Providing Confidence in Regional Maps in Predicting Where Nonnative Species are Invading the Forested Landscape

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Abstract.—Nonnative invasive plant species introduced to the South during the past century threaten to forest resources. Knowing their extent is important for strategic management and planning. We used U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis (FIA) field observations at ground-sampled locations to model the geographic occurrence probability of forest land in the sampled region, and selected nonnative invasive species in ground-sampled forest land locations. We chose kriging to interpolate and map features geostatistically, and to portray quantitative confidence in the estimates across the sampled region.

Nonnative invasive species are invading forest land. Inventory field crews, along with State partners, now record the presence and dominant cover of selected species in annual inventories in the South (USDA 2001). Using traditional numerical procedures, analysts can determine the area of timberland that contains these species, but maps provide additional information. One is able to quickly visualize the range and distribution of invasion hot spots, initiate hypotheses for species distributions, and provide tabular information to potential stakeholders. Maps help regional administrators, managers, planners and policymakers to quickly locate where nonnative invasive species occur, but more detail is needed to permit a discussion of strategies for managing nonnative invasive species and controlling their spread.

Simple dot maps of the approximate sample locations show the distribution of forest land as well as individual species, e.g., Beltz and Bertelson (1990). That same location information also may be used to interpolate the occurrence of these species between plot locations by generating a probability surface with a finer resolution than the original spacing. We report on interpolation procedures used in Rudis and Jacobs (in preparation) to map Japanese honeysuckle (*Lonicera japonica* Thunb.), privet (*Ligustrum* spp.), multiflora rose (*Rosa multiflora* Thunb. ex Murray), tree-of-heaven (*Ailanthus altissima* [Mill.] Swingle), kudzu (*Pueraria. montana* [Lour] Merr. var. *lobata* [Willd.] Maesen & S. Almeida), melaleuca (*Melaleuca quinquenerva* [Cav.] S. T. Blake), and royal paulownia (*Paulownia tomentosa* [Thunb.] Sieb. Zucc. ex Steud.) in selected States of the South.

Methods

We used plot coordinates that were nominally correct to within 800 m of the actual plot location. Land use at field plots and selected nonnative invasive species' presence and absence values on ground-sampled forest locations were data variables. We chose the survey years 1988 to 1995 as data were complete and species selection procedures were consistent within the then three FIA survey regions. For calculating forest land probability, State surveys included South Central States—Alabama 1990, Arkansas 1995, Louisiana 1991, Mississippi 1994, east Oklahoma 1993, Tennessee 1989, east Texas 1992; Southeastern States—Florida 1995, Georgia 1989, North Carolina 1990, South Carolina 1993, Virginia 1992; and Kentucky 1988.

We entered the selected data variables into a geostatistical software program (GS+ (Robertson 2000)). Calculations involved two essential steps. The first step was to assess the optimum range (the distance at which pairs of plot samples no longer influence one another and are statistically independent) and best-fit parameters from the best model (the model that minimizes the residual sum of squares while also retaining a high R-square value from the available data). The second step was to apply the parameters of the best-fit model to generate a grid surface through a routine called a kriging system (Krige 1951, Matheron 1963). We selected 1 km as the standard grid cell size and limited the range to the 16 plots closest to the 1-km grid cell.

Kriging variance provides data to produce a companion map showing reliability of the data for each grid cell value in the kriged map. These kriging variance values are mapped in

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conjunction with the cell values generated during the kriging routine. A higher number of plots within a close radial distance and the shorter the distance from the grid cell to each of the surrounding plots provide lower kriging variance values to show the better quality of these data. Areas of higher kriging variance may be compared to the same areas within the forest probability map to determine which areas are suspect to a high degree of error. These geographic areas of high error are then blocked out of the map to prevent the portrayal of potentially erroneous information.

Results

The kriging variance grid (fig. 1) showed the difference in density of the plot locations across the South through the portrayal of the kriging variance value for each grid cell. Geographic areas containing high numbers of plots in close proximity to one another exhibited low kriging variance for grid cells near those plots. Where plots were less dense or unevenly spaced, the kriging variance was slightly higher for neighboring grid cells.

For Southeastern States (Florida, Georgia, North Carolina, South Carolina, and Virginia), the Southeastern Coastal Plain contained roughly one plot per 1,100 ha; the Piedmont one plot per 1,400 ha; and the Mountains, one plot per 1,900 ha. Clumping of plots, as seen in the Mountains, produced a spotty effect, i.e., a patchwork of high and low kriging variance. Kentucky was an excellent example. The western portion averaged fewer plots than any of the other States in the South. However, in eastern Kentucky, the national forest land averaged a higher proportion of plots.

The South Central States (Alabama, Arkansas, Louisiana, Mississippi, eastern Oklahoma, Tennessee, and eastern Texas) had nearly uniform plot spacing due to the historical layout of plots on a 4.8-km x 4.8-km sample grid, i.e., one plot per 2,300 ha. Also, there were no field plots in western Oklahoma and western Texas and along predominantly swampland portions of Coastal Plain counties in Louisiana and Texas. This western portion of the map shows a uniform kriging variance across the South Central region with one easily seen exception: Plot spacing within the region's small national forests was denser, thus providing for lower kriging variance. Another exception, light areas within the map not easily seen, was along county lines. In such cases, the kriging variance map illustrates a somewhat

Figure 1.—*Kriging variance, Southern United States, 1988-1995. (South Central—Alabama 1990, Arkansas 1995, Louisiana 1991, Mississippi 1994, east Oklahoma 1993, Tennessee 1989, east Texas 1992; Southeastern—Florida 1995, Georgia 1989, North Carolina 1990, South Carolina 1993, and Virginia 1992; and Kentucky 1988.)*

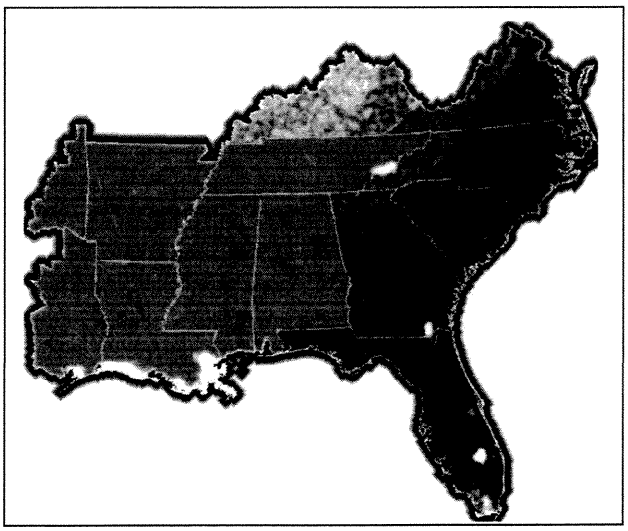
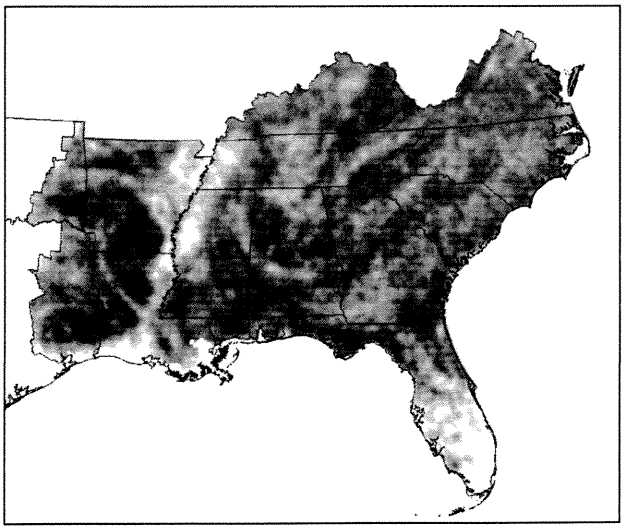


Figure 2. —*Forest land area from ground-sampled locations, Southern United States, 1988-1995. (South Central—Alabama 1990, Arkansas 1995, Louisiana 1991, Mississippi 1994, east Oklahoma 1993, Tennessee 1989, east Texas 1992; Southeastern—Florida 1995, Georgia 1989, North Carolina 1990, South Carolina 1993, and Virginia 1992; and Kentucky 1988.)*



larger spacing than the suggested 4.8-km distance for laying out the original plot grid.

Interpolation outside the grid of plots resulted in extremely high kriging variance values. Likewise, interior holes of no data are visible where ground-sampled information in areas reserved from timber production was unavailable for this study (e.g., Everglades, Great Smoky Mountains, and Okefenokee Swamp).

The forest probability map (fig. 2) portrays densely and sparsely forested areas of the South with a gradient from dark gray to light gray. Sparsely forested areas include south Florida, the Mississippi Alluvial Valley, the Arkansas River and Red River, Blackbelt Prairies, and Interstate Highway corridors. This map provides a method to block out the species grid surface layer to the grid cells having a minimum threshold forest land probability.

Discussion and Conclusion

Future plans for the location of plots include dropping some plot locations and adding others to form a regular grid network to provide for a more uniform statistical kriging variance across the entire South. As FIA and State partners implement the new wave of forest inventory plot designs across all States, more data will be available for modeling nonnative invasive species. When completed, occurrence maps will become available for detecting both the current status and change in distribution of nonnative invasive species.

New FIA procedures include refining all spatial data with more precise location information obtained from GPS units, which will improve the utility of the final map for linkage with other georeferenced data sources, and various other uses. At the same time, spatial accuracy also could be improved, especially in predominantly nonforest regions, with sampling of selected attributes on plots categorized as agricultural or urban land, but that contain forest land elements such as trees and other attributes of interest, i.e., nonnative invasive species.

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