment of slash pine growing in planted stands, by initial diameter class and survey period, Georgia Coastal Plain

Initial diameter class (inches)	Survey period					
	1961-1972			1972-1982		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	76	0.156	0.0102	401	0.136	0.0037
3.0-4.9	17	.116	.0118	277	.114	.0036
5.0-6.9	43	.119	.0092	191	.106	.0033
7.0-8.9	32	.105	.0057	102	.130	.0059
9.0-10.9	15	.117	.0145	33	.110	.0097
11.0-12.9	12	.095	.0137	14	.116	.0210
13.0-14.9	--	--	--	--	--	--
15.0-16.9	--	--	--	--	--	--
17.0-18.9	--	--	--	--	--	--
19.0 and larger	--	--	--	--	--	--

Table 24.--Average annual radial increment of loblolly pine growing in natural stands, by initial diameter class and survey period, South Carolina Piedmont

Initial diameter class (inches)	Survey period 1958-1968 Sample trees	1958-1968 Average radial growth	1958-1968 One standard error	1968-1978 Sample trees	1968-1978 Average radial growth	1968-1978 One standard error	1978-1983 Sample trees	1978-1983 Average radial growth	1978-1983 One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	513	0.053	0.0025	258	0.072	0.0043	316	0.051	0.0031
3.0-4.9	193	.066	.0036	181	.096	.0060	155	.064	.0050
5.0-6.9	159	.091	.0055	115	.111	.0066	143	.076	.0048
7.0-8.9	141	.111	.0050	132	.109	.0060	149	.086	.0047
9.0-10.9	102	.110	.0067	131	.105	.0040	175	.094	.0039
11.0-12.9	87	.112	.0068	83	.110	.0060	165	.077	.0036
13.0-14.9	64	.096	.0056	69	.110	.0081	107	.085	.0052
15.0-16.9	33	.107	.0083	63	.089	.0060	64	.077	.0060
17.0-18.9	18	.094	.0133	21	.103	.0111	59	.088	.0076
19.0 and larger	26	.106	.0111	20	.126	.0116	39	.091	.0076

Table 25.--Average annual radial increment of shortleaf pine growing in natural stands, by initial diameter class and survey period, South Carolina Piedmont

Initial diameter class (inches)	Survey period								
	1958-1968			1968-1978			1978-1983		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	438	0.055	0.0024	328	0.056	0.0029	299	0.033	0.0021
3.0-4.9	203	.068	.0035	227	.058	.0032	149	.036	.0032
5.0-6.9	167	.067	.0037	142	.068	.0038	126	.045	.0033
7.0-8.9	147	.069	.0046	141	.069	.0037	143	.043	.0035
9.0-10.9	102	.060	.0038	70	.063	.0051	104	.048	.0032
11.0-12.9	45	.072	.0075	43	.064	.0074	77	.049	.0049
13.0-14.9	25	.050	.0048	18	.067	.0100	26	.048	.0058
15.0-16.9	15	.079	.0131	7	.057	.0131	18	.063	.0107
17.0-18.9	5	.063	.0165	--	--	--	7	.053	.0075
19.0 and larger	4	.036	.0066	--	--	--	--	--	--

Table 26.--Average annual radial increment of loblolly pine growing in planted stands, by initial diameter class and survey period, South Carolina Piedmont

Initial diameter class (inches)	Survey period: 1958-1968			1968-1978			1978-1983		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	12	0.150	0.0395	23	0.160	0.0166	59	0.138	0.0123
3.0-4.9	11	.101	.0229	58	.151	.0100	61	.118	.0103
5.0-6.9	12	.146	.0216	31	.149	.0132	86	.114	.0080
7.0-8.9	12	.110	.0135	10	.109	.0172	89	.105	.0073
9.0-10.9	--	--	--	19	.139	.0138	82	.112	.0058
11.0-12.9	--	--	--	5	.191	.0360	33	.122	.0091
13.0-14.9	--	--	--	2	.146	.0552	12	.109	.0077
15.0-16.9	--	--	--	--	--	--	--	--	--
17.0-18.9	--	--	--	--	--	--	--	--	--
19.0 and larger	--	--	--	--	--	--	--	--	--

Table 27.--Average annual radial increment of loblolly pine growing in natural stands, by initial diameter class and survey period, South Carolina Coastal Plain

Initial diameter class (inches)	Survey period								
	1958-1968			1968-1978			1978-1983		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	594	0.077	0.0028	485	0.092	0.0035	594	0.091	0.0040
3.0-4.9	326	.092	.0036	303	.105	.0044	309	.077	.0044
5.0-6.9	316	.118	.0047	262	.117	.0050	315	.106	.0049
7.0-8.9	305	.140	.0044	313	.122	.0041	345	.108	.0040
9.0-10.9	296	.143	.0046	279	.137	.0045	398	.116	.0037
11.0-12.9	275	.122	.0037	265	.124	.0039	424	.129	.0032
13.0-14.9	228	.119	.0041	219	.117	.0042	342	.116	.0035
15.0-16.9	194	.113	.0041	179	.107	.0044	287	.109	.0036
17.0-18.9	111	.109	.0048	109	.102	.0051	216	.103	.0039
19.0 and larger	151	.094	.0042	153	.097	.0047	336	.097	.0035

Table 28.--Average annual radial increment of pond pine growing in natural stands, by initial diameter class and survey period, South Carolina Coastal Plain

Initial diameter class (inches)	Survey period								
	1958-1968			1968-1978			1978-1983		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	111	0.097	0.0074	87	0.081	0.0079	56	0.041	0.0059
3.0-4.9	73	.083	.0099	89	.077	.0072	76	.073	.0068
5.0-6.9	88	.094	.0078	87	.089	.0080	90	.067	.0057
7.0-8.9	101	.099	.0076	71	.091	.0084	105	.081	.0067
9.0-10.9	89	.107	.0061	83	.094	.0075	81	.093	.0084
11.0-12.9	54	.110	.0088	66	.084	.0075	89	.087	.0071
13.0-14.9	46	.100	.0081	43	.067	.0060	66	.086	.0069
15.0-16.9	12	.122	.0207	24	.084	.0184	45	.081	.0097
17.0-18.9	11	.080	.0164	17	.080	.0164	23	.081	.0138
19.0 and larger	9	.119	.0064	14	.066	.0204	25	.070	.0114

Table 29.--Average annual radial increment of longleaf pine growing in natural stands, by initial diameter class and survey period, South Carolina Coastal Plain

Initial diameter class (inches)	Survey period 1958-1968: Sample trees	1958-1968: Average radial growth	1958-1968: One standard error	1968-1978: Sample trees	1968-1978: Average radial growth	1968-1978: One standard error	1978-1983: Sample trees	1978-1983: Average radial growth	1978-1983: One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	69	0.071	0.0070	80	0.068	0.0053	82	0.063	0.0068
3.0-4.9	73	.094	.0070	62	.080	.0067	48	.077	.0074
5.0-6.9	109	.100	.0058	86	.083	.0058	67	.087	.0066
7.0-8.9	135	.109	.0042	98	.092	.0042	98	.097	.0048
9.0-10.9	144	.098	.0038	120	.080	.0032	140	.080	.0038
11.0-12.9	124	.069	.0031	116	.075	.0032	163	.080	.0045
13.0-14.9	62	.071	.0050	71	.065	.0043	116	.073	.0034
15.0-16.9	40	.056	.0046	37	.061	.0050	60	.076	.0044
17.0-18.9	14	.071	.0082	13	.054	.0090	28	.078	.0045
19.0 and larger	6	.056	.0206	5	.050	.0222	12	.067	.0173

Table 30.--Average annual radial increment of loblolly pine growing in planted stands, by initial diameter class and survey period, South Carolina Coastal Plain

Initial diameter class (inches)	Survey period 1968-1978			Survey period 1978-1983		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	77	0.151	0.0115	228	0.185	0.0088
3.0-4.9	68	.150	.0099	160	.175	.0093
5.0-6.9	51	.146	.0111	135	.136	.0091
7.0-8.9	18	.155	.0200	111	.138	.0081
9.0-10.9	9	.167	.0248	100	.151	.0075
11.0-12.9	7	.117	.0259	45	.153	.0088
13.0-14.9	--	--	--	19	.154	.0140
15.0-16.9	--	--	--	10	.155	.0242
17.0-18.9	--	--	--	--	--	--
19.0 and larger	--	--	--	--	--	--

Table 31.--Average annual radial increment of slash pine growing in planted stands, by initial diameter class and survey period, South Carolina Coastal Plain

Initial diameter class (inches)	Survey period					
	1968-1978			1978-1983		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	156	0.124	0.0049	75	0.083	0.0099
3.0-4.9	124	.117	.0059	124	.084	.0058
5.0-6.9	76	.124	.0071	153	.098	.0053
7.0-8.9	23	.136	.0163	146	.122	.0050
9.0-10.9	20	.107	.0163	79	.134	.0068
11.0-12.9	6	.132	.0061	25	.121	.0093
13.0-14.9	--	--	--	10	.138	.0261
15.0-16.9	--	--	--	8	.145	.0249
17.0-18.9	--	--	--	--	--	--
19.0 and larger	--	--	--	--	--	--

Table 32.--Average annual radial increment of loblolly pine growing in natural stands, by initial diameter class and survey period, North Carolina Piedmont

Initial diameter class (inches)	Survey period					
	1964-1974			1974-1984		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	53	0.079	0.0085	87	0.067	0.0072
3.0-4.9	49	.093	.0109	93	.059	.0057
5.0-6.9	82	.099	.0064	90	.074	.0061
7.0-8.9	81	.113	.0080	102	.085	.0052
9.0-10.9	64	.111	.0056	121	.100	.0050
11.0-12.9	48	.111	.0073	93	.097	.0046
13.0-14.9	28	.111	.0115	69	.089	.0053
15.0-16.9	21	.108	.0112	40	.099	.0084
17.0-18.9	5	.079	.0117	19	.093	.0078
19.0 and larger	14	.074	.0108	21	.100	.0118

Table 33.--Average annual radial increment of shortleaf pine growing in natural stands, by initial diameter class and survey period, North Carolina Piedmont

Initial diameter class (inches)	Survey period					
	1964-1974			1974-1984		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	59	0.076	0.0091	78	0.052	0.0049
3.0-4.9	94	.062	.0046	95	.043	.0044
5.0-6.9	170	.055	.0033	120	.048	.0039
7.0-8.9	170	.061	.0029	158	.048	.0024
9.0-10.9	148	.052	.0025	139	.044	.0025
11.0-12.9	73	.050	.0036	91	.044	.0028
13.0-14.9	31	.053	.0055	43	.033	.0039
15.0-16.9	16	.050	.0069	11	.039	.0075
17.0-18.9	4	.059	.0139	3	.051	.0122
19.0 and larger	3	.042	.0317	--	--	--

Table 34.--Average annual radial increment of Virginia pine growing in natural stands, by initial diameter class and survey period, North Carolina Piedmont

Initial diameter class (inches)	Survey period					
	1964-1974			1974-1984		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	112	0.064	0.0050	184	0.065	0.0045
3.0-4.9	105	.078	.0057	159	.050	.0031
5.0-6.9	109	.078	.0038	143	.066	.0035
7.0-8.9	75	.080	.0048	149	.064	.0028
9.0-10.9	51	.089	.0050	86	.065	.0038
11.0-12.9	20	.074	.0093	38	.068	.0053
13.0-14.9	5	.102	.0231	11	.059	.0130
15.0-16.9	7	.055	.0125	--	--	--
17.0-18.9	--	--	--	--	--	--
19.0 and larger	--	--	--	--	--	--

Table 35.--Average annual radial increment of loblolly pine growing in natural stands, by initial diameter class and survey period, North Carolina Coastal Plain

Initial diameter class (inches)	Survey period: 1964-1974			Survey period: 1974-1984		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	427	0.084	0.0032	409	0.071	0.0032
3.0-4.9	234	.080	.0040	290	.081	.0039
5.0-6.9	362	.088	.0033	310	.084	.0036
7.0-8.9	430	.106	.0031	356	.101	.0035
9.0-10.9	461	.100	.0026	346	.106	.0031
11.0-12.9	456	.094	.0023	364	.100	.0028
13.0-14.9	359	.091	.0026	350	.097	.0027
15.0-16.9	240	.081	.0031	227	.094	.0033
17.0-18.9	142	.083	.0043	138	.096	.0047
19.0 and larger	126	.069	.0036	139	.087	.0038

Table 36.--Average annual radial increment of pond pine growing in natural stands, by initial diameter class and survey period, North Carolina Coastal Plain

Initial diameter class (inches)	Survey period					
	1964-1974			1974-1984		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	330	0.050	0.0026	292	0.040	0.0023
3.0-4.9	193	.050	.0031	152	.051	.0028
5.0-6.9	238	.067	.0031	148	.053	.0028
7.0-8.9	207	.059	.0034	222	.076	.0040
9.0-10.9	235	.051	.0027	154	.060	.0035
11.0-12.9	179	.044	.0025	114	.052	.0036
13.0-14.9	87	.055	.0040	57	.051	.0041
15.0-16.9	42	.049	.0048	36	.063	.0068
17.0-18.9	17	.050	.0083	10	.068	.0131
19.0 and larger	6	.071	.0404	9	.053	.0095

Table 37.--Average annual radial increment of longleaf pine growing in natural stands, by initial diameter class and survey period, North Carolina Coastal Plain

Initial diameter class (inches)	Survey period 1964-1974			Survey period 1974-1984		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	48	0.048	0.0068	47	0.036	0.0050
3.0-4.9	47	.077	.0074	30	.042	.0075
5.0-6.9	74	.085	.0042	44	.072	.0064
7.0-8.9	87	.090	.0041	71	.066	.0042
9.0-10.9	53	.096	.0050	79	.073	.0036
11.0-12.9	54	.077	.0047	68	.070	.0041
13.0-14.9	25	.076	.0083	40	.067	.0035
15.0-16.9	7	.051	.0082	22	.068	.0052
17.0-18.9	3	.041	.0097	9	.056	.0109
19.0 and larger	--	--	--	4	.066	.0142

Table 38.--Average annual radial increment of Virginia pine growing in natural stands, by initial diameter class and survey period, North Carolina Mountains

Initial diameter class (inches)	Survey period 1964-1974 Sample trees			Survey period 1974-1984 Sample trees		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	12	0.064	0.0164	25	0.052	0.0095
3.0-4.9	19	.088	.0107	19	.059	.0113
5.0-6.9	21	.073	.0095	35	.064	.0070
7.0-8.9	25	.070	.0087	28	.064	.0076
9.0-10.9	16	.092	.0107	23	.051	.0058
11.0-12.9	6	.064	.0061	12	.076	.0083
13.0-14.9	4	.045	.0144	9	.060	.0113
15.0-16.9	--	--	--	--	--	--
17.0-18.9	--	--	--	--	--	--
19.0 and larger	--	--	--	--	--	--

Table 39.--Average annual radial increment of white pine growing in natural stands, by initial diameter class and survey period, North Carolina Mountains

Initial diameter class (inches)	Survey period					
	1964-1974			1974-1984		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	16	0.054	0.0120	54	0.041	0.0047
3.0-4.9	13	.104	.0180	12	.070	.0179
5.0-6.9	12	.102	.0225	11	.086	.0194
7.0-8.9	14	.115	.0168	12	.108	.0259
9.0-10.9	19	.125	.0113	13	.123	.0201
11.0-12.9	13	.169	.0184	14	.193	.0232
13.0-14.9	13	.148	.0185	13	.163	.0203
15.0-16.9	6	.176	.0250	10	.152	.0272
17.0-18.9	2	.186	.0464	11	.151	.0116
19.0 and larger	16	.126	.0192	20	.137	.0185

Table 40.--Average annual radial increment of Virginia pine growing in natural stands, by initial diameter class and survey period, Virginia Piedmont

Initial diameter class (inches)	Survey period 1967-1976			Survey period 1976-1985		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	433	0.064	0.0024	235	0.051	0.0031
3.0-4.9	278	.070	.0029	220	.050	.0028
5.0-6.9	216	.067	.0025	218	.057	.0028
7.0-8.9	209	.063	.0025	240	.055	.0021
9.0-10.9	105	.065	.0033	155	.059	.0024
11.0-12.9	62	.056	.0034	61	.044	.0037
13.0-14.9	23	.051	.0064	30	.045	.0051
15.0-16.9	6	.059	.0097	4	.044	.0069
17.0-18.9	--	--	--	--	--	--
19.0 and larger	--	--	--	--	--	--

Table 41.--Average annual radial increment of shortleaf pine growing in natural stands, by initial diameter class and survey period, Virginia Piedmont

Initial diameter class (inches)	Survey period					
	1967-1976			1976-1985		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	108	0.046	0.0041	42	0.068	0.0088
3.0-4.9	82	.054	.0042	45	.038	.0063
5.0-6.9	87	.047	.0044	55	.040	.0047
7.0-8.9	105	.049	.0034	76	.036	.0038
9.0-10.9	93	.053	.0032	72	.039	.0031
11.0-12.9	42	.046	.0040	44	.041	.0046
13.0-14.9	20	.045	.0049	26	.040	.0051
15.0-16.9	12	.057	.0063	5	.019	.0076
17.0-18.9	3	.049	.0291	4	.020	.0095
19.0 and larger	--	--	--	--	--	--

Table 42.--Average annual radial increment of loblolly pine growing in natural stands, by initial diameter class and survey period, Virginia Coastal Plain

Initial diameter class (inches)	Survey period 1966-1976			Survey period 1976-1985		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	268	0.082	0.0042	112	0.084	0.0068
3.0-4.9	196	.075	.0045	111	.071	.0056
5.0-6.9	181	.079	.0043	141	.077	.0048
7.0-8.9	225	.080	.0036	202	.077	.0035
9.0-10.9	285	.084	.0030	171	.075	.0034
11.0-12.9	218	.084	.0035	209	.079	.0032
13.0-14.9	139	.074	.0032	137	.073	.0033
15.0-16.9	82	.081	.0040	89	.075	.0046
17.0-18.9	56	.073	.0052	38	.079	.0062
19.0 and larger	45	.061	.0056	54	.057	.0042

Table 43.--Average annual radial increment of Virginia pine growing in natural stands, by initial diameter class and survey period, Virginia Coastal Plain

Initial diameter class (inches)	Survey period 1966-1976 Sample trees	Average radial growth	One standard error	1976-1985 Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	92	0.073	0.0066	32	0.057	0.0087
3.0-4.9	67	.083	.0059	46	.047	.0070
5.0-6.9	63	.074	.0064	41	.054	.0050
7.0-8.9	46	.078	.0053	48	.053	.0040
9.0-10.9	29	.071	.0059	36	.056	.0054
11.0-12.9	23	.070	.0085	22	.052	.0057
13.0-14.9	5	.073	.0138	13	.049	.0071
15.0-16.9	2	.046	.0260	4	.089	.0106
17.0-18.9	--	--	--	--	--	--
19.0 and larger	--	--	--	--	--	--

Table 44.--Average annual radial increment of slash pine growing in natural stands, by initial diameter class and survey period, North Florida

Initial diameter class (inches)	Survey period 1959-1970 Sample trees	1959-1970 Average radial growth	1959-1970 One standard error	1970-1980 Sample trees	1970-1980 Average radial growth	1970-1980 One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	685	0.048	0.0018	521	0.044	0.0019
3.0-4.9	468	.058	.0023	367	.055	.0030
5.0-6.9	320	.085	.0031	270	.073	.0035
7.0-8.9	222	.099	.0039	269	.078	.0030
9.0-10.9	170	.097	.0042	203	.081	.0033
11.0-12.9	118	.086	.0048	157	.075	.0037
13.0-14.9	76	.075	.0062	109	.069	.0040
15.0-16.9	32	.072	.0069	43	.065	.0073
17.0-18.9	13	.066	.0109	14	.082	.0020
19.0 and larger	10	.060	.0134	18	.060	.0069

Table 45.--Average annual radial increment of longleaf pine growing in natural stands, by initial diameter class and survey period, North Florida

Initial diameter class (inches)	Survey period 1959-1970			Survey period 1970-1980		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	98	0.082	0.0067	69	0.058	0.0079
3.0-4.9	96	.066	.0066	97	.063	.0054
5.0-6.9	127	.081	.0045	115	.077	.0051
7.0-8.9	208	.081	.0030	153	.076	.0033
9.0-10.9	221	.072	.0026	215	.069	.0024
11.0-12.9	126	.065	.0030	163	.065	.0029
13.0-14.9	50	.063	.0047	73	.060	.0040
15.0-16.9	14	.068	.0079	17	.065	.0090
17.0-18.9	4	.053	.0083	9	.070	.0124
19.0 and larger	--	--	--	--	--	--

Table 46.--Average annual radial increment of slash pine growing in planted stands, by initial diameter class and survey period, North Florida

Initial diameter class (inches)	Survey period 1959-1970			Survey period 1970-1980		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	197	0.093	0.0053	595	0.102	0.0025
3.0-4.9	77	.077	.0055	451	.103	.0023
5.0-6.9	48	.095	.0082	216	.108	.0032
7.0-8.9	16	.094	.0148	49	.122	.0060
9.0-10.9	14	.069	.0140	15	.104	.0107
11.0-12.9	10	.111	.0155	6	.117	.0320
13.0-14.9	--	--	--	--	--	--
15.0-16.9	--	--	--	--	--	--
17.0-18.9	--	--	--	--	--	--
19.0 and larger	--	--	--	--	--	--

Table 47.--Average annual radial increment of slash pine growing in natural stands, by initial diameter class and survey period, South Florida

Initial diameter class (inches)	Survey period 1959-1970			Survey period 1970-1980		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	103	0.068	0.0078	61	0.099	0.0092
3.0-4.9	39	.116	.0127	64	.103	.0082
5.0-6.9	42	.108	.0104	49	.106	.0084
7.0-8.9	46	.087	.0091	57	.105	.0077
9.0-10.9	64	.085	.0074	47	.096	.0078
11.0-12.9	46	.080	.0058	26	.085	.0114
13.0-14.9	27	.079	.0091	31	.066	.0056
15.0-16.9	14	.091	.0101	13	.054	.0086
17.0-18.9	4	.058	.0103	7	.089	.0173
19.0 and larger	--	--	--	4	.070	.0275

Table 48.--Average annual radial increment of loblolly pine growing in natural stands, by initial diameter class and survey period, Georgia Piedmont and Mountains

Initial diameter class (inches)	Survey period								
	1956-1961			1961-1972			1972-1982		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	(a)	--	--	895	0.079	0.0022	695	0.050	0.0018
3.0-4.9	799	0.156	0.0031	491	.094	.0029	464	.073	.0027
5.0-6.9	747	.149	.0034	487	.114	.0031	420	.089	.0028
7.0-8.9	725	.153	.0030	462	.120	.0032	470	.098	.0025
9.0-10.9	572	.148	.0031	426	.122	.0028	421	.107	.0026
11.0-12.9	369	.141	.0036	293	.116	.0033	344	.101	.0028
13.0-14.9	209	.145	.0050	172	.114	.0044	237	.102	.0035
15.0-16.9	106	.119	.0062	103	.100	.0050	134	.096	.0043
17.0-18.9	59	.133	.0091	56	.098	.0089	65	.091	.0066
19.0 and larger	51	.109	.0085	45	.095	.0078	50	.091	.0079

[a]Limited number of saplings were bored during third survey.

Table 49.--Average annual radial increment of shortleaf pine growing in natural stands, by initial diameter class and survey period, Georgia Piedmont and Mountains

Initial diameter class (inches)	Survey period: 1956-1961			1961-1972			1972-1982		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	(a)	--	--	677	0.061	0.0019	329	0.039	0.0018
3.0-4.9	558	0.117	0.0027	304	.071	.0031	246	.045	.0027
5.0-6.9	546	.108	.0026	363	.080	.0027	255	.058	.0028
7.0-8.9	494	.111	.0025	295	.082	.0030	248	.053	.0023
9.0-10.9	300	.111	.0032	233	.086	.0029	196	.059	.0026
11.0-12.9	163	.099	.0040	131	.074	.0034	123	.063	.0033
13.0-14.9	75	.114	.0060	61	.086	.0049	44	.059	.0059
15.0-16.9	27	.096	.0095	25	.067	.0078	24	.057	.0072
17.0-18.9	9	.093	.0161	9	.076	.0123	7	.054	.0040
19.0 and larger	7	.076	.0109	4	.069	.0086	8	.056	.0075

[a]Limited number of saplings were bored during third survey.

Table 50.--Average annual radial increment of slash pine growing in natural stands, by initial diameter class and survey period, Georgia Coastal Plain

Initial diameter class (inches)	Survey period								
	1956-1961			1961-1972			1972-1982		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	(a)	--	--	691	0.063	0.0021	628	0.046	0.0017
3.0-4.9	704	0.143	0.0032	347	.070	.0032	493	.057	.0023
5.0-6.9	766	.139	.0029	421	.086	.0027	320	.084	.0032
7.0-8.9	688	.133	.0025	439	.092	.0025	339	.090	.0031
9.0-10.9	399	.136	.0030	351	.094	.0025	247	.083	.0030
11.0-12.9	211	.132	.0042	218	.090	.0033	174	.081	.0037
13.0-14.9	83	.127	.0067	125	.089	.0046	87	.079	.0052
15.0-16.9	45	.134	.0086	62	.075	.0058	57	.082	.0056
17.0-18.9	22	.143	.0122	22	.092	.0096	22	.087	.0111
19.0 and larger	18	.133	.0146	29	.102	.0172	9	.083	.0206

[a]Limited number of saplings were bored during third survey.

Table 51.--Average annual radial increment of loblolly pine growing in natural stands, by initial diameter class and survey period, Georgia Coastal Plain

Initial diameter class (inches)	Survey period: 1956-1961 Sample trees	1956-1961 Average radial growth	1956-1961 One standard error	1961-1972 Sample trees	1961-1972 Average radial growth	1961-1972 One standard error	1972-1982 Sample trees	1972-1982 Average radial growth	1972-1982 One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	(a)	--	--	124	0.103	0.0078	90	0.076	0.0066
3.0-4.9	139	0.197	0.0094	76	.135	.0107	81	.092	.0073
5.0-6.9	126	.201	.0112	76	.149	.0123	57	.133	.0106
7.0-8.9	121	.185	.0099	67	.134	.0089	78	.133	.0089
9.0-10.9	136	.185	.0075	69	.156	.0092	99	.131	.0068
11.0-12.9	91	.172	.0091	72	.139	.0070	66	.132	.0095
13.0-14.9	74	.142	.0096	40	.127	.0106	58	.121	.0086
15.0-16.9	56	.133	.0112	39	.132	.0102	38	.133	.0112
17.0-18.9	27	.169	.0188	22	.100	.0103	25	.128	.0094
19.0 and larger	35	.110	.0096	30	.104	.0150	30	.106	.0093

[a]Limited number of saplings were bored during third survey.

Table 52.--Average annual radial increment of longleaf pine growing in natural stands, by initial diameter class and survey period, Georgia Coastal Plain

Initial diameter class (inches)	Survey period: 1956-1961			1961-1972			1972-1982		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	(a)	--	--	100	0.094	0.0057	42	0.054	0.0066
3.0-4.9	191	0.161	0.0056	44	.113	.0090	44	.094	.0098
5.0-6.9	247	.145	.0041	85	.134	.0054	55	.105	.0076
7.0-8.9	335	.125	.0028	122	.110	.0047	77	.088	.0045
9.0-10.9	244	.119	.0034	139	.099	.0038	109	.085	.0038
11.0-12.9	131	.116	.0050	79	.079	.0048	85	.074	.0040
13.0-14.9	60	.094	.0050	49	.083	.0056	53	.077	0045
15.0-16.9	17	.091	.0096	17	.064	.0069	19	.074	.0055
17.0-18.9	5	.087	.0212	7	.087	.0336	4	.091	.0134
19.0 and larger	5	.099	.0159	12	.066	.0058	6	.065	.0086

[a]Limited number of saplings were bored during third survey.

Table 53.--Average annual radial increment of loblolly pine growing in natural stands, by initial diameter class and survey period, South Carolina Piedmont

Initial diameter class (inches)	Survey period											
	1953-1958			1958-1968			1968-1978			1978-1983		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	(a)	--	--	513	0.053	0.0025	258	0.072	0.0043	316	0.051	0.0031
3.0-4.9	239	0.131	0.0060	193	.066	.0036	181	.096	.0060	155	.064	.0050
5.0-6.9	267	.124	.0049	159	.091	.0055	115	.111	.0066	143	.076	.0048
7.0-8.9	193	.138	.0057	141	.111	.0050	132	.109	.0060	149	.086	.0047
9.0-10.9	146	.121	.0051	102	.110	.0067	131	.105	.0040	175	.094	.0039
11.0-12.9	86	.121	.0068	87	.112	.0068	83	.110	.0060	165	.077	.0036
13.0-14.9	64	.119	.0068	64	.096	.0056	69	.110	.0081	107	.085	.0052
15.0-16.9	39	.094	.0073	33	.107	.0083	63	.089	.0060	64	.077	.0060
17.0-18.9	19	.087	.0129	18	.094	.0133	21	.103	.0111	59	.088	.0076
19.0 and larger	36	.110	.0138	26	.106	.0111	20	.126	.0116	39	.091	.0076

[a]Limited number of saplings were bored during third survey.

Table 54.--Average annual radial increment of shortleaf pine growing in natural stands, by initial diameter class and survey period, South Carolina Piedmont

Initial diameter class (inches)	Survey period											
	1953-1958			1958-1968			1968-1978			1978-1983		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	(a)	--	--	438	0.055	0.0024	328	0.056	0.0029	299	0.033	0.0021
3.0-4.9	379	0.096	0.0034	203	.068	.0035	227	.058	.0032	149	.036	.0032
5.0-6.9	307	.092	.0032	167	.067	.0037	142	.068	.0038	126	.045	.0033
7.0-8.9	252	.101	.0038	147	.069	.0046	141	.069	.0037	143	.043	.0035
9.0-10.9	154	.101	.0043	102	.060	.0038	70	.063	.0051	104	.048	.0032
11.0-12.9	84	.090	.0043	45	.072	.0075	43	.064	.0074	77	.049	.0049
13.0-14.9	34	.080	.0057	25	.050	.0048	18	.067	.0100	26	.048	.0058
15.0-16.9	21	.077	.0087	15	.079	.0131	7	.057	.0131	18	.063	.0107
17.0-18.9	11	.082	.0159	5	.063	.0165	--	--	--	7	.053	.0075
19.0 and larger	6	.064	.0095	4	.036	.0066	--	--	--	--	--	--

[a]Limited number of saplings were bored during third survey.

Table 55.--Average annual radial increment of loblolly pine growing in natural stands, by initial diameter class and survey period, South Carolina Coastal Plain

Initial diameter class (inches)	Survey period											
	1953-1958			1958-1968			1968-1978			1978-1983		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	(a)	--	--	594	0.077	0.0028	485	0.092	0.0035	594	0.091	0.0040
3.0-4.9	468	0.172	0.0052	326	.092	.0036	303	.105	.0044	309	.077	.0044
5.0-6.9	436	.161	.0049	316	.118	.0047	262	.117	.0050	315	.106	.0049
7.0-8.9	469	.170	.0044	305	.140	.0044	313	.122	.0041	345	.108	.0040
9.0-10.9	389	.162	.0047	296	.143	.0046	279	.137	.0045	398	.116	.0037
11.0-12.9	387	.153	.0040	275	.122	.0037	265	.124	.0039	424	.129	.0032
13.0-14.9	301	.143	.0039	228	.119	.0041	219	.117	.0042	342	.116	.0035
15.0-16.9	237	.134	.0040	194	.113	.0041	179	.107	.0044	287	.109	.0036
17.0-18.9	141	.135	.0055	111	.109	.0048	109	.102	.0051	216	.103	.0039
19.0 and larger	201	.129	.0041	151	.094	.0042	153	.097	.0047	336	.097	.0035

[a]Limited number of saplings were bored during third survey.

Table 56.--Average annual radial increment of longleaf pine growing in natural stands, by initial diameter class and survey period, South Carolina Coastal Plain

Initial diameter class (inches)	Survey period											
	1953-1958			1958-1968			1968-1978			1978-1983		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	(a)	--	--	69	0.071	0.0070	80	0.068	0.0053	82	0.063	0.0068
3.0-4.9	166	0.121	0.0053	73	.094	.0070	62	.080	.0067	48	.077	.0074
5.0-6.9	202	.130	.0047	109	.100	.0058	86	.083	.0058	67	.087	.0066
7.0-8.9	236	.122	.0037	135	.109	.0042	98	.092	.0042	98	.097	.0048
9.0-10.9	187	.109	.0038	144	.098	.0038	120	.080	.0032	140	.080	.0038
11.0-12.9	135	.096	.0041	124	.069	.0031	116	.075	.0032	163	.080	.0045
13.0-14.9	68	.090	.0048	62	.071	.0050	71	.065	.0043	116	.073	.0034
15.0-16.9	43	.078	.0055	40	.056	.0046	37	.061	.0050	60	.076	.0044
17.0-18.9	12	.072	.0097	14	.071	.0082	13	.054	.0090	28	.078	.0045
19.0 and larger	6	.087	.0152	6	.056	.0206	5	.050	.0222	12	.067	.0173

[a]Limited number of saplings were bored during third survey.

Table 57.--Average annual radial increment of pond pine growing in natural stands, by initial diameter class and survey period, South Carolina Coastal Plain

Initial diameter class (inches)	Survey period											
	1953-1958			1958-1968			1968-1978			1978-1983		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	(a)	--	--	111	0.097	0.0074	87	0.081	0.0079	56	0.041	0.0059
3.0-4.9	111	0.139	0.0083	73	.083	.0099	89	.077	.0072	76	.073	.0068
5.0-6.9	134	.157	.0081	88	.094	.0078	87	.089	.0080	90	.067	.0057
7.0-8.9	130	.145	.0071	101	.099	.0076	71	.091	.0084	105	.081	.0067
9.0-10.9	102	.149	.0071	89	.107	.0061	83	.094	.0075	81	.093	.0084
11.0-12.9	74	.140	.0088	54	.110	.0088	66	.084	.0075	89	.087	.0071
13.0-14.9	45	.128	.0097	46	.100	.0081	43	.067	.0060	66	.086	.0069
15.0-16.9	23	.145	.0148	12	.122	.0207	24	.084	.0184	45	.081	.0097
17.0-18.9	13	.140	.0161	11	.080	.0164	17	.080	.0164	23	.081	.0138
19.0 and larger	8	.176	.0338	9	.119	.0064	14	.066	.0204	25	.070	.0114

[a]Limited number of saplings were bored during third survey.

Table 58.--Average annual radial increment of loblolly pine growing in natural stands, by initial diameter class and survey period, North Carolina Coastal Plain

Initial diameter class (inches)	Survey period								
	1959-1964			1964-1974			1974-1984		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	(a)	--	--	427	0.084	0.0032	409	0.071	0.0032
3.0-4.9	580	0.132	0.0030	234	.080	.0040	290	.081	.0039
5.0-6.9	751	.125	.0028	362	.088	.0033	310	.084	.0036
7.0-8.9	755	.120	.0025	430	.106	.0031	356	.101	.0035
9.0-10.9	840	.126	.0022	461	.100	.0026	346	.106	.0031
11.0-12.9	750	.126	.0023	456	.094	.0023	364	.100	.0028
13.0-14.9	594	.120	.0024	359	.091	.0026	350	.097	.0027
15.0-16.9	413	.113	.0025	240	.081	.0031	227	.094	.0033
17.0-18.9	193	.114	.0042	142	.083	.0043	138	.096	.0047
19.0 and larger	228	.112	.0037	126	.069	.0036	139	.087	.0038

[a]Limited number of saplings were bored during third survey.

Table 59.--Average annual radial increment of pond pine growing in natural stands, by initial diameter class and survey period, North Carolina Coastal Plain

Initial diameter class (inches)	Survey period								
	1959-1964			1964-1974			1974-1984		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	(a)	--	--	330	0.050	0.0026	292	0.040	0.0023
3.0-4.9	268	0.102	0.0038	193	.050	.0031	152	.051	.0028
5.0-6.9	367	.100	.0030	238	.067	.0031	148	.053	.0028
7.0-8.9	298	.101	.0030	207	.059	.0034	222	.076	.0040
9.0-10.9	278	.099	.0030	235	.051	.0027	154	.060	.0035
11.0-12.9	190	.099	.0040	179	.044	.0025	114	.052	.0036
13.0-14.9	107	.094	.0051	87	.055	.0040	57	.051	.0041
15.0-16.9	54	.100	.0099	42	.049	.0048	36	.063	.0068
17.0-18.9	20	.075	.0125	17	.050	.0083	10	.068	.0131
19.0 and larger	16	.099	.0153	6	.071	.0404	9	.053	.0095

[a]Limited number of saplings were bored during third survey.

Table 60.--Average annual radial increment of longleaf pine growing in natural stands, by initial diameter class and survey period, North Carolina Coastal Plain

Initial diameter class (inches)	Survey period								
	1959-1964			1964-1974			1974-1984		
	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error	Sample trees	Average radial growth	One standard error
	Number	- - Inches - -		Number	- - Inches - -		Number	- - Inches - -	
1.0-2.9	(a)	--	--	48	0.048	0.0068	47	0.036	0.0050
3.0-4.9	123	0.099	0.0037	47	.077	.0074	30	.042	.0075
5.0-6.9	167	.110	.0032	74	.085	.0042	44	.072	.0064
7.0-8.9	147	.114	.0035	87	.090	.0041	71	.066	.0042
9.0-10.9	97	.108	.0038	53	.096	.0050	79	.073	.0036
11.0-12.9	60	.095	.0042	54	.077	.0047	68	.070	.0041
13.0-14.9	30	.091	.0056	25	.076	.0083	40	.067	.0035
15.0-16.9	14	.066	.0072	7	.051	.0082	22	.068	.0052
17.0-18.9	--	--	--	3	.041	.0097	9	.056	.0109
19.0 and larger	--	--	--	--	--	--	4	.066	.0142

[a]Limited number of saplings were bored during third survey.

Table 61.--Sample sizes, means ($\bar{X}$), and standard errors ($S_{\bar{X}}$) of inventory basal area (BA) and components of net annual growth for natural loblolly pine stands in the Georgia Piedmont and Mountains, by initial stand density and survey cycle

Initial stand-density class BA/acre (ft^2)	Survey cycle	Sample size	Initial inventory		Percent initial pine	Terminal inventory		Net annual growth		Components of net annual growth: Survivor growth		Ingrowth		Mortality	
			$\bar{X}$	$S_{\bar{X}}$	$\bar{X}$	$\bar{X}$	$S_{\bar{X}}$	$\bar{X}$	$S_{\bar{X}}$	$\bar{X}$	$S_{\bar{X}}$	$\bar{X}$	$S_{\bar{X}}$	$\bar{X}$	$S_{\bar{X}}$
		Number	BA/acre (ft^2)					BA/acre/year (ft^2)							
1-19	4	58	10.87	0.68	94	71.26	5.36	5.43	0.49	2.90	0.33	2.59	0.38	0.06	0.02
	5	20	11.95	1.21	89	41.39	4.03	2.88	.36	1.40	.26	1.69	.31	.21	.08
20-39	4	60	30.86	.79	89	80.67	4.49	4.50	.42	4.12	.37	.68	.16	.30	.05
	5	33	29.67	1.07	87	67.03	5.96	3.66	.58	2.90	.35	1.25	.36	.49	.13
40-59	4	66	50.35	.64	87	111.07	4.94	5.46	.44	5.46	.44	.45	.09	.44	.06
	5	37	50.93	.87	85	81.45	4.03	2.99	.40	3.48	.35	.27	.07	.76	.13
60-79	4	50	69.45	.78	84	117.04	3.86	4.26	.34	4.71	.32	.26	.04	.72	.11
	5	56	70.19	.80	85	96.38	3.35	2.56	.32	3.27	.22	.32	.05	1.03	.16
80-99	4	41	90.58	.79	87	138.41	4.34	4.30	.39	5.10	.31	.41	.08	1.20	.20
	5	39	89.97	1.00	83	115.92	4.29	2.53	.44	3.98	.30	.20	.04	1.65	.23
100-119	4	40	108.68	.86	87	162.41	4.21	4.81	.39	6.06	.36	.27	.06	1.52	.19
	5	44	108.19	.81	81	131.85	4.19	2.34	.42	3.85	.27	.38	.12	1.90	.30
120+	4	40	153.74	4.40	84	183.18	6.14	2.63	.46	5.27	.35	.21	.06	2.85	.35
	5	66	148.76	2.89	80	166.15	4.38	1.72	.39	4.10	.20	.21	.03	2.59	.29
All classes	4	355	66.16	2.38	88	117.34	2.68	4.60	.17	4.71	.15	.76	.08	.88	.07
	5	295	85.15	2.63	83	110.98	2.78	2.53	.16	3.50	.11	.48	.06	1.44	.10

Table 62.--Sample sizes, means ($\overline{X}$), and standard errors ($S_{\overline{x}}$) of inventory basal area (BA) and components of net annual growth for natural loblolly pine stands in the Georgia Piedmont and Mountains, by initial stand age and survey cycle

Initial stand-age class (years)	Survey cycle	Sample size	Initial age		Initial inventory		Percent initial pine	Terminal inventory		Net annual growth		Components of net annual growth: Survivor growth		Ingrowth		Mortality	
			$\overline{X}$	$S_{\overline{x}}$	$\overline{X}$	$S_{\overline{x}}$	$\overline{X}$	$\overline{X}$	$S_{\overline{x}}$	$\overline{X}$	$S_{\overline{x}}$	$\overline{X}$	$S_{\overline{x}}$	$\overline{X}$	$S_{\overline{x}}$	$\overline{X}$	$S_{\overline{x}}$
		Number	Years		- - - - BA/acre (ft^2) - - - - -					- - - - - - - - - BA/acre/year (ft^2) - - - - - - -							
1-19	4	35	6.87	0.44	36.57	6.66	90	114.60	8.94	6.99	0.60	5.67	0.64	1.78	0.39	0.46	0.18
	5	26	5.78	.66	55.59	8.56	84	87.50	8.84	3.12	.68	3.58	.55	1.13	.26	1.59	.45
11-19	4	71	15.22	.34	63.26	3.80	91	117.82	5.51	4.90	.37	5.41	.33	.48	.09	.99	.17
	5	97	15.82	.30	76.34	4.02	84	109.42	4.31	3.23	.33	4.26	.19	.53	.13	1.56	.19
20-29	4	22	24.37	.59	89.12	10.55	78	131.50	10.92	3.79	.61	4.64	.44	.32	.08	1.18	.39
	5	98	24.66	.30	93.74	4.30	85	116.97	4.76	2.29	.21	3.40	.15	.24	.03	1.35	.16
30-39	4	14	34.54	.61	71.32	9.64	80	96.25	11.77	2.26	.40	2.59	.38	.26	.09	.60	.25
	5	36	35.13	.44	114.85	7.73	81	134.11	8.71	1.90	.45	3.15	.29	.22	.05	1.47	.29
40+	4	6	49.77	4.34	74.17	12.73	79	95.52	16.54	1.92	.53	2.17	.52	.26	.11	.52	.19
	5	30	48.07	1.53	91.00	7.46	77	105.12	8.51	1.42	.43	2.32	.24	.34	.08	1.24	.32
All classes	4	148	17.83	.89	62.00	3.31	88	116.15	4.00	4.86	.28	4.96	.24	.73	.11	.84	.11
	5	287	23.72	.71	86.76	2.63	83	112.66	2.78	2.54	.17	3.57	.11	.42	.05	1.45	.10

Table 63.--Sample sizes, means ($\bar{X}$), and standard errors ($S_{\bar{x}}$) of inventory basal area (BA) and components of net growth for natural shortleaf pine stands in the Georgia Piedmont and Mountains, by initial stand density and survey cycle

Initial stand-density class BA/acre (ft^2)	Survey cycle	Sample size	Initial inventory		Percent initial pine	Terminal inventory		Net annual growth		Components of net annual growth: Survivor growth		Ingrowth		Mortality	
			$\bar{X}$	$S_{\bar{x}}$	$\bar{X}$	$\bar{X}$	$S_{\bar{x}}$	$\bar{X}$	$S_{\bar{x}}$	$\bar{X}$	$S_{\bar{x}}$	$\bar{X}$	$S_{\bar{x}}$	$\bar{X}$	$S_{\bar{x}}$
		Number	BA/acre (ft^2)					BA/acre/year (ft^2)							
1-19	4	54	10.42	0.68	93	55.79	4.19	4.09	0.38	2.07	0.18	2.19	0.31	0.17	0.05
	5	4	13.50	1.79	88	42.33	6.13	2.80	.74	1.61	.43	1.22	.47	.02	.01
20-39	4	43	30.15	.84	79	75.53	3.91	4.09	.36	3.66	.33	.72	.17	.29	.08
	5	13	33.88	1.57	92	61.72	7.42	2.70	.71	2.02	.28	1.02	.56	.33	.17
40-59	4	40	51.00	.97	80	93.68	4.51	3.85	.39	3.79	.27	.67	.25	.62	.14
	5	19	48.77	1.21	84	59.03	3.88	.99	.37	1.67	.20	.39	.10	1.08	.26
60-79	4	39	70.14	.86	86	104.71	3.95	3.12	.37	3.55	.32	.32	.06	.76	.13
	5	21	68.28	1.23	74	89.88	4.83	2.12	.44	2.84	.33	.27	.07	.99	.18
80-99	4	19	88.02	1.49	86	123.51	10.06	3.21	.84	4.01	.69	.18	.06	.97	.31
	5	20	92.38	1.36	81	121.24	8.41	2.82	.83	3.99	.56	.38	.07	1.56	.49
100-119	4	12	108.45	1.73	85	143.88	11.37	3.19	1.06	5.09	.73	.27	.11	2.16	.59
	5	19	110.26	1.46	79	134.82	7.92	2.37	.71	3.99	.55	.19	.06	1.80	.40
120+	4	12	149.38	6.94	84	170.98	7.21	1.93	.54	4.16	.32	.24	.11	2.48	.40
	5	15	139.95	3.94	75	154.39	8.97	1.43	.74	3.78	.39	.22	.06	2.57	.50
All classes	4	219	52.06	2.57	85	92.31	2.92	3.63	.18	3.41	.14	.91	.11	.68	.07
	5	111	80.15	3.47	81	101.65	4.36	2.09	.26	3.03	.19	.41	.08	1.35	.15

Table 64.--Sample sizes, means ($\overline{X}$), and standard errors ($S_{\overline{X}}$) of inventory basal area (BA) and components of net annual growth for natural shortleaf pine stands in the Georgia Piedmont and Mountains, by initial stand age and survey cycle

Initial stand-age class (years)	Survey cycle	Sample size	Initial age		Initial inventory		Percent initial pine	Terminal inventory		Net annual growth		Components of net annual growth: Survivor growth		Ingrowth		Mortality	
			$\overline{X}$	$S_{\overline{X}}$	$\overline{X}$	$S_{\overline{X}}$	$\overline{X}$	$\overline{X}$	$S_{\overline{X}}$	$\overline{X}$	$S_{\overline{X}}$	$\overline{X}$	$S_{\overline{X}}$	$\overline{X}$	$S_{\overline{X}}$	$\overline{X}$	$S_{\overline{X}}$
		Number	Years		- - - - BA/acre (ft^2) - - - -					- - - - - - - - - BA/acre/year (ft^2) - - - - - - -							
1-9	4	18	6.87	0.67	28.06	5.65	84	72.91	8.50	4.04	0.63	3.14	0.41	1.16	0.36	0.26	0.12
	5	12	7.73	.50	60.20	10.37	80	80.40	13.05	2.00	1.04	3.13	.72	.83	.24	1.96	.64
11-19	4	41	14.75	.43	44.40	5.61	81	94.65	7.63	4.53	.45	3.95	.40	1.11	.25	.53	.18
	5	18	16.68	.72	67.40	7.06	83	93.39	9.77	2.53	.48	3.30	.48	.26	.08	1.05	.24
20-29	4	18	25.68	.70	71.22	9.24	85	98.86	11.88	2.49	.61	3.38	.51	.36	.09	1.25	.29
	5	43	25.93	.43	90.00	5.35	85	111.23	7.26	2.05	.46	3.30	.32	.24	.04	1.49	.30
30-39	4	6	36.15	1.02	97.62	25.14	85	109.82	18.12	1.09	.73	1.92	.22	.41	.23	1.24	.60
	5	23	39.96	.60	92.70	7.89	71	112.12	10.08	1.92	.49	3.00	.38	.28	.07	1.35	.25
40+	4	10	47.19	2.22	70.00	9.38	79	90.05	9.81	1.81	.36	2.20	.26	.35	.12	.74	.22
	5	11	48.61	1.63	75.01	9.29	78	87.47	9.39	1.22	.37	1.74	.22	.38	.14	.90	.33
All classes	4	93	20.21	1.32	52.62	4.18	82	91.74	4.70	3.53	.29	3.37	.23	.85	.13	.69	.11
	5	107	26.39	1.10	81.89	3.48	80	102.52	4.44	2.01	.25	3.06	.19	.34	.04	1.38	.16

Table 65.--Sample sizes (N), means ($\bar{X}$), and standard errors ($S_{\bar{X}}$) of net annual basal area (BA) growth for natural shortleaf pine stands in the Georgia Piedmont and Mountains, by initial stand age, initial stand density, and survey cycle

Initial stand-density class BA/acre (ft^2)	Survey cycle	Initial stand-age class (years)														
		1-9			10-19			20-29			30-39			40+		
		N	$\bar{X}$	$S_{\bar{X}}$	N	$\bar{X}$	$S_{\bar{X}}$	N	$\bar{X}$	$S_{\bar{X}}$	N	$\bar{X}$	$S_{\bar{X}}$	N	$\bar{X}$	$S_{\bar{X}}$
			ft^2			ft^2			ft^2			ft^2			ft^2	
1-19	4	9	4.30	1.06	12	3.84	0.61	1	-0.09	--	--	--	--	1	1.86	--
	5	2	3.99	.40	1	1.04	--	--	--	--	--	--	--	--	--	--
20-39	4	5	3.78	.60	11	5.45	.73	3	4.78	1.85	1	3.62	--	--	--	--
	5	3	2.22	.62	2	2.90	.85	4	1.57	.21	2	1.44	0.03	1	2.75	--
40-59	4	1	2.03	--	6	3.61	.51	6	1.31	1.20	--	--	--	1	1.33	--
	5	1	-1.04	--	4	1.19	.70	8	1.09	.65	1	-1.82	--	3	1.31	0.50
60-79	4	3	4.35	2.19	5	3.36	1.48	2	2.67	.17	2	1.56	.56	5	2.18	.53
	5	2	2.62	.61	6	2.98	1.06	3	2.24	.37	8	1.91	.72	2	-.29	.32
80-99	4	--	--	--	4	7.36	2.68	2	2.18	.19	1	1.56	--	2	1.22	1.50
	5	2	4.47	5.37	2	3.39	2.28	11	2.53	1.20	3	3.35	1.78	2	1.38	1.71
100-119	4	--	--	--	2	6.20	.31	2	4.69	.03	1	-.43	--	--	--	--
	5	2	-1.89	3.16	2	3.74	1.46	11	3.21	.92	2	1.38	1.59	2	1.65	.25
120+	4	--	--	--	1	-.65	--	2	1.80	2.00	1	-1.32	--	1	1.57	--
	5	--	--	--	1	1.82	--	6	.56	1.42	7	2.15	1.04	1	1.27	--

Table 66.--Correlation coefficients (upper) and associated probability values[a] (lower) for initial inventory and stand age, net annual growth, and components of net annual growth, natural shortleaf pine stands in the Georgia Piedmont and Mountains, fourth survey

N=93	Initial inventory	Net annual growth	Survivor growth	Ingrowth	Mortality	Initial stand age
Initial inventory						
Net annual growth	-0.2155 .0380					
Survivor growth	.2624 .0111	0.7457 .0001				
Ingrowth	-.4079 .0001	.4522 .0001	-0.1298 .2151			
Mortality	.6081 .0001	-.5378 .0001	-.0546 .6029	-0.2414 .0198		
Initial stand age	.4184 .0001	-.3631 .0003	-.2084 .0450	-.2622 .0111	0.2049 .0486	

[a]Probability > | R | under Ho:RHo=0.

Table 67.--Correlation coefficients (upper) and associated probability value[a] (lower) for initial inventory and stand age, net annual growth, and components of net annual growth, natural shortleaf pine stands in the Georgia Piedmont and Mountains, fifth survey

N=107	Initial inventory	Net annual growth	Survivor growth	Ingrowth	Mortality	Initial stand age
Initial inventory						
Net annual growth	0.0425 .6637					
Survivor growth	.4524 .0001	0.7665 .0001				
Ingrowth	-.2664 .0055	.0634 .5168	-0.1220 .2106			
Mortality	.4114 .0001	-.6532 .0001	-.0439 .6538	0.0195 .8419		
Initial stand age	.1932 .0462	-.1077 .2693	-.1979 .0410	-.1977 .0413	-0.1217 .2117	

[a]Probability > | R | under Ho:RHo=0.

Table 68.--Sample sizes, means ($\overline{X}$), and standard errors ($S_{\overline{X}}$) of inventory basal area (BA) and components of net annual growth for natural slash pine stands in the Georgia Coastal Plain, by initial stand density and survey cycle

Initial stand-density class BA/acre (ft²)	Survey cycle	Sample size	Initial inventory		Percent initial pine	Terminal inventory		Net annual growth		Components of net annual growth: Survivor growth		Ingrowth		Mortality	
			$\overline{X}$	$S_{\overline{X}}$	$\overline{X}$	$\overline{X}$	$S_{\overline{X}}$	$\overline{X}$	$S_{\overline{X}}$	$\overline{X}$	$S_{\overline{X}}$	$\overline{X}$	$S_{\overline{X}}$	$\overline{X}$	$S_{\overline{X}}$
		Number	- - - - BA/acre (ft²) - - - - -					- - - - - - - - - BA/acre/year (ft²) - - - - - - -							
1-19	4	55	10.69	0.62	97	51.08	4.99	3.70	0.45	2.05	0.26	1.74	0.35	0.09	0.04
	5	26	10.71	1.12	91	34.11	4.12	2.28	.40	1.37	.27	.99	.29	.08	.04
20-39	4	64	29.25	.73	91	68.90	3.47	3.62	.31	3.04	.26	.69	.13	.10	.04
	5	52	29.36	.77	88	59.31	3.67	2.96	.36	2.72	.32	.41	.08	.17	.05
40-59	4	46	49.62	.93	93	89.13	4.78	3.63	.43	3.13	.29	.71	.30	.20	.07
	5	22	49.55	1.26	86	71.98	3.63	2.21	.34	2.72	.30	.13	.05	.64	.18
60-79	4	37	69.73	.94	92	109.76	5.41	3.67	.51	3.75	.41	.36	.11	.45	.21
	5	38	68.90	.88	87	93.85	4.26	2.46	.41	2.97	.35	.31	.08	.82	.14
80-99	4	21	89.07	1.21	87	126.10	4.19	3.41	.37	3.67	.36	.19	.09	.45	.11
	5	26	88.96	.97	89	124.07	3.04	3.48	.29	3.86	.34	.27	.07	.66	.14
100-119	4	21	110.30	1.30	85	154.26	7.02	3.98	.62	4.44	.48	.50	.26	.96	.18
	5	21	107.05	1.21	90	142.00	5.91	3.43	.56	4.28	.51	.17	.05	1.02	.28
120+	4	22	159.98	8.67	88	175.30	11.53	1.44	.85	4.04	.40	.15	.06	2.76	.74
	5	28	150.07	4.50	82	173.03	6.45	2.24	.44	3.40	.38	.25	.07	1.41	.24
All classes	4	266	56.50	2.75	92	94.45	3.14	3.48	.18	3.19	.13	.77	.10	.48	.08
	5	213	67.02	3.06	88	94.71	3.47	2.72	.16	2.98	.15	.37	.05	.63	.06

Table 69.--Sample sizes, means ($\bar{X}$), and standard errors ($S_{\bar{x}}$) of inventory basal area (BA) and components of net annual growth for natural slash pine stands in the Georgia Coastal Plain, by initial stand age and survey cycle

Initial stand-age class (years)	Survey cycle	Sample size	Initial age		Initial inventory		Percent initial pine	Terminal inventory		Net annual growth		Components of net annual growth: Survivor growth		Ingrowth		Mortality	
			$\bar{X}$	$S_{\bar{x}}$	$\bar{X}$	$S_{\bar{x}}$	$\bar{X}$	$\bar{X}$	$S_{\bar{x}}$	$\bar{X}$	$S_{\bar{x}}$	$\bar{X}$	$S_{\bar{x}}$	$\bar{X}$	$S_{\bar{x}}$	$\bar{X}$	$S_{\bar{x}}$
		Number	Years		- - - - - BA/acre (ft^2) - - - -					- - - - - - - - - BA/acre/year (ft^2) - - - - - - -							
1-9	4	29	5.78	0.47	35.94	5.94	96	86.75	6.98	4.65	0.49	3.43	0.38	1.40	0.45	0.18	0.08
	5	22	8.27	.52	31.45	5.79	88	69.72	8.85	3.76	.73	3.18	.64	1.15	.34	.57	.25
11-19	4	31	14.09	.45	44.42	6.64	91	91.41	9.57	4.29	.49	4.14	.46	.41	.11	.26	.11
	5	71	16.51	.31	63.03	4.68	87	96.19	5.67	3.26	.29	3.70	.28	.31	.06	.75	.12
20-29	4	19	24.80	.60	69.23	9.42	94	90.33	10.33	1.94	.27	2.55	.37	.11	.03	.72	.29
	5	61	24.62	.33	66.16	5.49	90	91.38	6.59	2.49	.23	2.83	.22	.25	.05	.59	.10
30-39	4	18	34.48	.58	85.06	14.74	80	122.59	15.79	3.44	.60	2.72	.35	.98	.48	.26	.13
	5	31	35.30	.48	84.88	7.44	91	107.29	8.57	2.19	.38	2.55	.30	.22	.05	.57	.17
40+	4	6	47.42	4.39	63.67	15.48	83	99.40	28.77	3.20	1.49	2.04	.66	1.21	.85	.06	.06
	5	25	45.85	.75	93.20	10.99	79	109.60	11.81	1.61	.31	1.86	.31	.32	.07	.56	.17
All classes	4	103	19.23	1.26	54.83	4.45	90	95.81	5.15	3.75	.26	3.28	.21	.78	.17	.31	.07
	5	210	24.27	.78	67.45	3.07	87	95.25	3.48	2.74	.16	3.00	.15	.37	.05	.63	.06

Table 70.--Sample sizes (N), means ($\bar{X}$), and standard errors ($S_{\bar{x}}$) of net annual basal area (BA) growth for natural slash pine stands in the Georgia Coastal Plain, by initial stand age, initial stand density, and survey cycle

Initial stand-density class BA/acre (ft^2)	Survey cycle	Initial stand-age class (years) 1-9 N	$\bar{X}$	$S_{\bar{x}}$	10-19 N	$\bar{X}$	$S_{\bar{x}}$	20-29 N	$\bar{X}$	$S_{\bar{x}}$	30-39 N	$\bar{X}$	$S_{\bar{x}}$	40+ N	$\bar{X}$	$S_{\bar{x}}$
			ft^2			ft^2			ft^2			ft^2			ft^2	
1-19	4	11	4.56	0.93	7	1.89	0.31	2	0.56	1.27	--	--	--	1	0.61	--
	5	8	2.81	.87	9	2.53	.79	6	1.60	.48	--	--	--	1	1.59	--
20-39	4	8	6.05	1.00	12	4.92	.89	4	1.65	.20	5	3.08	0.62	1	2.62	--
	5	10	4.68	1.31	17	3.36	.51	14	2.26	.46	7	2.21	.77	4	.70	0.25
40-59	4	4	4.12	.92	4	5.02	1.69	4	2.58	.53	4	4.27	2.62	1	1.02	--
	5	--	--	--	10	2.26	.58	8	2.58	.54	1	.21	--	3	1.76	.55
60-79	4	3	3.42	.76	3	5.24	2.03	2	2.68	.78	1	3.14	--	1	2.94	--
	5	2	6.07	.42	12	4.13	.81	14	1.83	.47	6	.59	.44	4	.65	.72
80-99	4	--	--	--	2	5.85	.59	3	2.04	1.16	1	1.04	--	--	--	--
	5	1	2.48	--	8	4.25	.55	7	3.13	.62	6	3.08	.57	3	3.54	.60
100-119	4	3	3.14	.51	2	4.75	.58	1	1.82	--	3	4.28	.75	2	6.00	4.41
	5	1	-1.01	--	9	3.22	1.11	7	4.07	.56	4	3.88	.57	--	--	--
120+	4	--	--	--	1	3.87	--	3	1.82	.57	4	3.10	.72	--	--	--
	5	--	--	--	6	2.76	1.15	5	2.82	1.02	7	2.10	1.13	10	1.75	.56

Table 71.--Correlation coefficients (upper) and associated probability values[a] (lower) for initial inventory and stand age, net annual growth, and components of net annual growth, natural slash pine stands in the Georgia Coastal Plain, fourth survey

N=103	Initial inventory	Net annual growth	Survivor growth	Ingrowth	Mortality	Initial stand age
Initial inventory						
Net annual growth	-0.0626 .5302					
Survivor growth	.2401 .0146	0.6939 .0001				
Ingrowth	-.1742 .0784	.6165 .0001	-0.0739 .4581			
Mortality	.5234 .0001	-.1847 .0618	.2117 .0318	-0.1265 .2028		
Initial stand age	.3527 .0003	-.2408 .0143	-.2067 .0362	-.0862 .3866	0.0749 .4520	

[a]Probability > | R | under Ho:RHo=0.

Table 72.--Correlation coefficients (upper) and associated probability values[a] (lower) for initial inventory and stand age, net annual growth, and components of net annual growth, natural slash pine stands in the Georgia Coastal Plain, fifth survey

N=210	Initial inventory	Net annual growth	Survivor growth	Ingrowth	Mortality	Initial stand age
Initial inventory						
Net annual growth	0.0013 .9851					
Survivor growth	.2824 .0001	0.8528 .0001				
Ingrowth	-.2363 .0006	.3279 .0001	-0.0183 .7926			
Mortality	.4703 .0001	-.2947 .0001	.1546 .0251	-0.1212 .0798		
Initial stand age	.3411 .0001	-.2689 .0001	-.2413 .0004	-.2153 .0017	-0.0421 .5441	

[a]Probability > | R | under Ho:RHo=0.

Table 73.--Sample sizes, means of initial inventory basal area (BA), percent of initial inventory in pine, and annual survivor growth for natural loblolly pine stands in the Georgia Piedmont and Mountains, by the initial stand density of survivor trees and survey cycle

Initial stand-density class BA/acre (ft^2)	Survey cycle	Sample size	Initial inventory[a]	Percent pine	Survivor growth	
			$\bar{X}$	$\bar{X}$	$\bar{X}$	$S_{\bar{X}}$
		Number	- - - - Ba/acre - - -		Ba/acre/year	
			ft^2	%	ft^2	
1-19	3	101	10.15	95	2.53	0.18
	4	56	11.04	94	3.19	.34
	5	31	12.75	86	1.88	.28
20-39	3	111	28.79	89	5.29	.27
	4	75	29.44	87	4.51	.37
	5	40	31.47	87	2.99	.32
40-59	3	103	48.49	88	6.29	.32
	4	79	50.66	88	4.94	.34
	5	49	50.54	87	3.55	.26
60-79	3	53	68.85	88	6.23	.44
	4	50	69.11	85	5.28	.32
	5	59	68.99	81	3.44	.20
80-99	3	35	88.94	84	6.51	.56
	4	48	89.70	87	5.77	.35
	5	40	88.22	80	4.26	.34
100-119	3	21	108.48	87	8.09	.70
	4	19	107.97	83	5.13	.47
	5	40	109.92	81	4.05	.22
120+	3	19	135.32	87	6.63	.55
	4	24	141.58	84	5.31	.38
	5	33	141.28	82	4.34	.29
All classes	3	443	47.01	87	5.29	.15
	4	351	57.09	88	4.77	.15
	5	292	71.19	83	3.53	.11

[a]Initial inventory excludes the initial basal area of mortality trees that died over each remeasurement period (equivalent to survivor tree initial inventory).

Table 74.--Sample sizes, means of initial inventory basal area (BA), percent of initial inventory in pine, and annual survivor growth for natural shortleaf pine stands in the Georgia Piedmont and Mountains, by the initial stand density of survivor trees and survey cycle

Initial stand-density class BA/acre (ft^2)	Survey cycle	Sample size	Initial inventory[a]	Percent pine	Survivor growth	
			$\bar{X}$	$\bar{X}$	$\bar{X}$	$S_{\bar{X}}$
		Number	- - - - BA/acre - - -		BA/acre/year	
			ft^2	%	ft^2	
1-19	3	65	10.38	90	2.12	0.17
	4	56	10.07	92	2.30	.16
	5	8	13.25	88	1.12	.31
20-39	3	63	28.90	85	4.10	.29
	4	47	30.12	77	3.63	.30
	5	22	32.40	89	2.07	.21
40-59	3	65	47.46	83	4.67	.26
	4	47	50.21	84	4.13	.28
	5	22	50.43	76	2.10	.23
60-79	3	24	67.17	89	6.04	.69
	4	33	68.74	85	3.38	.30
	5	15	67.15	78	3.36	.45
80-99	3	20	89.45	91	6.32	.58
	4	16	88.74	89	5.15	.87
	5	26	89.67	78	4.22	.45
100-119	3	7	108.43	85	6.40	.88
	4	8	110.70	77	4.19	.40
	5	13	108.08	82	3.88	.61
120+	3	7	133.14	92	5.91	.42
	4	6	136.85	88	4.30	.54
	5	5	139.20	68	4.95	.84
All classes	3	251	42.52	87	4.21	.16
	4	213	45.70	85	3.50	.14
	5	111	66.38	81	3.03	.19

[a] Initial inventory excludes the initial basal area of mortality trees that died over each remeasurement period (equivalent to survivor tree initial inventory).

Table 75.--Sample sizes, means of initial inventory basal area (BA), percent of initial inventory in pine, and annual survivor growth for natural slash pine stands in the Georgia Coastal Plain, by the initial stand density of survivor trees and survey cycle

Initial stand-density class BA/acre (ft^2)	Survey cycle[a]	Sample size	Initial inventory[b]	Percent pine	Survivor growth	
			$\bar{X}$	$\bar{X}$	$\bar{X}$	$S_{\bar{X}}$
		Number	- - - - BA/acre - - -		BA/acre/year	
			ft^2	%	ft^2	
1-19	3	129	9.95	97	2.40	0.21
	4	56	10.25	97	2.12	.25
	5	31	11.26	90	1.51	.23
20-39	3	93	29.30	93	4.51	.31
	4	65	29.12	90	3.13	.26
	5	54	29.70	88	2.84	.32
40-59	3	67	49.42	92	5.07	.39
	4	45	48.55	93	3.05	.29
	5	28	49.19	86	2.59	.26
60-79	3	49	68.33	89	6.80	.48
	4	41	70.32	91	3.86	.36
	5	32	67.25	87	3.56	.41
80-99	3	15	92.60	92	6.44	.63
	4	25	90.54	90	3.95	.37
	5	29	88.98	89	3.77	.43
100-119	3	19	110.32	85	7.00	.72
	4	14	107.31	81	4.64	.64
	5	20	107.60	89	3.73	.41
120+	3	8	148.25	73	7.17	.94
	4	16	146.28	86	4.23	.41
	5	18	149.85	80	3.59	.46
All classes	3	380	40.36	90	4.44	.17
	4	262	52.07	92	3.24	.13
	5	212	60.91	87	3.00	.15

[a]Third survey may include small amount of planted slash pine.

[b]Initial inventory excludes the initial basal area of mortality trees that died over each remeasurement period (equivalent to survivor tree initial inventory).

APPENDIX B: CONVERTING INCREMENT CORE MEASUREMENTS TO AARI

A four-step procedure was used to calculate an AARI value for each tree based on species, d.b.h., and radial growth (RG). The computed AARI was then used to estimate initial d.b.h. 5 years prior to the inventory, thus yielding a d.b.h. comparable to the d.b.h. at the beginning of a remeasurement period. Equation (1) was used to predict double bark thickness at breast height (DBBH) as a function of d.b.h.

$$DBBH = b_o + b_1(d.b.h.) \qquad (1)$$

Equation (2) was used to predict the ratio of double bark thickness to diameter inside bark (d.i.b.) at breast height (RATIO) as a function of d.i.b. at breast height.

$$RATIO = DBBH/(d.b.h.-DBBH) = b_o + b_1(d.b.h.-DBBH) \qquad (2)$$

The actual computing procedure involved four steps after the appropriate coefficients had been selected for the species being processed.

Step 1 - Use equation (1) to determine double bark thickness at breast height (DBBH).

Step 2 - Subtract estimated DBBH from d.b.h. to obtain estimated d.i.b. at breast height.

Step 3 - Use equation (2) to compute the ratio of DBBH to d.i.b.

Step 4 - Compute AARI from radial growth

$$AARI = \left| (RG/100.0) \times (2.00 + RATIO) \right| /2.0$$

Coefficients for equations (1) and (2), for saplings and larger trees, for the major southern pine species that are the focus of this study are as follows:

EQUATION (1) $DBBH = b_o + b_1 (d.b.h.)$

SPECIES	SAPLINGS			LARGER TREES		
	N	b_o	b_1	N	b_o	b_1
Loblolly pine	458	-0.040144	0.178064	5,955	0.478397	0.093657
Slash pine	790	0.157505	0.170501	4,671	0.590594	0.080857
Shortleaf pine	142	-0.040095	0.183498	2,162	0.543116	0.076310
Longleaf pine	103	0.045764	0.152571	2,517	0.495013	0.068751
Virginia pine	156	-0.043788	0.096549	1,160	0.206236	0.067180

EQUATION (2) $RATIO = DBBH/(d.b.h.-DBBH) = b_o + b_1\ (d.b.h.-DBBH)$

SPECIES	SAPLINGS			LARGER TREES		
	N	b_o	b_1	N	b_o	b_1
Loblolly pine	458	0.199900	-0.000215	5,955	0.234952	-0.006941
Slash pine	790	0.438536	-0.052724	4,671	0.283656	-0.013036
Shortleaf pine	141	0.244207	-0.011044	2,162	0.253204	-0.010866
Longleaf pine	103	0.276299	-0.022886	2,517	0.220846	-0.008894
Virginia pine	156	0.092489	-0.000444	1,160	0.140837	-0.004764

Initial d.b.h. 5 years prior to the third survey was calculated for each tree from the computed AARI.

$$\text{Initial d.b.h.} = \text{present d.b.h.} - (2.0 \times AARI \times 5.0)$$

Here is an example of how a typical tree was processed to obtain AARI and initial d.b.h.:

EXAMPLE: Species = Loblolly pine
d.b.h. = 10.0 inches
Radial growth = 15
Equation (1): DBBH = 0.478397 + 0.093657(d.b.h.)
Equation (2): RATIO = DBBH/(d.b.h.-DBBH) = 0.234952-0.006941 (d.b.h.-DBBH)

Step 1 Using equation (1), determine double bark thickness at breast height
DBBH = 0.478397 + 0.093657(d.b.h.)
DBBH = 0.478397 + 0.093657(10.0) = <u>1.414967</u>

Step 2 Compute estimated diameter inside bark at breast height
d.i.b. = d.b.h. - DBBH
d.i.b. = 10.0 - 1.414967 = <u>8.585033</u>

Step 3 Using equation (2), determine the ratio of DBBH to d.i.b.

RATIO = DBBH/d.i.b. = 0.234952 - 0.006941(d.i.b.)
RATIO = DBBH/d.i.b. = 0.234952 - 0.006941(8.585033) = <u>0.175363</u>

Step 4 Compute AARI from radial growth
$AARI = \left| (RG/100.0) \times (2.00 + RATIO) \right| / 2.0$
$AARI = \left| (15/100.0) \times (2.00 + 0.175363) \right| / 2.0 = \underline{0.163152}$

Initial d.b.h. = d.b.h. - (2.0 x AARI x 5.0)
Initial d.b.h. = 10.0 - (2.0 x 0.163152 x 5.0) = 8.368477

Sheffield, Raymond M.; Cost, Noel D.; Bechtold, William A.; McClure, Joe P.

Pine growth reductions in the Southeast. Resour. Bull. SE-83. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1985. 112 pp.

Forest Survey data and analyses of them indicate that pine growth in much of the Southeast has slowed. Eighty tables document growth changes, and analyses show that radial growth of individual trees and basal area growth of stands has slowed. Some possible causes are discussed.

KEYWORDS: Forest survey, forest inventory, Pinus, Piedmont Plateau, Coastal Plain, tree growth.

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