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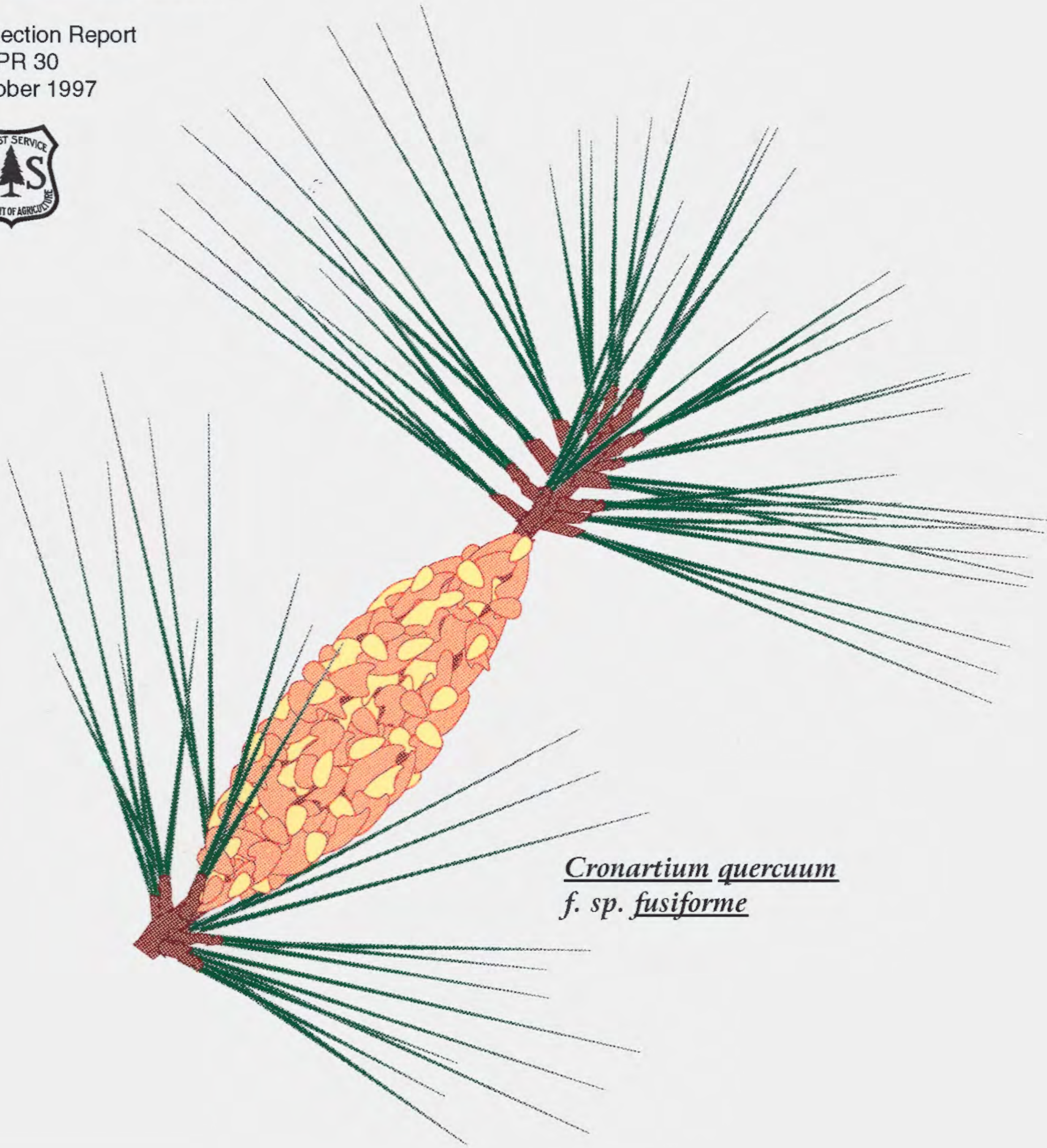
MONITORING INCIDENCE OF FUSIFORM RUST IN THE SOUTH AND CHANGE OVER TIME



Cronartium quercuum f. sp. fusiforme

MONITORING INCIDENCE OF FUSIFORM RUST IN THE SOUTH AND CHANGE OVER TIME

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MONITORING INCIDENCE OF FUSIFORM RUST IN THE SOUTH AND CHANGE OVER TIME

Fusiform Rust in the South

Fusiform rust, caused by the fungus Cronartium quercuum (Berk.) Miyabe ex Shirai f. sp. fusiforme on slash (Pinus elliottii Engelm. var. elliottii) and loblolly (P. taeda L.) pines, is native to the Southern United States. Since the 1930's, fusiform rust has developed into the most destructive forest tree disease of southern pines (Dinus and Schmidt 1977). Widespread planting of slash and loblolly pines, coupled with forest fire control programs, has resulted in increasing acreages of susceptible pines and increasing populations of the fungus' alternate host—oaks (Quercus spp.)—which are necessary for the fungus to complete its life cycle and cause infections of pines. Infection by the fungus results in the formation of swollen galls on susceptible pine stems and branches. Main-stem infections in pines less than 5 years old are likely to kill the tree (Campbell 1965, Nance and others 1981, Wells and Dinus 1978). Main-stem and branch infections occurring after age 5 normally do not kill a tree, but they often result in breakage during storms or merchantable volume loss at harvest (Webb and Patterson 1983). Slash pine is generally more susceptible and more damaged by rust than is loblolly pine (Goddard and Wells 1977). Rust incidence varies greatly from year to year and across sites due to varying weather patterns and local conditions. Incidence and impact of rust may be reduced by management activities, particularly the planting of rust-resistant sources or genotypes in high-risk areas. It is important to attempt to track rust incidence across the South to detect any significant changes or trends in rust levels over time.

Estimating the incidence of fusiform rust for a region as large as the South is extremely difficult. The cost of making a large, single-purpose survey to obtain such data is prohibitive, so if Southwide estimates are to be made, other currently existing data sets must be used. The only regional data available for making such estimates can be obtained from Forest Inventory and Analysis (FIA, formerly known as Forest Survey) of the USDA Forest Service, Southern Research Station (formerly the Southeastern and Southern Forest Experiment Stations). The FIA data is collected from several thousand sample plots in each Southern State on a 6- to10-year remeasurement cycle. Fusiform rust infection has been recorded since 1973 in most States (Jacobi and others 1981) and is uniquely suited to such surveys because it has a symptom that can be easily identified year round. Rust incidence has been previously estimated for five Southeastern States (Florida, Georgia, North Carolina, South Carolina, and Virginia) using FIA data (Anderson and others 1986) with somewhat different procedures than employed here. Now, FIA data that includes fusiform rust incidence from two or more survey cycles is available for each Southern State where rust occurs, allowing new estimates to be made and new comparisons of change over time.

Collection and Reliability Of Rust Data

Each FIA sample location (plot) consists of a permanent cluster of 10 sample points (delineated using a sampling prism with a basal area factor of 37.5 ft^2/acre) to tally trees $\geq$5 inches in d.b.h. Trees <5 inches in d.b.h. are tallied on small fixed-radius plots around the prism points. For fusiform rust, any pine $\geq$1 inch in d.b.h. is considered infected if it has a rust gall on the main stem or on a living branch within 12 inches of the main stem. These galls are potentially lethal, especially if infection occurred prior to age 5. Field crews are trained in the identification and recording of fusiform rust infection and are provided with manuals illustrating rust infection and recording procedures. Details of the data collection process can be found in "Field Instructions for the Southeast" and "Forest Survey Inventory Work Plan for Alabama" (administrative documents available from USDA Forest Service, Southern Research Station, Asheville, NC, and Starkville, MS).

In order to evaluate the reliability of rust infection data, field checks of a sample of FIA plots were made. Ten plots each of the slash and loblolly forest types were visited, and slash and loblolly trees were examined for rust infection. Results were compared to those of the regular field crews. In addition, 100 slash or loblolly trees in the area surrounding each FIA plot were surveyed for infection to evaluate how well the field plots represented rust infection nearby. To accomplish this, individual trees within the 10 prism points were identified, and any intervening trees were evaluated for rust infection. Next, trees outside the cluster of prism points were selected in an outwardly expanding area from the approximate center of the plot (i.e., the cluster of prism points) and evaluated for rust infection until a 100-tree sample was obtained.

Field checks showed that FIA field crews had 98- and 95-percent accuracy for recognition of fusiform rust on slash and loblolly pines, respectively. On uninfected trees, the accuracy rate of field crews was 100 percent for slash and 98 percent for loblolly. When plot infection was $\geq$10 percent, the 100-tree survey of the surrounding area confirmed it 100 percent of the time. Seventy percent of the time (at all infection levels), the estimate of the 100-tree sample was within 14 percent of the plot infection estimate and never varied by more than 20 percent.

Using Forest Inventory and Analysis Data to Track Rust

Data from the most recent survey in each State were used to estimate the current status of rust infection in each Southern State where rust occurs. In addition, data from the next-to-last survey was compared to the most recent in order to assess short-term changes in rust infection. Finally, in four States (Mississippi, North Carolina, South Carolina, and Virginia) where three surveys that contained rust data were available, we made a longer-term assessment of change in rust status.

The analysis was restricted to FIA plots with slash or loblolly pine forest types. For these plots a subset of the data was created from each survey that included State, forest type (slash or loblolly), ownership, number of infected pines (slash or loblolly) per acre, number of healthy pines (slash or loblolly) per acre, stand age, stand origin (planted or natural), and the appropriate plot expansion factors (for calculating State-level estimates of acres). State-level estimates of the number of acres with ≥10-, ≥30-, and ≥50-percent rust incidence were calculated by multiplying the number of plots with those levels by their associated plot expansion factors and summing the results. Estimates were made for the slash and loblolly pine types, planted and natural stand origins, and several ownership categories for each State. Statewide estimates of incidence (at the ≥10-percent level) are based on hundreds of plots per State and are, therefore, very reliable. Further breakdowns by host type, stand origin, or higher incidence levels result in less reliability because fewer plots occur in these classifications. Thus, the latter estimates should be viewed with more caution.

Current Status of Rust in The South

Host acreage by state, ownership, and rust infection level are presented in tables 1-8. Southwide, the current estimate of slash and loblolly pine host types is 47.9 million acres (table 1). Georgia has the most, about 9.4 million acres, while Oklahoma has the least, 465,000 acres. The majority of the acreage is owned by nonindustrial private forest landowners (51 percent) and the forest industry (42 percent). Over 13.4 million acres (28 percent) southwide have ≥10 percent of the slash and/or loblolly pines infected (table 2), and the proportion of infected acreage on nonindustrial private and industrial forest land is about the same as for all host acres. These percentages, of course, vary somewhat among States. Georgia has the most, with about 4.5 million acres having ≥10-percent infection, and Oklahoma the least, with 34,000 acres having ≥10-percent infection.

Slash and loblolly pine plots with ≥10-percent rust incidence are distributed over nearly the entire range of each species, as shown by the maps in figures 1 and 2. These maps provide a good visual approximation of the distribution and frequency of rust occurrence but not an absolute one. Even though several thousand plots are established in each State, many areas of potential pine hosts may not be represented by a plot or plots. Because rust incidence can vary considerably over relatively small areas, areas of high or low rust can be closely associated but not accurately characterized by one or more nearby plots. Also, States in the eastern half of the region (Florida, Georgia, North Carolina, South Carolina, and Virginia) have a more random distribution of plots, whereas States in the western half of the region (Alabama, Arkansas, Louisiana, Mississippi, and Texas) have a more systematic distribution. Thus, plot densities on the map do not absolutely represent rust prevalence. Nonetheless, the maps provide a good, visual representation of where rust is most commonly found on FIA plots.

Of the 13.4 million acres southwide with ≥10 percent of the trees infected, 29 percent is slash pine type and 71 percent is loblolly (tables 3-6). About 34 percent of the 11 million acres of slash pine type (table 3) and 26 percent of the 36.6 million acres of loblolly pine type (table 6) had ≥10-percent of the trees infected. For the slash pine type, the proportion of planted acres with ≥10-percent rust was twice that for natural acres (41 vs. 21 percent; tables 4, 5) while for the loblolly pine type, the proportion with ≥10-percent rust infection was rather similar for planted and natural acres (23 and 29 percent; tables 7, 8). The highest proportion with ≥10-percent rust for the slash pine type occurred in Louisiana (85 percent, natural acres), while the highest levels for the loblolly pine type

Figure 1.--Locations of Forest Inventory and Analysis plots that have slash pine forest type and ≧ 10-percent fusiform rust infection.

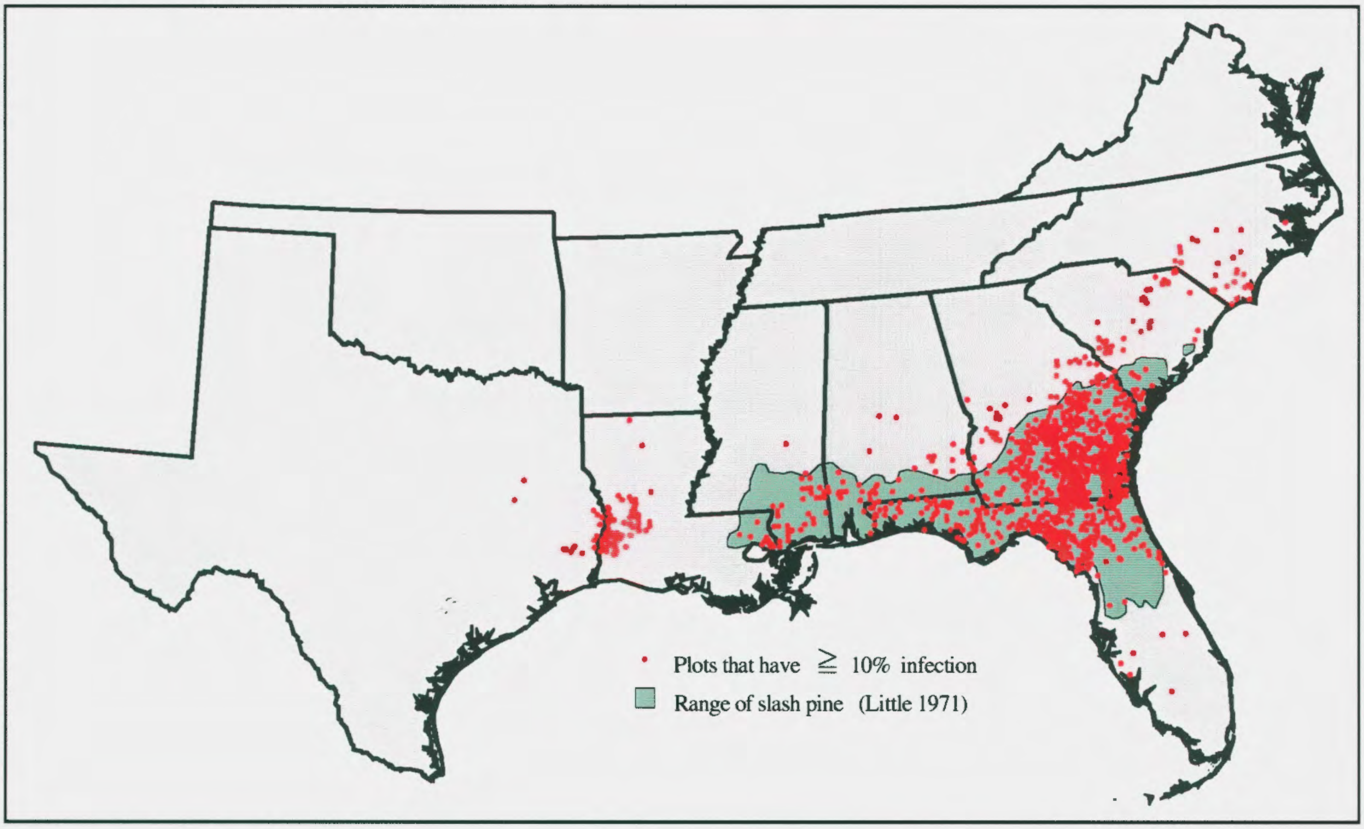
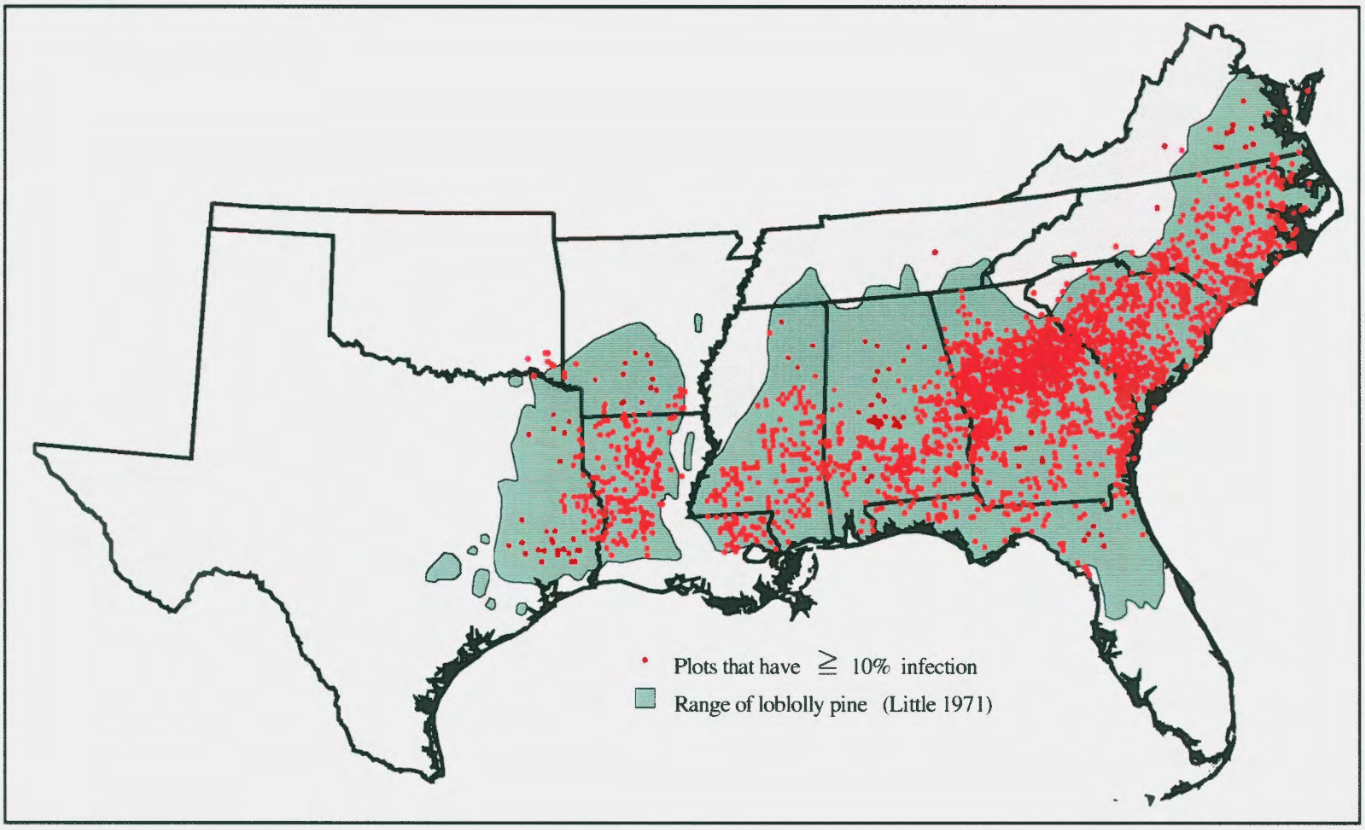


Figure 2.--Locations of Forest Inventory and Analysis plots that have loblolly pine forest type and ≧ 10-percent fusiform rust infection.



occurred in Georgia (58 percent, natural acres).

There were far fewer acres with ≥30- and ≥50-percent infection levels (tables 3-8). For slash pine, the proportion of acres with these levels of infection were 15 and 7 percent, respectively. In the loblolly type, only 9 and 3 percent, respectively, of the acres were at these levels. Individual State estimates varied considerably depending on species and stand origin. For instance, in Louisiana, the proportion of natural slash acres with a ≥30-percent rust level was 73 percent; at the ≥50-percent rust level it was 32 percent. In Georgia, natural loblolly acreage at the ≥30-percent infection level was 24 percent; at the ≥50 percent level it was 9 percent.

Monitoring Change in Rust Incidence Over Time

Data for the most recent survey in each State was compared to data from the next-to-last survey (tables 1-8) to examine changes in host acreage and rust infection over time. Changes in acreage on a percentage basis are presented in tables 9-14. Host acreage southwide had increased by about 4.3 million acres from the previous survey—a 10-percent increase (table 1). The proportions by ownership categories changed little.

Overall, for both natural and planted stands, slash pine acreage had decreased slightly (-6 percent) while loblolly pine acreage had increased (+16 percent) between the 2 most recent surveys (tables 9, 12). For both species, planted acreage increased (+7 percent for slash pine, +44 percent for loblolly pine; tables 10 and 13) while natural acreage decreased (-24 percent for slash, -14 percent for loblolly; tables 11 and 14) over the period between surveys. The number of acres with ≥10-percent infection did not follow these trends (tables 9-14). For planted slash pine, infected acreage decreased 3 percent while infected acreage of natural slash pine increased 1 percent. Similarly, planted loblolly acreage with ≥10-percent infection decreased 7 percent while infected acreage in natural stands decreased 3 percent. Changes in acreages at the ≥30-percent and ≥50-percent infection levels followed somewhat similar patterns regionwide. Changes at all levels varied from State to State (tables 9-14).

Long-Term Changes in Rust Incidence

Only four States have rust data from three surveys, so only a limited analysis of long-term changes in rust could be made. In the four states—Mississippi, North Carolina, South Carolina, and Virginia—there was a slight upward trend in the number of planted and natural acres of slash and loblolly pines (fig. 3). The trend for loblolly is much stronger than for slash pine (figs. 4, 5). Acreage with ≥10-percent rust infection increased from the 1970's to the 1980's (but only slightly in Virginia, where rust incidence is uniformly low) but decreased during the 1980's to the early 1990's (fig. 6). This was true for each species (figs. 7, 8). Magnitudes of change in infected acres between earlier and later surveys were not particularly different, although they, too, were highly varied (tables 9-14). For instance, the number of planted slash pine acres with ≥10-percent infection in North Carolina increased 32 percent from 1975 to 1984, while the number of planted loblolly acres in South Carolina with ≥10-percent infection decreased 9 percent over the same time span. Although

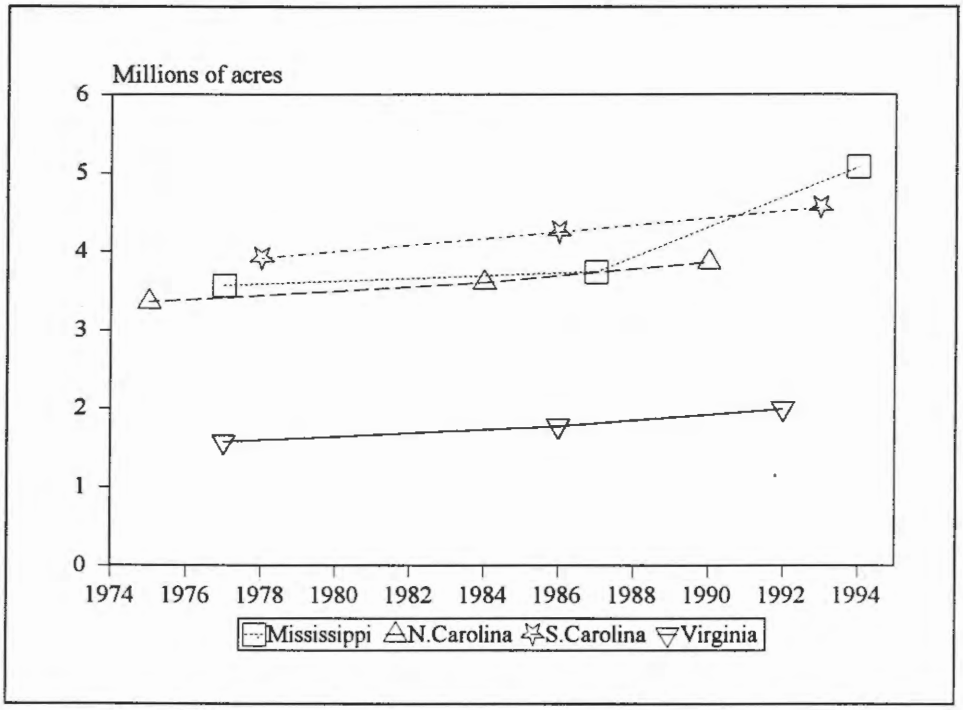


Figure 3.—Planted and natural slash and loblolly pine acreage, estimated from Forest Inventory and Analysis data for four States.

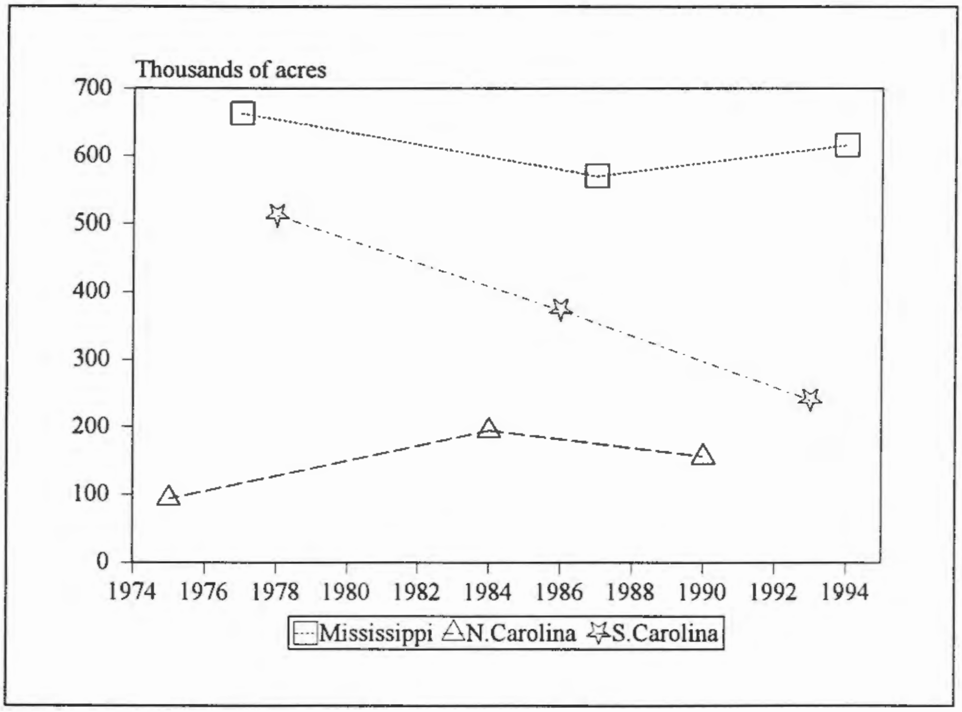


Figure 4.—Planted and natural slash pine acreage, estimated from Forest Inventory and Analysis data for three states.

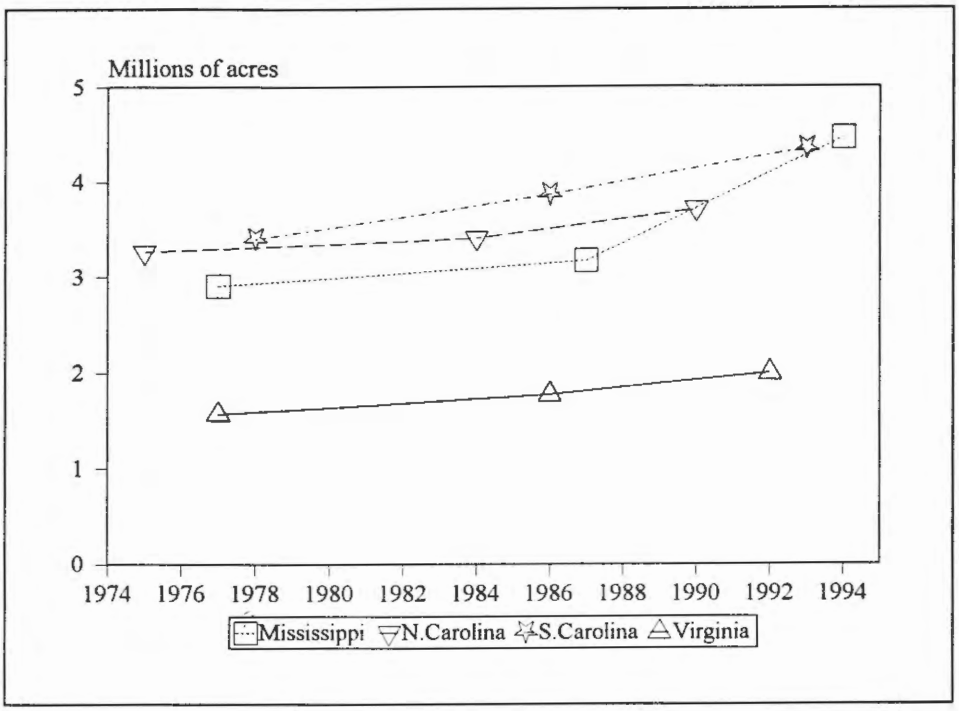


Figure 5.—Planted and natural loblolly pine acreage, estimated from Forest Inventory and Analysis data for four states.

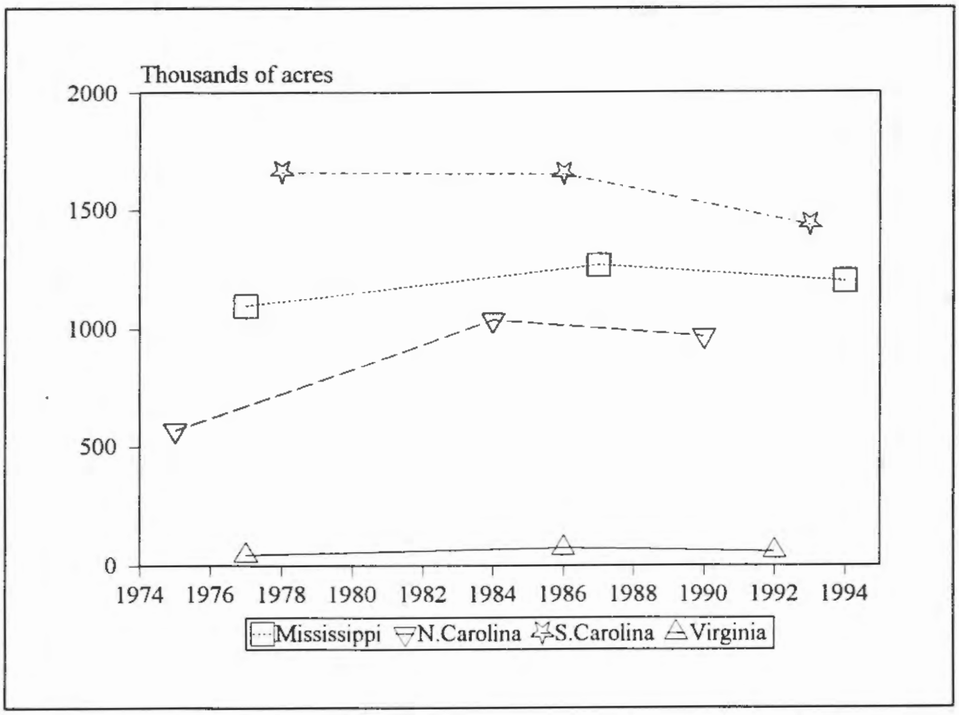


Figure 6.—Acreage of loblolly and slash pine with ≥10-percent fusiform rust infection, estimated from Forest Inventory and Analysis data for four States.

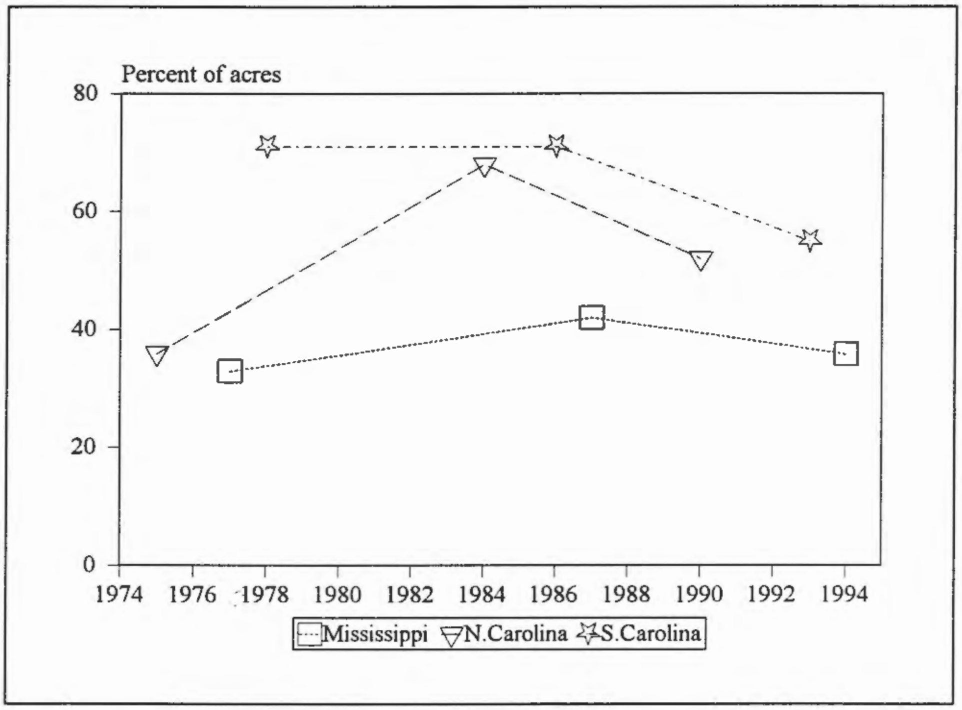


Figure 7.—Slash pine acreage with ≥10-percent fusiform rust infection, estimated from Forest Inventory and Analysis for four States.

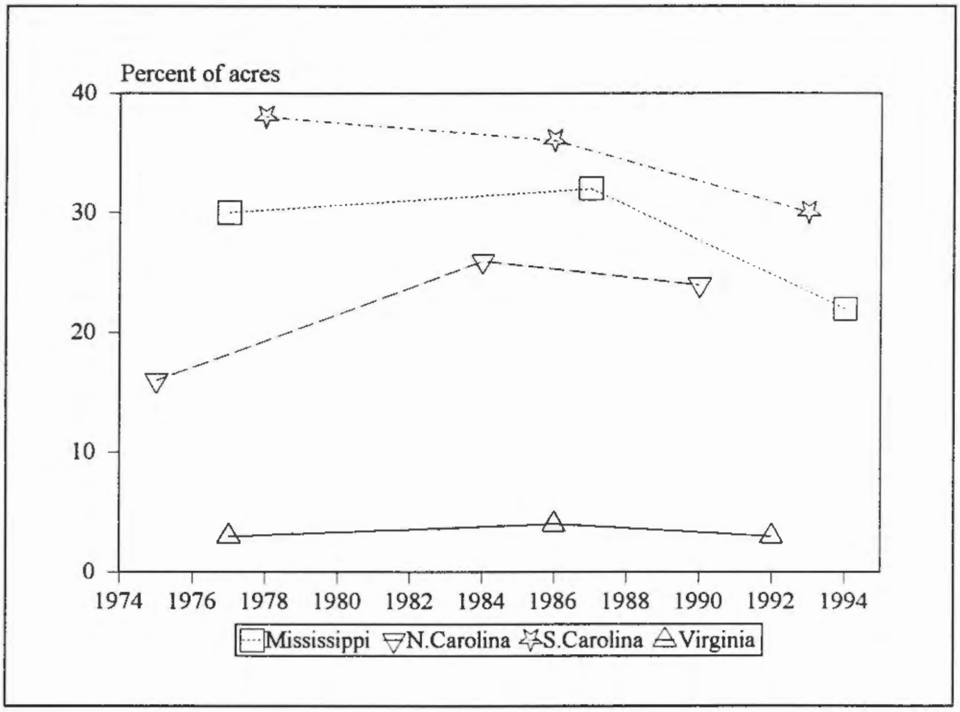


Figure 8.—Loblolly pine acreage with ≥10-percent fusiform rust infection, estimated from Forest Inventory and Analysis data for four States.

data with rust incidence is not available from the 1970's for other than these four States, these trends may well represent much of the rest of the South.

Rust Hazard Mapping

The rust infection recorded in the FIA data can also be used to map estimated hazard to rust. However, simple percentages of infected trees may not best represent hazard to new infections. To more realistically estimate the rust hazard, further restrictions were imposed on the FIA data sets. Slash and loblolly forest types were evaluated separately. For plots of natural origin, only those 5 to 15 years old were used—younger stands may not have expressed symptoms, and infected trees may have died in older stands—thus better expressing hazard for new plantings nearby. For plots of planted origin, only those with ≥30-percent infection were used—this potentially eliminates plots where the use of genetically resistant planting stock may have artificially lowered infection levels and thus confounded the estimation of hazard. These points were plotted on a map of the South by species. A grid was created from the point coverage (grid size was 1.86 miles or 3 km), and the infection percentage of each plot was used to calculate a weighted average for grid cells based on the inverse of the distance squared from each point. Grid cell values were interpolated from points within 99.4 miles (160 km) up to a maximum of 12 points. Grid cells were then classified as low hazard (0-9.9-percent infection), moderate hazard (10-30-percent infection) and high hazard (>30-percent infection). Grid cells were converted to polygons, and hazard rating was limited to counties with slash or loblolly occurrence as appropriate.

Maps were drawn to show slash and loblolly pine rust hazard zones (figs. 9, 10). These maps give a useful estimate of hazard to rust infection for both species over large areas of the South. They appear consistent with the ranges of the host species and our knowledge of where fusiform rust occurrence is most severe. Individual land management decisions, however, must be based on more localized rust hazard estimates made from nearby stands of host species. Survey methods for making such an estimate have been developed (Yandle and Roth 1971).

Conclusions

For any major disease, such as fusiform rust, it is vital that the distribution and incidence be estimated and change over time monitored. When dealing with an 11-State area and millions of acres of susceptible hosts, the task becomes exceedingly difficult. Distribution and incidence of rust as reported here is particularly useful because it is based on a relatively stable and recurring data set that will allow periodic southwide updates of rust status. As management strategies to reduce rust are more frequently applied, and as genetically resistant planting stock becomes more widely available, their effects on the status of fusiform rust can be monitored over time. In this analysis, slight regional trends toward a higher proportion of slash pine acreage with ≥10 percent rust and a lower proportion of loblolly pine acreage with ≥10 percent rust were detected. For individual States, the detected changes may be viewed as important by forest managers.

Figure 9.--Estimated fusiform rust hazard for slash pine based on infected Forest Inventory and Analysis plots.

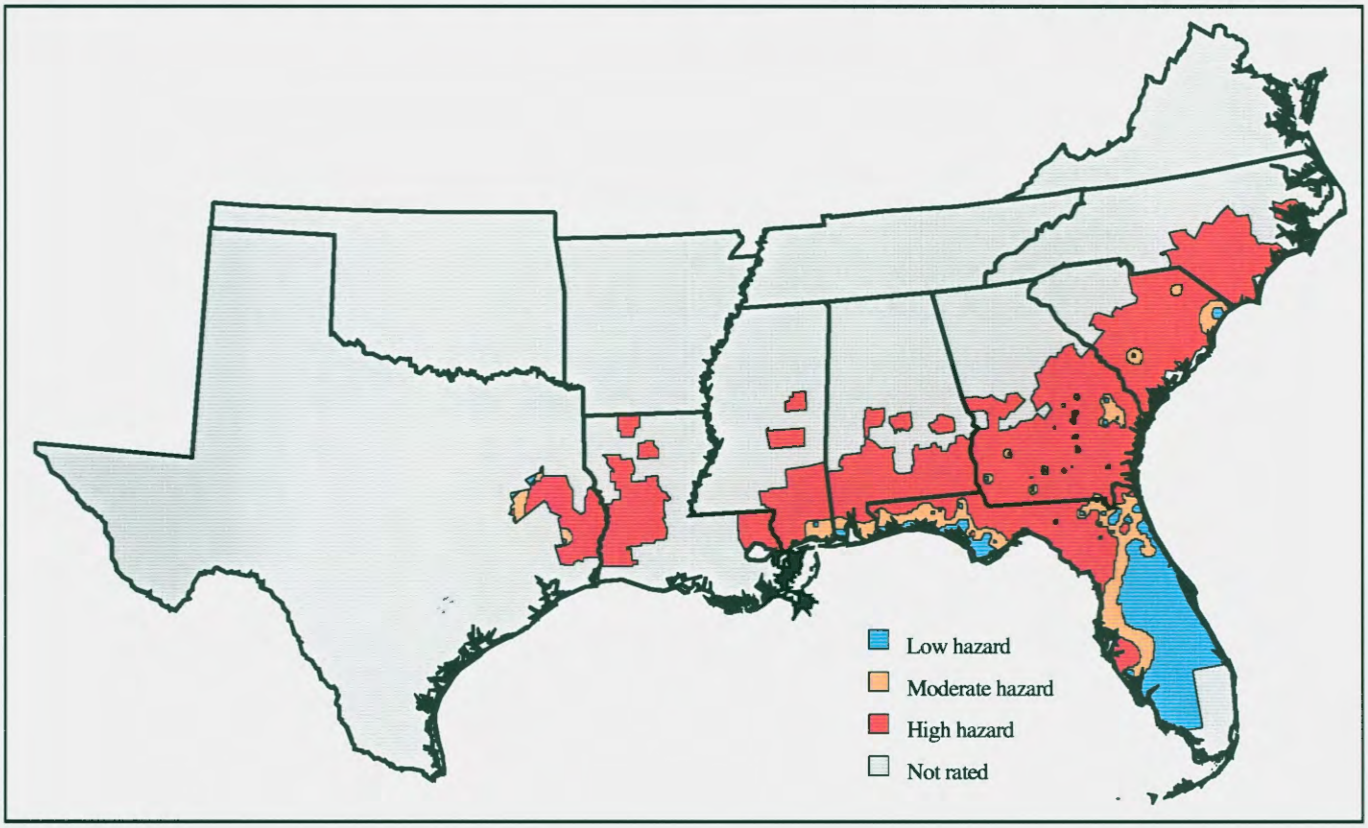
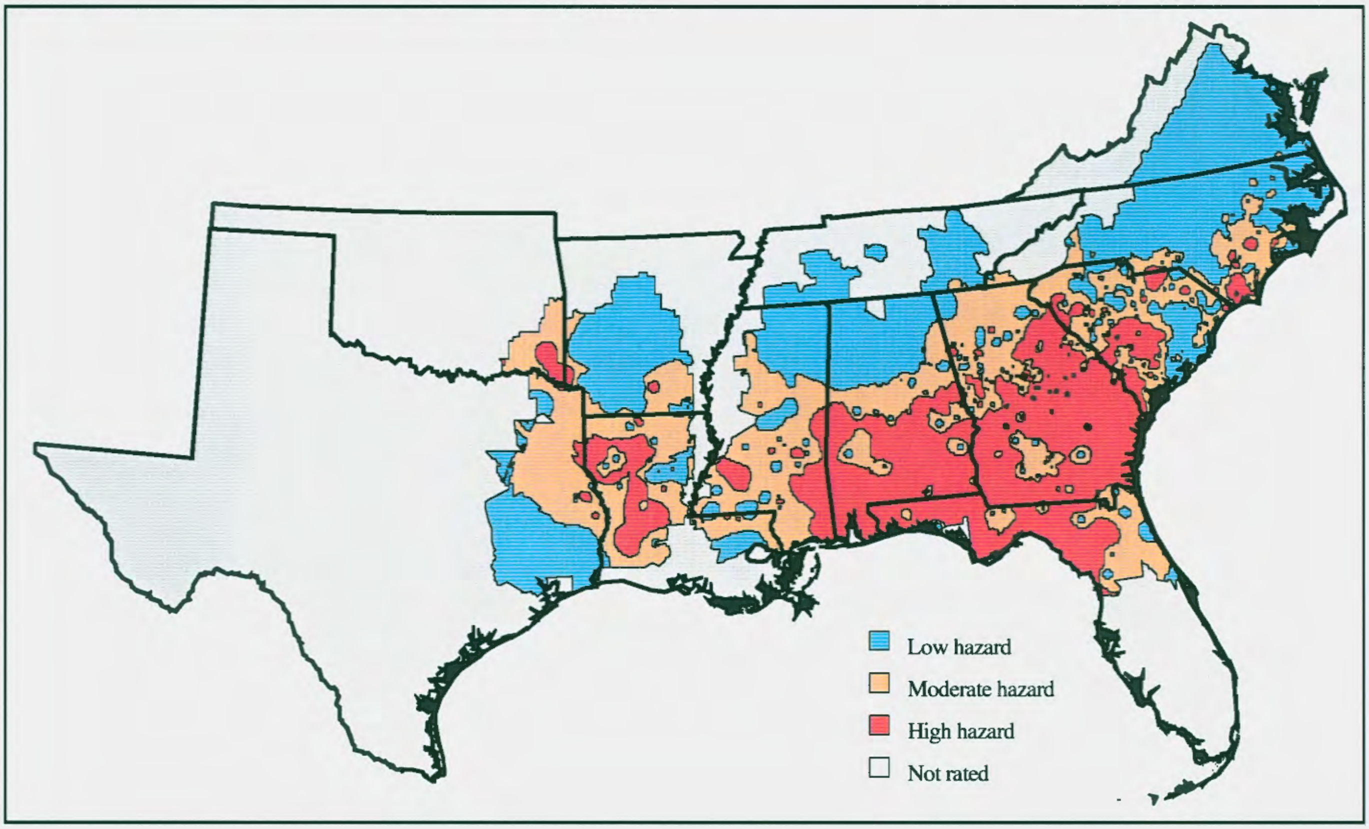


Figure 10.--Estimated fusiform rust hazard for loblolly pine based on infected Forest Inventory and Analysis plots.



For instance, in Louisiana, the number of acres of natural slash pine decreased from 133,000 in 1984 to 107,000 in 1991 (a 20-percent reduction), but the proportion of acres with ≥10-percent rust infection increased 21 percent (table 3). Or, in Mississippi, the number of acres of planted loblolly pine increased from 1.1 million in 1987 to 2.5 million in 1994 (a 125-percent increase), while the proportion of acres with ≥10-percent rust infection decreased 14 percent. Unfortunately, the real reasons for changes in the number of acres of trees with rust infections cannot be discerned from survey data. Planting of resistant host species or genotypes, variations in local and regional weather, and the great variety of management activities imposed on surveyed stands can all affect infection levels as can the effect of the disease itself (e.g., infected trees dying between surveys).

The actual impact of rust on forest stands is extremely difficult to assess. Rust may kill young trees, thus reducing stocking, but if sufficient numbers of healthy trees remain, no reduction in yield at harvest may occur. However, if stocking is severely reduced, yield reductions will occur. Volume loss can also accrue from trees that are deformed or degraded by infection but that will survive until harvest. Unfortunately, there is no direct way of assessing these losses from FIA data. In this analysis we used ≥10-percent infection as a minimum because levels lower than that were unlikely to affect stand management or yields.

Because only 2 survey cycles including rust data were available for all 11 Southern States, no regional, long-term trends in rust infection (if they exist) could be detected. Data from three survey cycles were available for four States and were compared. Data from 3 survey cycles will be available from all 11 Southern States in the future. At that time, a similar analysis can be performed to examine longer term trends.

Changes in rust levels reported here are the result of applying the methods described to the current and immediate past surveys in each State. Data on the number of acres reported here should not be directly compared to past reports on rust where different methods were used.

Landowners concerned with fusiform rust have a number of management options they can implement—the use of resistant planting stock, reduction of local oak populations, adjustments in planting density, and species/site matching. Also, managers may apply thinning strategies to reduce the effects of rust during midrotation and to capture volume that would otherwise be lost. Information on fusiform rust and management techniques are available for land managers interested in this disease (Anderson and others 1980, Powers and others 1993).

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Fusiform rust incidence and change over time were assessed using forest inventory data. The results aid in monitoring the status of this important disease and provide information on the impact of disease management strategies over time.