CHAPTER 8.

Invasive Plants on Forest Land in the United States

Christopher M. Oswalt
Sonja N. Oswalt

INTRODUCTION

The Forest Service, U.S. Department of Agriculture, considers a species to be invasive if it meets the following criteria: (1) the species must be nonnative to the ecosystem under consideration, and (2) the species' introduction must cause or be likely to cause economic or environmental harm or harm to human health (Executive Order No. 13112, Federal Register/Vol. 64, No. 25/February 8, 1999). Indeed, Pimentel and others (2005) last estimated the cost of prevention and eradication of invasive plant species in crop, pasture, and forest settings at approximately $27 billion every year. In fact, the cost of combating just the invasive tree melaleuca *(Melaleuca quinquefolia)* in the State of Florida was estimated at between $3 and $6 billion dollars in 2005 (Pimentel and others 2005).

On the Invasive Species Program Web site of the Forest Service, 54 plant species are recognized as invasive, presumably in forested systems (USDA Forest Service 2014). Long-term monitoring and assessment of invasive species occupation on the forest landscape is necessary to managers and policymakers for the obligation and direction of funds and other resources. Monitoring at a national scale can be difficult and expensive, however, given the regional nature of species distributions. Given the importance of monitoring invasive plants on U.S. forest land, units in the Forest Inventory and Analysis Program of the Forest Service have implemented efforts to track invasive plants in their regions. Up to this point in time, efforts by individual units have been unique and specific to those units (e.g., sample intensities and field protocols differ), thus no consistent method for identifying and tracking invasive plants has been applied nationwide. Efforts are underway to establish some modicum of consistency in measurement; however, for this paper we use data collected and compiled by each regional office. Our objectives were to produce a national map of invasive species infestation based on regionally collected data, which may be used to identify potential "hot spots" of invasion and which may serve as a baseline for future monitoring efforts. Additionally, we present regional analyses of data from the Southern United States, where a large number of invasive species impact forests in the continental United States.

METHODS

Data collected by the Forest Service Forest Inventory and Analysis (FIA) Program were assembled from each region of the United States. Occurrence, measured as the percent of forested subplots within a county with observed invasive plant species, was calculated across the continental United States and Hawaii. Each region and, in some cases, each State maintains a specific watch list to constrain monitoring to only the most important invasive plant species within a given area. Therefore, occurrence is based on regionally important species and is inconsistently measured across the United States.

The data used in the analysis spanned 1999 through 2011, depending on the State and region (table 8.1). Each region uses a distinct program for collecting invasive species data, though plans are underway to provide a nationally consistent method for future surveys. For this paper, data collection methods differed by region and, in some cases, State. Data were normalized to minimize differences between regions by calculating the number of forested subplots present in a county, the number of forested subplots with at least one invasive species present, and by generating a "percent invaded" statistic so that counties across the country could be compared in a consistent manner. County and regional comparisons are based on visual observations of mapped data. Rudis and others (2004) described data collection methods for the various regions, and specific data collection details are available through the FIA Web site at http://www.fia.fs.fed.us/library/field-guides-methods-proc/.

The temporal richness of the southern invasive plant data allowed for more detailed investigations of individual species across the region and spatial change in occurrence over time. Most plots in the southern region have been measured multiple times, including observations of 33 regionally important invasive plants. The number of invaded subplots and number of invaded plots were calculated.

Table 8.1—Regions, States, and data collection periods for invasive plants referred to in this publication

Region	States	Data collection period
Pacific Northwest	CA, OR, WA	1999–2009
Intermountain West	AZ, CO, ID, MT, NV, NM, UT, WY	1999–2009
North	CT, DE, IL, IN, IA, KS, ME, MD, MA, MI, MN, MO, NE, NH, NJ, NY, ND, OH, PA, RI, SD, VT, WV, WI	2007 –2011
South	AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA	2001–2011
Alaska		2004–2009
Hawaii		2010

Additionally, the most recent observations were compared to previous observations (typically a 5-year remeasurement period) for a select list of representative invasive plants [Japanese honeysuckle *(Lonicera japonica)*, Chinese tallowtree *(Triadica sebifera)*, cogongrass *(Imperata cylindrica)*, nonnative roses (*Rosa* spp.), and garlic mustard (*Alliaria petiolata*)]. Plots were categorized into one of four infestation categories: no infestation (no observation at time 1 or time 2); newly infested (no observation at time 1 and positive observation at time 2);

stable infestation (positive observations at time 1 and 2); or elimination (positive observation at time 1 but no observation at time 2). Plots categorized as elimination for a given invasive plant were removed from the analysis due to the difficulty in determining the exact cause of the change in status. Areas of high expansion pressure were mapped based on the density of newly infested and stable plots using a simple inverse distance weighting imputation approach on a dummy variable based on weights assigned to each of the infestation categories (Roberts and others 2004).

RESULTS AND DISCUSSION

Nationwide, 39 percent of forested subplots sampled for invasive plants contained at least one invasive species. Hawaii had the highest percentage of subplots with invasive plants present at 70 percent. In general (excluding Hawaii), invasive species were more prevalent on forested subplots in the East than in the West (fig. 8.1), while Alaska and the Intermountain region had the fewest incidences of invasion. Approximately 46 percent of forested subplots in the broader eastern region had at least one

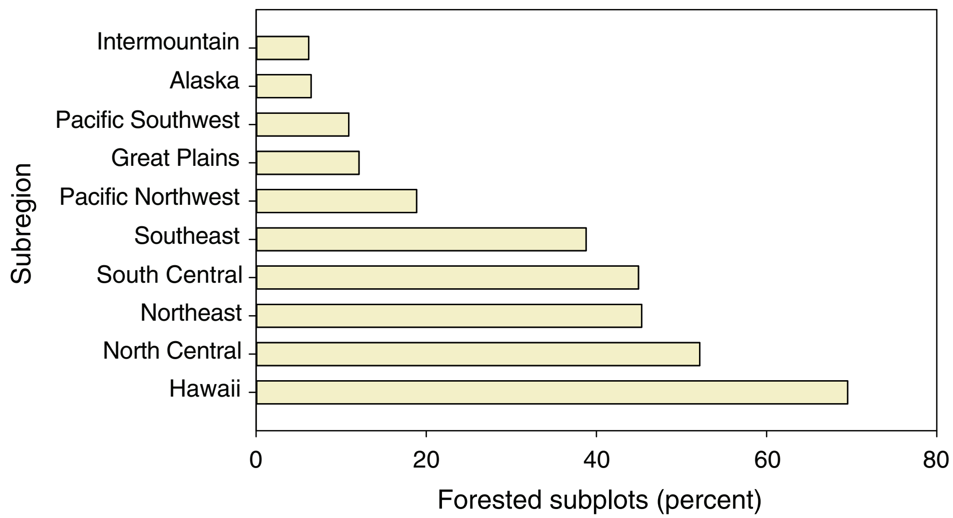

Figure 8.1—Percent of forested subplots containing at least one invasive plant, by subregion.

invasive species compared to only 6 percent in Alaska and 11 percent in the broader western region (fig. 8.2). Patterns of invasive species presence/absence also vary at the county level, as shown in figure 8.3. Highly fragmented landscapes (as in the North Central region) and major travel corridors (as in the Southeast) tended to exhibit higher percentages of forested subplots with at least one invasive species. Relationships between fragmentation and invasive species have been studied and recorded (Brothers and Spingam 1992, Luken and others 1997); however, other factors influence the abundance of invasive plants in particular regions. For example, some species like Chinese tallowtree, multiflora rose (*Rosa multiflora*), and autumn olive (*Elaeagnus umbellata*) were introduced and planted intentionally for various purposes including industrial use, hedgerows, and wildlife food.

In the Northern States, species infesting >5 percent of sampled plots included multiflora rose, reed canarygrass *(Phalaris arundinacea)*, garlic mustard, Japanese honeysuckle, buckthorn (*Rhamnus cathartica*), *Lonicera* spp., autumn olive, black locust (*Robinia pseudoacacia*), and Nepalese browntop (*Microstegium vimineum*; table 8.2). Multiflora rose had the highest rate of occurrence, appearing on 2,169 (25 percent) of 8,769 forested plots where invasive plants were monitored. Multiflora rose was over

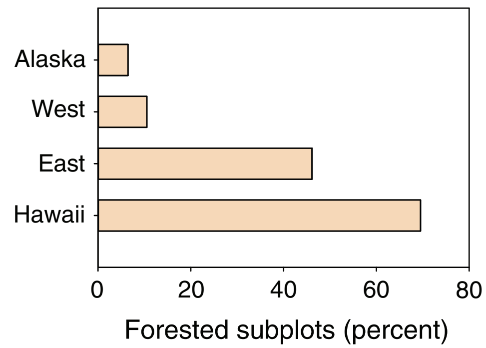

Figure 8.2—Percent of forested subplots containing at least one nonnative invasive plant, by major region.

three times as prevalent as the next most frequently recorded species, reed canarygrass, which appeared on 8 percent of monitored plots. Species infestation differed by State. In Delaware, for example, 44 percent of measured plots contained Japanese honeysuckle, compared to 19 percent with multiflora rose, while 71 percent of plots in Indiana contained multiflora rose. Ohio was overwhelmingly infested with multiflora rose, with 86 percent of measured plots containing the species. Nebraska differed from other Northern States in that Siberian elm (*Ulmus pumila*) was the most frequently recorded invasive, noted on 11 percent of plots. This is unsurprising given that Siberian elm experimental plantations were established throughout the Prairie States, and the tree

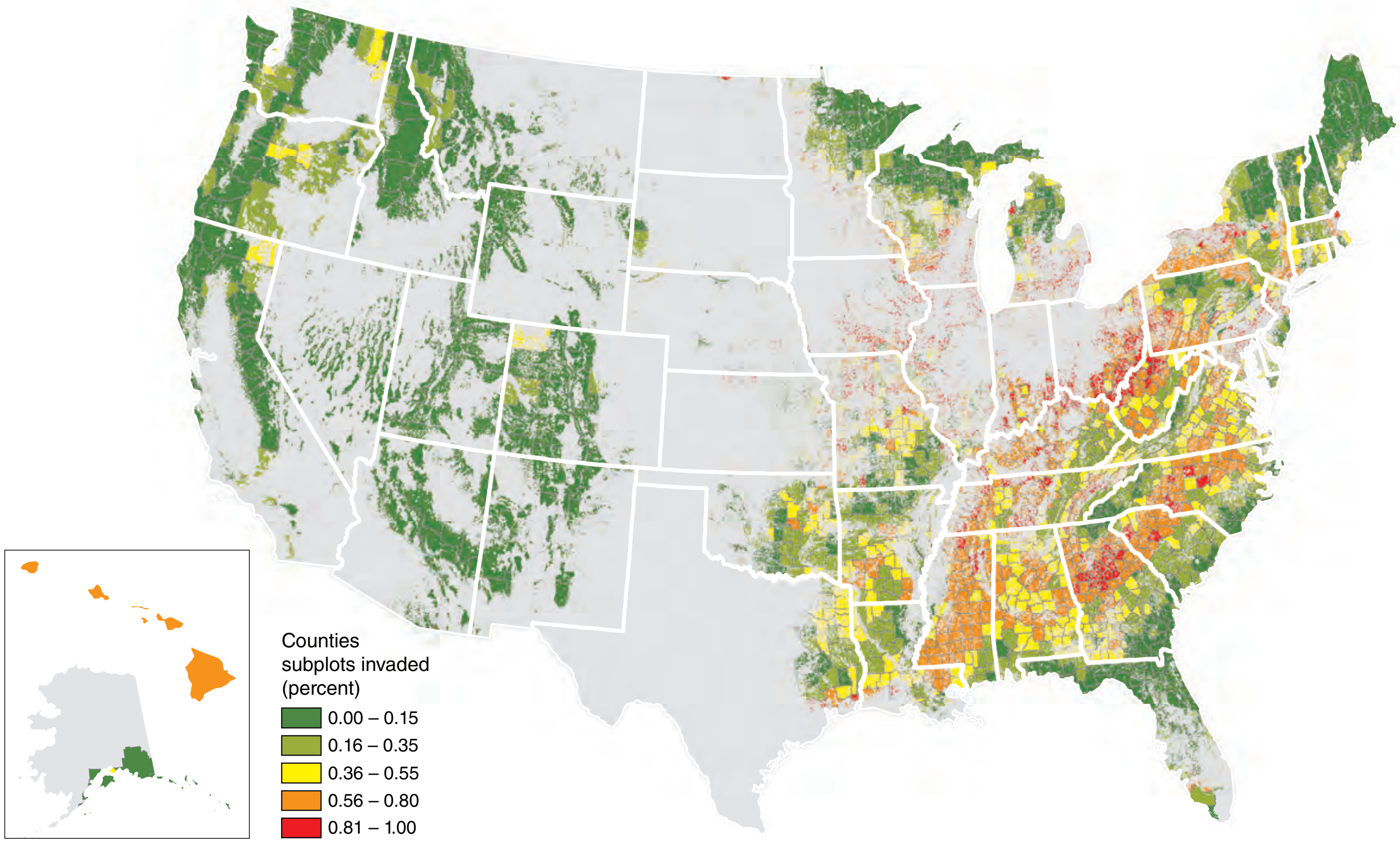

Figure 8.3— National map showing percent of forested subplots with at least one nonnative invasive plant, calculated at the county level. Forest/nonforest mask applied to the conterminous United States.

Table 8.2—Number and percent of forested plots in the Northern United States where monitored nonnative invasive plants were detected

Common name	Scientific name	Plots	
		number	*%*
Multiflora rose	*Rosa multiflora*	2,169	24.7
Reed canarygrass	*Phalaris arundinacea*	699	8.0
Garlic mustard	*Alliaria petiolata*	667	7.6
Japanese honeysuckle	*Lonicera japonica*	562	6.4
Common buckthorn	*Rhamnus cathartica*	511	5.8
Honeysuckle	*Lonicera*	489	5.6
Autumn olive	*Elaeagnus umbellata*	475	5.4
Black locust	*Robinia pseudoacacia*	461	5.3
Nepalese browntop	*Microstegium vimineum*	452	5.2
Japanese barberry	*Berberis thunbergii*	417	4.8
Morrow's honeysuckle	*Lonicera morrowii*	342	3.9
Canada thistle	*Cirsium arvense*	297	3.4
Amur honeysuckle	*Lonicera maacki*	270	3.1
Oriental bittersweet	*Celastrus orbiculatus*	238	2.7
Bull thistle	*Cirsium vulgare*	215	2.5
Glossy buckthorn	*Frangula alnus*	194	2.2
Tree-of-heaven	*Ailanthus altissima*	162	1.8
European privet	*Ligustrum vulgare*	157	1.8
Tatarian honeysuckle	*Lonicera tatarica*	122	1.4
Creeping jenny	*Lysimachia nummularia*	114	1.3
Showy fly honeysuckle	*Lonicera x bella*	96	1.1
Spotted knapweed	*Centaurea stoebe* ssp. *micranthos*	71	0.8
Dames rocket	*Hesperis matronalis*	68	0.8
Norway maple	*Acer platanoides*	55	0.6
Common barberry	*Berberis vulgaris*	49	0.6
Siberian elm	*Ulmus pumila*	49	0.6
Russian olive	*Elaeagnus angustifolia*	45	0.5
Common reed	*Phragmites australis*	31	0.4
Japanese knotweed	*Polygonum cuspidatum*	26	0.3
European cranberrybush	*Paulownia tomentosa*	20	0.2
Princesstree	*Viburnum opulus*	20	0.2
Leafy spurge	*Euphorbia esula*	18	0.2
Spotted knapweed	*Centaurea biebersteinii*	17	0.2
Purple loosestrife	*Lythrum salicaria*	17	0.2
Japanese meadowsweet	*Spiraea japonica*	14	0.2
Giant knotweed	*Polygonum sachalinense*	5	0.1
English ivy	*Hedera helix*	4	0.0
Louise's swallow-wort	*Cynanchum louiseae*	3	0.0
Bohemian knotweed	*Albizia julibrissin*	2	0.0
Saltcedar	*Polygonum x bohemicum*	2	0.0
Silktree	*Tamarix ramosissima*	2	0.0
Chinaberrytree	*Cynanchum rossicum*	1	0.0
European swallow-wort	*Melia azedarach*	1	0.0

was promoted as a hedge species in the 1950s (Klingaman 1999). Northern States with no single invasive species occupying more than 10 percent of measured plots included Maine, Michigan, New Hampshire, and Vermont (fig. 8.4). Maine had the lowest rates of infestation compared with other North Central and Northeastern States; no one invasive species occupied more than 2 percent of measured plots in Maine.

In the Southern States, Japanese honeysuckle was observed on >17,000 forested plots, or 43 percent of all forested plots where invasive plants were monitored (table 8.3). The prevalence of Japanese honeysuckle on southern forested plots obscured patterns for all other species; therefore, Japanese honeysuckle was removed from the analysis and select metrics were recalculated. The distribution of the number of southern counties across categories of the percent of subplots invaded by any monitored invasive plant (invaded class) was considerably different when Japanese honeysuckle was included compared to when it was not (fig. 8.5). Southern counties were

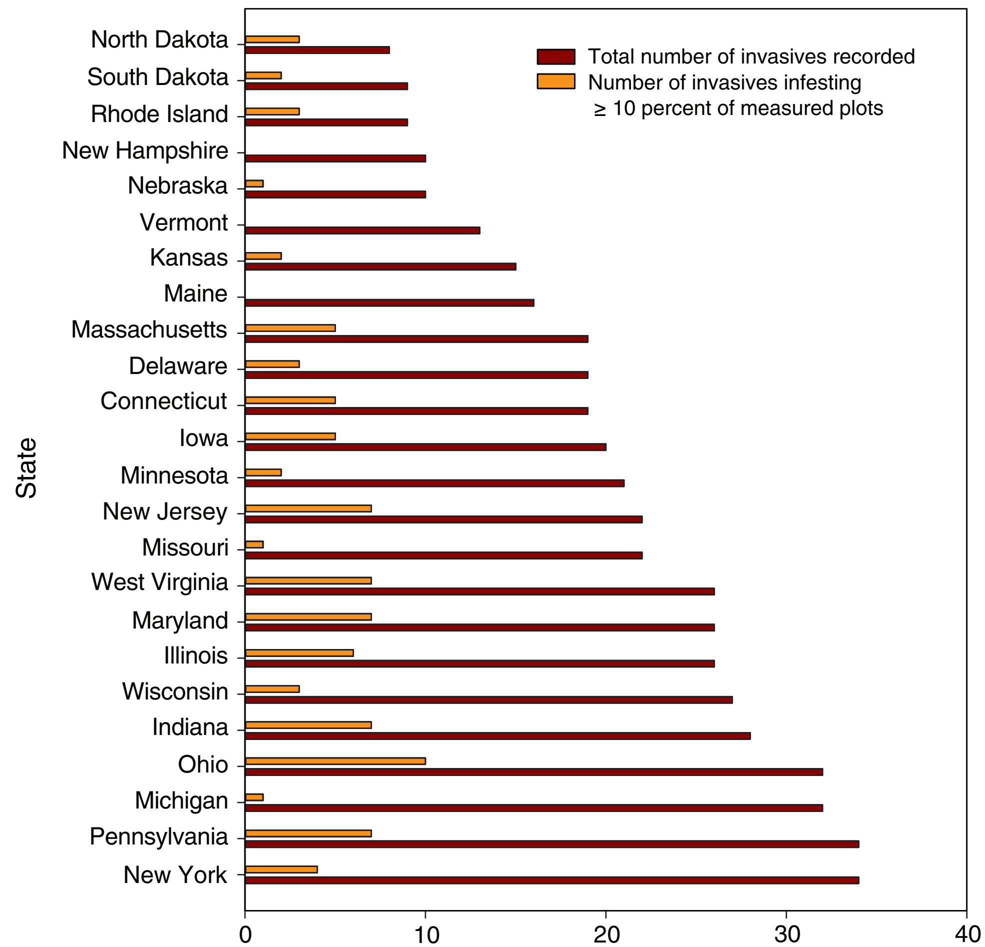

Figure 8.4— Number of invasive plants infesting ≥10 percent of measured plots compared with the total number of invasive plants recorded by State.

Table 8.3—Number and percent of forested plots in the Southern United States where monitored nonnative invasive plants were detected

Common name	Scientific name	Plots number	Plots %
Japanese honeysuckle	*Lonicera japonica*	17,212	43.3
Chinese/European privet	*Ligustrum sinense/L. vulgare*	8,260	20.8
Nonnative roses	*Rosa* spp.	3,469	8.7
Chinese lespedeza	*Lespedeza cuneata*	2,154	5.4
Nepalese browntop	*Microstegium vimineum*	2,067	5.2
Japanese climbing fern	*Lygodium japonicum*	1,731	4.4
Tallowtree, popcorntree	*Triadica sebifera (Sapium sebiferum)*	1,427	3.6
Shrubby lespedeza	*Lespedeza bicolor*	940	2.4
Tree-of-heaven	*Ailanthus altissima*	932	2.3
Silktree, mimosa	*Albizia julibrissin*	720	1.8
Tall fescue	*Lolium arundinaceum*	662	1.7
Chinaberry	*Melia azedarach*	550	1.4
Japanese/glossy privet	*Ligustrum japonicum/L. lucidum*	480	1.2
Bush honeysuckles	*Lonicera* spp.	468	1.2
Autumn olive	*Elaeagnus umbellata*	378	1.0
Kudzu	*Pueraria Montana* var. *lobata (Pueraria lobata)*	299	0.8
Princesstree, royal paulownia	*Paulownia tomentosa*	268	0.7
Sacred bamboo, nandina	*Nandina domestica*	161	0.4
Garlic mustard	*Alliaria petiolata*	143	0.4
Chinese/Japanese wisteria	*Wisteria sinensis/ W. floribunda*	141	0.4
Silverthorn, thorny olive	*Elaeagnus pungens*	134	0.3
English ivy	*Hedera helix*	120	0.3
Cogongrass	*Imperata cylindrica*	109	0.3
Wintercreeper	*Euonymus fortunei*	108	0.3
Nonnative vincas, periwinkles	*Vinca minor/V. major*	101	0.3
Nonnative climbing yams (air yam, Chinese yam)	*Dioscorea bulbifera/ D. oppositifolia*	96	0.2
Oriential or Asian bittersweet	*Celastrus orbiculatus*	77	0.2
Tropical soda apple	*Solanum viarum*	71	0.2
Winged burning bush	*Euonymus alata*	55	0.1
Nonnative bamboos	*Phyllostachys* spp., *Bambus* spp.	40	0.1
Russian olive	*Elaeagnus angustifolia*	22	0.1
Chinese silvergrass	*Miscanthus sinensis*	20	0.1
Giant reed	*Arundo donax*	6	0.0

distributed relatively evenly among many of the invaded classes below 75 percent when Japanese honeysuckle was included. However, when Japanese honeysuckle was removed, the distribution of counties was skewed heavily toward classes with smaller percentages of invaded subplots. The removal of Japanese honeysuckle reduced the mean percent of subplots invaded by 15 percent (fig. 8.6). Alabama, Mississippi, and Virginia each experienced the largest change when Japanese honeysuckle was removed from the analysis.

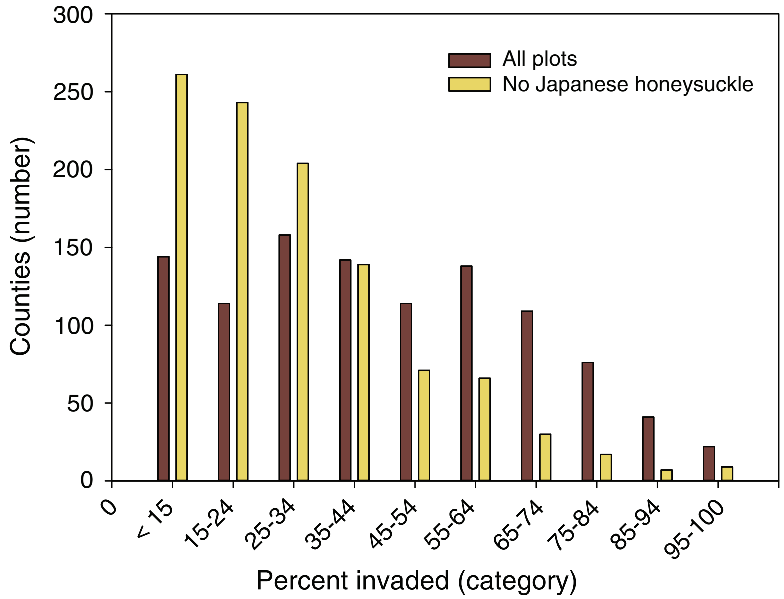

Figure 8.5— Comparison of the distribution of counties infested by percent invasion category, with and without Japanese honeysuckle.

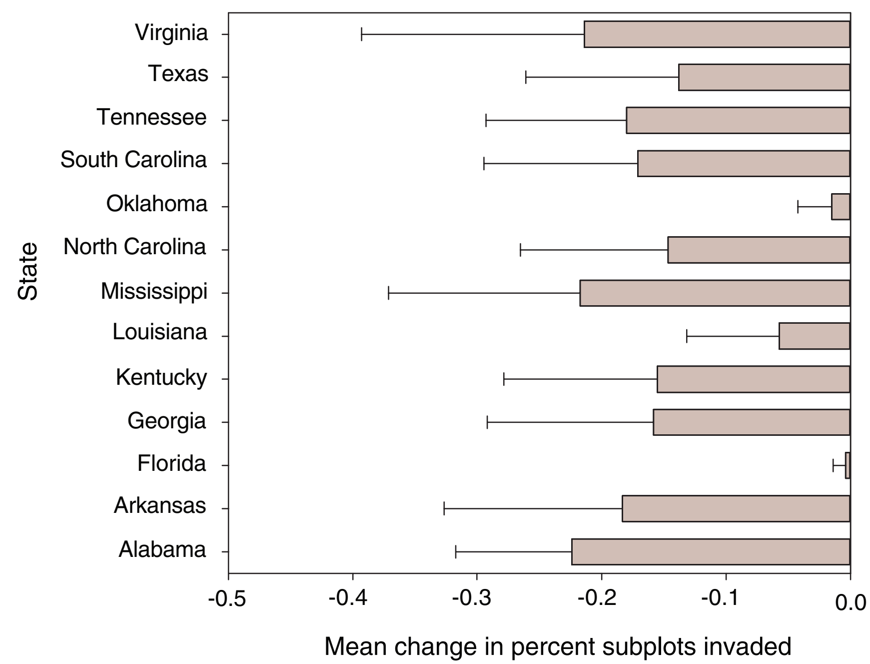

Figure 8.6— Change in mean percent of subplots invaded when Japanese honeysuckle was removed from analysis of southern Forest Inventory and Analysis plots.

The southern invasive plant data included numerous invasive plant species that currently cover large areas (e.g., Japanese honeysuckle) or are emerging as regionally significant forest invaders (e.g. cogongrass), and offered a valuable opportunity to evaluate recent changes in invasive plant distribution because of its temporal richness. Analysis of select species representing each of the plant life forms monitored by the Southern FIA program revealed that garlic mustard and cogongrass had the highest percentages of new infestations (table 8.4). For every plot where garlic mustard was previously noted there are now 12 newly infested plots. Such a high ratio of newly infested plots to stable plots suggests a high degree of active expansion relative to the observed population. In comparison, 76 percent of the plots where Japanese honeysuckle was observed during time 2 contained Japanese honeysuckle during the time 1 plot visit. At time 2, there were only 0.32 plots newly infested with Japanese honeysuckle for every stable plot. Tallowtree expansion activity relative to the observed population was one new plot for every stable plot. A smaller new-to-stable ratio for tallowtree, an invasive tree understood to be rapidly invading southern forests (Oswalt 2010), may be a result of a longer establishment time for trees versus herbaceous plants like garlic mustard. On the other hand, such a large new-to-stable ratio for herbaceous plants like garlic mustard may be influenced by improvements in identification skills by field personnel at time 2 after being exposed to additional invasive plant identification training. Additionally, year-round collection of invasive plant data in the Southern United States could potentially introduce some error or bias (Oswalt and others 2012).

Table 8.4—Percent of invaded plots and all monitored plots by select species and infestation class, showing changes in invasive plant distribution

Infestation class	Japanese honeysuckle	Cogongrass	Garlic mustard	Nonnative roses	Tallowtree
		percent of currently invaded plots			
Newly infested	24	68	92	47	51
Stable infestation	76	32	8	53	49
		percent of all monitored plots			
Newly infested	11.51	0.25	0.41	4.53	1.66
Stable infestation	36.30	0.12	0.04	5.17	1.59
New/stable ratio	0.32	2.09	11.50	0.88	1.05

Notable expansion activity was expected with an analysis of cogongrass due to the recent research activity focused on the species (Grebner and others 2010, Holzmueller and Jose 2011, Minogue and others 2012). Indeed, cogongrass had a new-to-stable infested plot ratio of >2. This indicates that for every plot where cogongrass has been found currently and in the past, there are two newly infested plots. The expansion pressure (fig. 8.7A) encircles the area where cogongrass is believed to have been introduced: the Gulf Coast of Mississippi, Alabama, and Florida around Mobile Bay

(Bryson and Carter 1993). The highest pressure exists in southern Mississippi, central Alabama, and the Florida panhandle.

Garlic mustard expansion pressure is located in the northernmost States included in the southern region (fig. 8.7B). Unlike cogongrass, garlic mustard was introduced in the North, probably New England (Welk and others 2002), and is currently spreading southward. The estimate of current expansion pressure for garlic mustard includes northern and central Kentucky, Virginia, western North Carolina, and northwestern Arkansas. While cogongrass is expanding rapidly north from the Gulf Coast, garlic mustard appears to be spreading rapidly from the North into the South.

This research illuminates the value of continuous, long-term monitoring of invasive plant species in understanding where resources may best be allocated to deter expansion, particularly into ecologically sensitive or protected areas. Knowledge of the expansion rates and directions of invasive plants is increasingly important in the context of global warming, which could increase rates of northern expansion of some species. Regional data viewed in a national context provides insight to policymakers and stakeholders, while national data provides context for local and regional research. Harmonization of data collection procedures across regions in the future will allow for further cross-region exploration of the data.

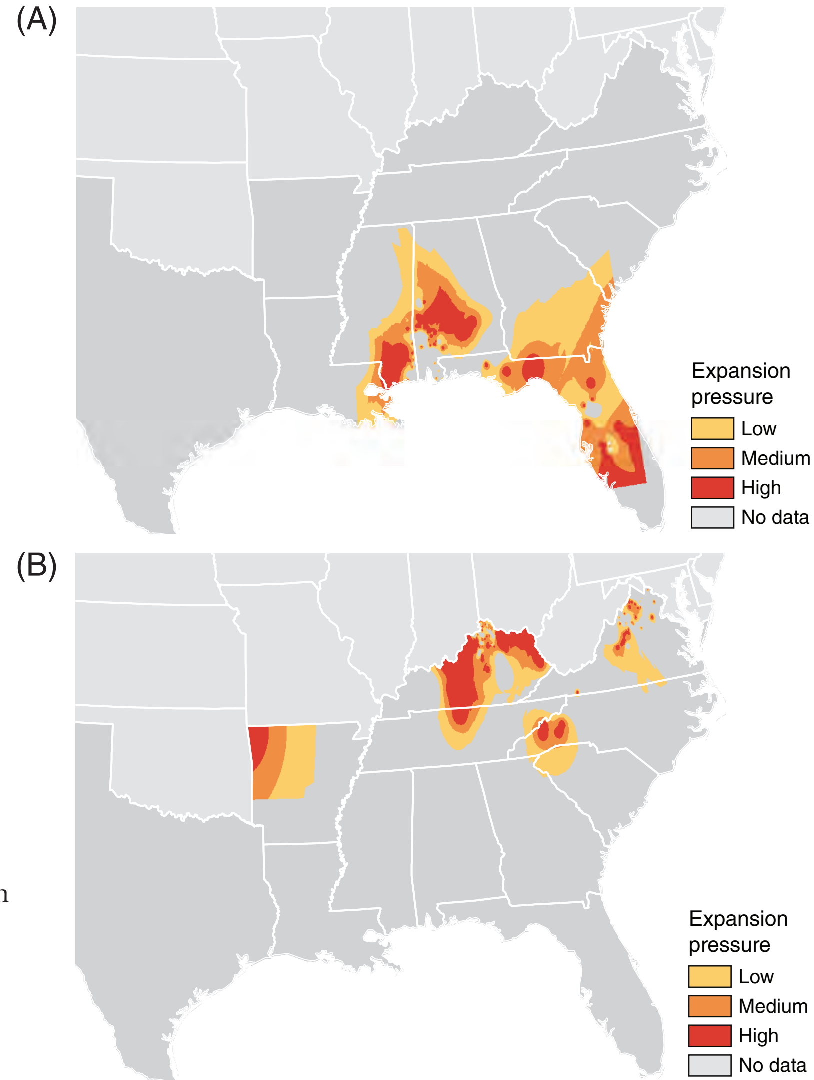

Figure 8.7— Expansion pressure of (A) cogongrass and (B) garlic mustard based on previously infested and newly infested plot locations.

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