

# Invasive Plants and Forest Ecosystems

Edited by

Ravinder Kumar Kohli

Shibu Jose

Harminder Pal Singh

Daizy Rani Batish



CRC Press  
Taylor & Francis Group

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# Preface

Plant species that invade an alien area and outgrow the native vegetation, establishing and increasing their own territory, often lead to negative economic, environmental, and social impacts. Even native species can behave like invasive species by their exponential spread. Similarly, not all non-native species are invasive. Many alien invasive species, however, do threaten the health and integrity of our terrestrial and aquatic ecosystems. As the human population explodes and trade becomes increasingly globalized, the transboundary movement of species from their places of origin to alien regions is escalating and is expected to continue so in the coming decades.

The ecological impacts of invasive species, in particular alien plants, on forest ecosystems have attracted the attention of researchers, managers, and policy makers the world over. Alien invaders are known to change the ecosystem structure and function, thereby minimizing the support for native flora, fauna and the provision of ecosystem services that directly benefit humans. There exists a large amount of scattered information on the ecology and management of alien invaders in forest ecosystems. The scientists and practitioners who attended the technical session, “Impact of exotic invasive plant species on forest ecosystems,” during the XXII-IUFRO World Congress, Brisbane, 2005, (Ravinder K. Kohli, organizer; Shibu Jose, rapporteur) resolved that an edited volume that captures the current state of knowledge would benefit the global forestry and natural resources community. Invited papers and voluntary posters were presented at this session, which represented a cross section of the current global research being conducted in a variety of forest ecosystems. The editors of this volume accepted the task enthusiastically and immediately started working on the project. Selected authors (who presented their work at the IUFRO Congress) and other prominent researchers were invited to submit manuscripts. After a peer review process, we selected 21 chapters for the current volume.

The chapters are grouped into four sections. The first section examines invasion ecology through both synthesis and original research articles. Seven chapters are included in this section. The second section also has seven chapters. These give readers a flavor of the ecological impacts of alien invaders and include examples from both tropical and temperate regions of the world. The third section is an exploration into the adaptive collaborative management strategies that are central to successful control of invasive alien plants. The first chapter in this section describes the concept of adaptive collaborative restoration in great detail. The second chapter discusses the ecology and management of the world’s number one invasive plant species of natural ecosystems. The remaining three chapters of the section give specific examples of invasive plant management, one each from a local, state, and country perspective. The fourth (last) section includes two chapters that discuss the socioeconomic and policy aspects of invasive species management using two examples, one from the tropics (Namibia) and another from the temperate region (the United States).

The book is intended as a reference book for students, scientists, professionals, and policy makers who are involved in the study and management of invasive alien plants in forested ecosystems of the world. We are grateful to a large number of individuals for their assistance in accomplishing this task, particularly the authors, for their commitment to the project and their original research or synthesis of the current knowledge. Moreover, the invaluable comments and suggestions made by the referees significantly improved the clarity and content of the chapters. We also extend our sincere thanks to John Sulzycki and Pat Roberson of CRC Press for their timely efforts in publishing this book.

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**Shibu Jose, PhD**, is an associate professor of forest ecology at the School of Forest Resources and Conservation (SFRC), University of Florida, Gainesville. He is also co-director of the Cooperative for Conserved Forest Ecosystems at SFRC. He received his BS (Forestry) from India and MS and PhD (Forest Science) from Purdue University. He holds an affiliate faculty status at the School of Natural Resources and the Environment and the Soil and Water Science Department. His current research efforts focus on production ecology and ecophysiology of intensively managed pine and hardwood forests, restoration ecology of the longleaf pine ecosystem, invasive plant ecology and management, and ecological interactions in agroforestry systems and mixed species forest plantations. He serves on the editorial boards of *Journal of Forestry* (editor), *Agroforestry Systems* (editor-in-chief), *Forest Science* (book review editor), and *Research Letters in Ecology* (associate editor). He teaches forest ecology, applied forest ecology, advanced forest ecology, and ecology and restoration of the longleaf pine ecosystem. The honors and awards he has received include the Aga Khan International Fellowship (Switzerland), the Nehru Memorial Award for Scholastic Excellence (India), the UF CALS Junior Faculty Award of Merit, Award of Excellence in Research by the Southeastern Society of American Foresters (SAF), the Stephen Spurr Award by the Florida Division SAF, and the Young Leadership Award by the National SAF. He has over 150 publications to his credit, including 5 books.

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# *Section I*

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## *Invasion Ecology*



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# 1 Invasive Plants: A Threat to the Integrity and Sustainability of Forest Ecosystems

*Shibu Jose, Ravinder K. Kohli, Harminder P. Singh, Daizy R. Batish, and E. Corrie Pieterse*

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## 1.1 INTRODUCTION

Charles Elton, a pioneer in population ecology, wrote of how ecological explosions were threatening the world (Elton 1958). Nearly half a century later, his early warning has become one of the most important environmental crises of our time. Biological invasions have caused more species extinctions than did human-induced climate change (D'Antonio and Vitousek 1992), and are the second leading cause of species extinctions after habitat loss. Biological invasion is one of the major reasons of biodiversity depletion. Invasive plants, in particular, are to blame for much of native species decline and ecosystem degradation (Wilcove et al. 1998). The invasion of native ecosystems by alien plants can lead to alterations in nutrient cycling, fire regime, hydrology, energy budgets, and native species abundance and survival (Mack et al. 2000).

Biological invasion occurs when species move from one geographical region to another, where they establish, proliferate, and persist (Mack et al. 2000). Several terms such as *introduced*, *nonnative* or *nonindigenous*, *exotic*, *alien*, *foreign*, or *invasive alien* have been applied to these species. In a community, a native species

is the one that is naturally found in a given area, whereas introduced or exotic species result from human-induced introductions or accidental entries. In addition, there are some species whose origin is not clearly known and such species are known as *cryptogenic* (Carlton 1996).

In fact, there is a stalemate regarding much of the terminology in the discipline of invasion ecology. Richardson et al. (2000), on the basis of their critical analysis and extensive surveys, have tried to provide a clear insight into this problem. According to them, an invasive species is a naturalized alien that produces a large number of reproductive offsprings at considerable distances from the parent plant, and thus spread over large area (Richardson et al. 2000). This is in contrast to casual alien species, which do not form self-replacing populations, and hence cannot perpetuate for a long time. However, the World Conservation Union (formerly International Union for Conservation of Nature and Natural Resources), the Convention on Biological Diversity (CBD), and the Global Invasive Species Programme (GISP) prefer to use the term *invasive alien species* (IAS). As per GISP, an IAS is that alien species which proliferates and spreads in the new environment in ways that are destructive to human interests (McNeely et al. 2001). IAS has been addressed under Article 8(h) of the CBD.

In a survey of peer-reviewed literature regarding invasions and alien species, Pyšek et al. (2006) found 329 papers and over 27,000 citations in the period 1981–2003, reflecting the rapid growth of the field. The majority of the most commonly cited papers are related to plant invasions. Although the economic and ecological damage caused by alien animal and microbe species is astounding, the scope of this book is limited to alien plant invasions of forested ecosystems in various parts of the world. Several recently published books have focused on biological invasions (e.g., Mooney and Hobbs 2000; Pimentel 2002; Myers and Bazley 2003; Ruiz and Carlton 2003; Mooney et al. 2005; Sax et al. 2005; Cadotte et al. 2006; Lockwood et al. 2006), which is a clear indication of the growing body of literature on the topic. It also shows the seriousness with which the issue is being addressed by the scientific community. Since forests are one of the ecosystems most seriously affected by biological invasions, and in particular by invasive plants, this book is dedicated to the treatment of invasive plants in forested ecosystems. Authors from around the world contributed to this volume, and chapters have been organized into four sections: Invasion Ecology, Ecological Impacts, Management of Invasive Plants, and Socio-economic Policy Aspects. We summarize the scope of each section here.

## 1.2 INVASION ECOLOGY

This section begins with a chapter (Chapter 2, by Daneshgar and Jose) on the proposed mechanisms of invasion. Despite the number of studies on IAS, no grand unifying theory of invasions has emerged. Rather, researchers have proposed a suite of theories and hypotheses relating to the invading species, the habitats invaded, and their interactions. Inconsistent and varying terminology and difficulty in predicting which species will or will not become invasive contribute to the challenge of developing an overarching theory of biological invasions (Shrader-Frechette 2001). Nevertheless, the combination of ecological effects, societal concern, and economic

costs have created the need for explanations of how to predict and prevent invasions and how best to treat them when they do occur.

The role of disturbance in the establishment and spread of invasive species is examined in Chapter 3 by Moser et al. These authors used the USDA Forest Service Northern Research Station's Forest Inventory and Analysis data for 2005 and 2006 and sampled for the presence and percent cover class of 25 selected nonnative invasive plant species in all the forested plots in the midwestern states (Indiana, Illinois, Missouri, Iowa, Minnesota, Wisconsin, and Michigan). Iowa, Indiana, and Illinois had relatively higher rates of invasive species presence, while Minnesota had the lowest. They also observed a strong latitudinal separation, particularly for woody invasives. Most subboreal forest types had lower percentages of invasive species. Similarly, Lake States of Minnesota, Wisconsin, and Michigan had lower invasive species presence than that in the southern-tier states. Grasses were particularly prominent in low-density or fragmented forestland. Metrics of disturbance and fragmentation, such as distance to road, county percent forest, or the forest intactness index, were significantly related to the presence and coverage of invasive species. They concluded that even the disturbance measures, lower basal area, and high road density could easily reflect the lingering influence of historic human disturbance as the microsite attributes that allowed invasive species to establish and expand.

Fei et al. argue in Chapter 4 that while disturbance and other landscape features play a major role in the establishment and spread of invasive plants, it is essential to determine how these factors influence the alien plant invasions. They used a geographic information system, high-accuracy global positioning system receivers, and high-resolution aerial photos to study the invasion patterns of alien plant species in eastern Kentucky. They have shown that invasive species occurrence was higher on or near roads than in the interior of the forest, although some species could establish in the forest interiors, where signs of anthropogenic disturbance were absent. Ground disturbance from harvesting, specifically skidding and road construction, could promote an increase in colonization and spread of invasive species.

Webster and Wangen (Chapter 5) use a case study from Michigan to explore the spatial and temporal dynamics of alien tree invasions. They used the example of *Acer platanoides*, a shade-tolerant invasive tree, and showed that because of the long generation times of trees relative to other organisms their invasion potential might not be easily recognized until they become a serious pest. With respect to the spatial spread patterns, they observed both thread-like patterns (e.g., roads and trails) and satellite populations that originated from human-mediated seed dispersal. The authors suggested that monitoring for invasive trees, therefore, should be proactive and where possible use risk assessment techniques to identify likely establishment sites. Using another case study, Dyer and Cowell (Chapter 6) demonstrated that habitat changes caused by the establishment of alien species through changes in natural disturbance regimes could steer communities to a new stable state, posing serious management concerns. Disruption of a natural disturbance—flooding, by the construction of a dam—caused invasive plants such as Japanese knotweed (*Polygonum cuspidatum*) and Reed canary grass (*Phalaris arundinacea*) to thrive at the expense of many resident overstory and understory plant species. These authors have shown that changes to disturbance regimes could alter both resource availability and

competitive interactions in favor of alien species, with adaptive traits not present within the native community.

In Chapter 7, Loeb examines the biogeography of invasive plant species in urban forests and parks. Pre-twentieth century plantings comprised one-third of the invasive tree, shrub, and herbaceous species found in the urban forests of the mid-Atlantic region of the United States. Many of these invasive plants were available from nurseries before 1900. He concluded that urban forests are disturbance communities and could serve as centers for spread of invasive plant species.

### 1.3 ECOLOGICAL IMPACTS

Invasive species have contributed to the decline of 42% of the U.S. endangered and threatened species (Wilcove et al. 1998). In other parts of the world, as many as 80% of the endangered species are threatened because of the pressures of nonnative species (Pimentel et al. 2005). IAS may be intentionally or unintentionally introduced to new ecosystems. When a species is introduced, it may have both positive and negative consequences. This complicates the matter of how and whether to attempt to control or eradicate such species. In plantation forest ecosystems, many planted tree species are exotic (Ewel et al. 1999), which may also be invasive outside of the plantations. Research focusing on invasive plants in forest ecosystems contributes to our understanding of biological invasions in general and vice versa. This section focuses on the ecological impacts of alien invasive plants on forest ecosystems the world over.

The first three chapters in this section are from Asia. In Chapter 8, Hossain examines the effects of alien invasive plants on hill forest ecosystems of Bangladesh. According to Hossain, in addition to invasive understory species, the introduction of alien tree species for plantation forestry has also threatened the integrity of natural forest ecosystems. The ecological status of some of the invasive plants in one of the biodiversity hotspots in the world, the Himalayas, is discussed by Kohli et al. (Chapter 9). They concluded that establishment and spread of invasive plants such as *Ageratum conyzoides*, *Lantana camara*, and *Parthenium hysterophorus* have displaced native plant species and deteriorated the quality of native forest ecosystems in the region. In Chapter 10, Fang and Wan describe ecological impacts and management considerations of the major invasive pests with several examples. The invasive pests, including plants, cost China more than US\$7 billion annually. These authors attributed the successful invasion and spread of the invasive species to anthropogenic factors, including intentional introduction and lack of rapid response mechanisms for eradicating potential invasive pests.

In Chapter 11, Nichols and Bristow discuss the invasive plants of subtropical and tropical Australian forests. Weeds cost Australia at least AU\$3 billion per year, and this estimate is only for the cost of control and of losses due to agricultural and pastoral weeds. According to the authors, in the subtropical rainforest area, *L. camara* and *Cinnamomum camphora* (camphor laurel) often dominate much of the landscape. Although *C. camphora* aggressively colonizes areas that could support rainforest or mesic eucalypt forests, forming multistemmed thickets of trees with little commercial value, it also colonizes bare land and degraded pastures, creating

conditions amenable for rainforest regeneration. Lantana has been threatening moist eucalypt forests and rainforests, and an estimated 80 plant species are threatened by the extensive coverage of the landscape by lantana. However, at the same time lantana has also become a keystone species for many species of animals. These authors also discuss the pine plantations in Australia, which cover  $\sim 1$  million ha, and ask the question if these species are invasive as well.

In Chapter 12, Schrader and Starfinger focus on intentional introductions and the procedures of pest risk analysis for alien plants in European forests. They describe an approach to evaluate the probability of establishment and spread of invasive alien plants and the magnitude of the associated potential economic and environmental consequences (risk assessment), and how to deal with the identified risk using the case study of *Prunus serotina*. They demonstrate that careless planting of alien trees such as *P. serotina* could lead to a variety of negative impacts on biodiversity and economic values. However, the forestry sector in Europe has long benefited from the use of nonnative tree species. According to these authors, reference to the ecological and economic damage posed by alien trees would not be sufficient to influence policy decisions and forest owners. They identify risk analysis as an effective and important step in dealing with the use of alien trees in forests.

A wide range of approaches and types of data have been used to inventorise and monitor invasive plants. Gray (Chapter 13), using the USDA Forest Service's Forest Inventory and Analysis data from forestlands in California, Oregon, and Washington, has shown that these data could be used not only to monitor the presence and spread of invasive plants, but also to assess relationships between the occurrence of invasive alien species and climatic, topographic, and stand variables. The results showed a high percentage of plots with alien species. According to the author, these results could be quite surprising to policy makers and the public, as many of these stakeholders regard most of the regions' forestlands as rather pristine and consider invasive species to still be an emerging threat.

The last chapter in this section (Chapter 14) by Collins and Jose addresses the changes in soil chemical properties as a result of invasion by cogongrass (*Imperata cylindrica*), one of the most notorious invasive plants of forest ecosystems of the southeastern United States. The ability of invasive species to alter soil biochemistry, both through nutrient acquisition and allelopathy, remains a relatively unanswered question in invasion ecology and could offer important insights to potential mechanisms for invasion success. Field studies were conducted at two sites, a logged site and an unlogged site in Florida, to test the effects of *I. cylindrica* invasion on soil chemical properties. Analysis of soil samples, taken pairwise (*I. cylindrica* invaded and noninvaded areas) at both sites, showed significant differences in soil  $\text{NO}_3\text{-N}$ ,  $\text{K}^+$ , and pH. Significantly lower levels of  $\text{NO}_3\text{-N}$  and  $\text{K}^+$  were observed in *I. cylindrica* patches than in the surrounding native vegetation. The authors attributed the lower levels of these nutrients to the extreme ability of *I. cylindrica* to extract available resources from the area it invaded. The soil of the *I. cylindrica* patch was more acidic than that of the surrounding native vegetation. Although no direct evidence of any mechanisms responsible for lowering soil pH in *I. cylindrica* invaded patches was given, the authors suspected allelopathy or the preferential uptake of ammonium as a plausible mechanism.



## 1.4 MANAGEMENT OF INVASIVE PLANTS

This section begins with a discussion of the adaptive collaborative restoration concept of invasive plant management (Chapter 15). Miller and Schelhas reiterate the need for a concerted holistic effort that integrates science with management to predict, manage, and mitigate the spread of invasive species. The adaptive collaborative restoration approach incorporates elements from three key ecosystem management trends from the 1990s: adaptive management, collaborative management, and restoration management. Collaborating across institutional and property boundaries and across local and national levels to carry out the complex tasks of detection, prevention, eradication, and restoration of invasive species through a science-based adaptive learning process could be the key to effective invasive plant management. While it could always be a work in progress, this approach provides a framework with the potential to successfully combat invasive species.

The ecology and management of *I. cylindrica*, one of the 10 most troublesome weeds in the world and perhaps the worst weed of natural ecosystems, are discussed in Chapter 16 by MacDonald. This grass is considered a weedy pest in over 73 countries and is observed in every continent except Antarctica. Following an account of the biology and impacts of *I. cylindrica*, management strategies are discussed in detail. Although preventive, cultural, mechanical, biological, and chemical measures are identified and described, an integrated approach using multiple methods is recommended as the most effective way to manage *I. cylindrica* infestations. In Chapter 17, Jenkins and Johnson describe the alien invasive plant management program at the Great Smoky Mountains National Park in Tennessee as a case study of alien plant management in the U.S. National Park System. Since 2000, the National Park Service (NPS) has created 16 exotic plant management teams to assist 209 national parks with exotic plant control. Between 1999 and 2004, the NPS controlled alien plants on over 76,000 ha. According to the authors, ~1 million ha still require control across the National Park System.

In Chapter 18, Beck focuses on the invasive weeds of Colorado forests and rangeland. Following a description of the forest types and rangelands and their current status, he discusses the major invasive plants and the current state of weed management efforts. Beck concludes that there has been progress in engaging more private and public land managers and landowners in the battle against invasive plants, albeit at a slow pace. He identified insufficient financial resources as one of the major limitations in Colorado and elsewhere in the United States in the battle against invasive species. The ecology and management of tropical Africa's forest invaders are discussed by Bosu et al. in Chapter 19. The introduction of alien plant species to tropical Africa dates as far back as the fifteenth century when the first Europeans arrived on the shores of the continent, but active and passive introductions of new species have continued throughout the centuries. Many of these introduced species now comprise a major proportion of the food, fiber, and wood resources on the continent. These authors describe some of the most troublesome invasive plants of tropical Africa and explain their management strategies. According to them, African scientists have realized the need to enhance the capacity and readiness to combat the spread of forest invasives on the continent, in particular with the

formation of the Forest Invasive Species Network for Africa (FISNA). FISNA seeks to bring all forest health experts on the continent to work toward achieving the common objective of invasive species management.

## 1.5 SOCIOECONOMIC AND POLICY ASPECTS

The two chapters in this section address the socioeconomic and policy aspects of invasive species management. Joubert (Chapter 20) opens the section with a description of forest ecosystems and the current status of invasive plant problems in Namibia, one of the driest African countries south of the Sahara. According to the author, aridity and associated low population density have resulted in a relatively modest invasive plant problem in Namibia; however, a combination of propagule pressure and increasing invasibility of forest ecosystems in the north could escalate the problem. Joubert reviews the current policies and legislation regarding invasive alien species and their control and concludes that effective policies and programs need to be in place to prevent the introduction of likely invaders and the eradication of populations that are still in their establishment phase, so that potential economic and ecological losses can be avoided.

In their chapter, Freeman et al. (Chapter 21) explore the economics, law, and policy of invasive species management in the United States. The threats posed by invasive species to natural resources and to the economy are discussed first, followed by an exploration into the historical evolution of U.S. invasive species policy. The policy mechanisms in place to prevent new invasions and to manage existing ones are also discussed. They conclude the chapter by commenting on future directions for invasive species management in the United States.

## 1.6 CONCLUSION

It is clear that both deliberate and inadvertent introductions of alien plants have caused significant changes in structure and the function of forest ecosystems around the world. Many ecological functions are supported by a suite of species that are characteristic of a particular ecosystem. Alien invaders tend to alter the characteristic species composition of ecosystems, often by forming monospecific stands. The chapters in this volume make one appreciate the gravity of the situation, in particular, in forested ecosystems. Although commonalities exist in the mode of introduction and the spreading of alien invaders in new habitats, the extent of damage by the invaders varies depending on the socioeconomic and ecological realities of the affected regions. Although a vast majority of the alien invaders are considered harmful, some of them have formed alternate steady-state communities and have become keystone species in certain ecosystems. However, all authors agree that invasive plant management should be a priority in the management of forested ecosystems so that their health and integrity can be sustained. Although public awareness is increasing, policy-guided action plans are necessary to address the invasive species problem so that serious economic and ecological threats can be alleviated.

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