# Nonnative Invasive Plants in South Carolina: Combining Phase-2 with Phase-3 Vegetation Structure and Diversity Pilot Data to Enhance our Understanding of Forest Health Issues

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***Abstract***—*Studies suggest that the Southeast is an area of primary concern with regards to the spread of alien plant species (Miller 2003, Stapanian and others 1998). Data collected by Stapanian and others in 1998 showed that Japanese honeysuckle (*Lonicera japonica*) occurred over 2 million acres in the Southeast, invading forests and displacing native species. Among the most important mechanisms for the early detection and prevention of the spread of nonnative species is monitoring on large spatial scales for the presence of alien species, and for the presence of vulnerable sites (in other words, sites affected by certain disturbance types) (Jose and others 2002). In the Southeast, a primary research priority is the need for better assessments of on-going biological invasion, for public and scientific use (Mack and others 2000). As one method for addressing this need, the Forest Service's Forest Inventory and Analysis program incorporates assessments of the presence of nonnative species into its Phase-2 forest inventory. Additionally, pilot studies are currently underway for a new forest health variable that would describe native and alien vascular plant diversity and extent. This paper describes results gleaned from 2002 to 2004 Phase-2 data combined with 2002 Phase-3 vegetation structure and diversity pilot study data in South Carolina, USA. While small sample sizes limit the reliability of statistical tests for the pilot study, the results from the 2002 pilot illustrate potential uses for the new Phase-3 variable in monitoring and detecting the spread and impact of nonnative species in Southern forests.*

## Introduction

Southern forest health can be noticeably affected by anthropomorphic stress, including the introduction of nonnative plant species. Humans continue to increase the rate of spread of alien species as populations soar and global travel becomes more commonplace (Pimental and others 2001, Mack and others 2000, Stapanian and others 1998). Research indicates that nearly 4,000 alien plants occur outside of cultivation in the United States (Stein and others 1996). While the current lack of available data limits the ability of scientists and economists to determine the impacts of introduced plant species on the environment and economics (Pimental and others 2001), these and other alien species cost the United States an approximated $97 billion in direct economic losses over an 85-year period (Stein and others 1996). In addition to the economic costs associated with the control of nonnative plant species, environmental costs are high. Invasive species have the ability to transform entire ecosystems through modifications of soil, water, and light resources (Gordon 1998, Stapanian and others 1998, Stein and others 1996). In addition, some plant species prevent forest regeneration through the formation of thick rhizomatous mats in the forest soil (Jose and others 2002). In some cases, regeneration is further prohibited through an increase in the aboveground biomass available as fuel. For example, forest fires occurring in pine forests of the Southeast containing the alien invasive cogongrass (*Imperata cylindrica*) burned at higher temperatures than forests containing only native species, damaging seedlings and preventing regeneration (Jose and others 2002).

Studies suggest that the Southeast is an area of primary concern with regards to the spread of alien plant species (Miller 2003, Stapanian and others 1998). In 1998, data collected by Stapanian and others showed that Japanese honeysuckle (*Lonicera japonica*) occurred over 2 million acres in the Southeast, invading forests and displacing native species. Similarly, Craver (1982) noted that nonnative honeysuckles, including Japanese honeysuckle, were found on commercial forestland in every county in South Carolina. In addition, current studies regarding the problematic regeneration of northern red oak on high-quality sites suggest that the invasive Nepalese browntop (*Microstegium vimineum*) may behave like cogongrass in preventing the establishment and development of seedlings (Oswalt and others 2004). Forest fragmentation due to agriculture, urban development, road construction, and other similar disturbances may increase the ability of alien species to invade forest ecosystems by increasing light availability and exposing bare mineral soil (Parendes and Jones 2000, Brothers and Spingarn 1992). Additionally, while alien species generally exhibit low levels of growth and distribution in the forest understory, removal of the forest canopy due to timber harvesting activities, development, or natural mortality often results in "explosions" of growth (Oswalt and others 2004, Barden 1987).

The United States Department of Agriculture (USDA) Forest Service (FS) has identified invasive species as one of the top four threats to forests in the United States in the twenty-first century. Among the most important mechanisms for the early detection and prevention of the spread of nonnative species is monitoring on large spatial scales for the presence of alien species, and for the presence of vulnerable sites (in other words, sites affected by certain disturbance types) (Jose and others 2002). In the Southeast, a primary research priority is the need for better assessments of ongoing biological invasion, for public and scientific use (Mack and others 2000).

As one method for addressing this need, the USDA FS Forest Inventory and Analysis (FIA) program incorporates rapid assessments of the presence of nonnative species into its Phase-2 (P2) forest inventory. In conjunction with presence/absence of alien species, field crews also estimate the distance of each plot center to agriculture, urban development, and roads. Additional studies are currently underway for a new Phase-3 variable that describes native and alien vascular plant diversity and extent.

The goals of this study were to: 1) quantify the occurrence of nonnative invasive species across the state of South Carolina using FIA data; 2) determine differences in nonnative species occurrence between physiographic and ecological regions; 3) examine impacts of plot distance from agriculture, urban development, and roadways on presence/absence and number of nonnative species present on plots; and 4) compare results gained from FIA P2 plots with results collected from a pilot study conducted during the same time period to evaluate the effectiveness of both methods in documenting nonnative invasive species.

# Methods

The USDA Forest Service FIA program collects data using a three-phase process. During Phase-1 (P1), aerial photographs are interpreted; broad classifications of forest versus nonforest areas are determined; and plot locations are identified. P2 consists of field data collection concerning tree variables on all plots, at the rate of 20 percent of plots in a given State per year (USDA Forest Service 2003). In this manner, data collection for an entire State is completed in a five-year cycle, though some data analysis may begin after a minimum of one year of collection (Stapanian and others 1998). The plots are arranged on an unbiased, systematic sampling grid across the United States. The grid is composed of hexagons covering approximately 2,428 ha (6,000 acres) each, with one sample plot located within each hexagon (USDA Forest Service 2003). Individual plots consist of four subplots with a radius of 7.3 m (24 feet). Field crews estimate the distance of each plot from agriculture, urban development, and improved roads based on aerial photos of each plot location (USDA Forest Service 2003). During the final phase (P3) of the inventory process, forest health monitoring data related to soil, down woody materials, crown health, and other variables of interest are collected on a subset (one-sixteenth) of the P2 plots. Detailed descriptions of both P2 and P3 data collection programs, copies of field guides detailing data collection methodology, and detailed definitions of FIA terminology may be found by accessing the USDA Forest Service FIA Internet site at http://fia.fs.fed.us/ and following links to FIA program information.

Nonnative invasive species information was collected on P2 plots beginning in February 2002 and extending through July 2004. Data collection consisted of noting the four most prevalent nonnative species present on a subplot, and estimating their abundances in approximated cover classes (USDA Forest Service 2003). Species were selected from a predetermined list of nonnative plants considered to be problematic in the Southeast (table 1) (Miller 2003). This data collection method provides some information regarding the most abundant nonnative species present on a given sample plot, but does not allow the data collector to record in excess of the four most abundant species. A total of 1,589 P2 plots were sampled at the time analysis began. Plots were included for analysis only if all subplots were fully forested (in other words, no nonforest conditions were included in the analysis), for a total of 752 analyzed plots (Miles and others 2001).

Because of the limited extent of nonnative species data collected on P2 plots, additional information is included from a pilot study conducted from May 2002 to September 2002. The P3 vegetation structure and diversity pilot study required the scientist to record the presence of all vascular plants occurring on a subplot, regardless of life form or U.S. nativity. Vegetative structure and diversity data collected for all vascular plants occurring within the four sampled subplots were combined to produce plot-level summaries. All vascular plants occurring on the subplots were identified to the most specific level possible. Unidentified plants were collected "off plot" and were submitted to local herbaria for identification (USDA Forest Service 2003). The PLANTS database nomenclature was used for all plants recorded (USDA-NRCS 2004). The PLANTS database designation of "invasive and noxious" species was also used to determine whether a plant was native or nonnative for analysis purposes (USDA-NRCS 2004).

The pilot study provided a total of 31 forested plots for P3 analysis. Because of logistical problems during data collection, data were not always complete at the plot level. The resulting heterogeneity of variance violates statistical assumptions, making the plot level data invalid for many statistical tests. In those instances, analysis was conducted at the subplot level, and results are labeled as such. Because of small sample sizes, and the lack of complete datasets for each plot, the reliability of statistical tests is limited and results should be viewed with caution. This report consists of separate analyses for the P2 and P3 datasets (in other words, data are not combined).

Statistical analyses of edited P2 data were conducted at the plot level statewide and by three FIA designated physiographic regions: the Piedmont, Southern Coastal Plain, and Northern Coastal Plain (fig. 1). Data were also analyzed by three ecological regions as defined by Keys and others (1995): the Southern Appalachian Piedmont, Coastal Plains and Flatwoods, and Atlantic Coastal Flatwoods. ArcMap 8.1 (ESRI 2001) was used to assign each county and its complement of plots to an ecological region (fig. 1). Data were consolidated using Microsoft database tools, and analyzed using a combination of SAS version 8.02 (SAS Institute 2001), NCSS (Hintze 2001), and Microsoft Excel statistical software. Chi-square tests for independence were used to determine whether the proportion of plots containing nonnative species differed across physiographic regions or ecological regions. Fisher's Exact Test was used to further explain any detected differences between regions. Logistic regression with backward variable selection was then used to select and evaluate impacts of plot distance from agriculture, urban development, and roadways on presence/absence and number of nonnative species present on plots.

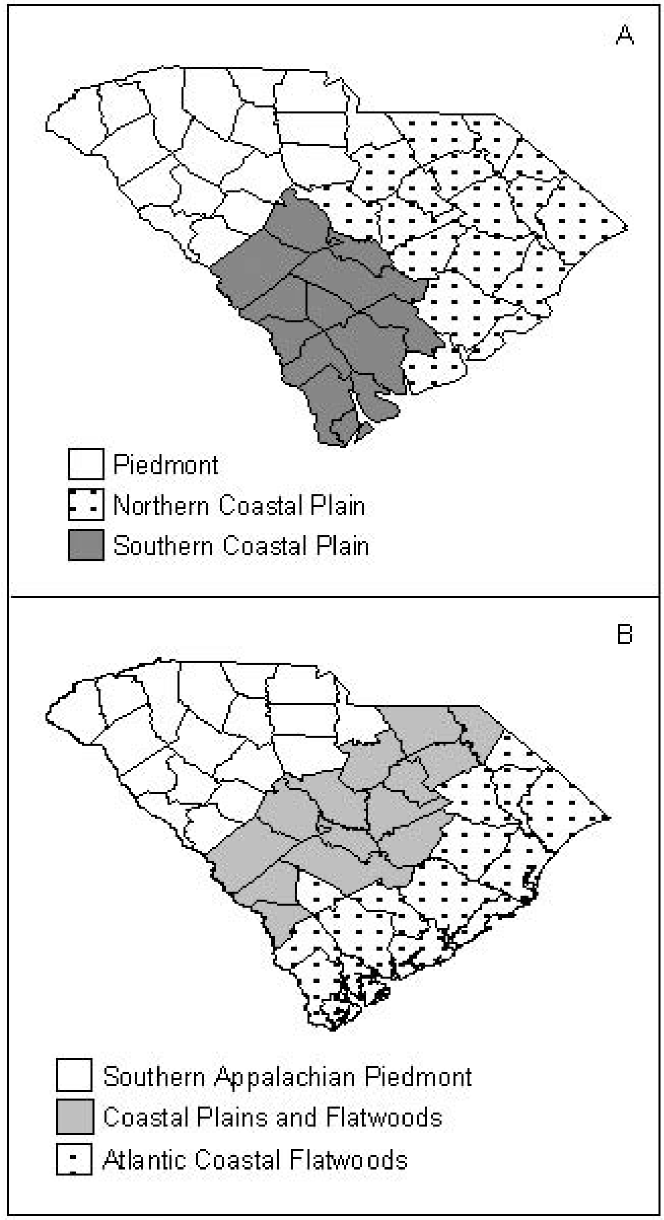


**Figure 1.** USDA Forest Service FIA physiographic regions (A) and ecological regions (B) as defined by Keys and others (1995).

Analyses of P3 data were conducted on data edited and compiled using a combination of SAS, NCSS, PC-ORD (McCune and Mefford 1999), and Microsoft Excel statistical software. Descriptive statistics are presented for P3 data, as well as results from a one-way analysis of variance using generalized least-square means.

# Results

## *P2 Results*

A total of 752 P2 forested plots were measured in 46 South Carolina counties in 2002 to 2004 for the presence of nonnative invasive plant species. Of those plots, 40 percent (n=300) contained at least one alien species; 15 percent (n=111) contained at least two; 4 percent (n=27) contained at least three; and less than 1 percent (n=4) contained four or more. A total of 21 nonnative species were detected using the FIA P2 sampling protocol (table 1). The most abundant nonnative invasive species identified was Japanese honeysuckle, occurring in 81 percent of all plots containing invasive plant species, and 32 percent (n=244) of the total number of forested plots sampled (table 1). These results are similar to Stapanian and others (1998) who found that Japanese honeysuckle is a leading problem in the Southeastern United States, followed closely by Chinese privet (*Ligustrum sinense*).

Physiographic units of South Carolina differed in the proportion of plots containing exotic species ($\chi^2$=175.80, p=≤0.001). The Piedmont region had a significantly larger proportion of plots containing at least one nonnative species compared to both the Northern and Southern Coastal Plains (p=≤0.001). In contrast, the proportion of plots containing at least one nonnative species was similar for the Northern and Southern Coastal Plains units ($\chi^2$=1.06, p=0.30) (table 2).

Similarly, the ecological regions defined by Keys and others (1995) differed in the proportion of plots containing exotic species ($\chi^2$=185.52, p=≤0.001). The Southern Appalachian Piedmont contains a higher proportion of plots with at least one nonnative species than either the Coastal Plains and Flatwoods region ($\chi^2$=82.59, p=≤0.001) or the Atlantic Coastal Flatwoods region

**Table 1.** Scientific names, common names and frequencies (percent of all forested plots occupied by a given species) of species evaluated using the USDA Forest Service, Forest Inventory and Analysis Phase-2 guidelines. Data are for South Carolina, 2002 through 2004. Species are in alphabetical order by scientific nomenclature.

| Species | Common name | Frequency percent |
|---|---|---|
| *Ailanthus altissima* (P.Mill.) Swingle* | tree of heaven | 0.27 |
| *Albizia julibrissin* Durazz.* | mimosa | 0.53 |
| *Alliaria petiolata* (Bieb.) Cavara & Grande | garlic mustard | 0.00 |
| *Arundo donax* L. | giant reed | 0.00 |
| *Celastrus orbiculatus* Thunb. | Oriental bittersweet | 0.00 |
| *Dioscorea spp.* | climbing yams | 0.00 |
| *Elaeagnus angustifolia* L. | Russian olive | 0.00 |
| *Elaeagnus pungens* Thunb.* | silverthorn | 0.13 |
| *Elaeagnus umbellata* Thunb.* | autumn olive | 0.66 |
| *Euonymous alata* (Thunb.) Sieb.* | winged burning bush | 0.13 |
| *Euonymous fortunei* (Tursz.) Hand.-Maz. | winter creeper | 0.00 |
| *Hedera helix* (L.) | English ivy | 0.00 |
| *Imperata cylindrica* (L.) Beauv. | congongrass | 0.00 |
| *Lespedeza bicolor* Turcz.* | shrubby lespedeza | 2.39 |
| *Lespedeza cuneata* (Dum.-Cours.) G.Don* | Chinese lespedeza | 3.59 |
| *Ligustrum japonicum* Thunb.* | Japanese privet | 2.79 |
| *Ligustrum sinense* Lour.* | Chinese privet | 8.51 |
| *Lolium arundinaceum* (Schreb.)* | tall fescue | 1.20 |
| *Lonicera japonica* Thunb.* | Japanese honeysuckle | 32.44 |
| *Lonicera spp.** | bush honeysuckle | 0.13 |
| *Lygodium japonicum* (Thunb. ex Murr.) Sw. | Japanese climbing fern | 0.00 |
| *Melia azedarach* L.* | chinaberry | 0.80 |
| *Microstegium vimineum* (Trin.) A.Camus* | Nepalese browntop | 1.06 |
| *Miscanthus sinensis* Anderss. | Chinese silvergrass | 0.00 |
| *Nandina domestica* Thunb. | nandina | 0.00 |
| *Paulownia tomentosa* (Thunb.)* | royal paulownia | 0.13 |
| *Phyllostachys aurea* (Carr. Ex A.& C.) Riviere* | bamboo | 0.13 |
| *Pueraria montana var. lobata* (Lour.) Merr.* | kudzu | 0.66 |
| *Rosa multiflora* Thunb. ex Murr.* | multiflora rose | 0.80 |
| *Solanum viarum* Dunal* | tropical soda-apple | 0.13 |
| *Triadica sebifera* (L.) Small* | tallowtree | 1.06 |
| *Vinca spp.* | periwinkle | 0.00 |
| *Wisteria sinensis* (Sims) DC.* | nonnative wisteria | 1.33 |

* Species detected on 752 forested plots in South Carolina during 2002-2004 sample seasons using Phase-2 methodology.

**Table 2.** Proportion of P2 plots containing at least one nonnative species. Data are presented by physiographic region and ecologic region. Physiographic region and ecologic region were evaluated separately.

| Ecological division | Sample size<br>number | Proportion containing nonnatives<br>percent |
|---|---|---|
| **Physiographic region** | | |
| Piedmont | 268 | 71.6 A[1] |
| Northern Coastal Plain | 272 | 20.6 B |
| Southern Coastal Plain | 212 | 24.5 B |
| **Ecologic region** | | |
| Southern Appalachian Piedmont | 268 | 71.6 A |
| Coastal Plains and Flatwoods | 218 | 30.3 B |
| Atlantic Coastal Flatwoods | 266 | 15.8 C |

[1] Results of Fisher's Exact Test. Means followed by the same letter are not significantly different at the alpha 0.05 level.

($\chi^2$=169.16, p<0.001) (table 2). The Coastal Plains and Flatwoods region also differed from the Atlantic Coastal Plain in the proportion of plots containing at least one exotic species ($\chi^2$=14.50, p=0.001). The proportion of plots containing an exotic species was slightly higher for the Coastal Plains and Flatwoods region than for the Atlantic Coastal Plain (table 2).

Logistic regression with backward variable selection identified the distance of a plot from improved roads, urban development, and agricultural land as significant in explaining the presence of nonnative species on a plot (p<0.001). However, predictability was very low ($r^2$=0.05) and plots were classified correctly only 71 percent of the time. Adding physiographic unit (p<0.001) to the model increased the r-square value to 0.22 with the percent of plots classified correctly 76 percent of the time. The low r-square values (and thus low predictability) could be due to sample size, estimation errors, or the absence of another variable that may be of more use for predictability measures.

### *P3 Results*

In 2002, a total of 31 plots were measured, but few (n=4) plots provided data from measurements taken at all four subplots. A total of 44 percent (n=71) of the available subplots were measured. There were 102 plant families represented in the dataset, excluding unknowns (specimens not identified due to immaturity, lack of flowering parts, or other reasons). A total of 537 unique records representing 2,391 individuals were collected. Of these, muscadine grape (*Vitis rotundifolia*) was the most abundant, occurring in 78 percent of subplots measured, and 77 percent (n=24) of plots. Red maple (*Acer rubrum*) followed closely in abundance, occurring in 67 percent (n=48) of subplots and 71 percent (n=22) of plots (table 3).

There were no differences in the mean number of all (native and nonnative) species per plot between the three physiographic regions of South Carolina (p=0.24). There were also no differences at the subplot level (table 4). However, the mean number of vascular plant species per subplot did differ between ecological sections (p=0.09) as defined by Keys and others (1995), with the largest number of species occurring in the Southern Appalachian Piedmont region ($\mu$=36.94 +/- 2.34), followed by the Coastal Plains and Flatwoods region ($\mu$=33.0 +/- 2.55), and the Atlantic Coastal Flatwoods region ($\mu$=27.7 +/- 3.48).

Nonnative species accounted for 6 percent (n=27) of all identified species, and 50 percent (n=14) of the alien species are also invasive. Although only 6 percent of all species recorded were nonnative, alien plant species occurred in 80 percent (n=25) of measured plots. In contrast, 73 percent (n=394) of native species occurred in less than 10 percent (n=3) of all plots measured, and 48 percent (n=258) occurred in only one measured plot. As in the P2 data, Japanese honeysuckle was the most abundant nonnative invasive, occurring in 28 percent (n=20) of the 71 subplots and 45 percent (14) of the 31 plots. Chinese privet followed in abundance, occurring in 17 percent (n=12) of subplots and 32 percent (n=10) of plots (table 5). P3 methods detected 27 nonnative species as compared to the 24 species detected by P2 methods. Nine of the species detected by P2 were also detected by P3, while 18 species were unique to P3. Small sample sizes prevent further analysis of the dataset.

## Discussion and Conclusion

The results of this analysis suggest that nonnative invasive species present a substantial threat to forest resources in South Carolina. This is supported by the more detailed P3 data, which indicate that although nonnative species comprise only a small percentage of all vascular plants found throughout the State, those few plants are alarmingly widespread. Currently, Japanese honeysuckle

**Table 3.** Scientific names, common names, and frequencies (percent of all forested subplots occupied by a given species) of the twenty most abundant species evaluated using the USDA Forest Service, Forest Inventory and Analysis Phase-3 guidelines. Data are for South Carolina, 2002. Species are listed in order of abundance.

| Scientific name | Common name | Frequency *percent* |
|---|---|---|
| *Vitis rotundifolia* Michx. | muscadine | 73.24 |
| *Acer rubrum* L. | red maple | 67.61 |
| *Smilax glauca* Walt. | cat greenbriar | 57.75 |
| *Pinus taeda* L. | loblolly pine | 56.34 |
| *Prunus serotina* Ehrh. | pond pine | 54.93 |
| *Liquidambar styraciflua* L. | sweetgum | 53.52 |
| *Diospyros virginiana* L. | common persimmon | 49.30 |
| *Gelsemium sempervirens* (L.) St. Hil. | evening trumpetflower | 47.89 |
| *Parthenocissus quinquefolia* (L.) Planch. | virginia creeper | 47.89 |
| *Quercus alba* L. | white oak | 42.25 |
| *Nyssa sylvatica* Marsh. | black gum | 40.85 |
| *Quercus laurifolia* Michx. | laurel oak | 40.85 |
| *Rubus argutus* Link | sawtooth blackberry | 40.85 |
| *Smilax rotundifolia* L. | roundleaf greenbriar | 40.85 |
| *Ilex opaca* Ait. | American holly | 36.62 |
| *Quercus nigra* L. | water oak | 36.62 |
| *Cornus florida* L. | flowering dogwood | 35.21 |
| *Quercus falcata* Michx. | southern red oak | 33.80 |
| *Toxicodendron radicans* (L.) Kuntze | poison ivy | 33.80 |
| *Vaccinium arboreum* Marsh. | farkleberry | 32.39 |

**Table 4.** Comparison of mean species per subplot by nativity and physiographic region using 2002 Phase-3 pilot study results. Results from analysis of variance (ANOVA) testing for differences in mean number of species by physiographic unit are given for each nativity category.

| Nativity (p-value) | Physiographic region | Mean number of species per subplot (+/- 1 s.e.) |
|---|---|---|
| Native (0.23) | Piedmont | 34.00 (2.12) |
| | Northern Coastal Plain | 30.42 (2.32) |
| | Southern Coastal Plain | 27.79 (3.16) |
| Nonnative (0.26) | Piedmont | 1.29 (0.24) |
| | Northern Coastal Plain | 1.08 (0.26) |
| | Southern Coastal Plain | 0.57 (0.36) |
| All species (0.17) | Piedmont | 36.94 (2.36) |
| | Northern Coastal Plain | 31.88 (2.58) |
| | Southern Coastal Plain | 29.79 (3.51) |

and Chinese privet appear to present the largest immediate threat to forest health. Japanese honeysuckle was often planted by wildlife managers and farmers as forage during late fall and winter (Stransky 1984, Craver 1982), and both plants are still offered as ornamental species in lawn and garden stores in the Southeast (S.N. Oswalt personal observation). These uses have resulted in their widespread propagation throughout the southern United States. Studies of the physiology of Japanese honeysuckle have revealed that the ability of the plant to remain semi-evergreen and photosynthetically active in the warm climate of the Southern states may result in a competitive advantage over native deciduous components of the vegetation community (Schierenbeck and others 1994). Similarly, the semi-evergreen to evergreen growth of Chinese privet may afford it an advantage over native deciduous shrubs and forbs. The ability of these species to dominate the understory of disturbed stands, potentially impacting the regeneration of economically important species makes this a cause for immediate concern (Mooney and Cleland 2001). Additionally, the potential decline in plant species richness that accompanies the invasion of exotic species could be detrimental to wildlife populations in South Carolina forests.

Interestingly, one species that has received great attention in the southern United States because of its widespread visibility along forest edges and gullies, Kudzu (*Pueraria montana*), was detected in less than one percent of the forested plots sampled. Kudzu has been described as "the vine that ate the South" in popular literature, owing to its ability to grow up to one foot per day during the growing season (Bergman and Swearingen

**Table 5.** Scientific names, common names, and frequencies (percent of all forested plots and subplots occupied by a given species) of nonnative species using the USDA Forest Service, Forest Inventory and Analysis Phase-3 guidelines. Data are for South Carolina, 2002.

| Scientific name | Common name | Frequency by subplot *percent* | Frequency by plot *percent* |
|---|---|---|---|
| *Ailanthus altissima* (P. Mill.) Swingle* | tree of heaven | 1.41 | 3.23 |
| *Alternanthera philoxeroides* (Mart.) Griseb.* | alligatorweed | 2.82 | 6.45 |
| *Blumea viscosa* (P.Mill.) Badillo | clammy false oxtongue | 1.41 | 3.23 |
| *Centella asiatica* (L.) Urban | spadeleaf | 2.82 | 6.45 |
| *Duchesnea indica* (Andr.) Focke | indian strawberry | 1.41 | 3.23 |
| *Eremochloa ophiuroides* (Munro) Hack. | centipede grass | 5.63 | 6.45 |
| *Hypochaeris radicata* L. | hairy catsear | 1.41 | 3.23 |
| *Kummerowia striata* (Thunb.) Schindl.* | Japanese clover | 1.41 | 3.23 |
| *Lespedeza cuneata* (Dum.-Cours.) G. Don* | Chinese lespedeza | 4.23 | 6.45 |
| *Ligustrum sinense* Lour.* | Chinese privet | 16.90 | 32.26 |
| *Lonicera japonica* Thunb.* | Japanese honeysuckle | 28.17 | 45.16 |
| *Melia azedarach* L.* | chinaberrytree | 2.82 | 3.23 |
| *Microstegium vimineum* (Trin.) A. Camus* | Nepalese browntop | 4.23 | 9.68 |
| *Murdannia keisak* (Hassk.) Hand.-Maz.* | wartremoving herb | 7.04 | 12.90 |
| *Paspalum dilatatum* Poir. | dallisgrass | 1.41 | 3.23 |
| *Paspalum notatum* Flueggé | bahiagrass | 2.82 | 6.45 |
| *Picris echioides* L. | bristly oxtongue | 1.41 | 3.23 |
| *Poa annua* L. | annual bluegrass | 2.82 | 6.45 |
| *Rosa multiflora* Thunb. ex Murr.* | multiflora rose | 1.41 | 3.23 |
| *Rumex acetosella* L. | common sheep sorrel | 1.41 | 3.23 |
| *Sambucus nigra* L. ssp. *canadensis* (L.) R. Bolli | common elderberry | 2.82 | 6.45 |
| *Sonchus oleraceus* L. | common sowthistle | 1.41 | 3.23 |
| *Stellaria media* (L.) Vill. | common chickweed | 1.41 | 3.23 |
| *Triadica sebifera* (L.) Small* | tallowtree | 1.41 | 3.23 |
| *Verbascum thapsus* L*. | common mullein | 1.41 | 3.23 |
| *Wisteria floribunda* (Willd.) DC.* | Japanese wisteria | 1.41 | 3.23 |
| *Wisteria sinensis* (Sims) DC.* | Chinese wisteria | 1.41 | 3.23 |

*Indicates species considered to be invasive by the USDA-NRCS PLANTS database (2004).

1999). However, while Kudzu threatens native diversity along forest edges and roadways where high levels of light are available, its shade-intolerance prevents it from penetrating the forest edge and invading the forest understory. Similar observations of low populations of Kudzu as compared to Japanese honeysuckle in east Texas have led some researchers to suggest that when considering forest health the emphasis previously placed on Kudzu should be shifted to the shade tolerant Japanese honeysuckle (Vic Rudis, Forester, USDA Forest Service, personal communication).

Edge effects associated with agriculture, urban development, and road construction are often considered as dispersal pathways when considering the potential of an alien species to invade forest ecosystems (Parendes and Jones 2000, Brothers and Spingarn 1992). The data from this study indicates that the distance of a forested plot from agriculture, urban development, or improved roads is significant in explaining the presence/absence of nonnative species from the site. However, those variables are not useful in predicting whether a plot would contain a nonnative species, making them of little value for identifying potential "hotspots" of invasion. Brothers and Spingarn (1992) suggested that the development of a thick wall of vegetation at the forest edge may discourage invasive plants from penetrating into the understory, suggesting that other factors may be more useful for understanding the spread of shade tolerant nonnative species in forested systems. More studies examining the multivariate effects of soil type, onsite disturbance, previous land use, and other environmental variables are necessary to fully understand and predict the potential of a nonnative species to invade a given forest. As the more detailed P3 vegetation structure and diversity data continue to be collected, further examination of these variables may provide some insight into how to recognize the potential for the invasion of nonnative species into forests in the Southeast. With additional P3 sampling, more statistically reliable information may be gained with regards to the impacts of certain types of disturbance patterns on the establishment and reproduction of vascular plant species, including nonnative species, once datasets reach a more statistically reliable sample size.

Differences in the proportion of plots containing nonnative species exist between the physiographic units, and between the ecological regions of South Carolina. Both analyses indicated that the Southern Appalachian Piedmont is particularly susceptible to colonization by nonnative species. These differences may be due to land use, differences in overall species richness, site productivity, length of growing season, forest type characteristics or other environmental differences (for example, soil, moisture, temperature, precipitation, elevation, aspect). For example, the predominately deciduous forest of the Southern Appalachian Piedmont may be more susceptible to invasion by semi-evergreen and evergreen alien species than the evergreen pine forests of the Coastal Plain. Additionally, Craver (1982) suggested that, in the case of nonnative honeysuckles, invasion was correlated with soil moisture and light availability. Incorporating future P3 soil data, forest type characteristics, vegetation community analysis, cover estimates, and utilizing larger sample sizes will aid in extracting important predictive variables from the data and in identifying potential trends.

Overall, the use of USDA Forest Service FIA P2 nonnative species data provides an indication of the current extent of invasive plants in Southern forest ecosystems. However, incorporating the new P3 variables add a wealth of previously unavailable information regarding the spatial arrangement and distribution of these species, the proportion of nonnative to native species, and the relative influence of the species over the plot (using cover and frequency estimates). Moreover, P3 methods do not limit the collection of nonnative species present on a subplot to four, as is the case for P2 plots. While the P3 methods resulted in the detection of only nine of the 21 species listed as invasive in the P2 methodology, the increase in the detection of other nonnative species suggests that, given a full sample, P3 methodology may increase our ability to detect nonnative invasive species. In the future, this may enable forest managers to identify species that may become invasive, or to identify areas that may be of particular concern.

## References


Barden, L. S. 1987. Invasion of *Microstegium vimineum* (Poaceae), an exotic annual, shade-tolerant, C4 grass, into a North Carolina floodplain. American Midland Naturalist. 118(1):40-45.

Bergman, C. and Swearingen, J. M. 1999. Kudzu. PCA Alien Plant Working Group. http://www.nps.gov/plants/alien/fact/pulo1.htm. [Date accessed: July 28, 2004].

Brothers, T. S. and Spingarn, A. 1992. Forest fragmentation and alien plant invasion of central Indiana old-growth forests. Conservation Biology 6(1):91-100.

Craver, G.C. 1992. Multiresource inventories: a technique for determining the distribution and extent of honeysuckle on commercial forest land in South Carolina. Res. Note RN-SE-317. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 11 p.

ESRI, Inc. ©2001. ArcMap 8.1. Redlands, CA.

Gordon, D. R. 1998. Effects of invasive, non-indigenous plant species on ecosystem processes: lessons from Florida. Ecological Applications. 8(4):975-989.

Hintze, J. 2001. NCSS and PASS. Number Cruncher Statistical Systems. Kaysville, UT. www.ncss.com.

Jose, S.; Cox, J.; Merritt, S.; Miller, D. L.; Shilling, D. G. 2002. Alien plant invasions: the story of cogongrass in southeastern forests. Journal of Forestry. 100(1):41-44.

Keys, J. Jr.; Carpenter, C.; Hooks, S. [and others]. 1995. Ecological units of the eastern United States—first approximation (map and booklet of map unit tables), Atlanta, GA: U.S. Department of Agriculture, Forest Service.

Mack, R. N.; Simberloff, D.; Lonsdale, W. M. [and others]. 2000. Biotic invasions: causes, epidemiology, global consequences and control. Issues in Ecology. 5:1-20.

McCune, B. and Mefford, M. J. 1999. Multivariate analysis of ecological data version 4.25. MjM Software, Gleneden Beach, OR.

Miles, Patrick D.; Brand, Gary J.; Alerich, Carol L. [and others]. 2001. The forest inventory and analysis database description and users manual version 1.0 Gen. Tech. Rep. NC-218. St. Paul, MN: U. S. Department of Agriculture, Forest Service, North Central Research Station.

Miller, J. H. 2003. Nonnative invasive plants of southern forests: a field guide for identification and control. Gen. Tech. Rep. SRS-62. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 93 p.

Mooney, H. A. and Cleland, E. E. 2001. The evolutionary impact of invasive species. PNAS, May 2001; 98:5446-5451.

Oswalt, Christopher M.; Clatterbuck, Wayne K.; Oswalt, Sonja N. [and others]. 2004. First-year effects of *Microstegium vimineum* and early growing season herbivory on planted high-quality oak (^ spp.) seedlings in Tennessee. In: Yaussy, Daniel A.; Hix, David M.; Long, Robert P.; Goebel, P. Charles, eds. Proceedings, 14th Central Hardwood Forest Conference; 2004 March 16-19; Wooster, OH. Gen. Tech. Rep. NE-316. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station: 1-9.

Parendes, L. A. and Jones, J. A. 2000. Role of light availability and dispersal in exotic plant invasion along roads and streams in the H. J. Andrews Experimental Forest, Oregon. Conservation Biology. 14(1):64-75.

Pimental, D.; McNair, S.; Janecka, J. [and others]. 2001. Economic and environmental threats of alien plant, animal, and microbe invasions. Agriculture, Ecosystems and Environment. 84(2001) 1-20.

SAS Institute, Inc. 2001. SAS/STAT user's guide. Version 8.2. Cary, NC: SAS Institute Inc. 846 p.

Schierenbeck, K. A.; Mack, R. N.; Sharitz, R. R. 1994. Effects of herbivory on growth and biomass allocation in native and introduced species of Lonicera. Ecology. 75(6):1661-1672.

Stapanian, M. A.; Sundberg, S. D.; Baumgardner, G. A.; and Liston, A. 1998. Alien plant species composition and associations with anthropogenic disturbance in North American forests. Plant Ecology. 139:49-62.

Stein, B. A.; Flack, S. R.; Benton, N. B. [and others]. 1996. America's least wanted: alien species invasions of U.S. ecosystems. The Nature Conservancy publication.

Stransky, J. J. 1998. Forage yield of Japanese honeysuckle after repeated burning or mowing. Journal of Range Management. 37(3):237-238.

USDA, NRCS. 2004. The PLANTS Database, Version 3.5 (http://plants.usda.gov). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

USDA Forest Service. 2003. Forest inventory and analysis Southern Research Station field guide. Version 2.0. U.S. Department of Agriculture, Forest Service, Southern Research Station. Knoxville, TN.