

# THE EXTENT OF SELECTED NON-NATIVE INVASIVE PLANTS ON MISSOURI FORESTLAND

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**Abstract.**—The Northern Research Station's Forest Inventory and Analysis Program (NRS-FIA) collects forest-related data throughout a 24-state region in the northeastern United States, ranging from North Dakota to Maine and Kansas to Maryland. Based on discussions with stakeholders and others, NRS-FIA found that the impact of non-native invasive plants (NNIPs) may be known at the local level but their regional abundance, impact, range, and rate of spread are not well understood. In 2005 and 2006, NRS-FIA sampled for the presence and percent cover class of 25 selected non-native invasive species on forested plots in the Upper Midwest states. The species were selected based on the threat posed to our forested ecosystems, the extent of their range, detectability of these species in summer or winter, and level of interest by our stakeholders.

This paper summarizes findings from 2 years of sampling in the State of Missouri. Data are summarized by forest type and the relationship between forest cover and the impact of human influences (represented by variations in overstory basal area and distance to roads) is examined. Fifty-eight percent of the plots sampled had no invasive species of interest on them. Of the 25 species sampled for in the 2005 and 2006 inventory panels, only 13 were found in Missouri and only three—multiflora rose, non-native bush honeysuckles, and Japanese honeysuckle—were found in any number. There was no apparent relationship between forest type and NNIP presence. We examined physiographic class code to determine any influence of topography (and—by extension—water availability/site productivity) upon NNIP presence. Site quality (higher site index for multiflora rose) and topography (level sites for multiflora rose and Japanese honeysuckle) were significantly related to invasive species presence. We found a significant relationship with mesic or hydric sites for multiflora rose and Japanese honeysuckle, although relatively few of our target species were found in hydric systems (a function of our species list and the emphasis on forested lands in Missouri). Finally, examination of distance to road, a surrogate for road density, found a significant negative relationship with multiflora rose and Japanese honeysuckle presence. Caution must be taken in interpreting these results. Since much of the landscape had been harvested and/or otherwise disturbed, the current road system might not reflect past patterns of habitation and transport.

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## INTRODUCTION

Non-native invasive plants (NNIPs)<sup>2</sup> are expanding their distributions across North America. NNIP occur in all the major plant-life forms found in forest ecosystems: trees, shrubs, vines, herbs/forbs, and grasses. Generally, vectors that contribute to the spread of non-native invasive plants, e.g., highways, contribute to the spread of more than one species or life form. Introduction, however, does not necessarily mean establishment. A specific sequence of timing and site must occur for an exotic to take hold in an ecosystem. Once established, NNIP threaten the sustainability of native forest composition, structure, function, and resource productivity (Webster and others 2006). Richardson and Pyšek (2006) outlined four factors of invasibility:

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<sup>2</sup>This paper will also refer to NNIPs as “exotics” or “invasives.”

disturbance, competitive release, resource availability, and competitive pressure. This paper examines some of these factors by documenting the relationship between exotic presence and forest type, overstory basal area, disturbance (road density), and site factors (site index, aspect, and physiographic class code).

## **STUDY OBJECTIVES**

This study has three objectives: document the distribution of species, compare invasive presence to site characteristics, and examine the role of disturbance in invasive species presence and coverage. The full extent of NNIPs has not been documented statewide on FIA plots in Missouri. A principal benefit of NRS-FIA's efforts was to provide an estimate of extent and location of exotics on the forested landscape of the State. Non-native invasive plants, like all plants, respond to supplies of water, nutrients, and light. Where these exotics excel is in their ability to capture and utilize these resources more quickly and more completely than their native competitors. This analysis searched for patterns of resource utilization and competitive advantage for the exotics. For the purpose of this paper, site characteristics included those variables pertaining to aspect and physiographic class code (topographic position). Human influence is responsible for both long-distance and local transport of the exotic species and often for creating the landscape that facilitates establishment and spread of the invasive. We examined both of these roles by evaluating the influence of distance to roads and the residual effects of a forest's disturbance history: overstory basal area and overstory diversity.

## **BACKGROUND**

Located at the intersection of several ecoregions, Missouri had many different presettlement forest compositions and structures, ranging from high upland forest in the Ozarks to bottomland ecosystems in the "Bootheel" to savannas and prairies in the northern and western parts of the State. The fertile soils of this region were ideal for farming, and settlers proceeded to clear the land for agriculture. In the heavily timbered areas of southern Missouri, large-scale commercial harvesting exploited the magnificent stands of shortleaf pine and other species, while subsequent fires and lack of scientific management resulted in a radically altered forested landscape (Beilmann and Brenner 1951). The combination of clearing, settlement, and timber harvesting created a highly fragmented landscape, offering many opportunities for non-native invasive plants to become established in forests.

## **METHODOLOGY**

Meaningful exotic-invasive plant inventory requires a large network of sample plots measured consistently over time. Over the past decade, the USDA Forest Service, Forest Inventory and Analysis (FIA) program has implemented an inventory system that seeks to achieve national and international consistency<sup>3</sup>. This system utilizes three phases of inventory designed to make estimates of forest extent, composition, structure, health, and sustainability: phase 1—remote sensing, phase 2—systematic grid of ground samples, and phase 3—subset of more detailed forest health ground-based samples (McRoberts 1999). For FIA purposes, the state of Missouri is divided into five inventory units. Based broadly on ecological characteristics, they are Eastern Ozarks, Southwest Ozarks, Northwest Ozarks, Prairie (in the north and western portion of the state), and Riverborder (along the lower Missouri and Mississippi Rivers).

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<sup>3</sup>Complete documentation of the plot design and all measurements is at <http://socrates.lv-hrc.nevada.edu/fia/dab/databandindex.html>.

**Table 1.—Non-native invasive plants surveyed on FIA plots in the Upper Midwest of the U.S., 2005-2006**

COMMON NAME	SCIENTIFIC NAME	COMMON NAME	SCIENTIFIC NAME
<b>Woody species</b>		<b>Grasses</b>	
Multiflora rose	<i>Rosa multiflora</i>	Reed canary grass	<i>Phalaris arundinacea</i>
Japanese barberry	<i>Berberis thunbergii</i>	Phragmites, Common reed	<i>Phragmites australis</i>
Common buckthorn	<i>Rhamnus cathartica</i>	Nepalese browntop, Japanese stiltgrass	<i>Microstegium vimineum</i>
Glossy buckthorn	<i>Frangula alnus</i>	<b>Herbaceous</b>	
Autumn olive	<i>Elaeagnus umbellata</i>	Garlic mustard	<i>Alliaria petiolata</i>
Non-native bush honeysuckles	<i>Lonicera</i> spp.	Leafy spurge	<i>Euphorbia esula</i>
European privet	<i>Ligustrum vulgare</i>	Spotted knapweed	<i>Centaurea biebersteinii</i>
<b>Vines</b>		Dame's rocket	<i>Hesperis matronalis</i>
Kudzu	<i>Pueraria montana</i>	Mile-a-minute weed, Asiatic tearthumb	<i>Polygonum perfoliatum</i>
Porcelain berry	<i>Ampelopsis brevipedunculata</i>	Common burdock	<i>Arctium minus</i>
Asian bittersweet	<i>Celastrus orbiculatus</i>	Japanese knotweed	<i>Polygonum cuspidatum</i>
Japanese honeysuckle	<i>Lonicera japonica</i>	Marsh thistle	<i>Cirsium palustre</i>
Chinese yam	<i>Dioscorea oppositifolia</i>		
Black swallowwort	<i>Cynanchum louiseae</i>		
Wintercreeper	<i>Euonymus fortunei</i>		

### NNIP Sampling Scheme

During 2005-2006, 100 percent of all Phase 2 forested plots were assessed for presence and cover of any of 25 non-native invasive woody, vine, grass, and herbaceous species of interest<sup>4</sup> (Table 1). If a species on the list was found, the percent cover was estimated and placed into one of seven codes, ranging from 1 (trace) to 7 (76 to 100 percent) (Table 2).

Spatial analyses were conducted using geographic information systems (GIS). Distances to roads were computed as the minimum Euclidean distance (m) from each plot center to the nearest road transect included within the Environmental Systems Research Institute, Inc. (ESRI, Redlands, CA) Street maps dataset (version 2005 with 2006 updates). Road density was determined by overlaying plot locations on the “Forest Intactness of the Conterminous United States, April 2001” dataset, distributed by the Conservation Biology Institute (Corvallis, OR). Road densities and other landscape metrics within this dataset, were estimated within forestland units defined by highways and urban areas that contained more than 50,000 people.

Distances from FIA plots (true plot location coordinates) to roads were calculated with a GIS, for each of five categories of roads within the ESRI Street Maps dataset. Distances were calculated simultaneously from all plots across the seven states to National Freeway, State Freeway, and Major Highway features. Processing

<sup>4</sup>This list was not exhaustive but represented those species likely to have a significant impact somewhere in the 11-state Upper Midwest.

**Table 2.—Cover codes and ranges of percent cover of non-native invasive plants used in recording invasive species' presence, FIA plots, 2005-2006**

Cover code	Range of percent cover
1	< 1 percent, trace
2	1 to 5 percent
3	6 to 10 percent
4	11 to 25 percent
5	26 to 50 percent
6	51 to 75 percent
7	76 to 100 percent

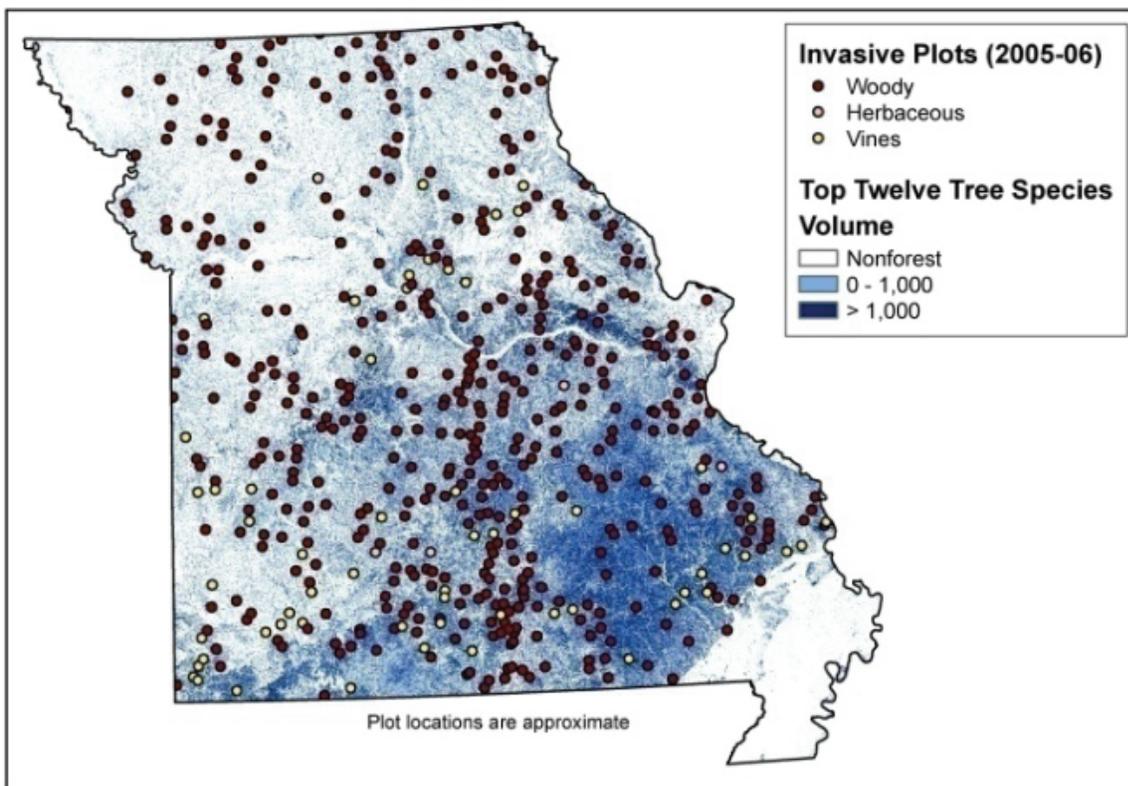


Figure 1.—Distribution of plots with non-native invasive plants in Missouri, 2005-2006. The blue shades in the background represent the volume (in  $\text{ft}^3 \text{ac}^{-1}$ ) of the top 12 tree species in the Upper Midwest.

the relationship between plots and the large number of local roads within Minor Highway and Local Street features was constrained to search for the nearest Minor Highway and Local Street within a 6 to 15 mile buffer radius of each plot. Buffer radius varied by state, including a 12-mile buffer around each state to allow for more representative calculations from plots near state boundaries.

During analysis, if a plot was missing a value for a specific combination of variables, we dropped the plot from the analysis for the variable.

## RESULTS

### Invasive Plants in Missouri Forests

Of the 25 species sampled for in the 2005 and 2006 inventory panels, only 13 were found in Missouri and only three—multiflora rose (457 plots), non-native bush honeysuckles (89), and Japanese honeysuckle (69)—were found in any number. Of the 1,264 plots sampled in this study 734, or 58 percent, had no invasive species of interest on them. Multiflora rose was the most frequently found species, present on 36 percent of the plots.

Figure 1 displays the distribution of invasives across Missouri's forests. The underlying forest volume map, for this and subsequent figures, was derived from a nearest neighbor imputation of FIA plots to a phenological series of satellite imagery from the Moderate-Resolution Imaging Spectroradiometer. The prominence of woody invasive species is particularly evident. Note the relative lack of herbaceous exotics on NRS-FIA plots.

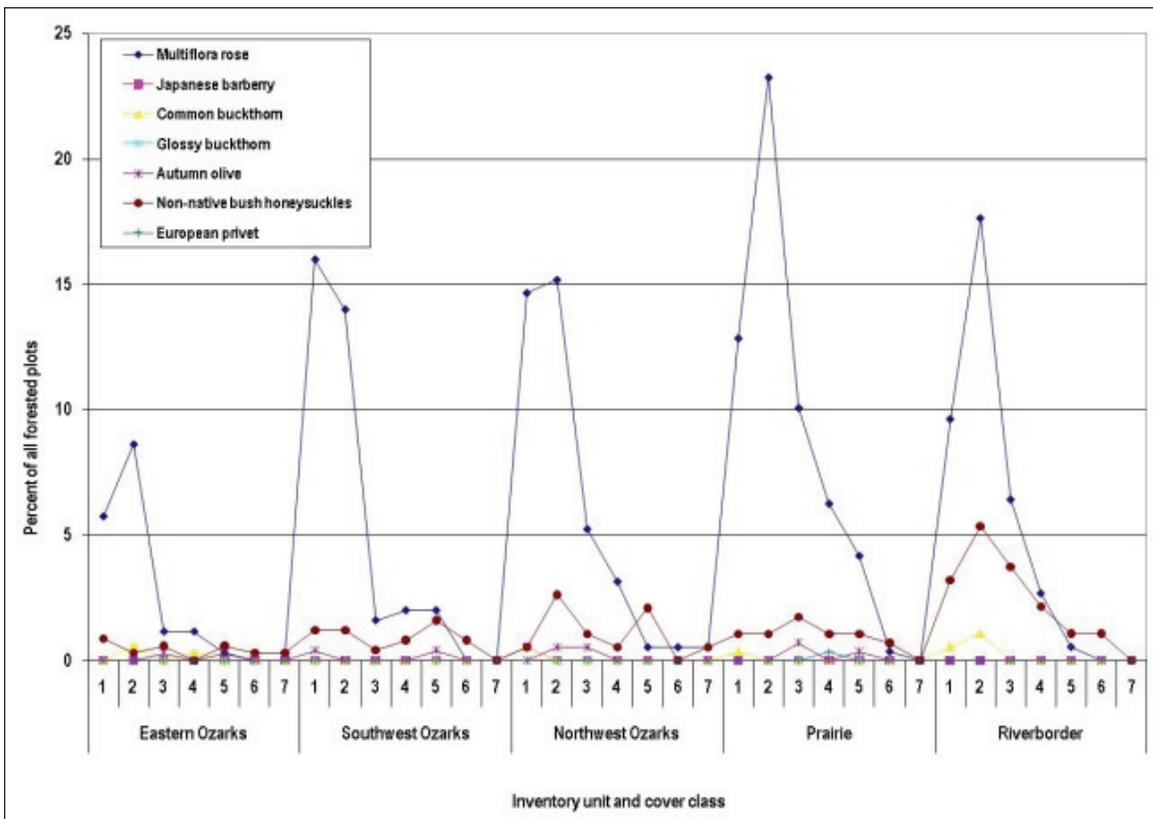


Figure 2.—Percentage of forested plots with non-native invasive woody plants in Missouri, 2005-2006. The numbers in the bottom axis represent cover codes from 1 (trace) to 7 (76-100 percent). Cover class “0”—no invasives found—not shown in order to preserve graphic scale.

Multiflora rose was found on more plots than any other invasive species, and was particularly prevalent in the Prairie and Riverborder inventory units (Fig. 2). These two units represent areas with some of the historically highest levels of Euro-American settlement and disturbance.

Herbaceous NNIPs were not particularly prevalent on NRS-FIA sample plots in Missouri (Fig. 3), although there were some local concentrations. Common burdock was the most frequently found species.

Among the vines, Japanese honeysuckle was the most numerous and had a large number of plots in the higher percent cover classes (Fig. 4).

Earlier, we documented the total number of plots with particular alien plant species. But when we looked only at the exotic species with the greatest percent cover on the plot, multiflora rose was again the most prevalent species on 381 plots or 30 percent of all plots sampled in 2005-2006, followed by non-native bush honeysuckles (74 plots/6 percent) and Japanese honeysuckle (56 plots / 4 percent) (Table 3; Figures 5-7).

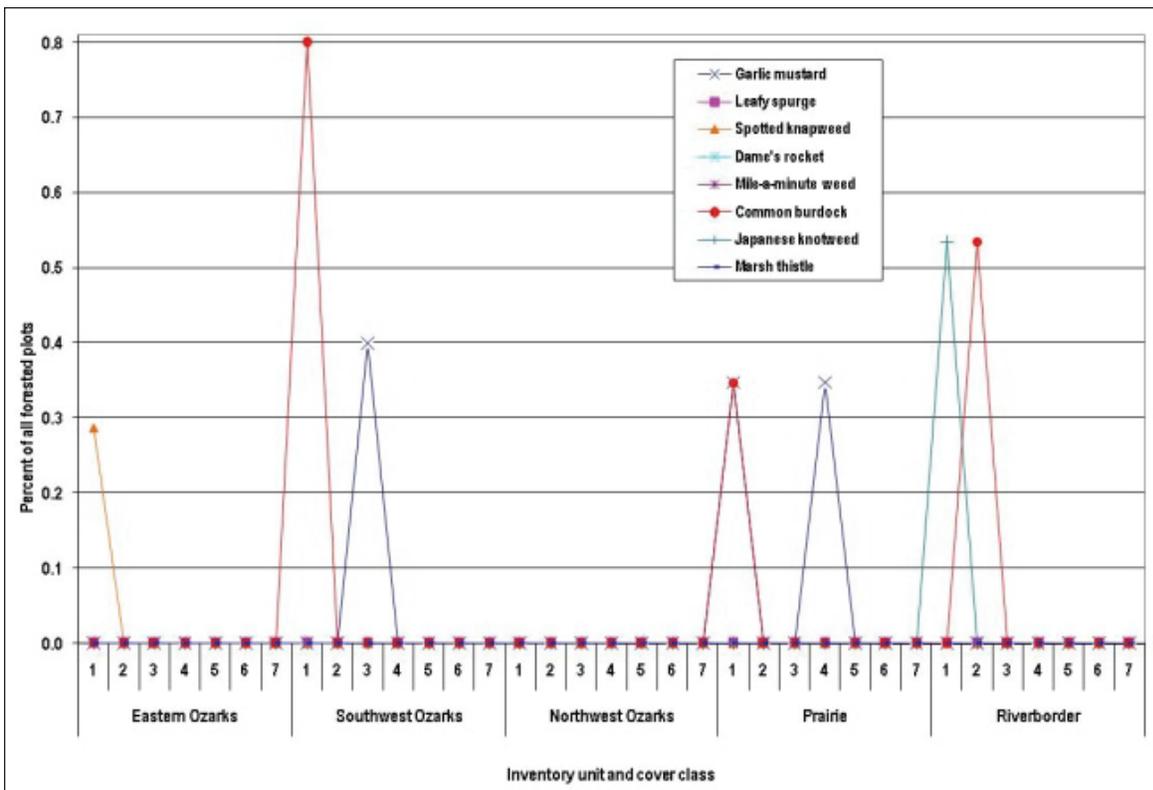


Figure 3.—Percentage of forested plots with non-native invasive herbaceous plants in Missouri, 2005-2006. The numbers in the bottom axis represent cover codes from 1 (trace) to 7 (76-100 percent). Cover class “0”—no invasives found—not shown in order to preserve graphic scale.

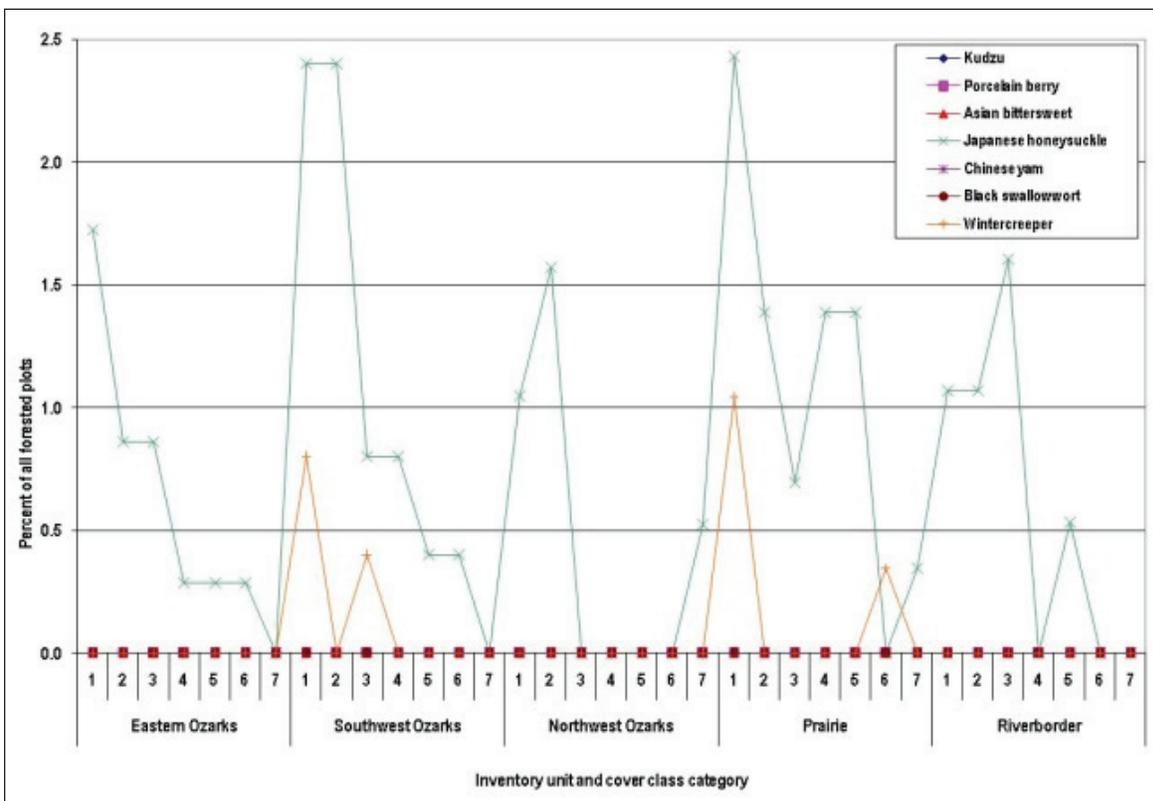


Figure 4.—Percentage of forested plots with non-native invasive vines in Missouri, 2005-2006. The numbers in the bottom axis represent cover codes from 1 (trace) to 7 (76-100 percent). Cover class “0”—no invasives found—not shown in order to preserve graphic scale.

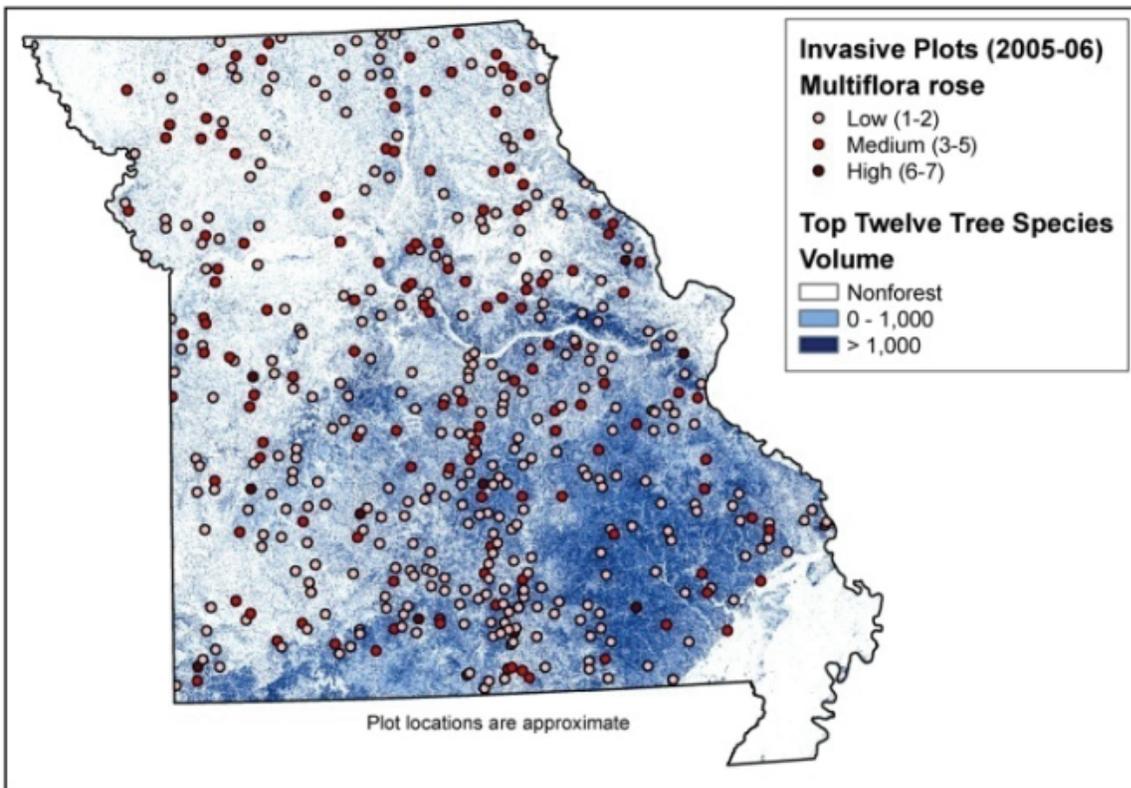


Figure 5.—Distribution of plots with multiflora rose present, by cover class, Missouri 2005-2006. The blue shades in the background represent the volume (in  $\text{ft}^3 \text{ac}^{-1}$ ) of the top 12 tree species in the Upper Midwest.

## Prominent Invasive Plants

### Multiflora Rose

Multiflora rose (*Rosa multiflora*) is a widespread shrub introduced as rootstock for ornamental roses in 1866 (Plant Conservation Alliance 2006). The species was distributed and planted widely for erosion control, “living fences” for livestock, and cover for wildlife. Multiflora rose spreads quickly and establishes dense cover that shades out other plants. Its seeds are dispersed by birds and remain viable in the soil for many years. It is currently found across the U.S. and is classified as “noxious” in several states. Control methods include mechanical and chemical methods that require repeated application for success, making control very expensive (Evans 1983).

### Non-native Bush Honeysuckles

Non-native bush honeysuckles are natives of eastern Asia and were brought to the U.S. to use as ornamentals and for wildlife habitat. Two of the most common NNIPs of the genus in Missouri are Morrow’s honeysuckle (*Lonicera morrowii*) and Amur honeysuckle (*L. maackii*). Fragmented forest remnants are vulnerable to honeysuckle invasion and establishment, particularly sites with limestone geology, which is prominent in Missouri. They frequently become well established on the forest edge (Luken and Goessling 1995). They not only outcompete native shrubs, but also reduce understory diversity by shading forest floor wildflowers. These *Lonicera* species produce small juicy berries that are eaten by many species of small mammals and birds. Honeysuckles are generally believed to have a minimal interval between dispersal and germination and a short-lived seed bank. The species relies on the heavy seed output and sprouting from buds at the base of the stems on large plants to increase its population size (Luken 1988).

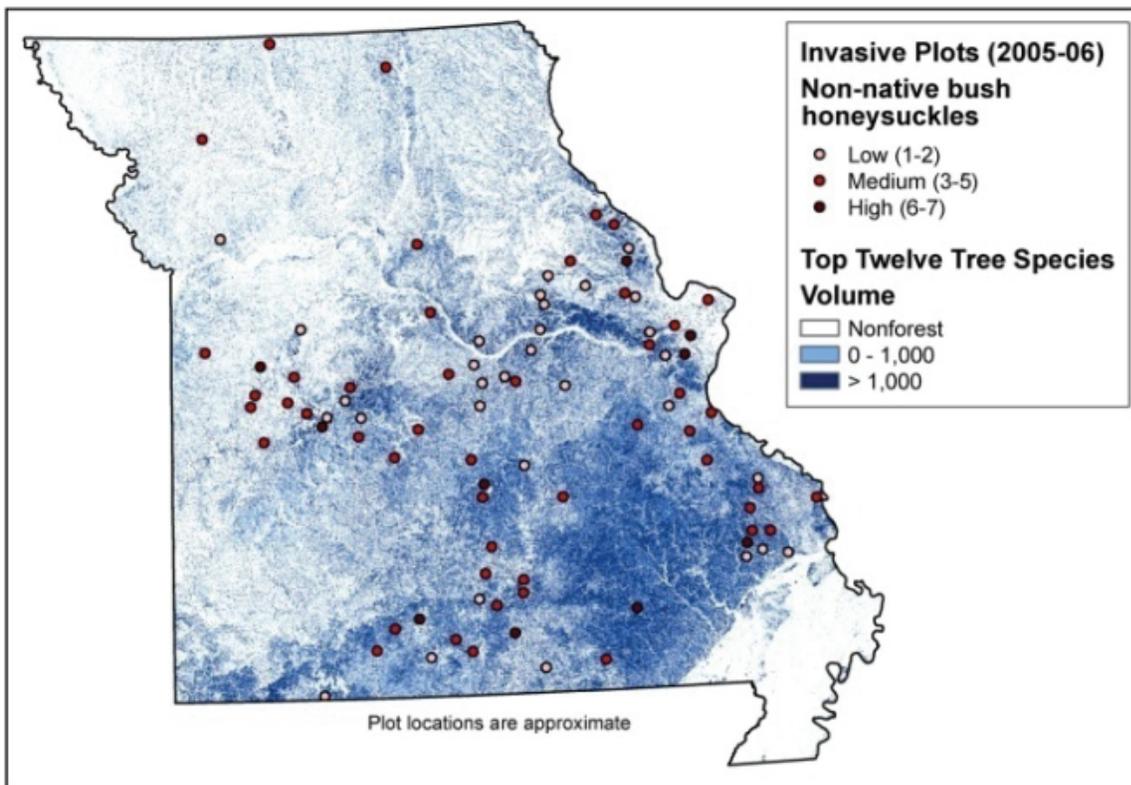


Figure 6.—Distribution of plots with non-native bush honeysuckle species present, by cover class, Missouri 2005-2006. The blue shades in the background represent the volume (in  $\text{ft}^3 \text{ac}^{-1}$ ) of the top 12 tree species in the Upper Midwest.

### Japanese Honeysuckle

Japanese honeysuckle (*Lonicera japonica*) is a persistent vine introduced as an ornamental and for erosion control and wildlife habitat in the mid-1800s (Plant Conservation Alliance 2006). The species thrives in a wide variety of habitats and quickly becomes established on disturbed sites (Rhoads and Block 2000). It can withstand shade and survive on marginal habitats until conditions improve (Ohio Department of Natural Resources 2001). It is currently distributed in most states including Hawaii, but is limited by cold temperatures and low precipitation (Plant Conservation Alliance 2006, USDA Nat. Resour. Conserv. Serv. 2007). Japanese honeysuckle spreads by vegetative runners, underground rhizomes, and seed dispersal, particularly by birds. It quickly becomes established and crowds out native plants, drastically influencing understory diversity.

### Non-Native Invasive Plants and Site Conditions

#### Site Class

A site's productivity benefits exotics and their native competitors alike. How a plant captures and utilizes soil resources relative to its competitors, determines the extent of its presence now and into the future (Newsome and Noble 1986).

There was a significant relationship between multiflora rose and site quality, but not for non-native bush honeysuckles or Japanese honeysuckle (Table 3). Invasive plants are known to be competitive on high-quality sites (Davis and Pelsor 2001) so the results partially support this idea. However, the collinearity between high site quality and present- or former human habitation (the primary influence behind the initial establishment of invasives) should be taken into account.

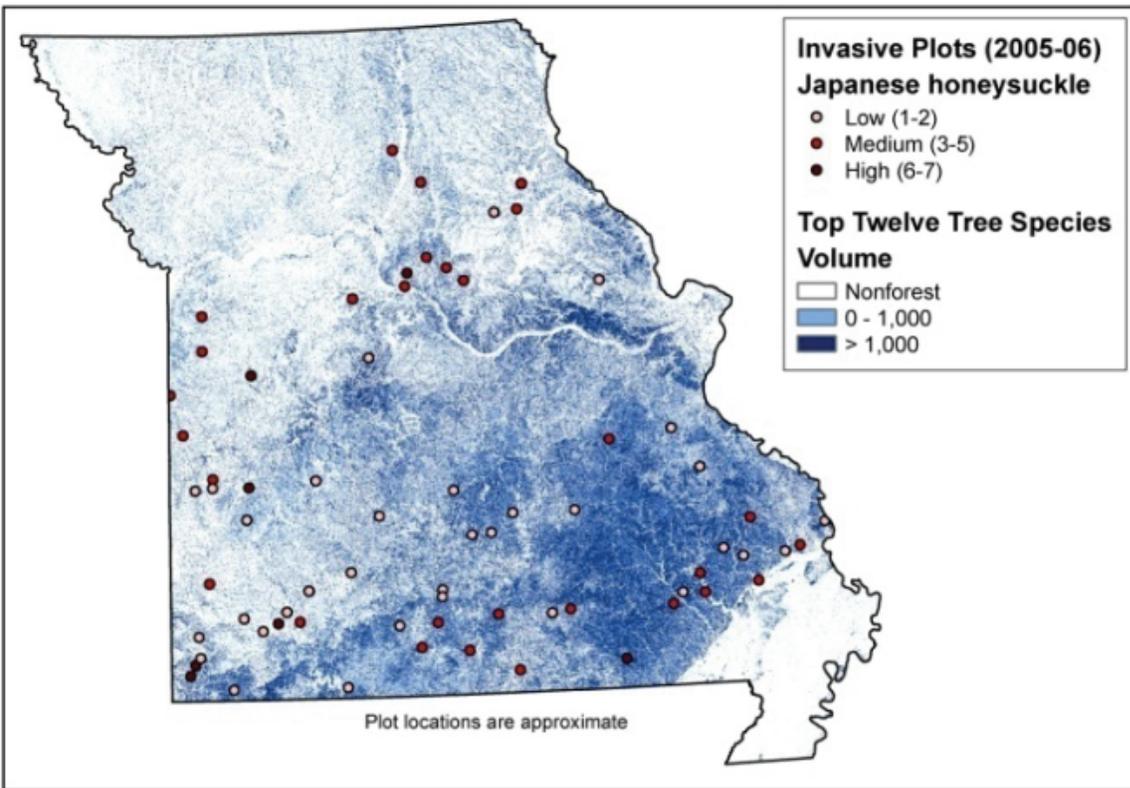


Figure 7.—Distribution of plots with Japanese honeysuckle present, by cover class, Missouri 2005-2006. The blue shades in the background represent the volume (in  $\text{ft}^3 \text{ac}^{-1}$ ) of the top 12 tree species in the Upper Midwest.

**Table 3.—Non-native invasive plant presence as a function of site class category, Missouri 2005-2006. Numbers in parentheses are the percentages for that site class category. (Multiflora rose:  $X^2 = 9.185$ , d.f. = 2,  $p=0.01013$ ; Non-native bush honeysuckles:  $X^2 = 6.45$ , d.f. = 2,  $p=0.0398$ ; Japanese honeysuckle:  $X^2 = 0.9481$ , d.f. = 2,  $p=0.6225$ ). Low = 0-50 ft (0-15.2 m) at 50 years, Medium 51-70 ft (15.2-21.3 m), and High = 71+ ft (21.3+ m).**

	Low	Medium	High
<u>Multiflora rose</u>			
Yes	109 (34)	228 (34)	120 (44)
No (Cover class = 0)	210 (66)	444 (66)	153 (56)
<u>Non-native bush honeysuckles</u>			
Yes	31 (10)	46 (7)	12 (4)
No (Cover class = 0)	288 (90)	626 (93)	261 (96)
<u>Japanese honeysuckle</u>			
Yes	14 (4)	39 (6)	16 (6)
No (Cover class = 0)	305 (96)	633 (94)	257 (94)

**Table 4.—Non-native invasive plant presence as a function of aspect category, Missouri 2005-2006. Numbers in parentheses are the percentages for that aspect category. (Multiflora rose:  $X^2 = 10.63$  d.f. = 2,  $p=0.004914$ ; Non-native bush honeysuckles:  $X^2 = 2.882$  d.f. = 2,  $p=0.2367$ ; Japanese honeysuckle:  $X^2 = 8.192$  d.f. = 2,  $p=0.01664$ )**

	Level	North-East aspects	South-West aspects
<u>Multiflora rose</u>			
Yes	125 (44)	168 (33)	164 (34)
No (Cover class = 0)	157 (56)	337 (67)	313 (66)
<u>Non-native bush honeysuckles</u>			
Yes	18 (6)	30 (6)	41 (9)
No (Cover class = 0)	264 (94)	475 (94)	436 (91)
<u>Japanese honeysuckle</u>			
Yes	25 (9)	22 (4)	22 (5)
No (Cover class = 0)	257 (91)	483 (96)	455 (95)

### Aspect

Given the patterns of rainfall and insolation, aspect is a surrogate for available soil moisture. This study searched for any relationship between aspect and the presence of the top three NNIPs.

Aspect significantly influenced location and extent of multiflora rose and Japanese honeysuckle in Missouri (Table 4); both species were more likely to be found on level aspects.

### Physiographic Class Code

The physiographic class code is a variable that represents the general effect of landform, topographic position, and soil on the moisture available to trees (Miles and others 2001). The bulk of the plots in this study are located on rolling uplands or dry slopes (Table 5). These results partially support Rejmánek (1989), who concluded that plant communities in mesic environments were more invasible than communities in more extreme environments. Xeric sites were difficult for germination and seedling survival (“abiotic resistance”) and hydric sites were often light-limited (from the point of view of invasives) due to the rapid growth of the species on site (“biotic resistance”) (Rejmánek and others 2004).

While all three species appeared to be correlated with mesic sites, broad physiographic class codes (hydric, mesic, and xeric) were significantly related only to the presence of multiflora rose and Japanese honeysuckle, not to non-native bush honeysuckles (Table 6). Japanese honeysuckle is known to be a vigorous competitor in mesic and riparian areas (Ohio Dept. of Nat. Resour. 2001). Multiflora rose is tolerant of a wide range of site conditions, including xeric sites (Missouri Department of Conservation 1997).

### Disturbance Factors and Non-Native Invasive Plants

NRS FIA crews note disturbances that have occurred on the Phase 2 plots since the previous inventory. It is possible to record up to three disturbance factors, with priorities assigned in the order of estimated impact on the plot. For the plots sampled in 2005 and 2006, the previous inventory was in 2000 and 2001, respectively. In this study, disturbance factors were compared to the most prominent invasive species on each plot. There was no significant relationship between the invasive species and disturbance types ( $X^2 = 39.98$ , d.f. = 80 ( $p=0.9999$ )).

**Table 5.—Number of plots by number of non-native invasive plants per plot and physiographic class code, Missouri 2005-2006**

Plot	Number of invasive plants present on plot				
	0	1	2	3	4
HYDRIC	1	0	1	0	0
Bays, Wet Pocosins	0	0	0	0	0
Beaver Ponds	0	0	0	0	0
Swamps, Bogs	0	0	0	0	0
Other Hydric	0	0	0	0	0
MESIC	291	247	65	6	1
Broad Floodplains Bottomlands	23	1	1	0	0
Flatwoods	15	17	2	0	0
Moist Slopes and Coves	7	7	1	0	0
Narrow Floodplains Bottomlands	34	31	8	0	0
Rolling Uplands	209	190	52	6	1
Small Drains	1	0	1	0	0
Other Mesic	2	1	0	0	0
XERIC	443	177	28	5	1
Deep Sands	1	1	1	0	0
Dry Slopes	359	143	19	5	0
Dry Tops	78	25	4	0	1
Other Xeric	5	8	4	0	0

**Table 6.—Non-native invasive plant presence as a function of broad physiographic class codes, Missouri 2005-2006. Numbers in parentheses are the percentages for that physiographic class code. (Multiflora rose:  $X^2 = 62.46$ , d.f. = 2,  $p=0.000^{*10-14}$ ; Non-native bush honeysuckles:  $X^2 = 5.12$ , d.f. = 2,  $p=0.0773$ ; Japanese bush honeysuckle:  $X^2 = 8.346$ , d.f. = 2,  $p=0.0154$ )**

	Hydric	Mesic	Xeric
<u>Multiflora rose</u>			
Yes	1 (50)	287 (47)	169 (26)
No (Cover class = 0)	1 (50)	321 (53)	485 (74)
<u>Non-native bush honeysuckle</u>			
Yes	0 (0)	53 (9)	36 (6)
No (Cover class = 0)	2 (100)	555 (91)	618 (94)
<u>Japanese honeysuckle</u>			
Yes	1 (50)	36 (6)	32 (5)
No (Cover class = 0)	1 (50)	572 (94)	622 (95)

**Table 7.—Presence of the three most prominent non-native invasive plants in Missouri by overstory basal area, in square meters per hectare, 2005-2006. Numbers in parentheses are the percentages for that basal area interval.**

Basal area, in m <sup>2</sup> ha <sup>-1</sup>	0+ thru 12	12+ thru 18	18+ thru 24	24+ thru 48	Total	Chi squared
All plots	364 (29)	625 (50)	248 (20)	16 (1)	1253	
No invasives present	165 (23)	390 (54)	159 (22)	12 (2)	726	$X^2 = 34.64$ , d.f.= 3, $p=0.000$
Multiflora rose	170 (37)	203 (45)	77 (17)	4 (1)	454	$X^2 = 24.84$ , d.f.= 3, $p=0.000$
Non-native bush honeysuckles	34 (38)	34 (38)	21 (24)	0 (0)	89	$X^2 = 7.305$ , d.f.= 3, $p=0.06278$
Japanese honeysuckle	24 (35)	33 (48)	12 (17)	0 (0)	69	$X^2 = 2.033$ , d.f.= 3, $p=0.5656$

### Overstory Basal Area

In order to comprehend the degree of overstory competitive influence on understory flora and the residual impact of past disturbance or management practices, we examined the relationship between NNIPs and overstory basal area. A vigorous tree overstory has the potential to suppress the growth and vigor of a plant understory. Our hypothesis was that low basal areas reflect minimal competition for light, water, and nutrients, but also could represent the lingering effects of past disturbances, such as wind damage, insect or disease attack, or recovery from overstory removal, or agricultural clearing.

The comparison of invasive presence by overstory basal area found only a significant difference between all plots and those plots with multiflora rose (Table 7), which appeared to benefit from reduced overstory basal area. Whether this result derives from the past disturbance events that might be associated with lower basal areas or the specific microenvironments associated with such open canopies, we cannot say.

### Non-Native Invasive Plants and the Influence of Roads

Highways and roads are the life's blood of the U.S. society and economy. The "car culture" that developed after the Second World War defined the pattern of settlement, commuting, and recreation activities that have left an indelible stamp on our landscape. Along with human habitation and recreation came non-native invasive species. Either deliberately or inadvertently, roads became conduits for these exotics to enter and alter natural ecosystems. Studies have found a relationship between distance to road and prevalence of exotic species (e.g., Watkins and others 2003). The influence is most pronounced within 30 meters of a road. Forman and Alexander (1998) could not document many cases where species spread more than 1,000 meters feet because of a road. For these reasons, this study assumed that the roads represent surrogates for human activity, rather than conduits for invasive exotics in and of themselves.

Table 8 displays the distribution of all plots, plots with no invasives, and the top three exotics by distance from the nearest road. At first, comparing relative proportions to all plots and plots without invasives did not seem to reveal a substantial difference. A majority of plots, regardless of invasive presence, were 328 to 1640 feet from the nearest road, and plots with invasives species displayed approximately the same proportion. Further analysis found, however, that invasive absence, multiflora rose, and Japanese honeysuckle were significantly related to the road variable. The distance influence is more dramatic at the greater distances, where the invasive species' proportions drop off while the proportion of plots with no invasives present increased in proportion to all of the plots in the study.

**Table 8.—Presence of the three most prominent non-native invasive plants categorized by distance from the nearest road, in feet, Missouri, 2005-2006. Numbers in parentheses are the percentages of the species for that distance interval.**

	Distance from road (feet)					Total	Chi squared
	0	0+ thru 328	328+ thru 1640	1640+ thru 3280	3280+ thru 9840		
All plots	4 (0.32)	249 (20)	721 (57)	233 (18)	57 (4.5)	1264	
No invasives present	0 (0)	129 (18)	406 (55)	149 (20)	50 (6.8)	734	$\chi^2 = 34.35$ , d.f.= 4, p=0.000
Multiflora rose	4 (0.9)	102 (22)	272 (60)	72 (16)	7 (1.5)	457	$\chi^2 = 27.19$ , d.f.= 4, p=0.000
Non-native bush honeysuckles	0 (0)	24 (27)	45 (51)	18 (20)	2 (2.2)	89	$\chi^2 = 4.827$ , d.f.= 4, p=0.3055
Japanese honeysuckle	0 (0)	21 (30)	41 (59)	7 (10)	0 (0)	69	$\chi^2 = 10.58$ , d.f.= 4, p=0.03165

## DISCUSSION

This study examined patterns of distribution and relationships with selected forest and site characteristics for 25 exotic species/species groups of interest in Missouri. Only three species—multiflora rose, non-native bush honeysuckles, and Japanese honeysuckle—were found in any number among the 1264 total plots. There seemed to be a logical connection with the study area and the potential for invasives. Oaks, the predominant forest type in Missouri, are mid-shade tolerants and rely upon disturbance to maintain their position in most parts of the genus' range (Johnson and others 2002)<sup>5</sup>. Missouri, particularly the Ozark Plateau, had a long history of natural and anthropogenic disturbances (Beilmann and Brenner 1951, Guyette and others 2002). Given the history of natural and human-caused disturbance and forest types whose shade tolerance means the growing space might not be completely occupied, we expected to find multiple relationships between NNIP and forest and site characteristics.

We found some relationship between multiflora rose and non-native bush honeysuckle presence and site quality; the species benefitted from higher site index values. The presence of multiflora rose and Japanese honeysuckle was found to be significantly related to level aspects. When we looked at physiographic class code for any influence of topography (and—by extension—water availability/site productivity) upon NNIP presence, we found a significant relationship with multiflora rose and mesic/xeric sites and Japanese honeysuckle and hydric/mesic plots plots. Relatively few of the target species were found in hydric systems, a function of the species list and the emphasis on forested lands in Missouri. When looking at disturbance, we found that multiflora rose significantly benefitted from lower overstory basal areas, but not the other species. Another measure of disturbance, distance to roads, was a significant, negative influence on multiflora rose and Japanese honeysuckle presence.

These results are not surprising; invasive species are known to thrive on sites with more available resources (Richardson and Pyšek 2006). In most parts of Missouri, level sites are more productive than those areas with steep slopes (but not always in the Ozarks; see Lawrence and others 2002). The challenge is separating the human influence from the ecological one. One could easily argue that our results reflect the heavily disturbed nature of Missouri's second- and third-generation forests, which either came back upon

<sup>5</sup>In fact, the lack of disturbance is resulting in a shift in species composition of regeneration in oak forests throughout the genus' range (Moser and others 2006).

abandoned farmland or pasture or were influenced by heavily disturbed adjacent land. The characteristics of the landscape that we found to influence invasive species presence may also be a significant influence on homestead choice by settlers. Even our disturbance measures, lower basal area and proximity to roads, could as easily reflect the human hand that originally placed the plants in that location as the microsite attributes that allowed them to subsequently thrive.

A posteriori analysis of invasive species at one point in time is usually not sufficient to evaluate trends in regeneration, expansion, or growth (Rejmánek 1989). The FIA database tracks disturbance and silvicultural treatments, but only in the interval since the previous inventory. The anthropogenic activities that resulted in the establishment of these non-native invasive species likely occurred many years ago. We are conducting a region-wide analysis, but repeated measures on a wide scale will be necessary to verify trends that, up to now, are little more than anecdotal in Missouri.

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