The Role of the Forest Service in Nonnative Invasive Plant Research

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Abstract

In many of our Nation's wildlands, invasive nonnative plants contribute to the endangerment of native species and lead to other severe ecological and financial consequences. Projected trends of increasing human populations and associated development and globalization will contribute to increases in the already high rates of introductions of nonnative plant species. Changes in climate are likely to alter species distributions, favoring the expansion of some nonnative species and contributing to the imperilment of additional native species. Declining oil supplies may also place pressure on wildlands for the production of sustainable supplies of small-diameter trees or other nonwoody biofuels. Given these trends, Forest Service Research and Development needs to be strategic in addressing invasive species issues in public and private forests and rangelands. We urgently need to prioritize both known and potential future invasive species and determine which ecosystems are most vulnerable to invasion. Quantitative risk analyses, assessment of critical pathways, plus data on effects of both the invaders and control methods on native biodiversity will aid in this prioritization process. Such lists will inform decisionmaking on potential preventative measures to keep potentially invasive plants out and also as a guide regarding which species to attempt to control and where to control them. Multidisciplinary research teams and quantitative monitoring protocols will facilitate the development of tools that both measure and minimize effects associated with invasive species and account for the stage of invasion. These tools will also need to address multiple stressors, including natural disturbances, current management practices such as livestock grazing and timber harvesting and thinning, and human-induced disturbances, such as exotic insect forest infestations and global climate change. Such knowledge will improve our ability to manage our forests and rangelands as ecosystems that are more resilient to future invasions and increase our success in restoring degraded systems.

Introduction

The introduction and spread of nonnative plant species are natural colonization and migration processes that occurred prior to human evolution, and such invasions have been documented by several early researchers (Darwin 1859, Elton 1958). However, recorded invasions of exotic plants and other exotic species since 1800 have increased at an accelerated rate, presumably due to increased intercontinental mobility (Liebhold et al. 1995). In the United States, plant introductions are currently allowed without prior risk assessments. While many nonnative plant species provide food and fiber, adorn our civilization, and facilitate habitat restoration and land management, some will spread widely and possibly alter ecosystem structure and processes in undesirable ways. These invasive species incur high costs in altered ecosystem services and in investments in their management and control. Invasive exotic plants constitute 8 to 47 percent of the total flora of most States in the United States (Rejmanek and Randall 1994). There are approximately 4,500 exotic species in the United States that have established naturalized populations and at least 15 percent of these cause severe harm (U.S. Congress, Office of Technology Assessment 1993).

Examples of negative ecosystem effects caused by invasive plants include alteration of food webs (Bailey et al. 2001, Kourtev et al. 1999), degradation of wildlife habitat (Schmidt and Whelan 1999), changes in fire (Brooks et al. 2004) and hydrological regimes (Gordon 1998), increases in erosion rates

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(Shafroth et al. 2002), and modifications of nutrient cycling (Ehrenfeld et al. 2001, Sperry et al. 2006). Nonnative plant species can also reduce biological and genetic diversity by hybridizing with native plants (White and Bowden 1947). It is estimated that the United States spends approximately $145 million annually in its attempt to control nonnative invasive plants in natural areas (Pimentel et al. 2000).

Forest Service Research and Development (R&D) plays an important role in meeting research needs involving invasive nonnative species in the Nation's forests and rangelands. Nevertheless, scarce resources mandate that the Forest Service focus its efforts strategically. This document outlines priority Forest Service R&D needs relating to invasive plant species threatening these wildlands.

Effective prioritization of research resources entails recognition of the wide variation in invasive effects, ecosystem vulnerabilities, and ecological and economic consequences of the spread of a nonnative species. In many second-growth, closed-canopy forests, some populations of nonnative species are small or confined to forest edges or canopy gaps; such species may be controlled. Without such efforts, areas only lightly invaded may become more severely affected in response to forest management, new disturbances, and/or a proliferation of invasive species (especially those that are shade-tolerant) propagules, threatening ecosystem structure and processes and the economic, environmental, and societal benefits derived from them. In other cases, nonnative species posing considerable risk to ecosystem integrity have spread widely and reached high densities, thus altering forest management priorities, and requiring long-term investments to mitigate effects. The Forest Service, with guidance from local, State, and Federal governments, must balance the relative value of wildland ecosystems, the potential magnitude of invasive effects, and the costs to society in its decisions to invest research resources into understanding these processes and developing tools to address them.

Multiple pathways for introductions and increasingly fragmented landscapes mean that Forest Service lands cannot be effectively managed without consideration of the landscapes in which they occur. Landscape and regional perspectives on invasion processes encourage cooperation with adjacent landowners, municipalities, and other agencies to address invasive species issues on national forest lands.

Strengths of Forest Service Research and Development

The Forest Service role results from its unique ability to make a difference nationally. The Forest Service has broad existing authorities and responsibilities, assigned to the Chief of the Forest Service; research expertise in land management, forestry, entomology, pathology, botany, ecology, and numerous other specialties; presence across the country and around the world; and relationships with every State and territorial agency with responsibility for invasive species. Few other agencies, universities, and organizations have such a long-term perspective on land management and research directions or such valuable assets for attracting partners (including long-term data sets, experimental forests, research natural areas, and quarantine facilities).

Forest Service researchers have a long history of collaboration with other agencies and research partners, facilitating effective management of invasive plants and identification of priority research issues and needs addressed at appropriate regional and landscape scales. Close associations with partners in universities, industry, and other Federal agencies facilitate collaborations to supplement Forest Service expertise. The geographic distribution of Forest Service research stations and broad land base that encompasses a wide variety of forests, woodlands, shrublands, and grasslands provide excellent opportunities to test research hypotheses and models at multiple geographic and temporal scales. The Forest Inventory and Analysis system within Forest Service R&D houses long-term national, regional, and local data sets that have recently been extended to collect data on some nonnative plant species in monitored plots. The broad research expertise among Forest Service scientists facilitates a multidisciplinary approach to the study of invasive species, development of tools for their management, and protocols for forest and rangeland restoration.

Key Future Issues

The 2000 Renewable Resources Planning Act (RPA) assessment (RPA 2000) projects growing U.S. populations (50-percent increase by 2050), especially in the southern and western regions. Population increases are expected to increase demand for forest services (especially recreational uses) and

increase the conversion of forests and rangelands to developed use, resulting in further subdivision and fragmentation. The forest land base is expected to remain relatively stable. The 2000 RPA projects aging forests in many parts of the country, changing their vulnerability to invasive species, insect and disease outbreaks, and fire. Projected changes in climate and atmospheric inputs such as nitrogen will affect species distributions and nutrient cycles and the duration, frequency, and intensity of forest disturbances such as fire, insects, diseases, drought, and storms. These scenarios, in combination with growing global trade, suggest that threats and effects of invasive plant species are likely to increase in the next 20 to 50 years, challenging the Forest Service research community to address landscape, regional, and national issues of invasive species management and mitigation.

Our ability to manage nonnative plant species invasions is linked with past, current, and future human values and associated land management activities as well as with sometimes conflicting priorities over the use of wildlands. For example, larger, more frequent, and more intense wildfires in dense and infrequently burned forests may enhance the spread of some disturbance-dependent invasive species. The spread of invasive nonnative plants associated with recreation, roads, habitat fragmentation, grazing, harvesting, tree thinning, prescribed fires, and fuel reduction activities may enhance populations of invasive species. The cultivation of potentially invasive plant species as biofuels could facilitate the spread of invasive species into the Nation's forests and natural areas. Furthermore, the use of forest lands to provide sustainable supplies of small-diameter trees to support biomass power could have the unintended consequence of introducing invasive plants into managed forests at unprecedented rates.

Priority setting for invasive species research should reflect societal values with respect to species, ecosystems, and ecological services. Is our highest priority to preserve ecosystem processes that are dynamic or to preserve a static ecosystem structure (Botkin 2001)? How do we address the needs of imperiled species against a landscape undergoing dramatic changes? How do we address changing priorities for ecosystem services given dramatic shifts in human population sizes, ethnic diversity, and age structure? How do we focus research on target species when confronted with rising rates of invasion?

Prevention and Prediction

Preventing the widespread establishment of nonnative species may be more cost effective than attempting to control full-blown infestations, which may not be economically feasible. Quantitative analyses are needed to better understand the distribution and abundance patterns of nonnative species populations, pathways of introduction, and habitats most at risk. The development of predictive models that identify areas likely to be negatively affected by nonnative species and accounting for sampling effort, climate, physiography, human population density, and other variables that reflect land use intensity is an important step in developing a national invasive species strategy. The concurrent development of improved pathway analytical methods that identify probable entry points and means and modes of introduction, establishment, and spread will support the development of stronger prevention programs. Research that addresses the social aspects of nonnative plant use will enhance our ability to institute prevention guidelines suitable to different cultural conditions.

Our poor understanding of factors that make plant communities susceptible to invasion limits our ability to provide management guidelines for preventing the introduction and spread of nonnative plant species. Ecosystem attributes, disturbances, and plant characteristics can all influence invasion rates. A better understanding of the role of stand structural attributes and altered disturbance regimes is needed, as is plant-focused research. High rates of pollen and seed rain from invasive plants and the long-term viability of seed in the soil may overwhelm the biotic resistance of even the most nonfragmented and native plant-dominated ecosystems. We need to better understand the roles of propagule pressure and the numbers, sizes, and distributions of invasive plant populations to better predict the dynamics of spread. Pathway analyses and models of spread should incorporate estimates of dispersal distances and predictions of safe establishment sites, both of which require a detailed understanding of each plant's reproductive strategies and physiology at various stages of development.

For both large-scale models of invasive species patterns and local-scale studies of the role of stand-level attributes, high-quality data sets are needed. Forest Service researchers will need to collaborate with universities and States to ensure that data on nonnative species are collected, verified, and

made available in Web-accessible databases. Ready access to taxonomic experts is critical for detecting and responding to populations of invasive species when they are small and manageable. Likewise, investments in forest monitoring plots, such as the Forest Inventory and Analysis system, may provide information on invasions relative to stand structural attributes and assist in predicting invasion trajectories and potential effects of invasions on community productivity and diversity.

Early Detection and Rapid Response

There is a need for a centralized, rapid, effective procedure for identifying potential new plant invaders. A user-friendly database of information on potential invaders and management methods would facilitate early response. Effective survey strategies and techniques are needed for detecting very small, isolated populations of newly established nonnative species and for predicting invasible habitats, perhaps based on habitat risk and vector assessments. Research is needed to determine the best tools for land-based, regional surveys of nonnative invasive species that are rapid, quantifiable, and repeatable.

We need to expand our proactive research role that will promote early and rapid management of plant invasions by Federal, State, and local entities when such invasions are small and controllable. Risk assessments at this stage should be based on plant population ecology and metapopulation models, especially dispersal rates, pathways, and distances. There is a need to develop tools to identify potentially invasive species, prioritize species for management attention, identify priority areas for treatment, and more successfully eradicate high-priority invaders with minimal nontarget effects. Spread models and forest growth and regeneration models that use various scenarios to predict species compositional changes (and associated economic losses in property values) over time and under different levels of control and management (including the do-nothing alternative) will provide scientific- and economic-based incentives to respond early and rapidly. There is a need for social science research focused on understanding the human behavior of those responding to the invasions, because the success of any new rapid response tool is dependent on the cooperation of a number of different people, including scientists, land managers, and amateur botanists, as well as public response.

Management and Mitigation

Rising rates of introduction coupled with the spread of increasing numbers of invasive plant species on forests and rangelands will challenge land managers to determine priorities for control and mitigation. Research quantifying ecological and socioeconomic effects of nonnative invasive plant species is critically needed to aid decisionmaking, focus management efforts, and develop a better understanding of the behavior of different species and ecosystems under different environmental circumstances. What are the likely long-term consequences of no management for a newly invasive plant species? Forest Service research into tool development should seek to maximize effects on target organisms and to minimize nontarget effects. In most cases, knowledge of the basic biology, population genetics, and population ecology of high-priority target species will be necessary to design protocols to mitigate their effects. Managers may also seek lessons learned from similar species and ecosystems to develop general protocols. Genetic changes in populations due to selection, hybridization, and the introduction of new genotypes may increase invasiveness; there is a need to understand the contribution of genetic variation in driving plant invasions.

Invasive plant managers will be able to take advantage of new tools, including remote sensing, genetic evaluation, landscape analysis, epidemiological modeling, and statistics. Integrated pest management using mechanical and chemical treatments, biological control agents, and vegetation management via prescribed fire and grazing will continue to play an important role in the mitigation of invasive plant effects. Research into the application, integration, and effects of a broad spectrum of tools is needed to improve efficacy, expand our ability to treat different ecosystem types, reduce undesirable effects, and address emerging invasive species. There is also a need for greater emphasis on the development of cost-effective and sensitive quantitative monitoring protocols to better assess the effectiveness of various control strategies.

Restoration and Rehabilitation

Mitigation of invasive effects and increasing resistance to future invasions are accomplished through restoration and rehabilitation activities. We need research to develop vegeta-

tion management protocols to restore ecosystem processes and reduce the effects of invasives, also recognizing those situations where restoration is neither feasible nor desirable (Lugo and Helmer 2004). There is a need to develop ecologically sound restoration methods that consider the contributions of genetics, population and community structure, and ecosystem processes to invasion resistance. Disturbance, high-propagule pressures, legacy effects such as seed banks, and changes in disturbance regimes and nutrient supply may impede long-term restoration success.

Land managers lack many basic tools for reducing the effects of invasive species on severely infested lands. Forest Service research can develop propagation techniques and reestablishment tools (Mahalovich and McArthur 2004, Monsen et al. 2004), address the consequences of using nonnative plants in rehabilitation, reduce seed contamination, and guide managers in decisionmaking. Forest Service researchers can develop guidelines on appropriate species and genotypes for rehabilitation projects.

Application and Communication

Effective communication and application of invasive species research will benefit from associated sociological research. There is a need to know how best to educate forest workers, landowners, agencies, public land users, nurseries, and highway departments on the importance of preventing the introduction of nonnative species, eradicating priority species, and restoring areas degraded by nonnative species invasions. Invasive plant management guidelines that have been carefully researched should be incorporated into existing forest management models and tools.

Web-based databases and networks on invasives are maintained by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service's PLANTS database (http://plants.usda.gov), National Invasive Species Information Center's Web site (http://www.invasivespeciesinfo.gov), National Park Service's WeedUS database (http://www.nps.gov/plants/alien/), regional and State Exotic Pest Plant Councils, Invasive Plant Councils, national heritage programs, and conservation data centers, e.g., Natureserve's http://www.natureserve.org/aboutUs/network.jsp. Forest Service research should contribute to these resources by providing science findings, syntheses, and guides. Nonetheless, traditional scientific publications will continue to provide the foundation of peer-reviewed knowledge about invasive plant species.

Timely and effective application of Forest Service research will require increased science delivery, communication, and collaboration with managers and regulatory agencies, including the USDA Animal and Plant Health Inspection Service and State agricultural and natural resource departments. The development of multiagency networks may enhance timely science application.

Future Top Priorities

- Quantitative risk analyses are needed to identify species that should not be brought into the United States or sold in nurseries and to prioritize research on individual species or species groups.
- Pathway analysis is needed to identify key pathways for species' introductions, vectors of species spread, probable points of entry for surveillance for early detection, education programs, and management planning.
- A better understanding of the shared characteristics, behaviors, and environmental thresholds of successful plant invaders is needed.
- Researchers and managers need ready access to taxonomic expertise for reliable early detection and risk assessment.
- The timely application of research results requires active interaction of researchers and managers as well as other technology transfer vehicles such as workshops for landowners and up-to-date information on Web sites and other user-friendly formats.
- There is a critical need to better understand the effects of invasive plant species on native biodiversity and on ecosystem services and to develop protocols that assess and reduce the effects of multiple stressors such as disturbances, climate change, and invasive species on rare and endangered species.
- Research is needed to aid in the recognition of habitats most vulnerable to invasions and to potential loss of biodiversity and alteration of ecosystem services.

- Research is needed to develop management and restoration strategies for high-priority species and high-priority habitats.
- We need a better understanding of the effects of different tools used to manage invasive species, their nontarget effects, and whether benefits are real.
- The development of "virtual" research teams that cut across regions and invasive species taxa should be used to better leverage Forest Service expertise in invasive species research. For example, Forest Service biological control efforts could be more synergistic, involving multiple areas of expertise and including Forest Service botanists, entomologists, ecologists, pathologists, sociologists, and people with expertise in monitoring plant population trends and nontarget effects.

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