
The Role of the Forest Service in the Economics of Invasive Species Research

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Introduction

Invasive species increasingly influence various sectors of the economy through their effects on agricultural, forest, range, aquatic, and urban ecosystems. Policymakers evaluating the actual and potential effects of invasive species are concerned with allocating scarce taxpayer resources among a variety of competing governmental actions. To make allocation choices, they need information about the costs and benefits of alternative policies. Unfortunately, little is known about the magnitude of economic damages caused by invasive species, the costs of alternative controls, or the underlying factors affecting invasion risks and spread rates, much less the effectiveness of money spent on invasive species management. Economists can provide a vision that synthesizes the connections among invasive species management options in ways that help decisionmakers. This comprehensive vision can improve the selection and targeting of resources to reduce economic, social, and ecological damages. This paper reviews past and current Forest Service research on the economics of invasive species, outlines specific research needs, and identifies possible emerging issues in invasive species economics and policy.

Roles of Forest Service Research and Development in the Economics of Invasive Species Research

The Forest Service, U.S. Department of Agriculture (USDA), is one of several Federal agencies that conduct or support research on the economics of invasive species. Other agencies include the USDA Economic Research Service (ERS), the U.S. Environmental Protection Agency (EPA), the USDA Animal and Plant Health Inspection Service (APHIS), and the U.S. Coast Guard. Each agency focuses its attention on invasive species issues

tied to its mission. For example, ERS focuses primarily on the effects of invasive species on agricultural systems, and the EPA focuses primarily on the effects of invasive species on aquatic ecosystems. Forest Service economics research focuses on issues affecting the management of invasive species on forests and grasslands.

Forest Service Research and Development (R&D) has a 25-year history of research into economic aspects of forest insects and disease, which forms the backdrop for newer efforts to understand economic dimensions of invasive species. Past research often focused on native pests, whose effects became increasingly important as forest management intensified and plantation forestry became more widespread in the latter part of the 20th century. Two examples are research on fusiform rust (*Cronartium quercuum* f. sp. *fusiforme*) and the southern pine beetle (*Dendroctonus frontalis*). Fusiform rust is a widespread and damaging disease of loblolly pine (*Pinus taeda*) and slash pine (*P. elliotii*) in the Southeastern United States. A central objective of much of the economics research was to identify how landowners could lower their risks of infestations and damages from fusiform rust. Economists collaborated in a study with silviculturists and forest pathologists to quantify the net benefits of the use of rust-resistant seedlings in pine plantations. In terms of benefits and costs, the study found that the benefits of the research embodied in the development of the rust-resistant seedlings were 2 to 20 times greater than the cost of the research (Cabbage et al. 2000). One economic study used a timber supply and demand model to evaluate the short-run timber price and overall economic effects of a large-scale infestation of the southern pine beetle in Louisiana and Texas. Some of the techniques used in that analysis formed the basis for other studies examining the effects of various kinds of forest damage agents (e.g., Butry et al. 2001, Prestemon and Holmes 2000). The pine beetle study established that the net economic effect of a large-scale infestation could total into the hundreds of millions of dollars, and that wealth transfers between winners and losers emerge from such catastrophic events (Holmes 1991).

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Invasive species have been the focus of more recent and ongoing economics research studies. The European subspecies of the gypsy moth (*Lymantria dispar*) has been in the United States for more than a century, but it was not until the latter half of the 20th century that economists took note of its apparent economic effects. The Slow the Spread (STS) Program, a Federal-State partnership designed to limit the spread of the gypsy moth, needed economic analysis to establish its economic efficacy. One Forest Service-funded study documented that the STS Program could generate 25-year benefits ranging from \$0.8 to \$3.8 billion, mainly derived from mitigating damages to residential landscapes (Leuschner et al. 1996, Sharov and Liebhold 1998, Sharov et al. 1998), which far exceed programmatic costs.

The international trade research into invasive species is focused on quantifying the overall timber market effects of a potential exotic invasion into the United States. Jointly funded by ERS, APHIS, and the Forest Service, the case study in that analysis focused on the Asian variety of the gypsy moth or its close relative, the nun moth (*L. monacha*). The published work quantifies how such an invasion into U.S. forests would affect all categories of forest products manufactured and traded by the United States. This long-run analysis was also able to quantify the potential effects of alternative intervention policies to limit the invasion risk by such moths (Li et al. 2007, Prestemon et al. 2006).

In addition to examining the commodity effects of forest invasive species, ongoing Forest Service research is investigating the nonmarket economic effects of exotic forest pests. Several nonnative invasive pests cause nonmarket economic losses that exceed the timber losses of affected species or are confined to noncommercial species. Failure to account for the nontimber economic effects therefore results in downwardly biased assessments of overall economic losses. In a northern New Jersey study area, for example, mortality of eastern hemlocks due to the hemlock woolly adelgid (*Adelges tsugae*) was estimated to reduce private property values by roughly \$14,750 per acre (Holmes et al. 2006, Huggett et al. 2008), which greatly exceeds the comparable per acre timber value lost. In a similar fashion, ongoing Forest Service studies in California indicate that Sudden Oak Death disease (caused by *Phytophthora ramorum*) causes large economic losses to residential private property values, while the timber losses from this disease are minimal (Holmes and Smith 2008).

Private landowners can take protective measures to reduce damages from nonnative pests and are likely to do so if perceived economic benefits exceed the control costs. Notably, the benefits of forest pest control actions taken by one landowner are shared by other forest landowners within a community (i.e., they are public goods). Consequently, some members of the landowner community will not take these benefits into account and will fail to take protective action. Forest Service research has shown that landowners who are most likely to participate in nonnative forest pest control programs are aware of the effects of their protective measures on other members of the community and that economic surveys can be used to identify community members who are most (and least) likely to participate in forest pest control programs (Holmes et al. 2008).

The absence of credible, nationwide estimates of the costs and economic losses caused by nonindigenous forest pests and pathogens limits the ability of policymakers to evaluate tradeoffs between economic effects and potential policy measures targeted at reducing those effects. Consequently, theoretically and empirically rigorous analyses are being developed to provide a foundation for estimating the aggregate economic effects from forest invasive species (Holmes et al. 2009). The modeling process quantifies key market and nonmarket economic effects using site-specific microeconomic analysis. Then the dynamic evolution of economic effects across landscapes is modeled as a spatial-dynamic process. Finally, by viewing economic costs and losses resulting from current invasions—specifically, the gypsy moth, hemlock woolly adelgid, Sudden Oak Death disease, and emerald ash borer (*Agrilus planipennis*)—as a sample drawn from an underlying stochastic process, statistical methods are used to estimate the overall distribution of effects, from benign to catastrophic, and the expected losses from future invasions are computed. This comprehensive research program is being developed at the National Center for Ecological Analysis and Synthesis through the collaboration of forest economists, entomologists, and pathologists representing Forest Service R&D, international forest research agencies, academic institutions, and The Nature Conservancy.

In summary, the Forest Service has partnered with sister agencies within the Federal Government and others to carry out economics research into invasive species. In spite of its documented and potential benefits to both the agency and to society, economics research has received a small share of

the invasive species funding within the agency. Economics research funding has been targeted at particular pests or narrow features of economic effects and tradeoff analyses rather than focusing on the overall science of the economics of invasive species. For example, to date, the agency has funded no large-scale effort to quantify the many economic effects of headline pests such as Dutch elm disease (*Ophiostoma novo-ulmi*) or the chestnut blight (*Cryphonectria parasitica*), although evidence suggests that their effects on Eastern forests may have been important (Schlarbaum et al. 1997). The research has not been sufficient to track the substitution effects of individual species losses on both market and nonmarket values in affected forests, which could lead to more scientifically sound policy decisions by lawmakers and land managers. Other new headline species, such as the emerald ash borer and the Asian longhorned beetle (*Anoplophora glabripennis*), have also escaped detailed economic analysis in terms of both their effects and their control efficacies. Furthermore, we are aware of no research that has been able to separately quantify the roles of international trade and international travel on risks of invasion and establishment of some potentially catastrophic pests in temperate and subtropical North American landscapes. Nor is there a thorough understanding of the roles of land use and economic activity on risks of invasive species introduction, establishment, and spread in the United States.

An economic approach to invasive species research provides several tangible benefits: (1) the economic effects of exotic species invasions on various economic sectors, including markets for goods (such as timber) and services, and on nonmarket values (such as aesthetics) can be identified and quantified; (2) the costs of invasive species control (including prevention, detection, slowing the spread, and eradication) can be evaluated in terms of their efficacy in reducing economic losses; (3) the broad-scale relationships between economic inputs and economic damages can be assessed using a suite of economic methods, including econometric analysis, mathematical models, and simulation studies; and (4) economic analyses can be framed in terms useful for policy analysis by identifying the economic tradeoffs inherent in a suite of alternative policies designed to prevent or control the invasion of exotic pests.

Historically, Forest Service research in the economics of invasive species has benefited from collaborations with other agencies. We anticipate that future research will be similarly structured, continuing to complement and enhance research

capacity both inside and outside the agency. Support for economic research on forest invasive species, however, has been quite limited; therefore, the opportunities for addressing the broader array of research questions are also limited. It makes sense, then, that economists familiar with the research describe the priorities to advance the discipline of the economics of invasive species.

Key Future Economics of Invasive Species Research Priorities

The lack of comprehensive economic assessments of the catastrophic damages caused by important invasive species on the production of market goods and nonmarket economic values, international trade, travel, and overall economic activity has meant that the Forest Service is unable to reasonably predict the long-run effects of current or future pests. In the following text, we describe research priorities that are essential in addressing these gaps in knowledge.

Priority 1: Optimal Allocation of Public Resources

Invasive species programs cover a range of management options, all of which compete for public resources. The tradeoffs between program costs and economic losses are often poorly understood. This lack of information makes it difficult to design programs that ensure the most effective use of public resources and virtually impossible to evaluate the efficiency of investment in these programs.

Allocation of scarce resources to prevention, detection, spread management, and eradication requires a framework that evaluates effects across the range of invasive species. Further complicating this process is the influence of other natural events (e.g., drought, fire) and human factors (e.g., trade, travel, land use change) on the introduction, viability, and spread of invasive species, as well as the effect of nonnative forest pests on wildfires and other disturbances. An integrated modeling framework is needed that links biological and economic models that address disturbance events and economic effects for comparing the benefits and costs of different allocation strategies. This type of modeling framework should be able to address temporal, spatial, and multiobjective goals. Key questions include the following:

- How should limited program resources be allocated among prevention, detection, and control, both offshore and domestically?
- What economic rules of thumb or formal tools efficiently allocate program resources among the following:
 - Alternative invasive pest guilds.
 - Pathways by which invasive species could enter the United States.
 - Commodities affected by or acting as conduits for invasive species entry.
 - Types of consequences (e.g., environmental and commercial).
- When should vulnerable imported commodities be banned or require particular control measures as a condition of entry?
- When and under what circumstances do economic considerations suggest that programs be terminated or shifted to an alternative program goal?

Priority 2: Incentives and Choices for Private Land Managers

Private landowners and land managers play an important role in invasive species management. Private owners manage most forests in the United States, and their choices can dramatically affect invasive species. Because private owners cannot capture economic returns from the public-good effects of some invasive species programs, they generally underinvest in invasive species management from the standpoint of social optimality. Various incentives, indemnity, or other compensation schemes are often needed to obtain cooperation from private landowners, whose actions affect the spread of an invasive species, or to compensate private entities for mandatory destruction of private (infested or diseased) property for the public good. Designing incentives or compensation programs and setting levels within those programs to obtain the desired behavioral response are inherently economic problems, often involving the potential for moral hazard or unintended consequences. Key questions in this area include the following:

- What are the economic implications of using insurance, regulation with indemnity, voluntary incentives, or other approaches to obtain needed behavioral responses?

- What concepts can guide the structure and level-setting within any or all such alternative approaches?
- How should assets be valued in indemnity or compensation schemes?
- How do nonmarket values get incorporated into appropriate incentives involving privately controlled resources?

A dynamic interchange also exists between agriculture and forestry. In much of the country, the owners of agricultural lands and forest lands are largely the same people. Land use changes between agriculture and forestry are driven partially by returns to investment in these alternative land uses. Agricultural policies, such as the Conservation Reserve Program, can alter incentives and affect the agriculture-forestry margin. It is unknown whether the presence of invasive species can alter land use decisions. Key questions include the following:

- Is changing land use an economically viable or rational response for landowners trying to minimize damages associated with invasive species?
- How are decisions about control methods affected when the landowner also has the option to change land use?
- Are landowner responses to invasive pests different for cropland and grazing land than for forest land?

Research could be undertaken to evaluate the potential for extending existing land use change models to incorporate how the presence of invasive species or perceived risk of invasive species affects land use decisions.

Priority 3: Integrated Risk Assessment and Forecasting

A major obstacle to the development of forest health protection programs, both within public agencies and with broad-based private landowner participation, is the prevalence of risk and uncertainty (e.g., Holmes et al. 2008). Although the risk associated with each stage of a biological invasion is rather low, the uncertainty associated with each risk estimate is quite large. Because the risk and consequences of a biological invasion can be influenced by management actions, and because the characteristics of an invasion might be of a kind not seen before, novel management approaches may be required. Although estimates of the average risk that an introduced species will become a pest can be computed using lists of introduced species for which their success or failure is known (e.g., Reichard and

Hamilton 1997), it is not known how well past invasions can realistically predict the risk of future invasions. Key questions are as follows:

- How should land managers make decisions about invasive species when scientific information about species introduction, spread, virulence, and damages is complex and incomplete?
- How can statistical or other models be used to update invasive species management strategies when new biological and economic information is revealed (and uncertainty is reduced)?

Priority 4: Public Awareness and Investments in Invasive Species Management

The risk and uncertainty associated with most biological invasions, combined with the public-good characteristics of invasive species programs, may help to explain why mitigation and adaptation strategies often lag far behind the initial arrival and establishment of invasive species. One key factor in developing a rapid response to invasive species is public participation (GAO 2005). This factor is especially important in the Eastern United States, where private forests dominate the forest landscape. Key questions include the following:

- What social and economic factors influence the likelihood that private forest landowners will take protective actions against invasive species?
- What are the risk preferences of private forest landowners regarding the threat of forest invasive species, and how do these preferences affect the likelihood of taking protective action?
- How do the forest protection investments made by some members of a community influence the likelihood that other community members will make forest protection investments?
- What are effective means of raising public awareness about the risks and consequences of a biological invasion?

Priority 5: Methods for Estimating Nonmarket Effects of Invasive Species

Market effects of invasive species are generally easier to measure than nonmarket effects. Data are usually more readily

available for conducting market effect analyses, and more biological information is usually available about how invasive species affect timber volume, crop yield, and forage production than on nonmarket measures. Yet, the nonmarket effects of invasive species are especially important when invasive species affect recreation (e.g., fishing), wildlife, biodiversity, or residential and urban areas. Better measures of nonmarket effects would enhance our ability to assess the broad range of economic and social effects of invasive species on ecological functions, human uses, and local and regional economies.

A number of methods exist for evaluating nonmarket effects, including hedonic pricing, contingent valuation, travel-cost method, and conjoint analysis. Applications of these methods to invasive species are relatively rare. Key questions include the following:

- How can existing nonmarket valuation methods be used to reliably evaluate the overall magnitude of nonmarket economic effects of biological invasions? How large are the economic threats to nonmarket values relative to timber values?
- Which members of society bear the greatest losses in nonmarket values due to invasive species?
- How do alternative invasive species management approaches affect the nonmarket values of forests?
- Can benefit estimates from the nonmarket valuation literature be appropriately transferred to invasive species analyses?
- How can estimates of damages to nonmarket economic values be translated into more effective policy solutions?
- What are the most efficient policies for reducing the nonmarket economic risks and effects of nonindigenous forest pests and pathogens?

In addition to improving our ability to estimate nonmarket effects of invasive species and related management approaches, a framework for monitoring social and economic effects of invasive species over time would be useful. This framework could be used to connect to major management initiatives such as the National Fire Plan, the National Recreation Strategy, and the National Invasive Species Management Plan.

Priority 6: Evaluating Optimal Policies of Invasive Species Management With Climate Change

As Earth's climate changes, vegetation communities and disturbance rates are likely to change. With such changes come potential avenues for introduction and establishment of exotic plants and animals into the United States. Important economic aspects that need addressing include the following:

- How quickly are invasive species risks evolving, particularly of invasion into the United States by plants native to tropical and subtropical biomes, and how should trade and other phytosanitary policies change to limit the expected net effects of these changes?
- What role will altered rates and severities of natural forest disturbances play in invasive species risk, and what would be the best management practices to apply in response to affected public and private lands?

Priority 7: Relative Effects of Trade, Travel, and Economic Growth

Government policies and private land management regulations may need continual review and revision to respond to the effects of increased trade, travel, and economic activity in the United States and worldwide. Programs and policies should be periodically evaluated to ensure they minimize the net effects of expected rises in invasive species introduction, establishment, and spread. Important questions to address include the following:

- What are the relative roles of trade, travel, and economic activity in affecting invasive species introduction, establishment, spread, and economic effects?
- How could the United States Government develop policies that would balance invasive species risks and the costs of invasions affecting the freedom of movement of goods and people across borders?

Structuring Forest Service R&D for Effective Economics of Invasive Species Research

The organizational structure of Forest Service R&D is not a barrier to effective research on the economics of invasive species. Economists have successfully collaborated internally

across units and research stations, with outside agencies, and with external cooperators to address common research interests. Despite this success, more could be done to encourage and facilitate improved cooperation between economists and biological scientists. Such collaborations could advance bioeconomic approaches to invasive species research, such as those pioneered by analysts such as Cabbage et al. (2000), Sharov and Liebhold (1998), and Sharov et al. (1998). Developing research projects across disciplines could yield research and technology transfer tools that have larger economic and societal benefits. Often, advances in economic research are limited by biological information.

Because Forest Service capacity for economics research is limited, cooperation within USDA and across Government agencies, with academia, and with other partners is critical to advancing the research agenda. Support for invasive species economics research has been quite limited in the Forest Service, and recent projects have often been funded from external sources.

Conclusions

Despite limited financial resources, economics research into invasive species has often been of high quality and impact, with published studies breaking new ground in economics and policy. Although international trade research has been more broadly focused on timber product market effects across multiple products and the Nation's set of international policies potentially affecting aggregate losses, much of the funded studies in invasive species have been more narrowly focused on particular pests. These efforts include those of current and urgent concern, including the hemlock woolly adelgid and Sudden Oak Death disease, and those of recent study, including the gypsy moth and some indigenous forest pests (southern pine beetle and fusiform rust). Much of this research successfully quantified the high net returns to Government research and invasive species management. It seems clear that additional efforts to quantify the effects and control costs, broad-scale factors involved in overall invasive species risks, and policy analysis will lead to additional successful efforts to document societal net benefits from research and management. With ongoing concerns of a changing climate and therefore a changing picture of invasive species risk and spread, in an era of limited Government spending, economic tools and economic

perspectives will be needed to prioritize both how research money is spent and how managers and decisionmakers should allocate scarce resources to address invasive species concerns.

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