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# Fusiform-Rust-Hazard Maps for Loblolly and Slash Pines

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ABSTRACT

Rust-hazard saps made from Forest Inventory and Analysis plot data show that fusiform rust on slash pine is most common in north-central Florida, in southeastern Georgia, and in areas north of slash pine's natural range. On loblolly pine, the disease is most common in central and southeastern Qeorgia and in portions of South Carolina. These maps show the general distribution of the disease over *large* areas sad should not be used to evaluate hazard on specific sites.

Keywords: Pinus taeda, Pinus elliottii, Cronartius quercuum.

Fusiform rust, caused by Cronartium quercuum (Berk.) Miyabe ex Shirai f. sp. fusiforme, is native to the Southeastern United States but was not considered to be a major problem prior to 1930. Shortly thereafter, its significance began to grow, along with intensification of cultural practices, especially pine planting, and increased occurrence of its alternate host (oak) (Dinus and Schmidt 1977). Now, fusiform rust is by far the most important tree disease in the Southern United States. Southwide, 13.8 million acres of pine forest are estimated to have 10 percent or more of the trees infected on or near main stems. About 2.5 million acres--6 percent of the slash (Pinus elliottii Engelm.) and loblolly (P. taeda L.) pine acreage--are estimated to have over 50 percent of the. trees infected (Anderson and others 1981). Stem infections in pines less than 5 years old are likely to kill the tree (Campbell 1965). Stem infections contracted after age 5 usually do not kill a tree but often cause breakage during storms or quality loss at harvest.

Phelps (1973) surveyed plantations across the South-and delineated areas of rust hazard for planted loblolly and slash pines. Squillace (1976) used Phelps' data plus supplemental data to develop isogram maps southwide, showing geographic variation patterns. While there has been interest in making another survey like Phelps', the work would be costly and the results would be questionable. Many plantations now contain genetically resistant stock, and low infection in these plantings would confound efforts to delineate areas of high rust hazard.

Forest Inventory and Analysis (FIA) (USDA Forest Service) crews have been collecting disease occurrence data for several years, and Powers and others (1975) used FIA disease occurrence data to estimate the losses caused by fusiform rust in the South. They estimated the annual loss at $28 million per year for the entire South. Since then, the values of products have changed, and incidence of the disease appears to have

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increased. Anderson and others (1986) estimated annual losses at $35,227,000 in the States of Virginia, North and South Carolina, Georgia, and Florida, FIA data include species, percentage of rust, and age, by location. We decided to see if these data could be used to construct hazard maps, instead of going back to the field and examining separate plots. This report presents the results of that effort.

## Methods

The forest resources in each Southeastern State are resurveyed by FIA at approximately 6- to lo-year intervals. During these inventories, FIA crews from the Southeastern Forest Experiment Station record occurrence of fusiform rust on loblolly and slash pines on permanent inventory plots. Each State has several thousand ground sample locations systematically distributed on its forest land. A lo-point cluster of plots is established at each of these sample locations, and variable radius plots are delineated with a prism with a basal factor of 37.5 $ft^2$/acre at five of these points. Trees less than 5 inches d.b.h. are tallied on fixed-radius plots around the five sampling points. A pine 1 inch or.larger in diameter is considered infected if it has a 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. Details of the data collection process can be found in "Field Instructions for the Southeast, 1982" (USDA Forest Service 1982). Additional information is available in a paper by Jacobiand others (1981).

The analysis was confined to FIA plots in the loblolly and slash pine forest types. For a plot to qualify, at least half its basal area had to be pine of these species. For these plots, the following useful data were available:

- State
- Survey Unit
- County
- Location
- Forest type: slash - 1;
  loblolly - 2
- Stand origin (planted or natural)
- Site class (l-5)
- Stand age (nearest year)
- Number of trees 1 inch d.b.h. and larger of all species per acre (nearest 10/acre)
- Number of infected pines 1 inch d.b.h. and larger per acre (nearest 10/acre)
- Basal area per acre of infected pines (nearest $ft^2$)
- Number of healthy pines 1 inch d.b.h. and larger per acre (nearest 10/acre)
- Basal area per acre of healthy pines (nearest $ft^2$)
- Basal area per acre of all species (nearest $ft^2$)
- Volume expansion factor
- Number of trees per acre in the 2- and 4-inch diameter classes (nearest 10/acre)

With-the use of these FIA data, hazard maps were constructed. Data for the maps came from the fourth surveys of Virginia (1977), South Carolina (1988), and North Carolina (1974) and from the fifth surveys of Georgia and Florida. Data for the maps were checked manually from computer printouts to find natural and planted stands between 5 and 15 years old. These were used as data points in the hazard maps. Each point was located on a'map along with the percentage of loblolly or slash pines infested at that point.

Plantation data were included only for stands in which at least 30 'percent of the trees were infected. All obser-, vations from naturally regenerated stands were entered.

The number of each stand was cross-referenced manually with another printout to determine the grid coordinates for each stand. Using the coordinates and the appropriate grid map, each data point was located and drawn on another base map.

The base map, including State outlines, was digitized on an Apple Graphics Tablet by using a program developed especially for this process. Then all the data points were digitized and stored. As the data points were digitized, the percentage of infection at each point was recorded on paper in the same order as it was digitized. Rust infection percentages were later entered into a separate file with the Applewriter IIe program.

Three data sets showed State outlines, data point locations, and fusiform rust infection percentages. These three data sets were uploaded to a mainframe computer program called "SYMAP" or Synagraphic Mapping System. The program is located at the Triangle Universities Computer Center (TUCC) in Raleigh, NC. The program was provided by the Laboratory for Computer Graphics and Spatial Analysis, Graduate School of Design, Harvard University.

The SYMAP program interpolated the hazard values between all data points based on their infection percentages, distance from each other, and other elective data given to the program. The interpolation procedure was based on a distance-weighted averaging technique provided in the SYMAP program. Hazard maps were then printed on an IBM printer with overprint capabilities.

The original map contained many small hazard zones, which implied greater accuracy than was possible with existing data. We therefore decided to incorporate these smaller zones into larger adjacent zones. This process was done by hand.

The accuracy of interpolation by the SYMAP program is greatly increased if it is not halted by State borders. The original map digitized for loblolly pine was one that included the States of Virginia, North Carolina, South Carolina, and Georgia. However, the borders between these States were excluded so as to allow free interpolation by the SYMAP program across the borders between all the data points. The same process was used for slash pine in Georgia and Florida.

The original maps (one for loblolly and one for slash) were printed at a scale of approximately 1:1,600,000. They were then reduced to their present size and redrawn on State maps with county lines. Each State was drawn separately from the original multi-State maps.

Independent sets of field data were used to check the maps. The independent data points were located on the hazard map, and observed rust incidence was compared with that predicted by the map. Thirty independent, nonpermanent loblolly field plots were established in central and southeastern Georgia. These plots consisted of 100 trees from 5- to 15-year-old loblolly pine stands located at random in the area. The same process was also repeated for slash pine in southern Georgia and northern Florida. In addition, knowledgeable individuals were asked to review the maps based on their field experience.

## Results and Discussion

Figure 1 shows three rust-hazard zones for slash pine in Georgia and Florida. The high-hazard areas (more than 30 percent of trees with infection on or within 12 inches of the main stem) in the natural range of slash pine are in north-central Florida and in southeastern Georgia. Rust hazard is also high for slash pine planted outside its natural range.

The high-hazard areas are normally bordered by areas of moderate hazard, which, in turn, are bordered by areas of low hazard. This pattern is consistent with rust infection in the field, and the computer mapping program was designed to create zones moving from high through moderate to low hazard. In some cases, areas of high and low hazard touch because space between the two areas was too small to not be biologically significant.

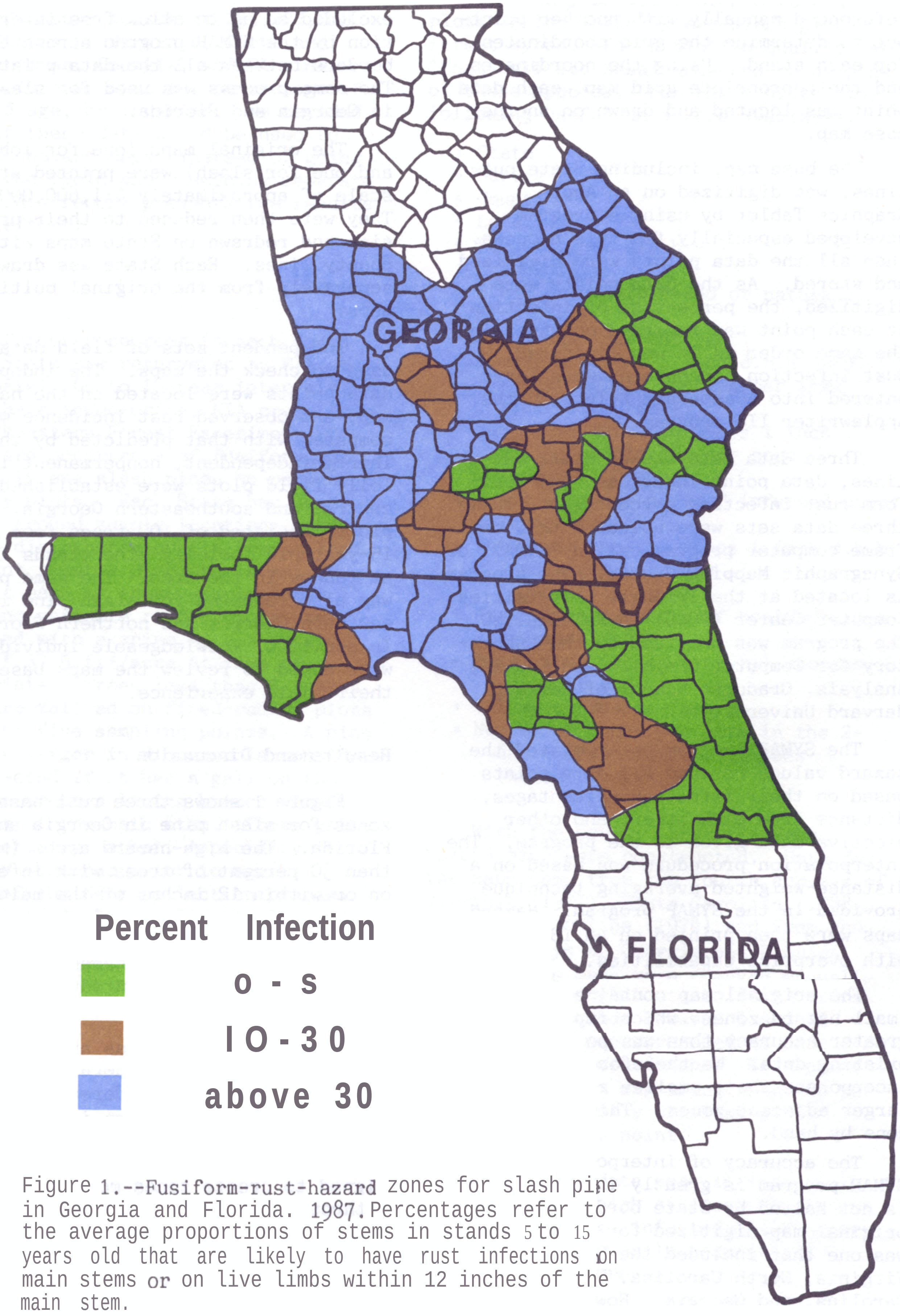


Figure 1.--Fusiform-rust-hazard zones for slash pine in Georgia and Florida. 1987. Percentages refer to the average proportions of stems in stands 5 to 15 years old that are likely to have rust infections on main stems or on live limbs within 12 inches of the main stem.

Figure 2.--Fusiform-rust-hazard zones for loblolly pine in Virginia. South Carolina. North Carolina, and Georgia. 1987. Percentages refer to the average proportions of stems in stands 5 to 15 years old that are likely to have rust infections on main stems or on live limbs within 12 inches of the main stem.

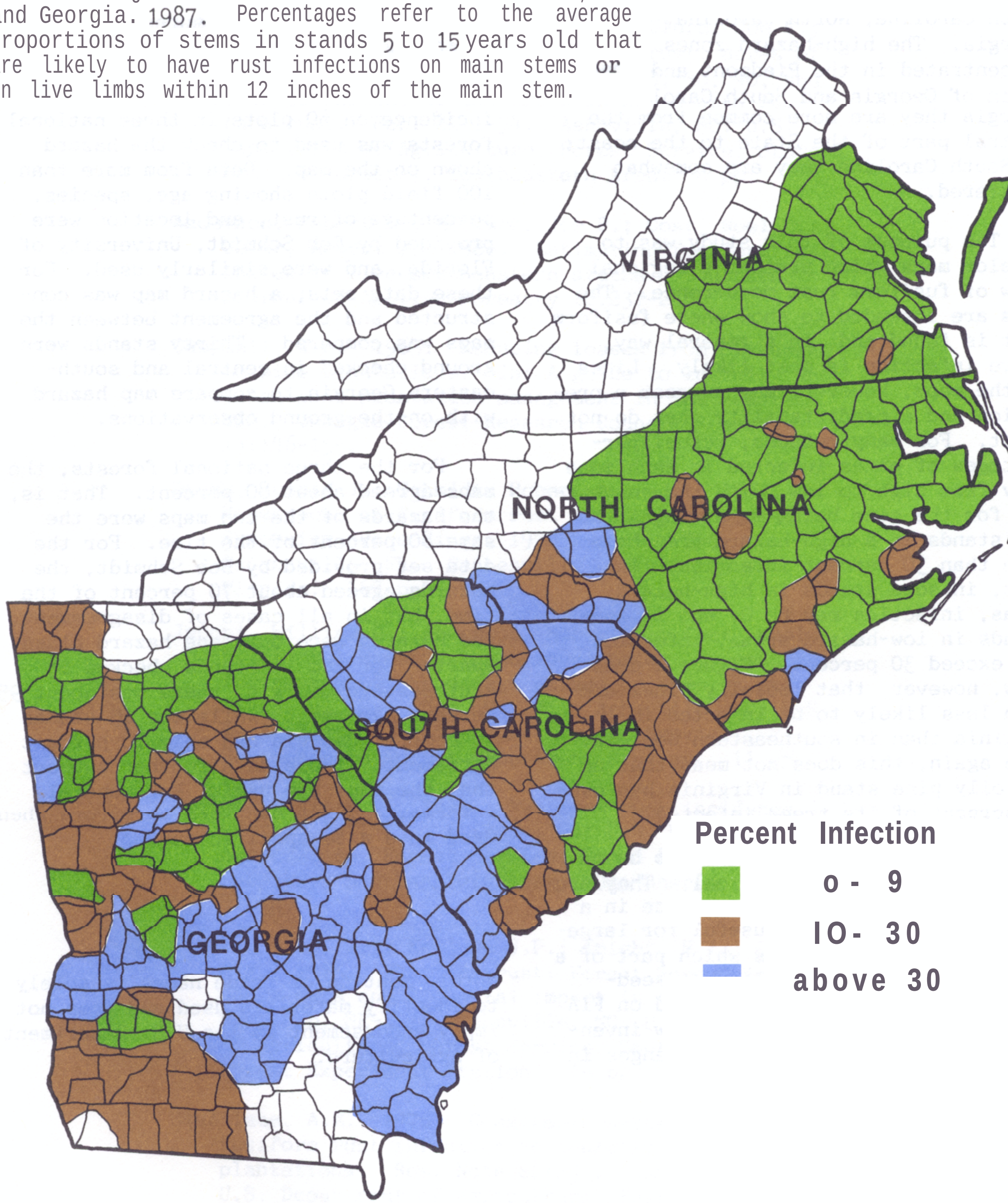

Figure 2 shows three rust-hazard zones for loblolly pine in Virginia, South Carolina, North Carolina, and Georgia. The high-hazard zones are concentrated in the Piedmont and Coastal Plain of Georgia and South Carolina. In Georgia they are more common from the central part of the State to the coast; in South Carolina they are somewhat scattered.

The purpose of this study was to develop maps which present a regional view of fusiform rust occurrence. The maps are intended to show where fusiform rust is found and, in a general way, where infection is most likely. Lines on the maps, however, may suggest a precision and a predictability that do not exist. For many reasons, actual percentages of pines infected in each zone vary from high to low, with the percentage for the zone being an average. Not all stands in a high-hazard area have more than 30 percent infection. In fact, in some stands in high-hazard areas, infection may be 0, and in some stands in low-hazard areas, infection may exceed 30 percent. Figure 2 does show, however, that loblolly pines are much less likely to be infected in Virginia than in southeastern Georgia. Once again, this does not mean that no loblolly pine stand in Virginia has over 30 percent of its trees infected.

The maps are not intended to be an on-the-ground management tool. They are designed to assess rust incidence in a general way and may be useful for large-scale decisions, such as which part of a State to deploy rust-resistant seedlings. Since the maps are based on FIA data, they can be updated as new inventories are completed to show changes in rust hazard over time. One of the advantages of the computer-based map procedure is that it ensures consistency of interpolation of the subsequent data.

In the validation process, rust incidence on 60 plots in three national forests was used to check the hazard shown on the map. Data from more than 100 field plots showing age, species, percentage of rust, and location were provided by Bob Schmidt, University of Florida, and were similarly used. For these data sets, a hazard map was constructed and the agreement between the maps was compared. Thirty stands were ground checked in central and southeastern Georgia to compare map hazard with on-the-ground observations.

For the three national forests, the maps agreed about 80 percent. That is, the hazards of the two maps were the same 80 percent of the time. For the data set provided by Bob Schmidt, the hazards agreed about 70 percent of the time, but in all cases of disagreement, the hazards were only one hazard class apart. For the 15 stands checked in southeastern Georgia, there was about 95 percent agreement, while the 15 stands in central Georgia had only 70 percent agreement. These data further support that the maps are useful for general information, but can lead to errors when used in a site-specific manner.

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Note: Mention of trade names is solely to identify materials used and does not imply endorsement by the U.S. Department of Agriculture.

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