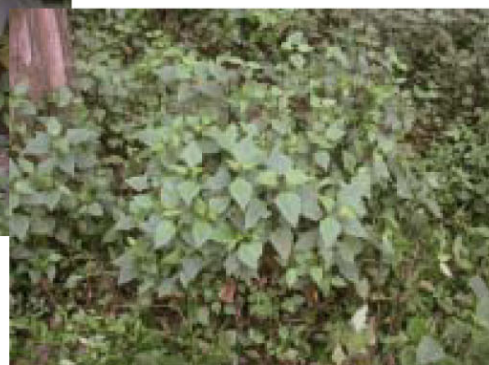
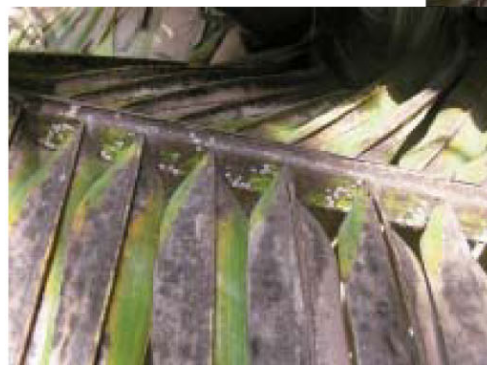


Asia-Pacific Forestry Commission

The unwelcome guests

**Proceedings of the Asia-Pacific
Forest Invasive Species Conference**

Kunming, China 17–23 August 2003



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Printed and published in Bangkok, Thailand.

© FAO 2005
ISBN 974-7946-77-7

RAP PUBLICATION 2005/18

The unwelcome guests

Proceedings of the Asia-Pacific
Forest Invasive Species Conference

Kunming, Yunnan Province, China

17–23 August 2003

Edited by Philip McKenzie, Chris Brown, Sun Jianghua and Wu Jian

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
REGIONAL OFFICE FOR ASIA AND THE PACIFIC
Bangkok, 2005

Foreword

The damage caused by invasive species imposes enormous costs on the forests of the Asia-Pacific region in terms of ecological destruction, economic losses and detrimental social effects. Overall losses associated with invasive species in many countries are estimated to account for around 1 percent of GDP, with the United States of America, for example, sustaining losses estimated at US\$137 billion per year. Forest losses comprise a significant portion of this.

Based on a recommendation made at the 19th session of the Asia-Pacific Forestry Commission, in Ulaanbaatar, Mongolia, the Asia-Pacific Forest Invasive Species Conference was organized and convened in Kunming, China. The importance of invasive species issues was underscored by the large number of participants that attended the conference and the broad international support given to the conference by a number of organizations. More than 136 participants from 20 countries attended the conference, which included field visits to various sites in Yunnan Province, where challenges posed by invasive species are being addressed.

One of the most important messages highlighted by the conference is that invasive species are an issue of global concern, which no single country can adequately address alone. The enormous synergies available through international cooperation were clearly understood by participants, who recognized that cooperation is essential in narrowing incursion pathways, as well as in triggering early response measures, and ensuring effective monitoring and control strategies.

The benefits of formalizing the information-sharing process among Asia-Pacific countries were underlined by a core recommendation to form an Asia-Pacific Forest Invasive Species Network and an associated Asia-Pacific Forest Invasive Species Working Group. The Asia-Pacific Forest Invasive Species Conference was based on the premise that success in developing and implementing solutions for invasive species can be achieved only by forming strong collaborative partnerships within and among countries. The establishment of a new Asia-Pacific Forest Invasive Species Network is therefore expected to be a major step forward in meeting the challenges posed by invasive species in the region.

This publication represents one element of ongoing efforts to promote sustainable forest management in the Asia-Pacific region and is composed of summaries of the technical presentations and the country reports submitted by the participants. It is hoped that this publication will provide valuable assistance to those responsible for formulating and implementing policies related to forest invasive species.



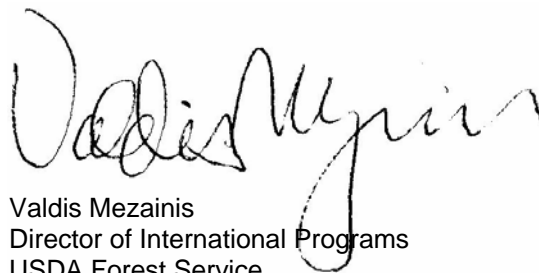
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Invasive species: an overview

The damage caused by invasive species imposes enormous costs on the forests of the Asia-Pacific region in terms of ecological destruction, economic losses and detrimental social effects. Overall losses associated with invasive species, in many countries, are estimated to account for around 1 percent of GDP, with the United States of America, for example, sustaining losses estimated at US\$137 billion per year. Forest losses comprise a significant portion of this.

In August 2002, the 19th session of the Asia-Pacific Forestry Commission convened in Ulaanbaatar, Mongolia. The proceedings incorporated an *In-session seminar on invasive species: regional cooperation in combating threats*. Among the recommendations from the seminar was a recommendation supporting:

technical meetings, to increase awareness and understanding of the issues and threats associated with invasive species, develop appropriate measures for dealing with these threats, and identify additional information and research needs.

In response to this recommendation, the Asia-Pacific Forestry Commission organized the Asia-Pacific Forest Invasive Species Conference. The conference was hosted by the Province of Yunnan, and was organized as an initiative of the Asia-Pacific Forestry Commission in technical collaboration with the Asia-Pacific Association of Forest Research Institutions (APAFRI), and the Food and Agriculture Organization of the United Nations (FAO). The conference was sponsored by the State Forestry Administration of China, the Chinese Academy of Sciences, the Natural Science Foundation of China and the United States Department of Agriculture Forest Service. More than 130 participants from 20 countries attended the conference. The main objectives of the conference were to:

- increase awareness of the threats of invasive species to forests and forest products;
- share experiences and knowledge related to dealing with invasive species issues; and
- develop proposals for regional cooperation and action in addressing invasive species problems.

The conference provided opportunities to share experiences and knowledge relating to the threats of invasive species to forests and forest products – and to develop proposals for regional cooperation and action in addressing invasive species problems. Thirteen technical papers were presented, covering issues ranging from pest risk assessments and incursion pathways to the use of the International Plant Protection Convention to manage invasive species affecting forests. The conference also held interactive working group sessions to help prioritize issues for action, and a panel discussion and plenary session in which an action plan for implementation was developed.

Ms Sally Campbell, Biologist Team Leader, USDA Forest Service and Mr Wei Diansheng, Director-General, Department of Silviculture, State Forestry Administration of China provided keynote addresses.

Ms Campbell outlined a global perspective on forest invasive species and told participants that invasive species are an accelerating problem worldwide due to increased trade, travel, and transport of goods. She also described some of the scientific, political and ethical challenges associated with invasive species, which include scarce resources to fund management and control activities, and human health issues relating to pest incursions and eradication activities.

In a presentation outlining the invasive species situation in China, Mr Wei told the conference that China has more than 8 000 forest pests, with 100 causing substantial damage. More than 8 million hectares of forest are affected each year. Economic losses are estimated at 6 billion yuan (US\$703 million) *per annum*.

Technical presentations explored specific aspects and challenges relating to invasive species, including sharing national experiences. Generic aspects of invasive species were covered in presentations dealing with:

- basic science and nature of the problem of forest invasive species;
- pest risk assessments and incursion pathways;
- FAO activities in relation to invasive species;

- ecological and economic impacts of invasive species incursions; and
- using the IPPC to manage invasive species affecting forests.

Case specific presentations were made on:

- developing a biosecurity strategy for Australia;
- managing invasive species threats to oil-palm and rubber in Malaysia;
- the unintended spread of introduced plantation species in India;
- *Acacias* and their invasiveness in secondary/disturbed forests in the wet tropics;
- pine wood nematode and other forest pathogens in Japan; and
- assisted natural regeneration – countering the impacts of *Imperata* grass infestations in the Philippines.

The strong participatory elements of the conference divided the participants into three breakout groups. The breakout groups were asked to consider knowledge and information gaps in relation to forest invasive species. Each breakout group was tasked with identifying five key regional issues and asked to develop a complementary action plan to address these. Groups proceeded by brainstorming for key issues and rationalising these into common groups and highest priorities. Potential actions to address these issues were suggested.

The key issues identified included:

- national, regional and international cooperation and collaboration between countries;
- capacity building and training;
- research needs and collaboration;
- policy development aspects;
- information development, management and sharing;
- quantification of ecological and economic impacts;
- pest management tools and strategies;
- taxonomy and characteristics of invasive species;
- risk assessment;
- deliberate introductions; and
- pathway management.

Conference outcomes

The concluding session of the conference encompassed a panel discussion chaired by Simmathiri Appanah on the topic “*Where to now on invasive species in Asia and the Pacific?*” Each of the five panelists made a brief presentation and the floor was then opened for discussion. Sun Jianghua made a brief presentation on initiating the Asia-Pacific Forest Invasive Species Network. Allan Bullard outlined information needs for managing forest invasive species in the Asia-Pacific region. Shekhar Kumar Niraj, Regional Deputy Director, Wildlife Preservation, Ministry of Environment and Forests, India, spoke about the need for international guidelines for managing invasive forest species. Gary Man, Asia-Pacific Program Manager, USDA Forest Service, addressed ways in which international and regional organizations can facilitate forest invasive species activities in the Asia-Pacific region. Mike Cole summarized some thoughts on where the region might go from here on the subject of invasive species.

Delegates participated in a wide-ranging discussion particularly focused around the establishment of an Asia-Pacific Forest Invasive Species Network and an associated Working Group, and how these might function.

Three key outcomes were agreed upon during the session:

1. An Asia-Pacific Forest Invasive Species Network should be established under the umbrella of the Asia-Pacific Forestry Commission. It was proposed that the Chinese Academy of Sciences would assume the role of task manager for coordinating the network.
2. An Asia-Pacific Forest Invasive Species Working Group should be established to develop a programme of collaborative activities.
3. Each APFC member country should nominate a focal point to serve as a point of contact for the Network and for collaborative forest invasive species activities.

Introductory session

Opening session

The opening session of the conference was chaired by Mr Wei Diansheng, Director-General, Department of Silviculture, State Forestry Administration. Mr Wei welcomed the participants and invited dignitaries and organizing agencies to make introductory remarks.

Mr Zhu Lieke, Deputy Administrator, State Forestry Administration, welcomed participants on behalf of the State Forestry Administration and outlined the central purpose of the conference. He noted that the Government of China attaches great importance to invasive species management, particularly given the serious problems that are arising in relation to invasive species in a number of areas of China. Around 7 billion hectares are affected by invasive species in China. He noted that the Asia-Pacific region has an excellent record of cooperation in a number of spheres and the conference would provide a great opportunity to enhance cooperation on invasive species.

Mr Kong Chui Zhu, Vice-Governor, Province of Yunnan, introduced the principal organizers and sponsors and welcomed the participants on behalf of the province of Yunnan. He outlined some of the key statistics relating to the geography, population and forestry sector in Yunnan. He also spoke about some of the key policies and programmes being implemented in China and Yunnan including the National Forest Conservation Programme and the logging bans in force in natural forests. He noted that invasive species constitute a major threat to China's forests and to forests throughout the world and, consequently, invasive species are a common responsibility among all nations. He noted that the conference provides an excellent opportunity for sharing information and for cooperation.

Mr Zhang Zuang Xin, President, Yunnan Branch of the Chinese Academy of Sciences, emphasized that invasive species are a problem common to all countries. He outlined the roles of the Chinese Academy of Sciences in relation to invasive species as well as describing some of the invasive species that constitute serious problems in China, including pine wood nematode and Crofton weed. He concluded by outlining a proposal for the establishment of an Asia-Pacific Forest Invasive Species Network. He noted the important roles such a network could play in international cooperation.

Mr Patrick Durst, Senior Forestry Officer, FAO Regional Office for Asia and the Pacific welcomed participants on behalf of FAO. He noted that the current conference had its roots in the 19th session of the Asia-Pacific Forestry Commission (APFC) held in Ulaanbaatar, Mongolia during 2002. He provided background to the history and functions of APFC. He noted that expanding trade has greatly increased the threat associated with invasive species, while some very high-profile pest invasions have captured the attention of the general public. He concluded by thanking collaborative partners and noting the strong collaborative approach in organizing the conference.

Mr Jerome Beatty, Deputy Director, USDA Forest Service, Forest Health Protection, noted that invasive species have a long history in the United States of America and have caused immense ecological and economic damage in many instances. The American chestnut and various species of western white pine have been decimated out by invasive diseases. The USDA classifies invasive species as one of the four predominant threats to US forests. He outlined the new USDA invasive species strategy and noted the strong collaborative links that have been developed with China. He hoped the conference would provide an opportunity for strengthening collaboration with other countries. He concluded that the enormous biological diversity of Yunnan's forests would provide an object lesson for participants of the need for action to protect forests from invasive pests and diseases.

Daniel Baskaran, Executive Secretary, Asia-Pacific Association of Forest Research Institutions (APAFRI) provided an introduction to the structure, roles and history of APAFRI. He described the various key supporting agencies to APAFRI and particularly their overarching objective to foster the development of forestry research for sustainable forest management in the Asia-Pacific Region. He noted that the membership of APAFRI presently stands at 67 research institutions including 16 Forest Research Institutes.

Introductory remarks

Patrick B. Durst

Senior Forestry Officer, Food and Agriculture Organization of the United Nations, Bangkok, Thailand

It's a great pleasure for me to be here this morning and offer a few remarks on behalf of the Food and Agriculture Organization and the Asia-Pacific Forestry Commission. We are here in Kunming to discuss one of the most interesting and challenging aspects of forestry development today – that is forest invasive species. The topic is of enormous importance to all the countries of the Asia-Pacific, and I'd like to highlight three important features:

- in this region we have island countries – or countries otherwise separated from the Asian mainland – that in the past were somewhat protected by distance from potentially destructive pests and diseases. But distance alone is no longer a safe defence;
- many countries in Asia and the Pacific are now actively engaged in major trading of forest products and other products that can act as vectors for forest invasive species. As a consequence, importing countries are increasingly susceptible to the threat of invasive species and exporters are more frequently affected by sanitary and phytosanitary arrangements put in place around the world; and
- all countries in the region have, at one time or another, been detrimentally affected by the introduction – sometimes planned, sometimes inadvertent – of forest invasive species. Some of these influences go back to the earliest species introduced by traders, centuries ago – such as rats, goats, dogs and cats.

The issue of invasive species has been present for a long time in our region, but for the forestry sector it has become critically important in the past few years. Expanding trade has greatly increased the threat associated with invasive species. At the same time, some very high-profile pest invasions have captured the attention of the general public; such as the longhorn beetle in the United States of America, tussock moth in New Zealand, and the pine nematode in Japan. These cases point towards the need to explore opportunities for action at regional levels, as well as reacting nationally and in global fora.

This brings us to the Asia-Pacific Forestry Commission, which I want to introduce to you, because it is an organization some of you may not be familiar with. The Asia-Pacific Forestry Commission (or APFC) is a statutory body of the Food and Agriculture Organization and FAO provides secretariat support for the Commission. But the Commission's actual membership is comprised of 28 countries within the Asia-Pacific region, and it is the member countries that shape the work of the Commission. To help develop its work programme, APFC convenes in general session every two years. The last general meeting was in August 2002, in Ulaanbaatar, Mongolia. At that meeting, the Commission organized a special in-session seminar on forest invasive species, which helped raise awareness of the issues and threats, and established the foundation for increased regional cooperation.

Among the recommendations from that seminar, was a call to:

"...support activities, including technical meetings, to increase awareness and understanding of the issues and threats associated with invasive species."

Thanks to the initiative of the Chinese Academy of Sciences, the State Forestry Administration of China and the USDA Forest Service, this conference is being convened as a direct follow-up to the recommendations of the Ulaanbaatar seminar.

We hope that as the conference progresses we will be able to explore several of the recommendations made at the Ulaanbaatar APFC meeting – particularly, recommendations to:

- develop regional invasive species strategies;
- develop a regional invasive species information network;
- establish means for identifying and sharing information on potentially invasive species and experiences in dealing with such species; and
- develop collaboration among various national and international organizations and programmes dealing with invasive species in Asia and the Pacific.

Ladies and Gentlemen, I want to conclude by thanking and congratulating our collaborative partners in organizing this conference. It's been a great pleasure to work alongside our friends in the Chinese Academy of Sciences and the State Forestry Administration. Both organizations have done a fabulous job to ensure the success of the conference – working closely with our local host – the Province of Yunnan, which has taken responsibility for the excellent local arrangements.

It has also been a pleasure to once again work with the Asia-Pacific Association of Forest Research Institutes (APAFRI) and the USDA Forest Service in organizing this conference. The USDA Forest Service, particularly, has been a strong and consistent supporter of APFC activities over the past several years.

For all the international participants – especially those who have not been to China before – I'm sure that by the end of the week you will come to understand why China is so famous for its hospitality and also why this country is advancing so rapidly, including in the field of forestry. The commitment, drive and dedication of the Chinese people are truly remarkable.

Personally, I'm very much looking forward to this conference. We have an impressive array of presenters and topics – and we have ample time to discuss the key issues relating to invasive species in the region. I hope you will find the conference productive, enjoyable and rewarding.

Introductory remarks

Jerome S. Beatty

Deputy Director, USDA Forest Service, Forest Health Protection

Good morning, Mr Zhu Lieke, Mr Kong Chui Zhu, Mr Zhang Zhuang Xin, Mr Patrick Durst, Mr Daniel Baskaran, fellow delegates, ladies and gentlemen. Thank you for the opportunity to make a few, brief, opening remarks at the beginning of this important meeting.

Invasive species have caused problems in the forests of the United States of America since the USDA Forest Service was founded, almost 150 years ago. Their impacts have changed the very nature and biological makeup of the forests we see and use today. Introduced diseases have removed or severely reduced several keystone tree species. For example: American chestnut in our eastern forests was attacked by the chestnut blight fungus and many species of white pines in our western forests were decimated by white pine blister rust. Invasive species cause millions of dollars of resource loss and cost millions of dollars annually in our efforts to eradicate new infestations, control the spread of established invasives, and to restore damaged ecosystems. Many of the specific activities in this area are described more fully in the US country report.

As you are all aware, the rate of introduction of – and the damage caused by – invasive species is increasing each year. In response, the Chief of the USDA Forest Service has recently identified invasive species as one of the four great threats to America's forest lands and directed Forest Health Protection to take the agency-lead in developing a national invasive species strategy. This strategy will build on ongoing activities and guide future management policy for the Forest Service.

We are indeed fortunate that China has offered to host this meeting. Not only because of their legendary hospitality, but, more directly, because of China's position as a major force in world trade and as a leader in forestry research and management. The future success of any collaborative efforts in managing invasive species will depend on the continued commitment of China and the State Forestry Administration to helping solve these serious issues. We in the USDA Forest Service look forward to continuing our existing collaborative efforts in managing invasive species as well as establishing new relationships with our partners at this meeting.

Finally, it is appropriate that we are meeting in the beautiful province of Yunnan, whose forests of are some of the most biologically diverse in the world. As development increases, this diversity is at risk from invasion by exotic species. Hopefully, actions decided upon at this meeting can help minimize that risk.

My fellow delegates and I are looking forward to an exciting, interesting, and productive meeting.

Thank you.

Technical presentations

A global perspective on forest invasive species: the problem, causes, and consequences

Sally Campbell

PNW Research Station, USDA Forest Service, Portland, Oregon, USA

Generally defined, an invasive species is a species:

- 1) that is non-native to the ecosystem under consideration; and
- 2) whose introduction will cause or is likely to cause economic or environmental harm or harm to human health.

Invasive species are characterized by one or more of the following traits: rapid growth rate, efficient dispersal capabilities, large reproductive output, and tolerance to a broad range of environmental conditions. Introduction and establishment of invasive species is an accelerating problem worldwide due to increased trade, travel, and transport of goods. Not only is the rate of these activities greater, but also the distances covered are greater over a shorter span of time. Introductions of invasive species can occur through many different pathways, ranging from trade in non-native plants and animals, to the entry of diseased fruit brought by tourists, to the movement of insect pests via ships, planes, trains, or trucks. Introductions can be either intentional (e.g., food crops, ornamentals, pets, livestock) or unintentional.

There are environmental, economic, human health, and political consequences resulting from the introduction and/or establishment of invasive species. Environmental consequences are numerous. According to Sala *et al.* (2000) invasive species are among the top drivers of environmental change, globally. Some consider invasive species to be the second greatest threat to threatened and endangered species in the United States of America, following loss of habitat (Wilcove *et al.* 1998, CBD News 2003). Mooney (2000) reports that invasive species can disrupt natural fire cycles, deplete water supplies, and eliminate species. In 2003, the Union of Concerned Scientists stated that invasive species are one of the most serious environmental challenges we face. Economically, the cost of invasive species is measured by the amount of resource damage as well as the cost of eradication and control. Worldwide, invasive species cause an estimated loss to agricultural crops of US\$55 billion annually (Bright 1999). In the United States of America alone, the estimated loss to all uses is US\$137 billion per year (Pimentel *et al.* 2000). More extensive documentation of ecological and economic impacts is needed, especially in developing countries. Consequences of invasive species on human health range from disease epidemics, to the human health impacts of increased pesticide use, to food and water shortages. Invasive species also have political consequences. Political consequences can be measured by the impact on sustainable development when invasive species damage food and water supplies; affect human health; or prevent governments and industries from selling some types of food products, selling living commodities, or using certain types of containers and packing materials.

The problem of invasive species can be addressed by first establishing a set of goals, including:

- preventing the introduction of new invasive species;
- early detection of new invasive species infestations;
- eradication of new infestations;
- control and management of established invasive species; and
- restoration of ecosystems degraded by invasive species.

Processes that will aid in achieving these goals include conducting invasive species risk assessments, carrying out pertinent research, monitoring ecosystems and invasive species, educating the public, collaborating with partners, developing policy and regulations, managing information, and measuring accomplishments. A number of challenges to achieving these goals exist. Scientific challenges include quickly elucidating diverse, complex aspects of a new invasive species such as its biology, epidemiology, and control approaches; the uncertainty of which species will become invasive, where they will be a problem, and when; the number of pathways and rate of spread; and the time lags between introduction and discovery, research results, treatment, policy development and implementation. Political challenges include the lack of awareness by agencies or governments; poor

communication and coordination between these entities; conflicting policies between entities; gaps in policy; and the ability to fund eradication and control efforts. Lastly, ethical challenges exist where such issues as animal rights, environmental and human health risks from pesticides and biological control agents, and the use of genetically modified organisms must be considered.

Success in meeting these challenges and developing and implementing solutions for invasive species can be achieved only if we form strong collaborative partnerships within and between countries.

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Alien forest pests and management practices in China

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Forest pests refer to all those organisms, such as pathogenic microbes, insects, nematodes, mites, mice, rabbits and certain plants that negatively affect the growth of forest vegetation and cause economic loss. There is an abundance of pest species living in the varied forests and climatic environments in China's widespread territory, causing severe damage to the forestry industry. With the rapid growth of trade, both domestically and internationally, the management of forest pests, especially alien pests, has become one of the most important aspects of forest management in China.

Brief introduction to forest resources in China

There are 158.9 million hectares of forests in China, covering 16.5 percent of the total territory. Among the existing forests, plantations play an important role, contributing 29.4 percent of the total, accounting for some 46.7 million hectares.

To further improve the forest resources and ecological environment, the central government initiated six major forest programmes nationwide:

- Natural Forest Protection Programme;
- Converting Farmlands to Forests Programme;
- Shelter-belt Forest Development Programme in Three-North and Yangtze River;
- Sand-preventing and Sand-combating Programme around Beijing;
- Wildlife Protection and Natural Reserve Development Programme; and
- Fast-growing High-yielding Timber Forest Bases Development Programme.

Some considerable progress has been achieved. For example, 10.5 million hectares of forest have been planted; 0.17 million hectares of land have been closed for reforestation; 87 400 hectares of small drainage areas have been harnessed for erosion prevention, and 4 324 supporting water resource facilities have been constructed. More than 1 400 natural resource conservation areas have been established.

Major forest pests and damage caused in China

Statistics indicate that there are more than 8 000 forest pest species in China, of which approximately 100 have caused significant economic loss. Important native pests include pine caterpillars, poplar defoliators, poplar longhorn beetles and pine bark beetles, which infest an area of approximately 8 million hectares, annually.

Important alien forest pests in China include pine wood nematode disease, fall webworm, pine greedy scale, slash pine mealybug (Table 1). These infest an area of approximately 1.3 million hectares, annually.

The annual direct loss to the forest industry is estimated at RMB10 billion yuan (US\$1.2 million). The economic losses caused by alien forest pests contribute 60 percent of the total losses, while occurring in only 20 percent of the total forest area.

Table 1: List of important alien invasive forest species in China

Common Name	Scientific name	Common Name	Scientific name
Pine wood nematode disease	<i>Bursaphelenchus xylophilus</i> (Steiner & Buhner) Nickle	Fall webworm	<i>Hyphantria cunea</i> (Drury)
Brown spot needle blight of pine	<i>Mycosphaerella dearnessii</i> Barr	Pine greedy scale	<i>Hemiberlesia pitysophila</i> (Takagi)
Pine red spot	<i>Dothistroma pini</i> Hulbary	Pine bark scale	<i>Matsucoccus matsumurae</i> (Kuwana)
Olive knot disease	<i>Pseudomonas syringae</i> pv. <i>savastanoi</i> (Smith) Young, Dea & Wikie	Nipa palm hispid beetle	<i>Octodonbta nipae</i> (Maulik)
Poplar mosaic virus		Banana moth	<i>Opogona sacchari</i> (Bojer)
Mile-a-minute weed	<i>Mikania micrantha</i> H.B.K	Loblolly pine mealybug	<i>Oracella acuta</i> (Lobdell)
Praxelis	<i>Eupatorium catarium</i> Veldkamp	Coconut beetle	<i>Brontispa longissima</i> (Gestro)
Canadian goldenrod	<i>Salidago Canadensis</i> L.	Asiatic palm weevil	<i>Rhabdoscelus lineaticollis</i> (Heller)
Crofton weed	<i>Eupatorium adenophorum</i> Spreng.	Red turpentine beetle	<i>Dendroctonus valens</i>

Alien forest pest management practices in China

The Chinese government and its forestry agencies have made great efforts to prevent and control the spread of alien forest pests, releasing a series of regulations and management procedures. The State Forestry Administration (SFA) has established a management framework consisting of:

- promoting integrated management;
- focusing on biological agencies (with prevention being a great priority); and
- establishing a PRA and pest risk early-warning network for imported plants and plant products.

Two functional bodies have been established to coordinate this: the Office of Alien Forest Pest Invasion Prevention, and the Forest Pest Identification and Inspection Center.

To prevent the invasion of alien forest pests, information exchange and the sharing of experiences is being promoted between related governmental bodies, such as the State Pest Quarantine and Inspection Administration, Ministry of Agriculture, Ministry of Science and Technology, and the State Environmental Protection Administration. Overseas pest epidemic information was collected and a new book entitled “Epidemic Database of Overseas High-risk Pests” was compiled and published. The compendium contains information on more than 400 species. Quarantine nurseries and non-quarantine-object nurseries are being constructed. Pest Risk Assessment reports are required prior to the import of plant material that has not previously been imported to China or for plant material that is considered to be high-risk. The newly imported plant material must be planted in the quarantine nurseries prior to obtaining permission for import.

In order to collect timely information on alien forest pest incursions, key national inspection stations have been established in 1 000 counties nationwide, with more than 8 000 inspection locations. Most of the abnormal phenomena in forests – for example, excessive numbers of dead trees – can be observed and identified in time to arrest pest incursions. The construction of quarantine and inspection facilities around sensitive and important conservation areas, such as Huangshan Scenic Area, has been given priority.

The government has initiated several IPM programmes, state level programmes for pine wood nematode disease, red turpentine beetle and fall webworm. At a provincial level, programmes have been initiated for pine bark scale, pine greedy scale and loblolly pine mealybug.

While taking IPM measures to control important alien forest pests, the establishment of healthy forests is also being promoted. In 2001, an experimental forest health programme was initiated in five counties along the Yangtze River. By taking comprehensive measures, mixed and compound storied

forests were restored or planted. With enriched biodiversity, the resistance to incursions and the recovery capacity of healthy forests was improved, thus restricting and controlling the development of pests.

Sound legislation is the basis for alien forest pest management. Besides the existing laws and regulations related to forest pest management, SFA is now drafting a new regulation entitled "Emergency controlling procedures for forest pest outbreaks", in which the control of emergent alien forest pests is an important component.

Public participation is an effective measure to prevent the occurrence and spreading of alien forest pests. The government has made great efforts to improve public awareness of the impacts of alien forest pests. The general public has learned of the damage caused, spread approaches and control measures for alien forest pests. Thus laws and regulations related to pest management are better understood and the man-made long distance transmission of forest pests has been reduced.

Challenges and suggestions

Even though a series of management measures for alien forest pests have been taken by the Chinese Government – and although considerable results have been achieved – there are still some great challenges facing the country.

- There is an increasing risk of invasion by dangerous alien invasive species as a result of the continued growth of cross-border human activities, and the resulting increase in the volume of economic trade.
- There is insufficient public awareness of the threats of alien invasive species. For example, local forest-tree species are often neglected when new forests are established, while too much attention is given to exotic species. This increases the possibility of pest invasions.
- It is difficult to block epidemic areas in order to halt the spread of a particular invasive species.
- There is insufficient infrastructure with regard to pest management facilities and a lack of professionals to collect and analyse data on invasive species. For example, pine greedy scale, loblolly pine mealybug, and red turpentine beetle are all common insects in their native habitats. However, in China, they are dangerous forest pests, causing great damage to infected forests. The government has acknowledged this problem and is taking action to improve the situation. However, to date, the basic data and information on alien invasive species, their occurrence, the economic losses caused and their environmental impacts are not clearly understood. The current national forest pest survey will be finalized in 2005.
- There is a lack of monitoring of important forest pests, resulting in the often-belated discovery of invasive species.

All of the above-mentioned challenges need to be resolved gradually. However, this is not a task that the Chinese Government can address on its own. There is a need for inter-governmental cooperation in order to address the problems related to invasive species. The Chinese Government strongly supports the idea of establishing an "Asian-Pacific Forest Invasive Species Management Committee", and is willing to cooperate with other countries or regions in the world to prevent the invasion of forest pests.

Pest risk assessments and incursion pathways

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Introduction

Invasive species are one of the greatest global natural resource concerns. In the United States of America, invasive species cost over US\$137 billion annually. Economic losses owing to non-native invasive forest pests are estimated at US\$4.2 billion per year from reduced timber yields and prices, the costs of direct control of these pests and the increased costs of managing lands affected by them. Ecological impacts of non-native forest pests include: tree species conversions, wildlife habitat destruction, degradation of riparian communities, increased fuel loading, increased damage from native pests and loss of overall biodiversity. Pest risk assessments and the identification of potential incursion pathways are two useful tools that have been developed to help address the issue of invasive species.

Pest risk assessments

The purpose of pest risk assessments is to identify non-native organisms that may be introduced, in order to determine the likelihood of their introduction and establishment, and to estimate the impacts of establishment (both economic and environmental). Good pest risk assessments are comprehensive, logically sound, practical, conducive to learning and open to evaluation. In the simplest terms:

Risk = Likelihood of introduction and establishment × Consequences of establishment

In assessing the likelihood of introduction and establishment of an organism, factors to consider include:

- history of previous interceptions;
- life history of the organism in the source area;
- reproduction potential and capability for large-scale population increases;
- host specificity and searching capability;
- ability to survive harvesting, handling and shipping;
- degree of difficulty to detect at point of entry;
- numbers and life stages translocated;
- likelihood of encountering suitable environment and hosts;
- distribution and abundance of potential hosts;
- methods of dispersal (natural, human-assisted, etc.); and
- cost of control measures.

To assess the consequences of an introduction and to help determine the need for and degree of action to prevent establishment, factors to consider include:

- economic importance of the host(s);
- effects on industries and consumers resulting from loss of the host(s);
- the potential for ecosystem destabilization and/or reduction in biodiversity (including reduction or elimination of keystone species, endangered or threatened species, etc.);
- non-target effects of control measures;
- potential for aesthetic damage;
- consumer concerns and political implications; and
- implications for trade.

Incursion pathways

Incursion pathways are the methods by which organisms can move from source areas to new areas. Identifying these pathways and determining the most likely routes of movement for specific organisms of concern provides us with a tool to intercept potential invasions and prevent the establishment of new invasive organisms by telling us where to look for these potential pests. Pathways can be categorized into three broad areas – transportation-related, “living” industries, and miscellaneous pathways. Transportation-related pathways include all the routes related to the movement of goods and people (air, aquatic, terrestrial movement; items used in shipping such as containers and packing materials; tourism, moving and personal travel; movement of pets, etc.). “Living” industries include such areas as the movement of living organisms for food, aquaculture, pets, livestock, movement of plants and plant parts, seeds, minimally processed animal and plant products, animal and plant residues and waste. Miscellaneous pathways include other aquatic routes such as interconnected waterways, interbasin transfers and dredge spoil, as well as other unapparent routes of movement such as storms and high winds.

Working together to develop and share pest risk assessments, to identify actual and potential pathways of movement of organisms of concern, and the simple sharing of information and increased communication on the vital subject of invasive species provides us with our best chance to prevent future establishment of new invasive species and to minimize the impacts of those already present.

FAO activities related to invasive species in forestry

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The Forestry Department of FAO has initiated a number of activities with regard to biosecurity issues in the forest sector. This is part of an interdisciplinary effort to assist member countries in addressing the problems faced with invasive species in forestry. With support from the FAO-Netherlands Partnership Programme, several activities have been initiated. These include reviewing and defining the biosecurity concept in forestry, promoting collaboration with other sectors and analyzing the impacts of invasive species at the national and international levels. To support this work, several studies are being undertaken to further define certain critical issues.

Despite the global interest in biosecurity, there continues to be little clear understanding of what it means to forestry. Nevertheless, as far as forests and trees are concerned, biosecurity issues are relevant in the following five disciplines:

- *forest protection and phytosanitary hazards* – this covers issues such as quarantine, legislation, and measures supporting the prevention and control of insect pests and diseases;
- *invasive alien species (IAS)* – due to increases in trade and travel, IAS are a growing problem. Invasive plants and animals may pose a risk to a specific forest species, habitat or ecosystem. Several programmes (IUCN, CBD, North American Forest Commission) are looking into the issues. Forest-trees may occupy degraded areas, including forests. There are concerns about the expansion of exotic trees and shrubs beyond their area of introduction;
- *introduction of foreign/improved germplasm* – the introduction of such material into areas where native genotypes exist can be a concern. Although this has not been highlighted in the case of forestry, focused studies are ongoing to ascertain risks;
- *genetically modified organisms (GMOs)* – there are increasing concerns about the environmental risks of introducing GMOs. FAO is closely monitoring the application of GM technologies in the forest sector, and is undertaking a global review of the status and trends of GM trees; and
- *genetic pollution* – FAO has compiled relevant literature on this issue.

FAO launched a number of fact-finding studies on invasive forest-trees, including studies of the intensity of invasiveness. The global review showed that out of 1 121 exotic tree species, 443 species might be considered invasive. While biologists have mainly undertaken the work, foresters are beginning to show concern about invasive species. The terminology has often been intractable, but FAO has begun to grapple with the issue.

In one case study in South Africa, 110 invasive woody species were found in the survey area, many of which were perceived to have negative impacts. In order to raise awareness and bring balance to the issue, the study is reviewing the regulations governing plantations and land use, and is developing control campaign materials for prevention. Another case study on a specific genus, *Prosopis*, which was introduced into Sahelian Africa was very revealing. The tree was introduced for soil conservation, fuelwood, desertification control, etc. While concern over its invasiveness has been expressed, the study revealed the issue is more complex. There are many circumstances where the tree has provided benefits. The study indicates that the period of introduction and local knowledge on the use of the species is critical, in weighing the costs and benefits of an invasive species. Another study was conducted on the effect of the introduction of foreign/improved germplasm, on eucalypts in Australia. The study showed that the risk of hybridization with native gene pools is very small. Nevertheless, some precautions need to be taken.

FAO has also developed simple databases on introduced, naturalized and invasive woody species. These databases are searchable, by species and by country, and include related literature and references. In addition, there is an international portal on food safety and animal and plant health. Information on international and national standards, regulations, official material relating to sanitary and other measures is also included. The information on sanitary and phytosanitary related standards is meant for consumer and environmental protection agencies, to facilitate international trade on such materials. In addition to the above, FAO is also assisting developing countries in capacity building on biosecurity issues.

Ecological and economic impacts of invasive species

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Invasive species are well recognized as having severe ecological, economic and social impacts. It is also well recognized that as a result of increasing trade and travel and the globalization of world economies that the invasive species problem is currently escalating.

Invasive species have features that enable them to establish, spread and dominate in countries that are outside their natural range. Plants and animals in the new host countries often lack defences and are therefore vulnerable to the new arrivals. Natural control mechanisms are often absent or ineffective against invasive species.

While invasive species are a major concern for all countries, open economies relying on primary production can be most severely affected. Countries with fragile economies, disturbed landscapes and a legacy of existing pest problems are also severely impacted.

Assessment of ecological impacts is likely to remain a significant challenge despite emerging resource economic methods, such as contingent valuation. It is also likely that ecological impacts will largely continue to be described in subjective terms.

Assessment of the impacts of invasive species on productive sectors and urban trees is more amenable to quantitative assessment. Economic impacts include crop production losses and the loss of access to premium markets. They also include spending on defensive measures such as:

- border protection;
- exotic pest detection and eradication; and
- pest control and management.

New Zealand spends some US\$175 million per year on defensive measures¹. It also spends significant sums on incursion responses. For example, it is estimated that almost US\$60 million will be spent responding to the painted apple moth.

Economic impacts of invasive species have been assessed as equivalent to some 1.4 percent of gross domestic product in the United States of America (US\$137 billion per year²) and some 0.9 percent of gross domestic product in New Zealand³ (US\$495 million per year).

New Zealand undertakes economic impact assessments for all newly arriving invasive species where a government eradication programme is being considered. These assessments include:

- determining affected sectors (urban trees, planted forests, horticulture, watershed protection etc);
- compiling known information on pest impacts;
- using expert opinion to generate further data;
- developing and evaluating impact scenarios; and
- undertaking sensitivity assessments of assumptions to determine the critical assumptions.

Where possible, financial values for impacts are determined; otherwise impacts are described in subjective terms. These economic impact assessments are a key consideration in decisions by the government on its response to exotic pest incursions.

¹ Ministry of Agriculture and Forestry internal paper on biosecurity funding.

² Pimental, D., *et al* 1999. "Environmental and Economic Costs Associated with Non-Indigenous Species in the United States."

³ Hackwell, K., and Bertram, G., 1999, "Pests and Weeds – A blueprint for action," compiled for the New Zealand Conservation Authority.

The International Plant Protection Convention (IPPC)

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The International Plant Protection Convention is a multilateral treaty for international cooperation in plant protection and is the phytosanitary standard-setting organization named in the WTO-SPS Agreement. While a number of provisions in the IPPC are shared with the WTO-SPS, the IPPC makes provisions for trade in a protection agreement and the SPS makes complementary provision for phytosanitary protection in a trade agreement.

The purpose of the IPPC is to secure common and effective action to prevent the spread and introduction of pests or harmful plants and plant products, and to promote appropriate measures for their control. The scope of the IPPC is not limited to trade. The IPPC includes both direct and indirect effects from weeds, invertebrates, diseases on agricultural plants, forests and wild flora. This includes biological control organisms. There are also provisions for research and other purposes. The original IPPC came into force in 1952, was amended in 1979, and further amended in 1997. As of April 2003, there are 120 Contracting Parties.

The key obligations of the IPPC are for the contracting party (country) to establish and administer a National Plant Protection Organization (NPPO), conduct treatments and certify exports, regulate imports and cooperate internationally with respect to sharing information on pests and regulations. Countries are expected to develop and consider phytosanitary standards. The key principles of the IPPC recognize the sovereign right for each country to regulate the entry of plants and plant products, but that measures should only be applied when necessary. Measures should be consistent with the risk, technically justified and the least restrictive, non-discriminatory and transparent (published).

An Interim Commission on Phytosanitary Measures (ICPM) has been established and is the governing body for the IPPC. This group works by consensus, and develops and adopts international standards for phytosanitary measures (ISPMs). The ICPM also promotes information exchange and technical assistance. The priority of new standards is decided by the ICPM. A working group of experts drafts the standard; the Standards Committee reviews the standard prior to country consultation. The Standards Committee reviews the country comments and when deemed ready to proceed, recommends adoption by the ICPM.

Existing International Standards

- Principles of plant quarantine as related to international trade
- Guidelines for pest risk analysis
- Guidelines for the establishment of pest free areas
- Guidelines for surveillance
- Export certification system
- Determination of pest status in an area
- Guidelines for pest eradication programmes
- Establishment of pest free production sites
- Guidelines for notification of non-compliance and emergency action
- Guidelines for regulating wood packaging material

The IPPC Secretariat provides official documents (ISPMs and reports), facilitates information exchange and maintains the IPPC web site. The International Phytosanitary Portal (IPP) lists countries' official contact points, contains official documents (ISPMs, reports) and generic phytosanitary information from countries. For more information:

International Plant Protection Convention Secretariat

Food and Agriculture Organization of the United Nations

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Key elements in developing a forest invasive species biosecurity strategy for Australia

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Australia is relatively free from many serious agricultural and plantation forestry pests, mainly because of its geographical isolation. This position is attributed to the fact that virtually all cultivated crops, many pasture species and a large proportion of Australia's plantation forest industries are based on exotic germplasm. Through rigorous quarantine action, and some good fortune, many serious agricultural pests have been excluded, while few indigenous pests have adapted to attack the exotic germplasm – a fact that can be attributed, in part at least, to Australia's unique flora. The impacts that new pests will have on Australian ecological and agricultural systems are, in many instances, little known. Pest risks are compounded by the wide diversity of ecological niches that Australia offers as points of incursion establishment, including both temperate and tropical environments.

The annual turnover of the Australian forest industry is valued at A\$15 billion (US\$10.7 billion). Protecting forests is becoming harder with the increase in global trade and travel. The risk of entry and potential establishment of exotic pests has increased the risk and threat of impact of these pests.

In addition to the natural pathway, through Northern Australia from Indonesia and Papua New Guinea, potential pest pathways to Australia include thousands of incoming air and sea freight containers and contents, 180 million mail items and over 9 million inbound passengers annually. Although numbers tend to vary from year to year, Australia must respond, annually, to approximately 40 newly recorded plant pests, 200 barrier breaches (pests that have been detected beyond the quarantine barrier but have not yet become established) and 15 000 pest interceptions at the quarantine barrier.

Preventing pest introductions is a major component in any invasive species strategy; however it is not zero-risk, with increasing pressure from both regulated trade and non-regulated trade (deliberate contravention of quarantine laws). Australia spends A\$166 million (US\$119 million) on quarantine activities annually and has spent over A\$200 million (US\$143 million) since 1996 on various plant pest eradication programmes.

On the ground response to incursions by exotic pests is only one aspect of an overall incursion management strategy. The effectiveness of a response to an incursion is heavily influenced by various factors prior to, during, and after, an exotic pest incursion. Consideration of a response to an exotic pest should not be seen as a stand-alone process, but part of an overall biosecurity and incursion management strategy.

A framework for preparing and responding to exotic pests can be seen in Figure 1. This framework includes three major stages that take into account input into the overall outcome of reducing the risk and impact of exotic pests before the pest becomes established (Pre-event), when the pest is detected (Response), and after the pest has been eradicated or managed (Recovery).

Experiences in responding to exotic pest incursions in Australia show that successful response programmes have similar characteristics indicating the suitability of some incursions to effective response and the need to handle invasive species in a total preparedness and response framework. Characteristics include:

- early detection and rapid implementation of containment procedures;
- outbreak(s) few and confined;
- outbreak site readily accessible;
- effective mechanisms for controlling movement of host produce and other items;
- poor adaptation of the pest to its new environment (edge of range);
- lack of genetic variability in the pest population and no behavioural changes;
- host or habitat specificity;
- low reproductive rate / few generations per year;

- sensitive monitoring techniques for high and low population densities;
- cost-effective control methods;
- trace-back investigation indicates few opportunities for secondary spread;
- programme justified by cost-benefit analysis; and
- public conviction that the pest is of potential economic importance; and
- effective awareness campaign.

Experience in Australia has also shown that there are key elements of invasive species preparedness and response that greatly influence the effectiveness of any response strategies. The following sections describe elements that have proven to be critical in Australia and are the focus of the development of Australian invasive species strategies.

Identification of pest threats and information on biology, ecology and control

There are numerous potential exotic pests that could threaten Australian forests to various degrees. The capacity to develop and implement surveillance programmes for all potential pests is limited. Where possible, it is desirable to begin with identifying and prioritizing pest threats to help rationalize and focus surveillance resources where most appropriate. However, this must be balanced with an overall capacity to detect pests, which may have not been seen as key pests, based on overseas experience. The nature of exotic pest invasions means that pests usually arrive in Australia without natural biotic and abiotic constraints and minor pests in their native environment can become major pests in Australia.

For example, the aphid *Essigella californica* was first found in Australia in 1998. National surveys quickly found it in all states despite forest surveillance programmes. The aphid is not known to be a major pest on *Pinus radiata* elsewhere, or in its native range, but in Australia there are indications that it is causing significant damage in some states. This highlights the difficulty in identifying key target pests and being able to adequately detect them early enough for effective response.

Asian gypsy moth (*Lymantria dispar*) has been identified as a potential key threat, and its destructive potential has been confirmed through research on host testing with Australian native species. Although the pest has not evolved with *Eucalyptus* species, it readily feeds on many, highlighting its potentially significant impact on both commercial and conservation forests. Australia conducts a pheromone-trapping programme in all temperate first ports of call – one step to help mitigate this risk.

Pest status in country

A sound knowledge of the pest status of Australia's plant industries and native flora is essential if we are to avoid costly false alarms arising from findings of suspected new incursions. Occasionally, owing to a lack of surveillance or appropriate notification and recording of an exotic pest, a response is falsely triggered. There have been cases where there have been valid records indicating that a pest has been present for some time, but a new finding of the pest has resulted in the initiation of the national response system because the older records were not readily accessible. In other cases, gaps in our knowledge of plant health status has meant that it is not possible to determine, with any confidence, the status of a newly discovered organism.

Clearly, if we don't know which pests are endemic it is difficult to determine, with any confidence, the status of a newly discovered organism. This is why arthropod and pathogen collections (and disease herbaria) containing validated and well-curated specimens are critically important. These collections hold information on a pest's distribution, life cycle and host(s) and provide a basis against which to compare unknown organisms and facilitate the accurate identification of suspect exotic pests.

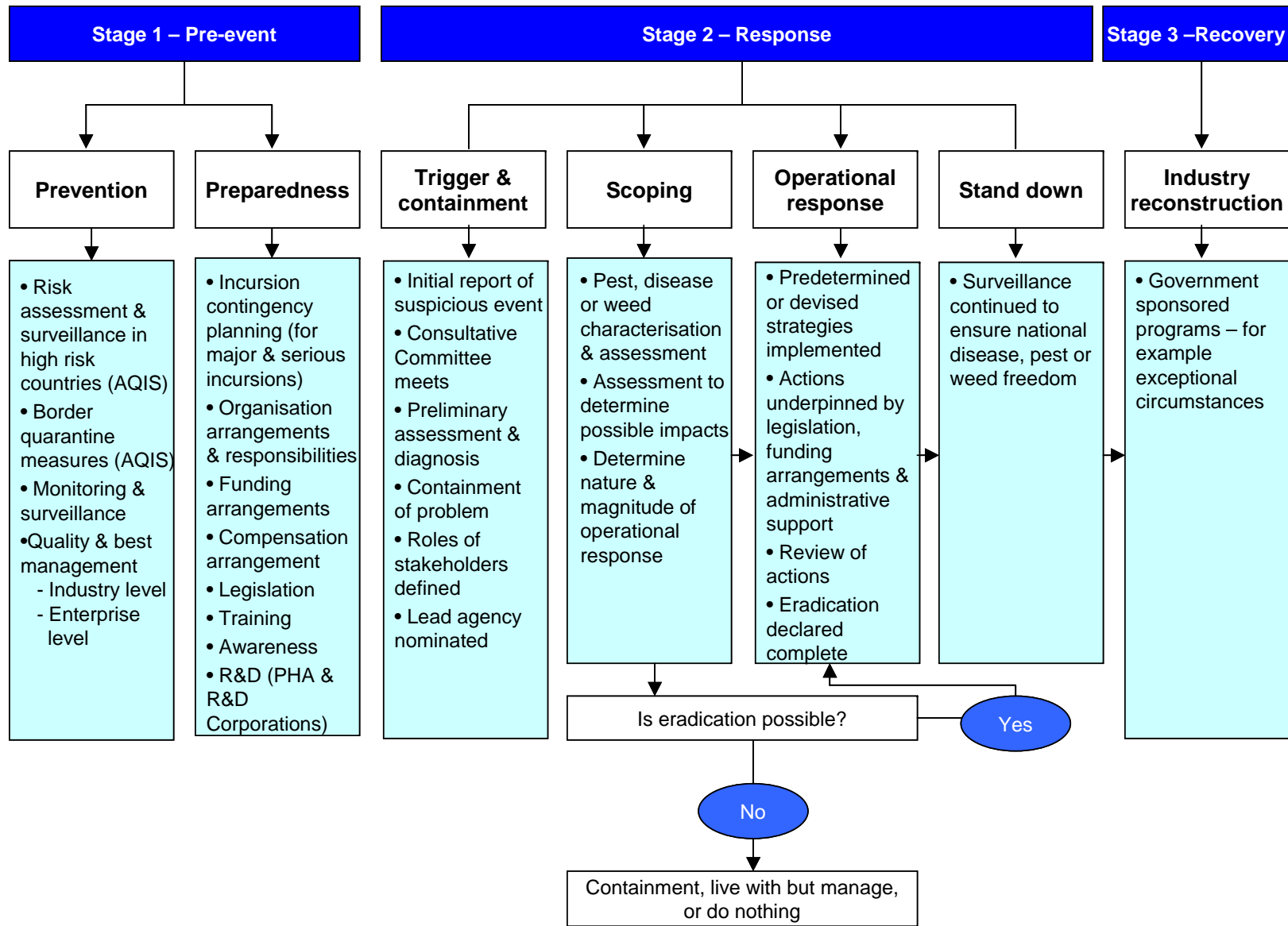


Figure 1: Framework for preparing and responding to exotic pests

Reference collections holding records of economically important pests are held by numerous organizations throughout Australia. The OCPPO (Office of the Chief Plant Protection Officer) and PHA (Plant Health Australia) are managing a project to improve the accessibility of these records through the development of an Australian Plant Pest Database, which links the diverse, geographically scattered databases throughout Australia so that all of the available data can be accessed from a single point via the internet. Support is also being provided for data entry and some validation of existing records.

Pest Pathways

The large number of exotic pests that pose a threat to Australia makes it difficult to take pre-emptive steps to address all of these – the resources are simply not available to do this. However, pathway analysis and risk assessment can be used to identify a “target list” of the more serious threats, keeping in mind that there still needs to be a generic capacity to respond to those pests that were not targeted and still are seen to be threats to Australia.

The following information sources may be drawn upon to determine entry pathways of exotic pests and to target potential pests: interception data collected by AQIS (Australian Quarantine Inspection Service), import statistics for host commodities and germplasm/nursery stock, quarantine import conditions, import risk analyses and market access proposals, scientific literature and databases such as the CABI Crop Protection Compendium and historical data.

Pest Impacts

A knowledge of which hosts are impacted or can act as a reservoir for establishment is essential for response decision-making. Any action to contain or eradicate a new pest needs to incorporate surveys of all host plants in the outbreak area, including those in commercial production areas, home gardens, parks and along roadsides. Various quarantine restrictions on host material to prevent intrastate and interstate spread of the pest may also be required. The speed of spread and the “invasiveness” of the pest, which includes information on dispersal characteristics, development rates and times, longevity, and vectors – among others – are important determinants of impacts.

Cost-benefit analysis is an important tool in consolidating and integrating various biological, operational and economic factors of an incursion, to allow for a more systematic analysis towards making decisions on response actions. It is a useful tool to help gauge the utility of response versus not responding, and other expenditures on non-response programmes. This analysis is done for all major incursion responses to varying degrees. However, the effectiveness of this analysis is often governed by a lack of information both biological and economic. Some components of cost-benefit analysis include:

- *Direct costs* – depending upon the type of pest, direct costs associated with eradication programmes may include:
 - surveys/monitoring;
 - research and diagnostics;
 - expert consultation;
 - equipment/machinery and vehicles;
 - materials and chemicals (pesticides/herbicides);
 - construction and/or maintenance of facilities;
 - awareness/education programmes and public relations;
 - salaries;
 - travel;
 - legislative/legal fees;
 - data management; and
 - contracting and/or other administrative costs incurred by plant health services.

- *Secondary costs* – for any eradication programme, there are often a number of less direct or harder to measure costs that may need to be considered, such as:
 - costs of detecting and eradicating a pest at low population levels;
 - likelihood of reintroductions;
 - possible adverse effects of eradication programmes on human health, non-target species, food, and the environment; and
 - costs to affected grower/s (loss in income, reduced value of personal/business assets, costs incurred as a result of possible quarantine restrictions, impacts on lifestyle). Subject to industry negotiation, some of these costs may be redressed with compensation.
- *Direct benefits* – the benefits of an eradication programme represent the sum of the costs that would be incurred if the programme were not implemented. The measurement of benefits depends on the ability to predict what impact an exotic pest would have if it were not controlled. Data are also required on the value of the industry(s) at risk. In current cost-benefit analyses of eradication programmes, benefits usually include one or more of the following:
 - preventing yield loss in host crops;
 - saving growers the cost of additional controls (e.g. pesticides) for the pest;
 - saving economic losses to Australia due to market access restrictions; and
 - saving costs to growers incurred as a result of disinfestation of host produce for the domestic market.
- *Secondary benefits* – other benefits of eradication programmes may include:
 - saving damage to private gardens, parks, nature strips, or uncultivated land (although the impact of a pest on amenities may be difficult to measure in dollar terms);
 - saving additional research and development costs;
 - preventing risks to human health;
 - saving structural adjustment costs in the affected industry;
 - saving costs to associated sectors; and
 - preventing negative impacts on the work/leisure environment and employment options.

Pest control strategies

A decision on the most appropriate control strategy will depend upon where the incursion was detected (i.e. commercial/non-commercial, urban or rural setting), the extent of the outbreak, distribution of hosts, biology of the pest, specificity of chemical treatments, and environmental sensitivities. Knowledge of the types of quarantine controls that would need to be established under state legislation to contain an outbreak and options for chemical/physical control of a pest form an integral part of effective incursion management.

Quarantine and offshore activities to prevent and prepare for incursion

Quarantine controls on the entry of plants and plant products at the border, regulated by AQIS, and quarantine policy based on risk assessment, conducted by Biosecurity Australia (BA), are designed to minimize the threats to Australia from incursions of exotic pests. In addressing new market access proposals, Australia is bound by the WTO SPS Agreement, which sets conditions – based on scientific principles and risk assessment – to protect agriculture industries from exotic pests, but, at the same time, facilitate trade in agricultural commodities. Approval is subject to BA assessing that applications for entry pose an acceptable level of risk, taking account of such matters as:

- the plant health status of agricultural industries in the country or region from which the commodities are to be sourced;
- the likelihood of pests of concern being transported with commodities and establishing in the importing country;
- potential damage that introduced pests might cause to crops and native flora; and
- the efficacy of phytosanitary treatments that might be used to manage identified risks.

Assessments made by BA in response to applications to access the Australian market are known as Import Risk Assessments (IRAs). In recent years, Australia has improved the transparency of its IRA process and encourages greater input from stakeholders.

Over the last two years, BAs forest health work programmes have included; progression of an IRA for five coniferous timber species from three countries, conducting Pest Risk Assessments (PRAs) of pine pitch canker and sudden oak death wilt, and risk assessments with regard to import of thuja logs and oversized kwila timber for construction.

BA is also currently conducting reviews on the importation of *Acacia* and *Casuarina* seed for sowing, in response to advice received from a Forest Germplasm Workshop of January 2002. It continues to progress the coniferous timber IRA consistent with international obligations, and has been involved in further work on suspended draft wood packing guidelines, in which the efficacies of proposed treatments with regard to pathogens are now subject to review.

Future forestry-related work for BA includes; a review of the species listed as being of forest and amenity significance (which require a two year post entry quarantine), progression of the coniferous timber IRA, further reviews for emergent *Phytophthora* species and nursery stocks, and continuing to provide advice to AQIS on timber imports and exports on an as-needed basis.

Surveillance and the ability to detect and delimit incursions

Surveillance is needed to improve our ability to detect exotic pests early. Early detection maximizes the effectiveness, lowers the costs, and increases the speed of completing eradication or suppression programmes, by being able to address a pest incursion when the population is smaller, less distributed, and not as well established. Failure to detect incursions soon after they have occurred is the major factor limiting our ability to implement effective response actions. In the overwhelming majority of cases, it is estimated that exotic pests have been present in Australia for more than a year before they are noticed and reported.

Successful containment or eradication of new pest incursions is predicated on early detection when the pest population is small, confined and not well established, although much also depends on the mobility of the pest and the proximity of the initial outbreak to host plants. While graft-transmissible pathogens and nematodes (except for those that are vectored by insects) are relatively immobile, many fungal and bacterial pathogens and arthropod pests have the capacity to spread rapidly – early detection of these is critical.

Surveillance is also needed to delimit and monitor pest incursions. The extent to which a pest population is distributed must be known to properly respond to and manage pest incursions. Ongoing pest monitoring gauges the effectiveness of eradication or suppression actions.

There are two major types of surveillance (as defined in the *International Standards for Phytosanitary Measures, Guidelines for Surveillance*) – specific surveys and general surveillance. Both specific surveys and general surveillance, which includes awareness programmes, are useful in various forms to be able to detect pest incursions at an early stage and increase the effectiveness of response programmes, while mitigating impacts while pests still have a limited distribution.

Specific surveys

Specific surveys include early warning programmes to detect exotic pests, and delimiting surveys to define and monitor exotic or endemic pest populations. These surveys usually require more resources and incur relatively higher costs. Specific surveys are dependent on the following factors: targeted pest(s), scope of survey based on the biology, ecology, likely pathways of entry of the pest (to indicate geographic area), sample units, timing, and methodologies including:

- sampling procedures including sampling type such as pest trapping and plant sampling;
- crop inspection including indication of the sensitivity or statistical rigor of the survey and sampling;
- diagnostic procedures; and
- quality assurance procedures.

To maximize survey effectiveness and increase the likelihood of detecting pests, surveys should take into account the reported distribution of the pest, pest biology/ecology and climatic range and the distribution of potential host plants.

Specific surveys are based on target pests and utilize sample-survey methodologies. Regrettably, there are other factors that influence this approach and undermine its potential for success, such as availability of appropriate technologies acceptable to trading partners and domestic users, local expertise, experience in identification, and access to national and international databases for verification.

Trace-backs are also important to try to identify the source of an outbreak and to fully delimit an incursion. Tracing is an investigative process that requires the cooperation of the owners of affected premises to determine where the pest may have come from and whether it may have been spread to other properties. The movement of plants and plant products (including nursery stock/seeds), equipment, vehicles and people to and from the affected premises must be thoroughly investigated.

Surveillance activities offshore and at the border are also part of the overall surveillance network to provide surveillance information to predict potential problems or detect pests before they have had a chance to arrive at or pass through the quarantine barrier. Both can give a profile of potential problems that may require further surveillance action.

Surveillance activities at the quarantine barrier offer a primary line of defence against exotic pest incursions, as well as giving a profile of the pests that Australia is being exposed to – for further consideration in response planning. These activities include:

- the development and implementation of effective and appropriate sample/survey procedures to detect exotic pests in various import pathways, such as ship inspections for AGM and timber inspections for pests;
- surveillance to ensure that appropriate import requirements have been met to address the risk of pests being introduced through various import pathways, such as seed and germplasm inspections and treatments, and wood treatments; and
- the development and implementation of tracking systems to target high-risk pathways for inspection and potential tracebacks, such as the AQIS computer record management and data interrogation system.

General surveillance

General surveillance is the process whereby pest information is gathered through a variety of sources other than specific surveys. General surveillance is dependent on an effective education and awareness programme to allow stakeholders to readily recognize the pest or appropriate pest symptoms and a communication and reporting system to allow potential detections to be reported and appropriate action to be taken.

This type of surveillance is relatively low cost and does not require specific technology. It is the act of detecting a disease, pest or a weed based on knowledge of a local area or recognizing symptoms previously encountered in publicity or awareness material. To increase the effectiveness of this type of surveillance, a wide range of stakeholders should be included. These are characterized by the use of a range of stakeholders and awareness programmes that enable the detection of pests during the course of normal activities. In Australia, most plant health surveillance is general surveillance due to the costs and limited methodologies for specific surveys. Improving the awareness of growers, agribusiness, and others involved in the plant industries, can harness many eyes to be on the look out for the new and the unusual.

Training on how and when to monitor for pests, on procedures for sampling suspect material, and notifying the relevant authorities, is an integral component of any general surveillance strategy. There are a number of approaches that can be taken by industry and government agencies to raise industry/community awareness of exotic plant pests. These include the production of “ute” guides, fact sheets or illustrated brochures on pests of concern, placing articles in industry magazines, newspapers and other popular publications, local radio and television coverage, training on the recognition of exotic pests and symptoms, and displays/exhibits at agricultural and community shows – among other things. Important information to include in general awareness programmes includes: significance of the pest, host range, distribution, pathways, favourable conditions for symptom

development, potential impact on industry, symptoms to watch out for, importance of reporting an outbreak or suspect material, and who to contact. An exotic forest pest booklet has been prepared and distributed to over 5 000 forest health stakeholders in Australia to enhance capacity to detect and report major exotic pests.

A clear notification procedure is essential to capture general surveillance information. A national pest hotline has been developed to be used during national surveillance and response campaigns. There is also a project through OCPPO to develop a national exotic pest notification system and a specific industry-based exotic pest surveillance network, to capture ongoing surveillance activities being carried out by a variety of plant health stakeholders.

The present system for detecting exotic pest incursions in Australia is based on a combination of specific monitoring activities, general surveys across northern Australia, state government and industry awareness programmes, and *ad-hoc* reporting (by growers, members of the public, etc).

The success of incursion management relies heavily on grower participation in passive or general surveillance to increase the chance of early detection of exotic pests. Currently, the OCPPO and Plant Health Australia (PHA), have developed a national plant pest hotline telephone reporting system, with associated targeted publicity awareness material, to more effectively capture potential detection information through general surveillance activities. The Department of Agriculture Forestry and Fisheries (DAFF) has produced a field guide to exotic pests of forest and amenity trees and timber to encourage early reporting of suspect outbreaks of these pests.

States have the major role surveying forest health. Annual surveys of plantations and routine general surveillance of commercial forests are conducted by state forest agencies. The surveys in native forests target key areas and perceived high-risk zones.

The Commonwealth, through state government agencies, runs a national trapping programme for Asian gypsy moth. The national Asian gypsy moth trapping programme serves as an early warning system to detect incursions of exotic Lymantrid species entering through Australian ports. It is funded by DAFF and coordinated by the OCPPO. Ships and shipping containers are seen as likely pathways for entry, so the trapping programme is centred in the first ports-of-call. The programme is based on a network of Delta traps on a 1-kilometre grid out to 2 kilometres from port facilities, and a 2-kilometre grid from the boundary of the 2-kilometre zone out to 5 kilometres from the port facility centre. Actual trap numbers per port facility vary, with a maximum of 40 traps per port. The surveillance network includes over 450 traps. Field monitoring/servicing of traps is carried out by state agriculture or forestry agencies.

The Northern Australia Quarantine Strategy (NAQS) is a programme of AQIS that is responsible for monitoring and surveillance to provide advanced or early warning of exotic pest threats. The purpose of the programme is to limit the opportunity for exotic pests to establish and remain undetected in remote areas. Surveillance targets are based on pest risk analyses that identified northern Australia as a pathway for entry of exotic pests of major plant host groups.

Exposure of NAQS scientists to exotic pests in the region builds expertise and increases confidence that exotic pests will be detected in regular surveys across northern Australia. The onshore component of the NAQS monitoring and surveillance programme covers a coastal band, 20 kilometres in width, across northern Australia, from Broome in the west to Cairns in the east. NAQS activities also extend offshore to East Timor, Papua New Guinea and Indonesia. The initiative includes trapping for exotic fruit flies on the islands of the Torres Strait, as well as a public awareness programme known as Top Watch.

Pest diagnostic capacity

Early detection of suspect exotic pest incursions, followed by rapid and accurate diagnosis, is essential if opportunities for eradication are to remain viable. The development and maintenance of appropriate diagnostic procedures to accurately diagnose plant pests – and in particular, exotic plant pests – are essential components of any pest preparedness and response activities. It is obvious that the correct and timely identification of exotic pests is essential in not only triggering response actions, but also in confirming negative results. A decision on whether to eradicate, contain or manage an outbreak of an exotic pest must be made quickly and depends on an ability to obtain a rapid and accurate diagnosis of the organism involved.

There are a number of factors that constitute good diagnostic capacity. These include: taxonomic or diagnostic expertise to identify target organisms, both in the laboratory and field, access to validated reference specimens and associated records, dedicated laboratory facilities with the necessary equipment, chemicals, etc, required for specialist diagnostic tests. In the event of a serious incursion, these facilities must be able to handle a high volume of samples and, if necessary, be registered as quarantine areas by AQIS – subject to controls on the movement of personnel, plant material and equipment, nationally-agreed protocols and minimum standards for diagnostic testing. Systems should exist for auditing to ensure reliability of tests and national coordination to avoid unnecessary duplication of services and to make the most of a declining pool of resources for diagnostic work.

In 1998, a *Bursaphelenchus sp.* nematode was detected on various pine species in Melbourne. Local government workers initially reported the dying pines. As a precaution, a national response was developed that included a survey and eradication of infected pines in Melbourne. Infected pines showed a syndrome of sudden decline and death, but the syndrome was not consistent and was compounded by other disease and abiotic factors such as salt levels. Pathogenicity testing and diagnostics have proven difficult and no confirmation of the species, or illustration of it being a pest, has been made to date. During the national surveys many previously undescribed nematodes were found (not causing primary disease). This case highlights the lack of understanding of current plant health status, roles of exotics in a new ecosystem and lack of plant health capacity to diagnose potential plant pests, especially those that may not be of major pest status elsewhere.

Diagnostic services in Australia are provided via a combination of government laboratories (state agencies and CSIRO), commercial laboratories, universities, and pest and disease specialists who perform diagnostic duties as part of their job. A recent assessment of the current status of diagnostic capacity in Australia found that:

- although overall resources allocated to plant pest diagnostics are substantial, resources in certain disciplines (especially nematology and bacteriology) have declined in recent years, potentially compromising national capability in these areas; and
- documented procedures for identifying exotic pests of concern are not generally available and there is little quality control to ensure the delivery of standardized techniques such as those used in veterinary laboratories in Australia.

The OCPPO and PHA have recognized the importance of strengthening diagnostic capacity and are committing resources to the development of national diagnostic standards for priority exotic plant pests as well as a diagnostic network to identify and network domestic and international diagnostic expertise to be used in pest identifications.

For forestry, diagnostic protocols being developed include: pine pitch canker (*Fusarium circinatum*), *Eucalyptus* rust (*Puccinia psidii*) and *Bursaphelenchus* spp. Key elements of protocols and a national network include:

Stage 1: Initial detection

- Diagnostic information:
 - pictures of organism/keys/CDs, hosts, symptoms, etc;
 - information and pictures on how to distinguish from closely related, but not important, species; and
 - level of confidence that can be expected in initial diagnosis.
- Notification/reporting:
 - lines of reporting for the suspect incursion – who the specimen should be sent to, and an alternate (Stage 2 diagnosticians).

Stage 2: Intermediate diagnosis – "alters" to confirm tentative diagnosis

- Protocol for handling material, including:
 - data to be collected with specimens;
 - number of specimens needed;
 - stages of specimens required;
 - how/when to collect specimens;
 - preservation of specimens;
 - postage and handling of specimens;
 - specimen tracking, document control; and
 - contracts.
- Diagnostic information:
 - diagnostic tools (keys, images, kits etc) including:
 - accepted level of confidence;
 - quality assurance methods; and
 - other organisms likely to be confused with.
- Reporting:
 - lines of responsibility and communication; and
 - expected time frames for diagnosis, notification and full alert, etc.

Stage 3: Specialist diagnosis – agreed reference laboratory verifies diagnosis

- Diagnostic information:
 - agreed protocol for diagnostic methodology;
 - standard reference material required (specimens, literature, etc); and
 - level of confidence/ quality assurance.
- Reporting

Communication roles and responsibilities

A clear understanding of incursion management procedures needs to be effectively communicated to a wide range of plant health stakeholders. These should encompass several areas, such as, initial detection and reporting, through to compliance with quarantine and control activities. A lack of a strategy for ensuring that there are functional lines of communication between government agencies, industry bodies and other stakeholders can impede the effectiveness and acceptance of incursion responses. Communication strategies need to identify the key industry players to be contacted in the event of an exotic pest outbreak, and to ensure that industry is aware of appropriate procedures for liaising with incursion activities including media, especially during the early stages of an incursion. Effective systems for management and coordination at the Commonwealth, state and industry level are essential for the success of incursion response programmes.

Current biosecurity planning in coordination with governments and industry is developing industry specific communication and management strategies to effectively identify agreed government, industry and public involvement.

Legislative authority to respond to an exotic incursion

Recommendations made by the Consultative Committee (CC) for response actions are carried out under state legislation, which for Queensland is the Plant Protection Act 1989, for Victoria is the Plant Health and Plant Products Act 1995, and so on (the relevant acts are listed in Table 2). These acts enable government agencies to:

- enter properties to survey for an exotic pest;
- inspect, treat and take samples of plants or plant products;
- establish quarantine zones;
- restrict the movement of plants, plant products, equipment, vehicles and other sources of contamination;

- issue orders for the destruction of infested plant material; and
- require owners of affected premises to implement quarantine or pest eradication measures.

In the event of a new incursion, it is primarily the state plant protection legislation listed in Table 2 that will be utilized to respond. The Commonwealth Quarantine Act 1908 operates alongside relevant state acts and has broad coverage over matters of quarantine concern in Australia. However, in cases where a state law is inconsistent with a Commonwealth law, the Commonwealth law prevails and the state law is invalid. Areas where legislation could impact on effective response to an exotic incursion include:

- actions to control or eradicate an exotic pest may not be able to be applied on all land (e.g. national parks, world heritage areas, Aboriginal land). The Australian Environmental Protection and Biodiversity Act has major consideration and precedence when response programmes have potential impact on biodiversity and other environmental values on protected and key ecosystems;
- where there is no legal requirement under state plant health acts (with the exception of Tasmania) to report suspect new incursions, possibly hampering early reporting;
- when not all state plant protection agencies are able to immediately establish quarantine measures to contain or eradicate an exotic pest;
- where few state plant protection agencies have specific powers to destroy healthy plants and establish buffer zones to prevent the spread of an outbreak; and
- there is no uniform position across the states on the matter of compensation for losses incurred as a result of eradication actions.

Funding and compensation

Currently, incursion funding requires negotiation with the relevant Finance Department in the state/territory and Commonwealth, on the occasion of each incursion. There are no funds in reserve to mount immediate action, such as delimiting surveys, where an outbreak is suspected or confirmed. In practice the affected state(s), in view of the emergency, proceeds with containment operations before funding is settled on the expectation of reimbursement on a customary 50:50 cost-sharing basis. A further complication is that emergency actions by an affected state must frequently be taken before the nature of the containment actions is endorsed through the Consultative Committee process, in expectation that the state's actions will be ratified retrospectively.

The Plant Health Committee (PHC) considered the matter of standardization of costing for eradication campaigns in 1998 (PHC 18). It recommended to the Standing Committee for Agriculture and Resource Management that cost-sharing arrangements should cover the full costs of diagnostic services (including on-costs) and the direct costs of other response actions, such as salaries for existing and additional staff, with the states covering basic infrastructure costs (i.e. on-costs/overheads). In addition, the PHC agreed that cost-sharing arrangements should only be applied to targeted surveys to delineate the extent of an outbreak, concentrating primarily on the edges of the known outbreak site, and to restore pest-free-area status in the outbreak area.

The general principles governing Commonwealth/state cost-sharing arrangements for response actions are now reasonably clear-cut and there is usually agreement between the states and Commonwealth on what is and isn't covered under these arrangements. However, the specific details of cost-sharing can be less clear, especially in cases where there is debate on whether the programme is an eradication campaign or a suppression programme. Approval of funding by the Primary Industry Standing Committee (PISC) is not guaranteed and considerable negotiation on the part of officers in both state and Commonwealth departments can be required to secure funding. PISC agriculture agencies and individual agricultural industries are currently developing and negotiating cost sharing models between governments and industries. The core principle being applied is that the level of contribution by government or industry would be based on the pest's level of impact and benefits of control/eradication to an industry versus the public.

Defined endpoint and monitoring

The outbreak of an exotic pest may result in an immediate loss of access to interstate and international markets, until certain conditions can be met or eradication is declared. For exporting industries in particular, the costs associated with restrictions on host produce can be significant.

While there are IPPC guidelines on eradication and developing area freedoms, these guidelines are generic. Before initiating a response programme, clear goals and milestones should be set; based on biological and operational factors, ongoing monitoring and review of the programme, and the likelihood of success. Factors such as increased distribution, ineffective controls, and persistence – among others – can trigger the legitimate closure of a programme and/or direct it into developing area freedoms, or ongoing management. If the pest outbreak is restricted to only a part of the country it is possible to use surveys to establish areas that are unaffected by the disease. “Pest Free Areas” (area freedom) can be used to underpin access to local and overseas markets for various plant products provided that these are established, maintained, and verified as being pest free in a manner consistent with the IPPC standard.

An increased level of preparedness and response planning

In 2000, the national Forest Health Committee released a Generic Forest Incursion Management Plan (GIMP) to facilitate preparedness and response actions to potential new incursions of exotic pathogens or invertebrate pests into Australia.

Currently, Plant Health Australia, in association with various members, is developing specific industry biosecurity plans, which – at this time – do not include forest industries, but may serve as a model for future development of emergency response planning. Key elements to developing appropriate response plans include:

- identification and assessment of pest risks;
- risk mitigation strategies;
- surveillance and diagnostic strategies;
- response procedures and defined roles and responsibilities; and
- termination and post eradication strategies.

It is impractical to develop pest-specific planning for all the numerous potential plant pests and, therefore, a generic system is required that can offer procedures to facilitate rapid development of pest-specific responses based on incursions. In Australia, there is a generic incursion management plan that offers a structured approach to assess and respond to incursions through the Plant Health Committee, Forest Health Committee and/or Australian Weeds Consultative Committee, which are composed of technical and policy staff from relevant government agencies. In Australia, the majority of exotic pest responses are managed under generic incursion management due to the number and scope of pest incursions and potential pest incursions. In most instances, appropriate and timely diagnostics, quarantine, management, communication and funding decisions have been made.

Specific pest response plans can be developed for targeted key pests and those that have very high potential impacts. In pest-specific plans, information on biology and ecology – such as host ranges, agreed diagnostic procedures, quarantine procedures, management procedures, communication and funding – is developed prior to an incursion and can aid in a rapid response and a clear understanding of roles and responsibilities. While pest-specific plans can assist in the decision and response process they are not static and require constant updating. There is currently a major initiative to involve governments and industry in developing biosecurity strategies for key specific pests, to enable more defined funding arrangements and a better level of preparedness.

Factors whose development prior to an incursion aid in effective responses include:

- Prevention:
 - barrier quarantine; and
 - regional planning and cooperation.

- Preparedness:
 - profile of the industry(ies) at risk;
 - threat identification – based on pathway analysis and risk assessment;
 - data sheets for target pests;
 - surveillance;
 - awareness and training;
 - diagnostic capacity;
 - knowledge of industry pest status;
 - agreed host list;
 - agreed position on funding (and compensation) for eradication;
 - analysis of legislative framework; and
 - research and development opportunities identified.

- Response planning:
 - procedures for initial response alert;
 - protocols for surveying, sampling and tracebacks;
 - control strategies (including quarantine control);
 - cost-benefit analysis;
 - criteria for recommending eradication;
 - procedures for retaining market access;
 - communication strategy; and
 - management and coordination (including roles and responsibilities).

Managing invasive species: the threat to oil-palm and rubber – the Malaysian plant quarantine regulatory perspective

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Abstract: Currently, the acreage of oil-palm and rubber in Malaysia is 3.3 million hectares and 1.47 million hectares respectively. Both crops are among the country's major agriculture exports and have contributed significantly to foreign exchange earnings. At present, Malaysia is very fortunate that the majority of dangerous pests or alien invasive species that could destroy agricultural industries are still not found in the country. These include *Microcyclus ulei* (P. Henn) V. Arx., the pathogen responsible for the South American Leaf Blight (SALB) disease for rubber, and fusarium wilt (*Fusarium oxysporium* f. sp. *Elaeidis*) for oil-palm. The introduction of invasive pests or diseases – whether by accident or otherwise – could spell disaster for Malaysia, which estimates total revenue from exports of rubber and rubber products to be 10 billion ringgit (US\$2.6 billion) and oil-palm export earnings of 17.4 billion ringgit (US\$4.6 billion). In view of the threat posed by invasive species, this paper highlights several measures that have been instituted to counter these threats. In Malaysia, the management of invasive species includes the prevention, eradication, containment and suppression of such pests. The Plant Quarantine Act 1976 and Plant Quarantine Regulations 1981 provide a legal framework to manage and prevent the introduction and occurrence of an invasive species. Plant quarantine activities provide the first line of defence in managing invasive species of plants. The effective implementation of this Act could prevent their potential introduction or their establishment. Besides plant quarantine measures, other activities conducted to assist in managing threats posed by invasive species are also highlighted. When species appear to spread widely and are permanently established, the control measures taken are aimed at reducing the pest population and reducing the effects or damage. An integrated management technology involving suitable combinations of cultural, chemical, biological, physical and mechanical methods is recommended. Research bodies – either government or private – have played important roles in helping regulatory bodies, extension agencies, individuals and the general public, in managing invasive species.

Introduction

Malaysia is traditionally an agricultural country. Although Malaysia has broadened and diversified its economy through industrialization, agriculture remains an important sector. In terms of land use, agriculture takes up nearly 7 million hectares representing about 22 percent of the available land in Malaysia. The bulk of agricultural land is devoted to rubber, oil-palm and rice. At present, oil-palm, rubber, and the timber sector, form a major part of the country's exports and contribute significantly to foreign exchange earnings.

Nevertheless, the area under rubber is on the decline, down to 1.47 million hectares since a peak in the 1980s. The decline in production has led to the closure of many processing plants, especially the smaller and less efficient ones, due to a shortage of raw materials. Thus, the import of raw materials from other producing countries is on the increase to meet the demands of local processors and rubber product manufacturers. Revenues from rubber, including downstream industries, are about 10 billion ringgit (US\$2.6 billion). The area of oil-palm has increased to some 3.3 million hectares, and has export earnings of about 17.4 billion ringgit (US\$4.6 billion). The industry has remained resilient in the face of many challenges and has continued to contribute significantly to the national economy.

Many factors such as insect pests, pathogens and weeds can limit the production of crops. At least 30 percent of crop losses can be attributed to pests. Owing to the increasing flow of international traffic, tourism, and demand for new germplasm and crop varieties, it is increasingly difficult for the plant quarantine system to safeguard Malaysia from the entry of exotic pests.

Invasive species of rubber and oil-palm in Malaysia

Malaysia is fortunate in that the majority of invasive species affecting both rubber and oil-palm plantations, such as *Microcyclus ulei* (P. Henn) V. Arx., the pathogen responsible for the South American leaf blight (SALB) disease for rubber and the fusarium wilt *Fusarium oxysporium* f. sp. *Elaeidis* for oil-palm, have never become established. An overview of the most important pests and diseases for rubber and oil-palm is given in Table 1. Examples of invasive weed species affecting oil-palm and rubber in Malaysia are listed in Appendix 1 of this paper.

Table 1: Major pests and invasive species to oil-palm and rubber not yet recorded in Malaysia

Scientific Name	Common Name
Oil-palm	
<i>Fusarium oxysporium</i> f. sp. <i>Elaeidis</i>	Fusarium wilt
<i>Cecospora elaeidis</i>	Cercospora leaf spot
<i>Rhadinaphelenchus cocophilus</i>	Red ring disease
<i>Phytomanas staheli</i>	Sudden wilt
<i>Rhynchophorus palmarum</i>	Palm weevil
<i>Leptopharsa gibbicarina</i>	Lace bug
Rubber	
<i>Microcyclus ulei</i> (P. Henn) V. Arx	South American Leaf Blight
<i>Thanatephorus cucumeris</i>	Target leaf spot
<i>Phyllachora huberi</i> or <i>Catacauma huberi</i>	Black crust/Black scab
<i>Erinnyis ello</i>	Sphinx moth
<i>Leptopharsa hevea</i>	Lace bug

The first major economic impact of SALB was experienced when it destroyed two of the earliest large rubber plantations at Belterra and Fordland in Brazil in the 1930s (Holiday, 1970 and Hilton, 1955). A plantation established in 1935 by Goodyear, in Panama, was completely destroyed by SALB by 1940 (Holiday, 1970). Since then SALB has remained as a major obstacle to a viable natural rubber industry in South America. The introduction of this invasive pathogen would spell disaster for the plantation industry in Malaysia. The industry employs an estimated 40 000 workers and any factor that poses a threat will create social problems. Therefore, the role of plant quarantine is important in order to manage and prevent the entry of alien species and diseases by regulating the import of agricultural commodities.

Plant quarantine legislation in Malaysia

In most countries, plant quarantine is the first line of defence against the introduction of exotic or invasive pests and diseases, by regulating the flow of plant materials. The Plant Quarantine Act 1976 and the Plant Quarantine Regulations 1981 came into force in 1976 and 1981 respectively and are implemented by the Department of Agriculture (DoA). The Act provides a broad legislative framework for the Director of Agriculture and his appointed officers to destroy, remove or treat plants or pests that affect the agriculture of the country. In addition, there are provisions under the Act that provide Plant Quarantine Officers and Inspectors with the authority to isolate, manage, contain and eradicate any dangerous or exotic pests, as deemed necessary. The Act also provides adequate provisions to call upon relevant bodies or organizations in the country to collaborate and to enforce any action to eradicate or control pests and diseases. The Act prohibits the import and possession of noxious plants and pests.

The DoA has jurisdiction over the import of plant species, plant products, growing media/rooting compost, beneficial organisms, plant pests and carriers of plant pests. Under the regulations, special emphasis is given to procedures for the import of plants from the American tropics and the West African cocoa region, where serious pests of rubber, oil-palm and cocoa occur. In addition, under the Plant Quarantine Regulations 1981 oil-palm and rubber are classified as restricted materials.

The export of plants is controlled under the Customs Order (Prohibition of Exports) 1988. Any export of plants requires an export license issued by DoA. These regulations assist in managing and preventing the movement of plants or pests of an invasive nature into other countries.

Plant quarantine regulatory measures against invasive species of rubber and oil-palm in Malaysia

Malaysia has established stringent plant quarantine measures and procedures to prevent the introduction of dangerous pests or invasive species of oil-palm and rubber. These measures and procedures are discussed below.

1. Restrictions on the importation of planting materials

The Plant Quarantine Regulations have provisions to restrict the import of planting materials and agricultural products. The import of any rubber or oil-palm planting materials is prohibited EXCEPT:

- when imported for research purposes or on a government-to-government basis; AND

- such plant material has been subjected to quarantine in Malaysia or shipped to an intermediate country, where SALB is not present, for treatment consisting of washing with disinfectant and repackaging of the consignment; AND
- an import permit has been obtained from the plant quarantine authority and a phytosanitary certificate conforming to the phytosanitary measures of Malaysia accompanies the consignment.

For consignments imported under refrigerated conditions, for example fresh fruit and vegetables, specific treatment of the consignment is required, regardless of the length of the journey to Malaysia. The treatment is as follows:

a) Air/flight:

- an import permit from the DoA is required; and
- the consignment has to be reshipped to an intermediate country, where SALB is not present, for treatment consisting of washing with disinfectant and repackaging of the consignment.

b) Vessels:

- fresh fruits or vegetables must be washed with water;
- after washing, the water has to be treated with fungicide to kill any SALB spores present;
- the original packaging has to be burned and the consignment repacked; and
- the inside of the container has to be sprayed with fungicide to ensure that all SALB spores present are killed.

For the import of agricultural goods (in dry and unrefrigerated condition) by vessels from South American tropical countries where SALB is present, the following treatment is required:

- an import permit is required; and
- the consignment can only be opened for inspection and release 40 days after the export date.

If the import of the consignments does not comply with the conditions stipulated above, the consignment will either be refused entry or disposed off.

2. Measures for passengers on direct flights from the American tropics and African regions

Direct flights from the American tropics and African regions have commenced in order to develop social relationships and promote trade with these regions. This will result in a tremendous increase in the movement of people and trade, which also increases the risk of introduction of dangerous pests. The most threatening disease due to these direct flights is SALB. The following measures have been implemented (for passengers on direct flights from the American tropics and Africa) to prevent the introduction of SALB:

a) Interception of passengers and baggage:

i. Plant Quarantine Declaration Card

A Plant Quarantine Declaration Card was introduced to facilitate the interception – by Immigration and Plant Quarantine Officers – of travellers from the American tropics. Passengers coming from the American tropics have to report to Plant Quarantine.

ii. In-flight announcement

Malaysian Airlines makes an in-flight announcement, requesting passengers who have been to the American tropics within the past 30 days to report to the Plant Quarantine counter on arrival.

iii. Passenger and cargo manifest

The airline provides Plant Quarantine officers with the passenger and cargo manifest in order to assist the officers in intercepting passengers and cargo from the American tropics.

iv. Notification

Malaysian citizens who intend going to the American tropical region are required to inform the DoA about their journey by filling in form PQ10. They are advised to break their journey in countries where SALB is not present, for at least three days, where their clothes can be washed. The PQ10 form helps the Plant Quarantine Inspector to intercept travellers and take necessary measures when they return to Malaysia.

v. Double tagging

Double tagging of baggage from the American tropics to assist in the interception of the baggage.

vi. Separate compartment and conveyor for baggage

Baggage from direct flights from the American tropics to Malaysia is separated using different stowage compartments and conveyors.

b) Treatment for passenger

i. Floor-mat soaked with Dettol

The shoes of the passengers arriving from the American tropics are disinfected by walking over a floor-mat soaked in a 5 percent solution of Dettol. The mat is located on the passenger loading bridge.

ii. Air tunnel

An air tunnel is used to dislodge any SALB spores potentially attached to a passenger's body. The air tunnel is equipped with a blower, sucking devices, herpa filter and UV lights. If any spores are present they will be dislodged from the passenger's body and sucked through a herpa filter, where the spores will be trapped. The UV lights, at the top portion of the air tunnel, are switched on after all passengers have passed through the air tunnel to kill off any spores remaining inside the air tunnel compartment.

iii. X-ray machine

An X-ray machine is installed in the green lane at Kuala Lumpur International Airport, to detect any agriculture materials that are not declared by the passenger.

iv. Treatment of baggage

Baggage arriving from the American tropics is placed under UV lighting to kill any SALB spores attached to it.

3. *Pest risk analysis (PRA)*

A PRA is conducted for any import of oil-palm and rubber planting materials into the country. The PRA identifies and determines the following:

- the pathways for the pest to enter the region;
- the level of risk associated with each pathway;
- possible options for risk mitigation;
- the strength of measures that may be recommended to mitigate the risk; and
- the uncertainty associated with current information regarding the pest, its risk and management.

The significance of this uncertainty is used in determining appropriate measures.

A technical committee consisting of the relevant government agencies, researchers and universities is established to conduct the PRA.

4. Inspection at entry point

All imports of goods are subject to primary inspection at the port of entry. If, upon inspection, the imported goods or plant materials are found to be harbouring a pest, the plant quarantine inspector may:

- a) instruct the owner to treat the goods or plant materials;
- b) seize and dispose off the goods or plant materials; or
- c) refuse entry.

5. Post entry quarantine (PEQ) screening

Imports of plants and other regulated items that are of high risk – such as plants belonging to the Plamae and Hevea families – are subject to post entry quarantine measures including:

- a) thorough examination or observation for the presence of pests – the period would be one-to-two years for perennial crops or for a particular period to allow a particular disease to express the symptoms on the plant; and
- b) further treatment prior to the release of the plant materials.

The PEQ unit of the Department of Agriculture at Serdang, Malaysia conducts all post entry screening of plant materials.

Other activities implemented to manage the invasive species threat

Other activities implemented to assist in managing the threats posed by invasive species include:

1. Amendment of the plant quarantine legislation

The protection of agriculture has been, and continues to be, the primary focus of the DoA efforts to prevent invasions by non-natives species into the country. However, for the effective enforcement of these regulations, there is a need to amend the legislation to more thoroughly address invasive issues and problems. Currently, the DoA is in the process of amending the Plant Quarantine Act 1971 to adequately address invasive species issues.

2. Monitoring survey and surveillance

The Rubber Board and Oil-palm Board of Malaysia, with the assistance of DoA personnel, conducts a biannual monitoring survey for the early detection of dangerous pests.

3. Contingency plan for the eradication and control of dangerous pests

Malaysia formulated an emergency contingency plan for the eradication of SALB in 1988, in the event that SALB is detected in the country. The contingency plan identifies and delineates the roles, duties and responsibilities of all agencies and rubber plantation owners that form part of the programme. The plan recommends, *inter alia*, conducting detection surveys for SALB and procedures for its eradication, if detected.

4. National technical committee on alien invasive species (AIS)

A technical committee on AIS has been established in Malaysia. The committee comprises members from government related agencies. The Ministry of Agriculture (MOA) spearheads the technical committee. The committee assists in:

- a) identifying national needs and priorities;
- b) creating mechanisms to coordinate national programmes;
- c) enhancing cooperation across sectors to improve detection, eradication and control of AIS;
- d) promoting awareness of multi-sectoral threats and involves all stakeholders – including local and indigenous committees – in national strategies, decisions and action plan; and
- e) collaborating regionally and internationally to tackle the growing threat.

The Department of Agriculture, under the Ministry of Agriculture, and ASEANET will be organizing a national workshop on AIS in Kuala Lumpur.

5. Training

Training is an important aspect of capacity building. There is a need for enhanced training in both knowledge and skills in identifying the causal organisms of dangerous oil-palm and rubber pests. Plant quarantine staff, pathologists and entomologists at entry point need to be trained to become competent in detecting, intercepting and identifying the pests. The Rubber Board Malaysia has provided assistance in training some of our plant quarantine staff at the entry point. However, more regular training of this nature should be carried out in future.

6. Creating awareness

There is a general lack of awareness by the public of the dangers posed by the introduction of invasive species. Creating awareness can be achieved by various means such as distribution of pamphlets, public talks, meetings, dialogue and training with regard to the importance and threats of invasive species. Two pamphlets on SALB have been produced and distributed by the Department of Agriculture to all the Embassies in the American tropics, traveling agents, airlines and the tourist authority for providing information regarding the importance and prevention of the introduction of SALB into the country.

7. Notification of participants and delegates coming from South American/West African regions

Many international and regional meetings, conferences and conventions have been hosted by Malaysia recently. A system has been established in Malaysia that any organization hosting such an event, where delegates come from the American tropics or West Africa, is required to inform the DoA of these participants. The DoA makes the necessary arrangements to brief the organizers and participants on threats and impacts of a potential introduction of AIS.

8. Research

Research institutions of government-related agencies such as the Rubber Board Malaysia and Universities conduct a research and development programme in collaboration with the DoA, with a focus on prevention and control of invasive species. Research has been conducted on screening techniques at airports and the monitoring and identification of spores trapped in the air tunnel. Both government and private research organizations play an important role in helping regulatory bodies and the general public in managing invasive species.

Conclusions

The plant quarantine law and regulations need constant review and amendment in order to ensure that the issue of invasive species is properly addressed. Emphasis will also need to be given to increase capacity building and human resource development in order to develop a work force of highly trained, specialized, motivated and visionary personnel, and in enhancing the efficiency and quality of plant quarantine services in prohibiting and limiting the entry of invasive species into the country.

In addition, international, regional and national cooperation and coordination efforts are of paramount importance to minimize the impact of invasive species, as well as detecting, controlling and eradicating invasive species that are pests to agriculture and wild flora.

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Appendix 1: List of invasive weeds in oil-palm and rubber in Malaysia.

Common Name	Scientific Name	Suspected origin	Distribution
Siam weed	<i>Eupatorium Adoratum</i> L.	North America	Throughout Malaysia
	<i>Asystasia coromandeliana</i> Nees		Peninsular Malaysia
Mile-a-minute weed	<i>Mikania micrantha</i> L.	South America	Throughout Malaysia
Goose grass	<i>Eleusine indica</i>	Africa	Throughout Malaysia
Creeping sensitive plant	<i>Mimosa invisa</i>	Tropical America	Throughout Malaysia

When good trees turn bad: the unintended spread of introduced plantation tree species in India

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Introduction

Alien invasive species (AIS) have been identified as one of the greatest threats to biodiversity around the globe, second only to habitat destruction (Singh, 2001). The introduction of AIS, either intentionally or accidentally, is a by-product of increasing international trade and travel. Intentional introductions of plants are mostly for use in forestry, agriculture, fisheries, aquaculture, landscaping, etc. Accidental introductions are helped by travel and imports of various items such as wood, food, etc. In either case, alien plants with weedy characteristics can have a serious impact on the various ecosystems with a range of negative effects, e.g. competition with indigenous flora and fauna, changes in nutrient cycling and hydrology, disrupting overall economic stability of local communities, and impacting on human health. Thus, biological invasion has become one of the most challenging environmental issues faced by humanity today – a matter of global concern.

Quantitative and/or qualitative information on positive and negative impacts of AIS on our environment are rather patchy. At a global level, information is either lacking or incomplete on the alien species involved and the extent of invasion by them. It is reported that in the United States of America, direct and indirect impacts of invasive species have contributed to the decline of 46 percent of all threatened and endangered species (Anonymous, 2003). The estimated number of invasive plant species in the country is known to be around 1 400, which occupy an area of 40 million hectares. Undoubtedly, monitoring, surveillance and eradication of AIS should be a matter of huge economic concern for individual countries. For example, AIS bring about losses of more than US\$137 billion in the United States of America, of which the share of invasive plants is around 10 percent of the total. The available statistics for India indicate that losses of some US\$130 billion occur annually (Anonymous, 2003). Whatever the cost may be, the unintended spread of invasive species continues unabated, despite earnest efforts to manage them, especially in developing countries.

Invasions by alien species are recorded from all the seven geographical regions on the globe. As for invasive plants, a species list is available for most regions, though it is far from complete. "Toppers" in the list for the Asia-Pacific region include: *Eichhornia crassipes* (water hyacinth) and *Salvinia molesta* (aquatic weeds), *Chromolaena odorata*, *Lantana camara*, *Parthenium hysterophorus*, *Mikania micrantha*, *Mimosa invisa* and *Ageratum conyzoides*. However, there is a dearth of information on exotic trees that have become invasive after their introduction in forest plantations worldwide. This information is very essential, because these invasive trees can upset sustainable management of forest plantations and impact heavily on forest ecosystems.

A literature survey indicates that 277 tree species used in forestry worldwide are apparently invasive. Of these, 83 species are reported from Africa, 10 from Europe and 14 from Asia (Murphy and Haysom, unpublished). A majority of the invasive trees belong to Fabaceae, Pinaceae and Myrtaceae. Little information is available on why these trees were introduced in the first place, exact dates of introduction, extent of area initially planted, the spread, ecological and economic impacts, details of management, etc. With this background, an attempt has been made in this paper to examine the invasion and spread of introduced plantation tree species in India and the problems associated with these.

Exotic invasive trees in India

India is one of the mega-biodiversity countries in terms of flora and fauna because of its unique geographical position, varied climate and other factors. Of the country's 328 million hectares, approximately 20 percent is under natural forests. Five percent of the natural forests have been declared protected areas. The country has 500 wildlife sanctuaries, 89 national parks and 13 biosphere reserves. The types of natural forests range from alpine to tropical evergreen. Forests in northeast and southwest India (Western Ghats) are very rich in biodiversity and are recognized as a biodiversity hotspot (Nayar, 1997). As in other parts of the world, a wide spectrum of plants has been introduced to India through international trade and travel. Of the total plant species recorded from India, 40 percent have been identified as being alien (Saxena, 1991). The list of alien species is

increasing every year because of the large number of possible routes for alien species to enter and become established in the country. About 25 percent of the introduced species in India became invasive in a short period of time (50-100 years) (Murphy, 2001).

The main tree species introduced to India for forestry purposes include *Eucalyptus* (several species of which *E. grandis* and *E. tereticornis* dominate), *Acacias* (*Acacia auriculiformis*, *A. mangium* and *A. mearnsii* being the main species), *Prosopis juliflora* and *Leucaena leucocephala*. There are also several other minor species and some others introduced for non-forestry purposes. The extent of area planted under these species varies greatly between the different states and reliable data are unavailable for the whole country. Eucalypts were introduced in the late 1800s from Australia, mainly for raising pulpwood and fuelwood plantations. Eucalyptus now comprises 25 percent of India's plantation estate and is a major source of income for farmers in central and northwest India. *Acacias* were also introduced from Australia, and are used for reforesting disturbed lands, for timber, fuelwood, etc.

Of these introduced tree species, eucalypts and *Acacias* have not generally shown invasiveness and they generally demand a lot of care for proper growth. Although coppicing is a common feature for *Eucalyptus*, regeneration and spread are unknown. Likewise, though regeneration is a characteristic feature of *A. auriculiformis* and *A. mangium*, spread has not been observed. However, invasiveness has been recorded for the other three species in the list, viz. *Leucaena leucocephala*, *Prosopis juliflora* and *Acacia mearnsii*. It must be mentioned here that the available information on the extent of invasion by these species, their positive/negative impacts, methods for management etc. are purely qualitative. Quantitative data have yet to be generated. There is also no comprehensive information on the extent of area planted with these species, their ecology and how they interact with indigenous species. Let us now consider the various aspects of these three tree species in some detail.

***Leucaena leucocephala* – Fabaceae**

Leucaena, a native of southeastern Mexico, was introduced into Asia in the 19th century. The precise dates of its introduction to India are unknown. However, it became popular in the country as a versatile tree in the 1970s. The species has now been introduced and grown across all continents except Europe and Antarctica (Anonymous, 1980). Of the three subspecies of *L. leucocephala*, subsp. *leucocephala* is the only one widely introduced outside Mexico.

Rationale for introduction

Leucaena is a hardy species that can grow on a wide range of sites and soils (except highly acidic soils). It is used for a variety of purposes such as fuelwood, charcoal, pulpwood, fodder, furniture making, soil improvement, etc. The species is also used in reforesting watersheds and slopes and reclaiming marginal, disturbed and degraded lands. These are probably the reasons for its introduction to tropical and subtropical countries. It is considered to be essentially a tropical species, requiring warm temperatures for optimum growth.

Distribution in India

The species has been planted in 21 states and two union territories in the country. Extensive areas have also been planted with *Leucaena* in central and northwest India.

Leucaena as an invasive species

It is an aggressive colonizer of degraded and disturbed sites and spreads naturally through seeds, which are produced in large numbers (Hughes, 1998). The species is noted to grow gregariously outside plantation boundaries and agricultural areas in northwest, central and south India. Its weedy nature is mostly reported from the states of Karnataka, Andhra Pradesh, Tamil Nadu, Punjab and Rajasthan. Invasiveness is especially noted in agricultural situations, or when it is used in land rehabilitation. Outside India, *Leucaena* is recorded as a weed in about 20 countries where it has been introduced, including Philippines, Sri Lanka and Vanuatu (Baguinon *et al.*, 2003; Weerawardane and Dissanayake, 2003).

Control

Mechanical control through slashing is widely practiced, but because the species coppices readily, slashing has not been effective. Chemical control through use of 2,4-D and other herbicides has been attempted in some states but with limited success. Biological control has been considered in Hawaii

(Smith, 1985) and South Africa (Neser, 1994), but discouraged by the economic importance of the tree. However, proposals for releasing a seed-feeding bruchid in South Africa are still under consideration (Neser, 1994). Formation of inter-specific hybrids with *Leucaena esculenta* and *L. diversifolia* is an impediment for biocontrol.

***Prosopis juliflora* – Fabaceae**

Prosopis juliflora, a native of Central and South America, is a small to medium-sized evergreen or deciduous spiny tree, with a short, crooked trunk and large crown. It is highly regarded as a fuelwood source in many tropical countries. *Prosopis* occurs worldwide (in 52 countries) with wide distribution in South America, Africa, South and Southeast Asia and Australia (Anonymous, 1980). The tree was introduced in India in 1880, in Ananthapur district, Andhra Pradesh State, to solve the acute fuelwood crisis.

Rationale for introduction

Prosopis is a multipurpose tree used as timber, fuelwood, charcoal, animal feed and also for reclamation of wastelands and sand dunes. It is a tough and resilient tree, adaptable to all frost-free semi-arid climatic regions (Hocking, 1993). The species will coppice, pollard and regenerate rapidly and is suited to a wide range of sites and soil types. In India, *Prosopis* fulfils the fuelwood needs of millions of households.

Distribution in India

It occurs in 11 states and two union territories mainly in the semi-arid zones. Widespread occurrence is reported from Tamil Nadu, Andhra Pradesh and Karnataka states. Extensive areas of wastelands in the capital, New Delhi, are occupied by *Prosopis*.

Prosopis as an invasive species

Prosopis grows gregariously on abandoned agricultural lands and all types of degraded and wastelands. Its weedy nature has been reported in the states of Tamil Nadu, Andhra Pradesh, Gujarat, Haryana, Karnataka and parts of Uttar Pradesh. Goats, which feed on the pods, aid in dispersal and spread. The tree has been reported as a weed from many countries including Philippines, Sri Lanka and Sudan (Baguion *et al.* 2003; Weerawardane and Dissanayake, 2003). *Prosopis* was introduced in Sri Lanka in 1880 for land reclamation. Currently it is reported to be spreading rapidly in the coastal belts of southern and western provinces. Widespread occurrence was also found in the Bundala National Park, severely affecting the ecosystem (Weerawardane and Dissanayake, 2003).

Socio-economic relevance of the tree in India

In parts of Tamil Nadu state (Ramanathapuram district), farmers find it profitable to allow growth and colonization of *Prosopis* in their dry lands compared with cultivating cereals and millets (Nambi, 2000 – personal communication). The trees are allowed to grow for a few years and are then converted to charcoal, thereby contributing significantly to the socio-economic situation in the state. A similar situation was also noticed in Ananthapur district in Andhra Pradesh and Bellary in Karnataka. Apart from providing means for farmer livelihoods, *Prosopis* also meets demands for fuelwood.

Control

Eradication programmes against *Prosopis* have been attempted in several countries through chemical and mechanical methods but proved unsuccessful. In India, use of herbicides has been attempted in the past but no information is available on control measures adopted now. Because cutting promotes regeneration, mechanical methods of control cannot be recommended. Like *Leucaena*, inter-specific hybridization with a closely related species, *Prosopis pallida* is common and it challenges attempts for biocontrol. One reliable method of control is thinning and pruning of seedlings to less dense spacing, which accelerates the self-thinning process. This will promote growth of *Prosopis* and increase soil fertility through nitrogen fixing and decomposition of nitrogen rich litter. It is observed that the resultant growth of the ground cover (indigenous species) discourages or reduces establishment of *Prosopis* seedlings.

***Acacia mearnsii* (black wattle) – Fabaceae**

Acacia mearnsii, a native of southeastern Australia, is one of the fast-growing trees of the highland tropics, widely used as a source of tannin, fuelwood, charcoal, poles and green manure (Anonymous, 1980). It is also used for soil erosion control and soil improvement. The species was introduced in India in the early 1800s and now occupies approximately 20 000 hectares in the country.

Rationale for introduction

Its multipurpose use and ability to grow in a broad spectrum of soils and sites prompted introduction. Black wattle is mainly grown in highland areas (altitudes above 1 000 metres) in the country. Tannin industries based on the species are operated in several tropical and subtropical countries.

Distribution in India

It is grown in the states of Andhra Pradesh, Assam, Karnataka, Kerala, Maharashtra, Meghalaya, Tamil Nadu and West Bengal. The species is known to occur in 25 countries in the tropical and subtropical regions of the globe. Extensive areas under black wattle exist in Brazil (200 000 hectares), South Africa (160 000 hectares) and East Africa (30 000 hectares). In addition to these, there are unrecorded plantings in agroforestry systems in many countries.

Black wattle as an invasive species

Black wattle is an aggressive colonizer due to its hardy nature and high competitive ability (Boucher, 1980). In India, invasiveness has only been reported from the states of Kerala and Tamil Nadu, but perhaps this only means that the invasiveness has escaped attention in other areas (Von Lengerke and Blasco, 1989; Sankaran, 2002). In most parts of the Nilgiris (Tamil Nadu), where it was introduced as early as 1831, it has virtually taken over the shola forests (southern montane wet temperate forests) and grasslands (Von Lengerke and Blasco, 1989). Khan (1978) has reported that bird diversity was extremely low in *A. mearnsii* plantations, compared with adjacent shola forests in the Nilgiris. Noble (1967) cautioned that planting of exotics like *Acacia* and eucalypts in the Western Ghats will be highly detrimental to the shola forest ecosystem. Black wattle is reported as a weed in several other countries including South Africa (Adair, 2002). The spread is helped by production of large numbers of seeds, which remain viable for several years. Seed dispersal is through birds and animals.

Control

Seed feeding insects have been introduced in South Africa to control seed production of black wattle, which has been successful to a large extent. However, its value as a crop has produced protests against adopting biocontrol measures. Control measures are not attempted anywhere in India. The state forest departments are unaware of the magnitude of the problem of *A. mearnsii* invasion in the different states.

Invasiveness of *Acacia mearnsii* – a case study from Kerala

Acacia mearnsii was introduced in to the state of Kerala in 1981, with the main intention being the conservation of natural grasslands in high altitude areas. It now occupies approximately 3 200 hectares in the Munnar and Marayur forest ranges (at altitudes 1 000 metres to 2 200 metres) in the Idukki Forest Division. The tree is used locally as fuelwood, for poles, and as a shade tree in tea plantations. Collection of bark and gum by local people is also observed.

The establishment of plantations was mostly unsuccessful because the trees failed to grow on the shallow soils in the grassland due to root coiling. However, the trees eventually invaded adjacent natural shola forests, where soil depth was greater. The spread was facilitated by seed dispersal by birds and animals like bison and deer. The collection of tree branches by local people for fuelwood purposes also contributes to seed dispersal. Thus, *A. mearnsii* is well established in the shola forests, suppressing natural vegetation in most of the localities where it was introduced.

Surveys carried out by the Kerala Forest Research Institute (1999-2002) indicated that black wattle has invaded deep inside shola forests at Mannavan shola (altitude 2 400 metres), Vattavada (1 800 metres), Rajamalai (2 140 metres) and Kolukkumalai (2 480 metres). The current extent of spread is estimated to be around 10 percent of the original planted area in these localities. It is

expected to attain unmanageable levels in the near future causing irreversible damage to the shola forest ecosystem.

Shola forests in the Western Ghats are very rich in flora and fauna (Nair *et al.*, 2001). They are considered ecologically unique, because they harbour many endemic species. Some of these species are thought to be endangered or threatened (Table 1). There is great concern that black wattle may cause extinction of vulnerable and critically endangered species among these if its spread to the shola forests continues at the present pace. A careful study may reveal the extent of damage that has already been done.

Table 1: Rare, endangered and threatened species in montane shola forests of Kerala, India

Family	Species	Habit	Status
Acanthaceae	<i>Justicia notha</i>	Herb	Critically endangered
Annonaceae	<i>Polyalthia rufescens</i>	Tree	Endangered
Apiaceae	<i>Pimpinella pulneyensis</i>	Herb	Possibly Extinct
Apiaceae	<i>Vanasushava pedata</i>	Herb	Rare
Araceae	<i>Arisaema barnesii</i>	Herb	Threatened
Asteraceae	<i>Vernonia heynei</i>	Shrub	Critically endangered
Asteraceae	<i>Helichrysum perlanigerum</i>	Herb	Endangered
Asteraceae	<i>Anaphalis travancorica</i>	Herb	Rare
Asteraceae	<i>Vernonia saligna var. nilghirensis</i>	Shrub	Vulnerable
Balsaminaceae	<i>Impatiens elegans</i>	Herb	Critically endangered
Balsaminaceae	<i>Impatiens anaimudica</i>	Herb	Endangered
Balsaminaceae	<i>Impatiens denisonii</i>	Herb	Endangered
Celastraceae	<i>Euonymus angulatus</i>	Tree	Vulnerable
Elaeocarpaceae	<i>Elaeocarpus recurvatus</i>	Tree	Vulnerable
Ericaceae	<i>Rhododendron arboreum ssp. nilagiricum</i>	Tree	Rare
Gentianaceae	<i>Exacum courtallense</i>	Herb	Rare
Lauraceae	<i>Actinodaphne salicina</i>	Tree	Endangered
Lauraceae	<i>Neolitsea fischeri</i>	Tree	Vulnerable
Melastomataceae	<i>Medinilla malabarica</i>	Shrub	Vulnerable
Melastomataceae	<i>Sonerila speciosa</i>	Herb	Vulnerable
Myrtaceae	<i>Eugenia calcadensis</i>	Tree	Critically endangered
Myrtaceae	<i>Syzygium densiflorum</i>	Tree	Vulnerable
Oleaceae	<i>Chionanthus linocieroides</i>	Tree	Endangered
Orchidaceae	<i>Coelogyne mossiae</i>	Herb	Vulnerable
Poaceae	<i>Isachne fischeri</i>	Herb	Rare
Poaceae	<i>Isachne setosa</i>	Herb	Threatened
Rubiaceae	<i>Hedyotis buxifolia</i>	Shrub	Rare
Smilacaceae	<i>Smilax wightii</i>	Climber	Rare
Symplocaceae	<i>Symplocos pendula</i>	Shrub	Endangered
Valerianaceae	<i>Valeriana hookeriana</i>	Herb	Endangered

The survey revealed the spread of *A. mearnsii* to Eravikulam National Park (2000 metres), a protected area, which is home to the endangered mountain goat, Nilgiri tahr (*Hemitraegus hylocrius*), (Rice, 1984). The species is planted in areas like Kattumala, Koyyamala and Kumarikkal (all approximately 2 500 metres in altitude) close to the Park from where it may have entered Eravikulam National Park. Previous reports show that the number of endemic species and the food species for the Nilgiri tahr in the grasslands decreased with the age of black wattle plantations in these localities (Karunakaran *et al.*, 1998). For example, while the number of endemic species was 14 in the grasslands without *A. mearnsii*, it was only three in the grasslands planted with the species (10-yr-old plantation). Additionally, the number of weeds was more (22 species) under *A. mearnsii* compared with non-planted grassland (2).

Invasion of black wattle into *Eucalyptus grandis* and a *Pinus-Cupressus* mixed plantation at Gundumalai (Munnar forest range) has also been observed. *A. mearnsii* virtually suppressed growth

of the plantation species, overgrowing and covering the entire plantation area. Use of the species as a shade tree in tea plantations in certain areas has accelerated its spread to new localities. In summary, the biodiversity of the shola forests in Kerala is under serious threat due to the unchallenged invasion by black wattle, necessitating the urgent adoption of control measures.

What makes a plant species invasive?

This is an open question for which satisfactory answers cannot be easily found. However, a few generalizations can be made from the available evidence. Small seed mass, production of a large number of seeds palatable to animals, short interval between seed crops, availability of fertile land for easy colonization, animal dispersal of seeds, high competitive ability and short juvenile period are a few of the important factors that promote invasion. Other factors like absence of natural enemies in the introduced area, ability to regenerate easily and thrive in a wide variety of sites and soil types and faster growth rate compared with indigenous flora are also significant. Early prediction of potential invasiveness of a species may help in preventing introduction of such species, but reliable tools are yet to be developed for such predictions (Dulloo *et al.*, 2002).

Management of alien invasive trees

A lack of awareness among foresters, policy-makers and other stakeholders of the negative impacts of alien invasives is cited as a major impediment preventing their management (Boudjelas and Saunders, 2002). However, it may be noted that in certain cases, even if the negative impacts are known, control methods are not attempted in view of the large investment already made on these trees and the socio-economic benefits. *Prosopis* and *Leucaena* are possible examples of this from the Asia-Pacific region. More generally, the development and implementation of control/management methods are defeated by a general lack of qualitative/quantitative information on invasive trees present in each country, lack of skills and experience. It could also be due to a lack of information on existing tools. Another point is that worldwide, coordinated and cooperative approaches have never been made to understand the ecology of AIS and develop methods for their management (Boudjelas and Saunders, 2002). This has made sharing of information very difficult.

Given the background of the already known enemies, let us now examine whether there are any potential species that are awaiting their turn to become invasives in India? Data indicate that there are several tree species introduced to India for forestry purposes, which are weedy elsewhere, but not yet in the Indian situation. Foremost among these is *Paraserianthes falcataria* (L.) Nielson, which is a native of the Moluccas, New Guinea and Solomon Islands, and has been planted widely in South India. *P. falcataria* is reported to be weedy in the Seychelles islands (Dulloo *et al.*, 2003). Likewise, *Swietenia macrophylla* King is another species that is weedy in Philippines and Sri Lanka (Baguion *et al.* 2003; Weerawardane and Dissanayake, 2003). There may be many more. Because we know the potential of these trees to become weedy, attempts need be made at the earliest possible juncture to prevent their spread. Periodic cutting and removal of these trees and rapid replanting of gaps with seedlings of indigenous species may be practiced as a first step to arrest spread.

Future needs

Efforts are primarily needed to identify all the invasive tree species present in each region. Attempts also need be made to understand the population ecology and autecology of the species and to quantify the extent of invasion and the ecological and economic impacts. To facilitate this, cooperation between countries in each geographical region is necessary. Such cooperation will pave the way for information sharing, capacity building and developing practical guidelines for managing the tree weeds. Additionally, each country needs to review existing quarantine regulations and make necessary changes, so as to prevent accidental introduction of exotics. Countries should also make arrangements for raising awareness on invasives among foresters and the common public through its agencies. It would be ideal if national forest policies contained clauses for control/management of exotic invasive species. As far as control measures are concerned, an integrated approach involving biological, chemical and mechanical methods would prove more successful than the use of any single method.

Acknowledgements

The authors thank Dr J.K. Sharma, Director, Kerala Forest Research Institute, India for encouragement. Dr Sankaran also wishes to thank FAO for providing financial support to participate in the Asia-Pacific Forest Invasive Species Conference held at Kunming, P.R. China during 17-22 August 2003. Thanks are also due to Dr N. Sasidharan, Scientist, Kerala Forest Research Institute and Mrs. Parkruthy Srivastava, Divisional Forest Officer, Munnar for their help.

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Acacias – are they a threat as invasive species in the wet tropics?

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Introduction

An invasive alien species has been described as a species that is new to a region and that has a negative impact on the new environment, ecologically, economically or socially. Invasive species have been reported to cause large economic losses, are threats to human health and welfare, and to sustainable development. The question now being asked is, “are the *Acacias* that have been introduced into the wet tropical regions beginning to prove to be invasive?” This paper expounds on the pro and cons of these *Acacias* and tries to provide a rational answer to this issue.

In Malaysia, there are two commercial species of *Acacia* introduced from Aru Island and New Guinea. These are the *Acacia mangium* and the *Acacia auriculiformis*. *Acacia auriculiformis* was introduced as an ornamental species over a hundred years ago and is now seen growing on vacant lands and in areas uninhabitable by other tree species. It is a durable species, less susceptible to rot than *Acacia mangium*. *Acacia mangium* on the other hand, is a promising fast-growing multipurpose tree species indigenous to northern Australia (Nicholson, 1981), as well as Papua New Guinea (Jones and Tham, 1980) and the islands of eastern Indonesia (NRC, 1983). It was first introduced to Malaysia (Sabah) as a firebreak species for the *Pinus caribaea* stands that were established in the early sixties (Lim, 1988). The species was later found suitable for plantation establishment due to its growth performance on a wide variety of soil and habitats (Tham, 1976; Nicholson, 1981). In Malaysia, both *A. mangium* and *A. auriculiformis* are classified as exotic species.

Properties of Acacias

Basically, *Acacias* are legumes. They nourish the soil by introducing/fixing nutrients such as nitrates into the soil, thus making the soil rich in nitrogen. The species are hardy and can survive on very lateritic and generally poor soils, where nothing else will grow. During their growth on such poor soils, *Acacias* help to enrich the soils and make them suitable for growing other more sensitive trees and crops. It is because of this very special characteristic of these species that they have been introduced as plantation species in Malaysia. In terms of wood properties, the wood is of reasonable quality suitable for normal and untreated garden furniture that do not come in direct contact with the ground. The wood is also relatively easy to work with, it has good bending and nailing properties and seasons well when the correct drying schedule is provided.

Commercial potential of Acacias

There is potentially a large market for certified *Acacia* products. Current applications include garden articles that are much sought after in France. In Japan, *Acacia* wood is also sought after for furniture, joinery and laminated floors for trucks etc. IKEA, the famous Swedish company, has started to use *Acacia* timber from certified sources for its furniture industry. The advantage of using *Acacia* is that the long-term availability of the timber can be safely ensured. Currently there is enough *Acacia* timber available that exploiting *Acacia* makes good commercial sense.

Ecological appeal of Acacias

There are a number of good reasons why commercial exploitation of *Acacias* – whether plantation-grown or from wildings – is an environmentally friendly and beneficial effort, regardless of the source.

Each cubic meter of *Acacia* timber extracted helps to preserve some indigenous/native trees in their natural habitat. Furthermore, *Acacia* is only planted on already degraded forestlands and this eliminates the need to clear native forest for establishing forest plantations. It is an excellent and ideal species to ameliorate soils that have been badly degraded such as tin tailings, bris-soils (a sandy, unstructured, soil type with low nutrient content and poor water retention qualities) and other heavily damaged types of soils. It helps to rehabilitate alang-alang (*Imperata cylindrica*) infested areas. In some cases it is used as a nurse tree in planting native species that need shade in the early stages of growth. Being pioneer species, when the native species canopy grows above the *Acacia* trees, the *Acacia* automatically fades off due to the shading effects. In a nutshell, *Acacia* plantations help to reduce the pressure on natural forests.

Diseases in *Acacias* of the wet tropics

Acacia plantations in the wet tropics are relatively free of disease, when compared with *Eucalyptus* (Old et. al., 2000). With extensive plantations being established with mono species of *Acacia*, fungal pathogens can be expected to be a problem in the future. The potential diseases of *Acacia* can be classified under four broad groups. These can be elaborated as follows:

➤ *Foliar diseases*

These include fungal spots, blotches, tip necrosis, powdery mildews and rust fungus. The rust fungus for example has been reported to be a serious problem in the plantations of Sabah. Effective fungicides are available to control such foliar diseases.

➤ *Stem canker disease*

The most common of the stem diseases is the pink disease that is very prevalent in rubber plantations. Methods to control stem canker are well established and hence it need not be viewed as a serious problem.

➤ *Root rots*

These root diseases are regarded as a serious threat to *Acacia* plantations in successive rotations. Such phenomena are severe, particularly when the roots from previous plantations are not completely removed. Particularly now, with the zero burning concept, roots are not completely removed and these pass on the root rot fungi to new plantings. The most common root disease noted is white rot fungi.

➤ *Heart rot*

Heart rot in *Acacia* is a seriously-studied disease of tropical *Acacias*. Trees affected by heart rot show stem defects and wasting away of the heartwood of the *Acacia* tree. When this disease strikes, the recovery rate for sawntimber is greatly reduced. However, if the timber is to be used for the production of pulp, such a defect is of minimal consequence. It is now believed that by proper selection of the appropriate provenance for specific sites, the attack of heart rot can be minimized or possibly even eliminated.

It is clear that plantation forestry based on *Acacias* in the wet tropics will have to consider diseases as a major factor in the management of stands for sustained productivity. The areas that warrant specific studies include nursery hygiene, silviculture, site management and tree improvement to minimize disease impacts during successive rotations.

Classification of *Acacias* in the tropics according to the source

According to where *Acacias* are found in Malaysia, they can be classified into three groups:

➤ *Afforested plantations*

This includes managed large-scale plantings on previously marginal land that includes alang-alang and belukar (shrub) land. *Acacia*, being a legume, grows best on nitrate deficient soils. It adds nutrients and thus improves the quality of the soils, while preventing laterization.

➤ *Reforested plantations*

These include plantations raised and managed on areas cleared of original primary native forest. On such soils the first rotation crops are very healthy and vigorous due to the presence of good amounts of leaf-litter and abundance of carbon and other nutrients present in the soil.

➤ *Feral or wild plantations*

Feral or wild plantations include trees that have proliferated on marginal land along the boundaries of plantations, forest clearings, rural areas and vacant land around town. Wild strains of hybrid *Acacia* (mangium x auriculiformis) can also be found on the peripheral zones between the *Acacia* plantations and rural settlements, where *A. auriculiformis* is grown for its ornamental value. As it is extremely hardy and prolific, *Acacia* gradually diminishes the potential rejuvenation of the original biota, which it colonizes in its early stages.

Are *Acacias* really invasive species in the tropics?

From the foregoing, what can be deduced as to the inherent feature of *Acacias*? Are they invasive or non-invasive? There are always two sides to a coin and, consequently, there are both pros and cons with anything we generally work with. What is important is that we have to evaluate whether the

benefits outweigh the negative aspects of the species. We need to look at the problem in the right perspective, which relates both to the economic and ecological perspectives.

From the economic perspective, *Acacia* produces excellent fibres that are good for pulp and paper. *Acacias* are easy to establish in plantations and their rotation cycle is very short, compared with most of the native species found in the tropics. The trees, if properly nurtured, will also produce fairly good timber for furniture and other panel products. Because of its ease in establishment and quick growth cycles, long-term availability and sustainability of the species for the industry can also be assured, thus, making *Acacias* good candidates for plantations in the tropics.

From an ecological perspective, in the wet tropics, to date there has been no report that says that *Acacias* penetrate natural undisturbed forest. They have, however, been reported to colonize areas that are left vacant after very heavy disturbances such as mining and other activities, which render the soil totally unsuitable for other indigenous species. On such soil types, *Acacias* serve as soil erosion control species and furthermore enhance the quality of such soils by fixing nitrogen and improving the soil carbon content through shedding and accumulation of its leaf litter. It has been reported to be an excellent species to rehabilitate land overrun by *alang-alang*. Finally, in very open areas in the wet tropics, *Acacias* have been successfully used as nurse trees for the revegetation of such land with climax native species.

Conclusion

Therefore from the above, the following conclusions can be drawn in regard to *Acacias*:

- in the wet tropics, *Acacias* appear to be more beneficial than a pest. However, this conclusion may not hold true for those regions in the dry tropics where, in nature, large tracts of open spaces in the forest and in savannah tracts occur. In such a landscape, invasion of *Acacias* is a great possibility;
- if proper management of the plantations is ensured, untoward spread of the species can be minimized; and
- not all exotic species are directly invasive but they need to be evaluated objectively.

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Pine wood nematode (*Bursaphelenchus xylophilus*) and other forest pathogens in Japan

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This presentation summarizes the recent situation of some invasive forest pathogens in Japan, with particular emphasis on the notorious pine wilt disease caused by the pine wood nematode.

The pine wilt disease

The pine wilt disease, caused by the pine wood nematode (*Bursaphelenchus xylophilus*), is the most serious disease in Japanese pine forests. And the nematode is a typical example of an invasive pathogen.

The damage was first found in Kyushu, southern Japan in the early 20th century and quickly spread northward. At first, the cause of damage was considered to be the result of bark beetles. However, in 1971, the damage was demonstrated to be a wilt disease caused by a new pine wood nematode, which was thought to be endemic to Japan. In 1972, the Japanese pine sawyer was shown to be the vector of the nematode. In 1979, the pine wood nematode was first reported in North America, and the Americans thought, "we've been invaded from Japan". In 1981, the nematode was confirmed to be the same species that had already been found in North America in 1934.

At present, pine wilt is also causing serious damage to forests of China, Taiwan, and Korea. Very recently the nematode was also found in Portugal.

The nematode is widely distributed in North America, but American pines are resistant to it, so it causes no damage to American pines. The nematode is believed to have arrived in Japan in pine logs more than 100 years ago from North America. Conversely, chestnut blight invaded the United States of America from Japan more than 100 years ago, killing many American chestnut trees. However, Japanese chestnut is resistant to this pathogen.

Records over the period 1977 to 2001 show that the total amount of wood damaged by pine wilt was greatest in 1979. It was almost 2.5 million m³. Recently, it has been depressed to less than 1 million m³ a year. But this is still a severe rate of loss.

The northern limit of the distribution area of the pine wood nematode is almost exactly the same as the distribution area of its vector (the Japanese pine sawyer). Recently, the northern limit has not shifted much.

The disease cycle of the pine wilt disease is very unique. The causal nematode is carried by the Japanese pine sawyer (*Monochamus alternatus*) and invades pines when the sawyer feeds on new shoots of healthy pines. The pine wood nematode has several special characteristics, which impede the water conductivity of the xylem. Thus, this disease is caused by cooperative work between the nematode and the pine sawyer.

Phylogenetic comparisons among isolates of the pine wood nematode based on mtDNA have been reported by Hamaguchi *et al.* (2000). *Bursaphelenchus mucronatus* is a morphologically similar species to the pine wood nematode, but it has a very weak pathogenicity to pines. Both species belong to completely distinct groups from each other. In the pine wood nematode, *B. xylophilus*, three different lineages were found. This result suggests that there might be multiple invasions of the nematode from North America to Asia. Similar studies using larger samples are needed to know the exact root of the invasion of the nematode.

To date, enormous amounts of labour and money have been required for controlling this disease. However, complete control of the disease has not been achieved. The most important point in the control measure is the eradication of the source of infection. Spraying insecticide on pine forests at infection time is very effective, however the widespread application of insecticide has a large negative impact on the environment. Recently, control measures stressed the following two points:

- 1) concentrated control for important pine forests over a limited area; and
- 2) conversion of less important pine forests into other tree species.

Needle blight of Japanese cedar caused by *Cercospora sequoiae*:

Japanese cedar, *Cryptomeria japonica*, is one of the most important sources of lumber in Japan. Cedar seedlings, in central Japan, first exhibited signs of a needle blight around 1910. It has since spread throughout Japan as an epidemic disease. The causal fungus of the disease was confirmed as *Cercospora sequoiae*, which already had been found in the United States of America on the giant sequoia. Fortunately, appropriate control measures were established by spraying chemicals in nurseries.

Pitch canker of Ryukyu pine:

Pitch canker caused by *Fusarium circinatum* is known as one of most serious diseases of pines in California, southeastern United States of America and Mexico. In Japan, the pitch canker was found on Ryukyu pine in Amamioshima Island, southern Japan, in 1989, and now the disease appears in wider areas in the Ryukyu Islands. There has also been a recent Korean report (Lee *et al.*, 1998) concerning an exotic pine. Careful monitoring of the extent of the damage is necessary because Japanese black pine is known to be susceptible to the pathogen. We are still unsure whether the disease was introduced from abroad or if it is endemic.

Examples of invasive insects to Japan:

Fall webworm (*Hyphantria cunea*) is a typical exotic pest that has invaded Japan from the United States of America. Since first found in 1947, widespread damage to endemic ornamental trees has occurred. Recently, beetles from Southeast Asia are causing damage to Japanese palm trees.

Threats to endemic species by some insects imported as pets:

Some insects imported as pets, mostly beetles with beautiful bodies, are causing a new problem (Makihara, 2003). Many escaped beetles attack Japanese plants, or mate with endemic species. These are a threat to genes of endemic species. A different regulation system is needed to address these problems.

Plant quarantine system in Japan:

Most of the forest products exported from Japan are wood-packing materials. The quarantine procedure for these differs, depending upon the importing country. Bonsai pines exported to the EU are first quarantined for two years at the growing site in Japan to check for rust diseases. The import of seeds, living woody plants and logs are subject to quarantine and a phytosanitary certificate issued by the exporting country is required. If any pests are found at the inspection, they are sterilized or the materials are incinerated. Completely processed lumber and wood chips are not subject to quarantine. Tree seedlings without soil, logs, and lumber can be imported from any country, except for certain tree species from some designated countries to guard against specific pests.

In spite of the quarantine system, it is possible that many exotic species are still entering Japan. Examples of detection of invasive pests at import plant inspection are as follows:

- for six years, from 1980 to 1986, many bark beetles were found from imported logs in Japan. Among these, 160 species were described as new species. This suggests difficulty in identifying these insects when they are found;
- in 1999, bark beetles were found 13 000 times in imported logs, including dangerous bark beetle vectors of pathogenic fungi from such genera as *Dendroctonus*, *Hylastes*, *Ips*, *Monoctonus*, *Platypus*, *Scolytus*, and *Tomicus*; and
- in 2000, harmful insects and pathogens were found 62 times on ornamental woody plants. These incidents show the real possibility of invasion by exotic pests hidden in logs and living plants.

Conclusion

As a conclusive summary of this paper, the following points need to be emphasized:

- exotic forest pathogens have the potential to destroy forest ecosystems in invaded countries;
- it is always possible to be invaded by a new exotic pathogen;
- insects imported as pets are a threat to endemic species; and
- acquisition of data on the geographical distribution of individual microorganisms and insects based on exact taxonomic knowledge is needed to prevent damage by new invasive species.

Acknowledgements

The author thanks Mr H. Makihara and E. Irei for their kind supply of pictures used in the presentation made to the conference.

Assisted natural regeneration: countering the impact of *Imperata* grass infestation in the Philippines

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Bio-invasive species in the Philippines are most evident in old areas of reforestation and plantations, where exotic species have been introduced and from where they have spread. Of the more than 60 exotic species identified, only eight are potentially competitors and invasive species, usually only where the forest is already degraded. Two of these species in particular are noted for invading degraded forest and retarding ecological succession. However, by far the greatest invasive species of degraded forest, especially such lands when subjected by migrants to shifting cultivation and seasonal fires, is *Imperata cylindrica*. This grass has taken over several million hectares of the Philippine uplands. There have been multiple attempts, using various different techniques, to regain these lands and bring them into productivity. However, one less-recognized approach is Assisted Natural Regeneration (ANR). ANR has been undertaken by the government on many sites, usually as pilot efforts to improve degraded forest. ANR is also carried out by some communities in *Imperata* – or locally known as cogonal – lands. This paper gives an overview of *Imperata* grass in the Philippines and a brief account of community management by the practice of lodging cogon.

The problem of *Imperata* infestation is that it primarily affects the uplands. The actual or potential area infested is about 9 million hectares of scrub and cogonal lands that are subject to shifting cultivation and occasional burning, although figures are not wholly comparable and compatible. The biogeophysical impacts of *Imperata* include:

- acting as fuel and altering fire regimes;
- displacing native regenerative vegetation;
- changing hydrologic regimes;
- reducing control of sedimentation and soil erosion;
- encouraging eutrophication of waters;
- changing the biodiversity; and
- reducing recruitment of species.

These all affirm the need for a return to the natural vegetation of a more utilizable and sustainable cover.

Looking at the management of the uplands over the last 50 years, there has been little focused effort to address the spread of *Imperata*. Corporate forest management led lowland migration to the uplands, expanding the social need for slash-and-burn (1960s-1980s). The government never comprehensively focused on improving grasslands, when leasing grazing rights and the extent to which government focused on *Imperata* through reforestation was not socially adapted and had limited impact. Tenurial rights of some 20 million people began in the 1980s, but only recently impacted on a larger area. Such community based management established tenure, but limited good practice. ANR strategies have not been sustained nor made socially responsive. Though ecological and economic concerns are integral to the response, they are not the primary factor. The problem is the socio-political-strategic programming needed with commitment and accountability from the top.

The cultural history of the Philippines helps give some indications as to how *Imperata* infestation might be dealt with over time. There have been significant social migrations to the uplands over the past 50 years, either from the lowlands or neighbouring islands. In many cases, logging operations left behind a substantial workforce, without a livelihood. The migrants had little means to sustain the productivity of the land, nor little reason to invest for the long-term, as they were legally viewed as squatters. Only recently has tenure been granted to many of these shifting farmers, however, support skills for managing *Imperata* lands are lacking.

Traditional utilization of *Imperata* lands varies. In many areas in Northern Luzon, photographs at the turn of the nineteenth century show less forest around villages than is present today. Old people tell of the distances they had to go to collect wood and that the elders had started planting pine trees from

the forests in abandoned *uma*. These woodlands are now part of the integral management of the terrace system, called *batangan* for the Kankanay or *muyong* for the Ifugao. Places for livestock are carefully managed by fire to enhance regeneration, without burning into the forest. Thousands of hectares of land are traditionally managed in this way. Much of the forest in the Philippines is within the cultural zone of indigenous peoples and more attention needs to be given to the indigenous management of grasslands and thus, return to better utilization.

Traditional *Imperata* minimization occurs in communities where there has traditionally been a long engagement and dependence on forest ecosystems that is not quickly disregarded. Slash-and-burn among traditional people is known as *kaingin*. Fields may only be planted for 2-3 years to avoid intensive use and family groups collectively decide the next field in rotation. Cogon is maintained in limited areas for household purposes such as re-roofing. Although croplands are now becoming more permanent due to multiple pressures, community practices may also include abaca planting and restocking of forest rattan. Such intensive land use, along with tree species, gives new aspect in agroforestry, while sustaining a relation with the forest and prevents the incursion of *Imperata*.

Looking more at national level development planning, plantation zones and production concepts such as the timber corridor concept have developed. One such plan is for the Caraga region in Northern Mindanao. The impacts, however, have not been well thought out: about 50 percent of one province becomes part of the plantation, it is expected to produce approximately 400 000 cubic meters of logs per year, 56 percent of the regional total. However, with indigenous peoples constituting 30 percent of the population and 65.9 percent of land area as ancestral domain lands, land utilization and productivity impacts a large area, with the concomitant loss of social cohesion and ownership.

The land conversion costs of *Imperata* lands call for an investment cost for the first rotation of approximately US\$700 per hectare. Site preparation is 25 percent of the cost, with seedling releasing and weeding constituting an additional 25 percent. Less investment is needed for the second rotation. There are new technical options of soil sterilants for non-crop areas and multiple applications of non-selective herbicide but they have not been used on a large scale. The result is that secondary forest is often selected for the establishment of plantations, so that an immediate return from harvesting trees can be used for investment. However, a new culture of small tree farmers with 5-10 hectares is emerging. These farmers enjoy a comparative advantage over the large-scale plantations in labour inputs, biodiversity recruitment and diversification and greater silvicultural options.

The impact of plantations on *Imperata* land rehabilitation is not entirely clear. They can utilize *Imperata* land and may arrest degradation if they focus on improved site management. They may create local work opportunities and improve social services, while contributing to the national economy, in the short-term. However, long-term nutrient availability is depleted and it is unclear as to the impact on future sustainability options and ecological services. Furthermore, the broader area land use by local people and local government is weakened.

In summing up the experiences of the last fifty years, particularly in the area of social forestry transitioning to community-based management of the Department of Environment and Natural Resources, a number of points can be made. Local communities must ensure sustainability, where the community stake is not derived from the salaries and allowances received from DENR and externally funded projects. But, benefits have not accrued from what has been planted; hence, DENR management has generally failed to introduce ANR to communities.

Plantations and the recognition of existing land uses have often been in conflict, partly because people have devised methods for utilizing areas for agriculture with some trees and areas maintained for a specific purpose. The main conflicts, with plantation establishment are: unclear land tenure for Community-based Forest Management (CBFM) and Certificates of Ancestral Domain Claimants, and a lack of community consultation during the planning process.

Assisted Natural Regeneration may be found in areas where individual communities practice resource diversity and where Certificate of Land Ownership Agreements (CLOAs) are awarded by the Department of Agrarian Reform (DAR) for sites utilizing *Imperata* lands. The lodging of cogon and selected weeding are seen as best practices in these areas. The cost of ANR is a small percentage of conventional reforestation techniques. What needs to be highlighted are sites that engage communities. On the whole, programmes need to embrace the importance of ANR and establish the integral management of the uplands with communities wherein ANR has a major role.

Forest land plantations are being reviewed by DENR. Action is also being undertaken regarding CBFM, including monitoring and apprehension of illegal CBFM logging activities and demanding the accountability of officials for permits. There is a call for departmental coordination in the granting of upland tenure and reassessing community resource use permits and forest protection responsibilities. There are new efforts to create awareness and skills training and a redesigning of ANR programming. Further dialogue towards process-driven and action-oriented systems is needed along with developing venues for entering markets for timbers sustainably grown on rehabilitated lands.

Important requirements are to:

- sustain action encounters with Indigenous Peoples and reinforce the directives of the National Commission on Indigenous Peoples, National Anti-Poverty Commission, and broader socio-cultural programmes;
- refine CBFM and meet legal markets as well as environmental responsibilities;
- revise watershed protection planting, local stakeholder involvement, support local tree farmer initiatives and collaborate with upland CLOAs;
- reinforce lodging of *Imperata* and daily conversion practices and select ANR sites beneficial to communities not as silvicultural projects; and
- establish realistic grazing lease charges and engage local government in the preparation and management of all programmes including plantations.

Infestation is not a one-time problem to be solved, but rather a condition to be managed. The utilization of multiple adaptive management approaches can result in better and long-term strategies in effective control of *Imperata* and assist regeneration in a more continuous manner by giving greater security to communities.

Country reports

Forest invasive species strategies in Australia

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Background

Importance of invasive species issues in Australia

Australia is relatively free from many serious pests of agriculture, including plantation forestry, through its geographical isolation. This position is attributed to the fact that virtually all cultivated crops, many pasture species, and a large proportion of Australia's plantation forest industries, are based on exotic germplasm. Through rigorous quarantine action, and some good fortune, many serious agricultural pests have been excluded and few indigenous pests have adapted to attack the exotic germplasm – a fact that can be attributed, in part at least, to Australia's unique flora.

The annual turnover of the Australian forest industry is valued at A\$15 billion (US\$10.4 billion). Protecting it is becoming increasingly hard due to increases in global trade and travel. The risks of entry and potential establishment of exotic pests has increased the risk and threat of impacts of these pests.

In addition to the natural pathway, through northern Australia from Indonesia and Papua New Guinea, potential pest pathways to Australia include thousands of incoming air and sea freight containers and their contents, 180 million mail items and over 9 million inbound passengers annually. Although numbers tend to vary from year to year, Australia must annually respond to approximately 40 newly recorded plant pests, 200 barrier breaches (pests that have been detected beyond the quarantine barrier but have not yet established) and 15 000 pest interceptions at the quarantine barrier.

Preventing pest introductions is a major component in any invasive species strategy; however, it is not without risk, with increasing pressure from both regulated trade and non-regulated trade (deliberate contravention of quarantine laws). Australia spends A\$166 million (US\$115 million) on quarantine activities annually and has spent over A\$200 million (US\$139 million) since 1996 on various plant pest eradication programmes.

In many instances, the impacts of new pests on Australian ecological and agricultural systems are little known. This uncertainty is compounded by the diverse ecological niches that Australia offers – as points of incursion establishment – in both temperate and tropical environments.

Australia's relative freedom from many plant pests of exotic trees, and the lack of information on the potential impact of exotic plant pests on native plant species, intensifies the importance of appropriate strategies for invasive species. Responding to invasive species also highlights the requirements for, and gaps in, basic plant health capacity issues such as surveillance and diagnostics.

Asian gypsy moth (*Lymantria dispar*) has been identified as a potential key threat, and has since been confirmed, through additional research on host testing with Australian native species. Although the pest has not evolved with *Eucalyptus* species, it readily feeds on many, highlighting its potentially significant impact on both commercial and conservation forests. Australia conducts a pheromone-trapping programme in all temperate first ports-of-call – one step to help mitigate this risk.

The aphid *Essigella californica* was first found in Australia in 1998. National surveys quickly found it in all states despite forest surveillance programmes. The aphid is not known to be a major pest on *Pinus radiata* elsewhere, or in its native range, but in Australia there are indications that it is causing significant damage in some states and research is continuing. This also highlights the difficulty in identifying key target pests and being able to adequately detect them early enough for effective response.

In 1998, a *Bursaphelenchus* sp. nematode, similar in taxonomy to *B. hunanensis*, was detected on various pine species in Melbourne. The dying pines were initially reported by local government workers. As a precaution, a national response was developed that included a survey, and eradication of infected pines in Melbourne. Infected pines showed a syndrome of sudden decline and death, but the syndrome was not consistent and was compounded by other disease and abiotic factors such as salt levels. Pathogenicity testing and diagnostics have proven difficult and to date no confirmation of the species, or illustration of it being a pest, has been made. During national surveys, many previously

Table 1: Forest types of Australia

	ACT	NSW	NT	QLD	SA	TAS	VIC	WA	Total ⁽²⁾
▪ <i>Acacia</i>	0	1 251	1 613	6 984	1 939	74	63	4 563	16 487
▪ <i>Callitris</i>	0	1 240	386	387	261	1	56	0	2 331
▪ <i>Casuarina</i>	0	1 000	14	216	763	1	4	40	2 038
Eucalypt malle	0	23	0	122	6 044	0	1 171	4 969	12 329
Eucalypt woodland	21	2 475	21 900	35 199	1 761	1 627	1 063	12 973	77 019
Eucalypt open	95	19 722	5 960	3 385	44	847	5 328	2 240	37 621
Eucalypt closed	0	0	51	0	0	0	0	39	90
Mangroves	0	3	356	196	19	0	2	173	749
<i>Melaleuca</i>	0	44	1 593	5 301	1	1	96	0	7 036
Other	0	415	738	1 059	34	19	135	398	2 798
Rain forest	0	486	224	2 885	0	598	16	5	4 214
Total native forest	116	26 659	32 835	55 734	10 866	3 168	7 934	25 400	16 2712
Hardwood plantation	0	54	2	20	28	120	129	235	588
Softwood plantation	15	270	5	181	115	75	216	103	980
Total plantation⁽¹⁾	15	324	7	201	143	195	345	338	1 568
Total Forest	131	26 983	32 842	55 935	11 009	3 363	8 279	25 738	164 280

Source: National Forest Inventory, 2003 (1) National Plantation Inventory, March 2002.

Note: (1) column or row totals may not add up due to rounding; (2) the plantation total includes 1 400 hectares of unknown species.

undescribed nematodes were found (not causing primary disease). This case highlights the lack of understanding of current plant health status, the role of exotics in a new ecosystem and lack of plant health capacity to diagnose potential plant pests, especially those that may not be major pests elsewhere.

The greatest proportions of the plantation estate are relatively evenly distributed across the three states of New South Wales (NSW), Western Australia (WA) and Victoria (VIC). The most extensive hardwood plantation areas occur in WA, Tasmania (TAS), and VIC, while the most extensive areas of softwood plantations are in NSW, VIC and Queensland (QLD) (Table 1).

Australian hardwood plantations are dominated by *Eucalyptus* species, supplemented by a small proportion of tropical rain forest and other hardwood species. Of the total hardwood species, *Eucalyptus globulus* comprises 62 percent (311 340 hectares) and other eucalypts comprise 19 percent (95 360 hectares). Softwood plantations are predominantly *Pinus radiata*, totalling 716 540 hectares (74 percent of total area of softwood species). Other softwoods including the native *Araucaria cunninghamii* and exotic *P. caribaea* and *P. elliotii* are significant in QLD, while WA has a significant *P. pinaster* resource.

Key forest pests in Australia

Vertebrate pests

Animal pests are responsible for a suite of destructive impacts including: browsing and ringbarking of mature and juvenile vegetation, competition for food and habitat, erosion, and predation of native fauna. For a comprehensive breakdown of pests, processes or agents impacting on forested areas please refer to Appendix 1.

Foxes are the most widespread exotic animals adversely affecting forested ecosystems. Occurring across mainland Australia, they have severely affected populations of small ground-dwelling mammals. Extensive (and expensive) baiting control programmes have reduced fox populations, but eradication is not foreseen.

Cats are a widespread problem across Australia, particularly in NSW native forests. The NSW National Parks and Wildlife Service estimated in 1997 that there were 400 000 feral cats in NSW alone, and around 12 million feral cats across Australia. These predators have a significant impact on native fauna. Baiting, trapping and shooting are used to manage these pests.

Rabbits are a major agricultural and environmental pest across most of Australia, costing between A\$600 million (US\$417 million) and A\$1 billion (US\$695 million) annually. Competing with native animals for food and habitat, they have contributed to the reduced numbers of many native animals. Rabbits destroy the landscape and are a major cause of soil erosion through the prevention of regeneration of native vegetation, foraging on foliage and ring-barking trees. A concentrated and integrated management programme exists for rabbits and includes biological (myxomatosis, calicivirus), chemical (baiting and fumigation) and mechanical control methods (shooting, fencing, warren destruction). In South Australia (SA), the numbers of rabbits are generally low – due to rabbit calicivirus disease (RCD) and other control programmes – however, even at low numbers, their impacts remain severe. Although the overall number of hares in SA is less than that of rabbits, their impact is equally severe in forested areas.

Kangaroos have a widespread and moderate impact in most states. Wallabies account for approximately 80 percent of browsing damage on regenerated juvenile trees following forest harvesting in VIC (1994-1996). In TAS, bark-stripping of young trees by wallabies is prevalent in 10-20 percent of 3-5 year-old *Pinus radiata* plantations, but mortality resulting from ring-barking (girdling) is rare. Possums also cause significant, localized damage by ring-barking upper stems and causing top death in older trees of *Pinus radiata* plantations.

Pigs have a severe and widespread impact on agricultural and native ecosystems across Australia, particularly in the Australian Capital Territory (ACT) and QLD. Rooting of soil causes physical damage and erosion, soil fauna is affected and some pathogens can be transmitted (for example, the fungal pathogen *Phytophthora cinnamomi*). Ground cover is destroyed, the composition of plant communities can change, and invasion by weeds often ensues.

Invertebrate pests

Eucalypt forests, woodlands and plantations are regularly browsed by a wide range of native insects including; leaf-chewing chrysomelid beetles, scarab beetles, sawflies, leaf skeletonizer moth larvae, and sap-sucking psyllids. Infestations are sometimes severe and repeated. Control programmes have been conducted in plantations where attacks may result in reduced growth and damaged form. Except for chronic attacks, eucalypts are generally resilient and able to replace their foliage after infestation subsides.

Where control of severe insect infestations in young plantations is required, insecticides are sometimes used. One of the problems with this approach is that the insecticide can also harm beneficial insects – i.e., those that reduce the population of the pest through predation or parasitism.

The gumleaf skeletonizer (*Uraba lugens*) causes very widespread and severe defoliation of entire natural eucalypt stands in all states, across a range of climatic and vegetation types, but generally few trees are killed. In plantations, impacts are not usually severe and controls not necessary. In WA this pest has been selected as a target species in the newly implemented FORESTCHECK monitoring programme, together with jarrah leaf miner (*Perthida glyphopa*) and bullseye borer (*Phoracantha acanthocera*).

Stick insect (phasmid) outbreaks, for example *Didymuria violescens*, occur cyclically in mature eucalypt forests in high elevation regions in NSW and VIC, where entire patches or hillsides of mature eucalypts (e.g. *E. viminalis*, *E. delegatensis*, *E. regnans*) are sometimes totally defoliated. Population monitoring and outbreak predictions are made by monitoring egg numbers in soil and litter.

Christmas beetle infestations occur at the forest/cleared land interface, particularly in red gum communities in VIC, but also in blue gum and flooded gum plantations in eastern Australia. These pests are difficult to control, so breeding strategies are being developed to produce resistant strains of eucalypt. Prolonged chronic outbreaks of sap-sucking psyllids, (for example in red gum forests and woodlands in VIC), which often involve *Cardiaspina* spp., can result in tree dieback and death.

Wingless grasshoppers cause total defoliation in young eucalypt plantations, particularly during droughts, and have been significant in several states including WA and SA. Pest management programmes are sometimes necessary.

Pests of exotic pine plantations that can reduce the commercial productivity of these forests include the pine-killing woodwasp (*Sirex noctilio*), Monterey pine aphid (*Essigella californica*), and the five-spined bark beetle (*Ips grandicollis*).

Sirex generally attacks stressed pine trees. Wasp numbers sufficiently high to cause significant attack do not generally develop in vigorous healthy stands, but this has been known to happen. In SA and VIC between 1987 and 1989, the *Sirex* wasp killed more than 5 million *P. radiata* trees (with a combined value of \$10-12 million). The National *Sirex* Control Strategy programme facilitates an integrated pest management approach based on ensuring low *Sirex* wasp populations, through the maintenance and release of virulent strains of the introduced nematode *Beddingia siricidicola*, as well as a range of parasitoid wasps, as biological controls. The programme also encourages optimum plantation thinning practices and site selection to minimize the occurrence of stressed trees in high-risk areas. Regular trapping and surveillance programmes monitor *Sirex* levels. Controls are implemented to avoid major outbreaks.

The Monterey pine aphid – first observed in Australia in 1998 – is able to infest a range of pine species and has since been detected in most pine-growing areas in all states. Thus far, mild to severe defoliations have been recognized in *Pinus radiata* plantations in VIC, NSW and SA, but the effects on growth yield are still to be assessed. Aphid levels are being regularly monitored in most states using standard foliage beating methods during surveys.

Ips grandicollis is a serious pine bark beetle pest accidentally introduced from the northern hemisphere and is able to infest all plantation pine species grown in Australia. The beetle has been present in Australia for at least sixty years and occurs in all mainland states and the ACT, but is absent from TAS. Pheromone traps are used to monitor beetle presence and beetle numbers in some states. Population levels build up primarily on fresh logging debris or in damaged or severely stressed standing trees. The beetle is also able to vector blue stain fungi such as *Ophiostoma ips*. A range of parasitoids has been introduced into Australia to limit beetle numbers.

Weeds

Blackberries (*Rubus fruticosus* sp. agg.), gorse (*Ulex europaeus*), *Lantana* (*Lantana camara*) and pampas grass (*Cortaderia* spp.) are examples of exotic plants that have become naturalized pests in Australia. These species compete with native flora in forests and woodlands, and can reduce biodiversity and other values. These four species are included in the Weeds of National Significance programme under the National Weeds Strategy. Pest plants also interfere with crop trees in commercial forest plantations, with associated negative effects on human access, tree establishment and growth, and product yield.

Blackberries occur in all jurisdictions, except the Northern Territory (NT). They are the single most widespread pest plant threat across southern Australia, mainly in regions with annual rainfall more than 750 mm. Current costs and changes in area affected are difficult to calculate. Estimates approximate to 9 million hectares, including non-forested landscapes. Control of blackberry in forests is primarily by spraying with herbicides. Strains of a blackberry rust fungus (*Phragmidium violaceum*), introduced into Australia during the past 20 years, have had variable but limited success as biological controls. An enhanced major long-term strategy for blackberry management and eradication on a statewide basis has recently been implemented in VIC.

Gorse is more problematic as a weed in TAS and southern VIC than elsewhere in Australia. In TAS alone, the estimated annual cost of production loss in 2001 was A\$1 million (US\$694 894) and the cost of control and rehabilitation was A\$700-1 500 (US\$486-1 042) per hectare. Under the National Weeds Programme A\$750 000 (US\$521 122) was applied to the Tasmanian Gorse Strategy in 2002.

Lantana infests approximately 4 million hectares, predominantly in the coastal forests and woodlands extending from far north QLD to southern NSW, but also occurs to a small extent in parts of the NT, WA and VIC. Whole ecosystems and many species are affected, while others are threatened, by this shade-tolerant, invasive plant, which develops dense shrubby thickets that out-compete native species. Environmental impacts also include major reductions in invertebrate and avian biodiversity. This, in turn, may increase the severity of crown defoliation diebacks in forest or woodland overstoreys. *Lantana* is gradually extending further inland. Integrated control measures include introduced sap-sucking insects and fungal leaf rust. Cutting back the plant, however, results in stimulated shoot proliferation.

Pampas grasses occur as weeds in VIC, TAS, NSW, SA and WA. National and/or regional weed strategies are in place. In TAS, a state-wide eradication programme, implemented in 1998, successfully resulted in the removal of tens of thousands of pampas plants.

Scotch broom (*Cytisus scoparius*) is particularly invasive in the Barrington Tops national park area, in NSW, across an area of about 50 000 hectares. A major protective weed eradication and integrated management programme has been implemented there.

Bitou bush (*Chrysanthemoides monilifera* spp. *rotundata*) is listed as a key threatening species in NSW. It mainly invades dune vegetation systems, but also encroaches into coastal forest and woodland communities. Biological controls such as bitou tip moth have been used with some success, forming part of the management strategy there.

Boneseed (*Chrysanthemoides monilifera* spp. *monilifera*) is more widespread across various environments and is found in southern NSW, VIC, southeastern SA and TAS. Spread by seed, it invades a range of woodland and forest types. Biological controls have not been successful so far, and eradication is by conventional means, including fire.

Willows (*Salix* spp.) have been recognized as serious invaders of streams within many forested parts of southern Australia, with TAS, VIC, NSW and the ACT the most affected. Guidelines for identification and eradication of particular willow species from inappropriate environments have been prepared in a range of jurisdictions and eradication programmes have been implemented, particularly in the last five years. For example, an interstate cooperative programme has been conducted for willow removal in the Genoa River catchment in the eastern border region of NSW and VIC. The Tasmanian government has implemented restrictions on the import, sale, and planting of particular problematic willow species.

Pathogens

With the exception of the soil or water-borne pathogen *Phytophthora cinnamomi* – widely considered to have been accidentally introduced into Australia after European settlement – native forests, woodlands or plantations are affected mainly by indigenous plant pathogens. In plantations of non-native species, however, pests and pathogens are primarily of overseas origin. Table 2 contains an excerpt from a manual, “*Forests and timber: a field guide to exotic pests and diseases*” that was developed, as part of an overall exotic pest general early warning strategy, through consultation with a wide range of forest health scientists through the Forest Health Committee.

Table 2: The main insects and pathogens affecting forests in Australia

Insects	Pathogens
Formosan subterranean termite	Pine wood nematode
Western drywood termite	Annosus root and butt rot
Asian longhorn beetle	Black stain root disease
Burnt pine longicorn beetle	Blue gum mycosphaerella
Drywood longicorn beetle	Casuarina blister bark
European house borer	Chestnut blight
Hoop pine weevil	Dutch elm disease
European spruce bark beetle	<i>Eucalyptus</i> rust
Mountain pine beetle	Pine pitch canker
Powder post beetle	Western gall rust
Asian gypsy moth	
Nun moth	
White spotted tussock moth	
Black carpenter ant	
Wood wasp	

Source: “Forests and timber: a field guide to exotic pests and diseases”, Australian Quarantine and Inspection Service (AQIS) website.

The root-rotting fungus *Phytophthora cinnamomi* (and a number of other *Phytophthora* species) kill a wide range of plants in susceptible areas (predominantly regions with more than 600 mm annual rainfall). *Phytophthora cinnamomi* has caused significant death of commercially important eucalypt species, such as jarrah (*E. marginata*) in WA, silvertop ash (*E. sieberi*) in southeastern Australia and young plantations of Gympie messmate (*E. cloeziana*) in QLD.

However, the most significant impacts are on biodiversity. Quantitative nationwide data are limited in their capacity to clearly distinguish the area and impacts in forests and woodlands from those in vegetation types such as heathlands. As many as 2 000 of the estimated 9 000 native plant species in

the southwest of WA are susceptible to *P. cinnamomi* root rot disease and 39 threatened species are currently identified for protection from *P. cinnamomi* in TAS.

Phytophthora is a “key threatening process” in the Environment Protection and Biodiversity Conservation Act 1999, with a National Threat Abatement Plan for *P. cinnamomi* released in 2001. *P. cinnamomi* spread is controlled through hygiene protocols and management zones for the protection of threatened flora. Forestry, national park and local agencies in many jurisdictions have implemented plans to restrict pathogen spread. Intensive monitoring is undertaken in WA to identify the distribution of the disease in commercial forests and conservation areas and to designate protectable areas free of the pathogen.

A wide range of chronic or episodic crown dieback syndromes, often with significant tree mortality and accompanying impacts on ecosystems, occur to some degree in native forests and woodlands in all states. These are usually of complex origin, associated with combinations of factors such as: climatic stresses, land management practices, severe insect attacks and imbalance in insect predator levels.

Pathogenic fungi are not generally the primary factors, but canker-causing fungi – including *Cryphonectria eucalypti* (formerly *Endothia gyrosa*) and *Botryosphaeria* spp. – often have a significant secondary role. Definition of the syndromes and causal agents is often difficult and it is hard to clearly delineate the affected areas because of the wide range of land tenures involved.

Rapid expansion of native hardwood plantations in Australia has seen defoliating diseases become more significant. These are mostly episodic, depending on factors such as local climatic conditions, age, and the genetic composition of plantations.

While few fungal leaf diseases of eucalypts are economically damaging in commercial or environmental plantations, significant exceptions include several native *Mycosphaerella* spp. – the most serious being *M. cryptica* and *M. nubilosa* in young blue gum (*E. globulus* and *E. nitens*) plantations in southern Australia, *Cylindrocladium quinqueseptatum* in young eucalypt plantations in northern QLD, and *Quambalaria pitereka* in young spotted gum (*Corymbia* spp.) plantations in humid areas of NSW and QLD. Control measures include selection for genetic resistance to these foliar pathogens in plantations. Such diseases are less debilitating in natural forests and woodlands, where inoculum levels are usually low.

In cool temperate rain forest in TAS and VIC, myrtle wilt disease (caused by the native pathogenic fungus *Chalara australis*) attacks myrtle (*Nothofagus cunninghamii*), through wounds in stems and branches. Although myrtle wilt disease is widespread in undisturbed forest, damage to trees associated with road building and logging can increase the activity of this disease.

Root and butt rots caused by *Armillaria* spp., most significantly *A. luteobubalina* in eucalypt forest predominantly in southern Australia, cause small patch deaths of a range of plant species. *Ganoderma* spp., *Rigidoporus vinctus*, and *Phellinus noxius* in QLD kill a low, but increasing, percentage of trees in a similar way. Species affected include: young hoop pine (*Araucaria cunninghamii*), rain forest species, eucalypts and *Acacias* – especially in regrowth forests or second rotation plantations.

Acacia species in a wide range of land tenures and forest ecosystems are affected by species of native gall or phyllode rust fungi *Racospermyces* and *Uromycladium*. These can cause severe defoliation and effects on form, and even tree death. Impacts in natural stands are usually small, whereas in plantations, for example of *Acacia mangium* in northern Australia, severe levels of phyllode rust have warranted investigations for disease resistance.

In *Pinus radiata* plantations of up to 15 years of age, in areas where climatic, topographic and stand conditions are suitable, the exotic needle-cast fungus *Dothistroma septospora* – first recorded in Australia in 1975 – is a primary pathogen able to cause severe needle loss. The northern tablelands of NSW and small areas in southeast QLD are worst affected, but the disease is also sometimes significant in the tablelands of southern NSW and in northeast VIC. Thinning is used as an ameliorative measure, but aerial spraying with low concentrations of fungicide is also occasionally carried out. The disease is absent from SA and WA – and, although present in TAS, causes little damage. Relatively little significant needle blight has occurred during the past five years because of drought conditions over much of the *P. radiata* estate. Planting of disease-resistant stock is currently undertaken to reduce disease impacts in highly prone locations in northern NSW.

The fungus *Sphaeropsis sapinea* is associated with top death and occasional mortality of *P. radiata*, usually on drought-prone sites, in most states of Australia. Needle-cast associated with the fungi *Cyclaneusma minus* and *Lophodermium* spp. also occurs in many *P. radiata* growing regions.

Key institutions involved in Forest Invasive Species strategies

Commonwealth Government

There are two portfolios within the Commonwealth Government that have legislative responsibilities for addressing invasive plant pests:

- **Environment Australia** (EA; www.ea.gov.au). Legislative powers are provided under the Environment Protection and Biodiversity Conservation Amendment (Wildlife Protection) Act of 2001; and
- **Agriculture, Fisheries and Forestry – Australia** (AFFA; www.affa.gov.au). The legislative backing for the plant protection activities of this department is provided under the Quarantine Act of 1908.

Within AFFA there are three functional groups with responsibilities for matters relating to plant health. These are:

- **Biosecurity Australia** (BA), which is responsible for quarantine policy and negotiations relating to access to Australia's – and other countries' – markets, for commodities that carry a quarantine risk;
- the **Australian Quarantine and Inspection Service** (AQIS) with responsibility for enforcing quarantine legislation at the border, including surveillance of our sparsely populated northern borders and cooperative programmes with Indonesia, East Timor and Papua New Guinea to survey for selected exotic pests; and
- the **Office of the Chief Plant Protection Officer** (OCPPO), which is a relatively new unit within AFFA, (having been established in 1998), with the responsibility for coordinating national responses to exotic plant pest emergencies. Among other things, the OCPPO works with countries of the Asia-Pacific region to improve the flow of information on plant pests and assist with the development of basic plant health infrastructure – particularly diagnostic capability and the development/rehabilitation of pest collections and plant disease herbaria. These collections are fundamental to the capacity of countries needing to describe the health status of their agricultural and forest industries.

Plant Health Australia

Plant Health Australia (PHA, www.planthealthaustralia.com.au) is a public company that was established in 2000 to:

- be the key adviser on plant health issues for industry and government;
- promote international and domestic confidence in Australia's plant health status;
- develop effective and auditable plant health management systems; and
- commission, coordinate and manage agreed plant health programmes.

Members of PHA include the Commonwealth Government, all state/territory governments, and at least 15 peak industry bodies. The joining of forest industries is currently under negotiation.

State and territory governments

The state and territory departments, which maintain responsibility for invasive plant pests, have a large network of regional offices that undertake a range of plant health activities, including: diagnostics, surveillance, collection management and research.

In many states, the management of agricultural, forest and environmental pests is the responsibility of separate departments, cooperating to meet common objectives in maintaining high standards of plant health. The principal agencies responsible for the management of invasive pests of agriculture and forestry in each state/territory are listed in Table 3.

Table 3: Overview of the principle agencies involved in invasive species management in Australia

State / territory	Department
New South Wales Agricultural pests Forest pests	NSW Agriculture (www.agric.nsw.gov.au) State Forests of NSW (www.forest.nsw.gov.au)
Northern Territory Agricultural and forest pests	Dept. of Business, Industry and Resource Development (NT) (www.nt.gov.au/dbird/dpif)
Queensland Agricultural and forest pests Rangeland and environmental weeds	Dept. of Primary Industries (QLD) (www.dpi.qld.gov.au) Dept. of Natural Resources (www.dnr.qld.gov.au)
South Australia Agricultural pests Forest pests	Primary Industries and Resources (SA) (www.pir.sa.gov.au) Forestry SA (www.forestry.sa.gov.au)
Tasmania Agricultural pests Forest pests	Dept. of Primary Industries, Water and Environment (www.dpiwe.tas.gov.au) Forestry Tasmania (www.forestrytas.com.au)
Victoria Agricultural and forest pests	Dept. of Primary Industries (www.dse.vic.gov.au/dpi) Dept. of Sustainability and Environment (www.dse.vic.gov.au/dse)
Western Australia Agricultural pests	Dept. of Agriculture Western Australia (www.agric.wa.gov.au)

Institutional responsibilities for invasive plant pests

Under the Australian Constitution, agricultural production, including plant health, is a state/territory matter. Figure 1 shows a map of Australia indicating the state and territories.

The Commonwealth (Federal) Government's interest and accountability for plant health stems from its responsibilities for trade and quarantine. This dichotomy in responsibilities for plant health matters, including surveillance for exotic plant pests (which includes insect pests, plant pathogens and weeds) and their management within Australia, has been bridged through consultation and various institutional arrangements that have evolved over time.

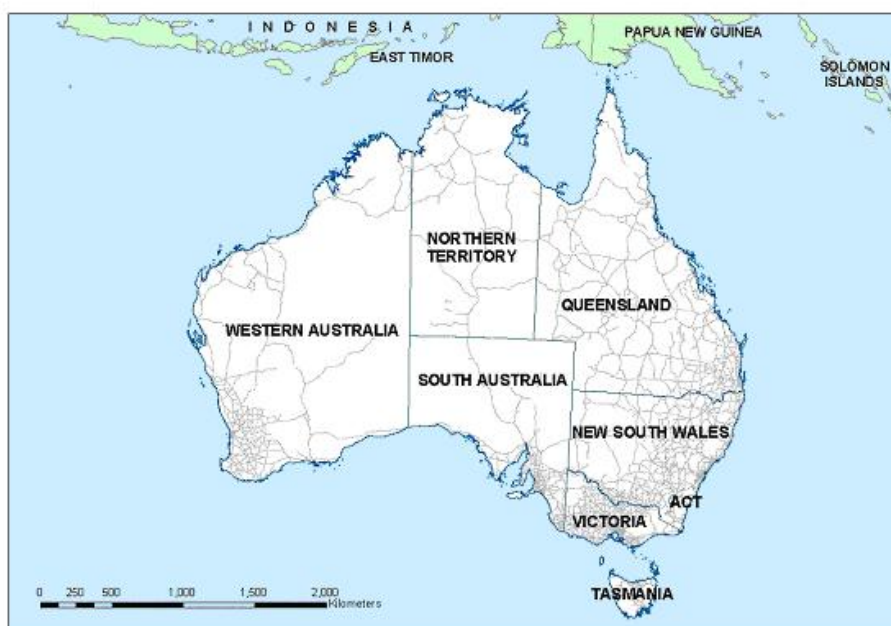


Figure 1: Map of Australia showing the state and territory borders.

The responsibilities of the different parties involved in managing plant health and responding to invasive plant pests in Australia can be summarised as follows:

The role of the Commonwealth is to:

- provide quarantine controls at Australia's international borders to reduce the risk of entry of exotic plant pests;
- provide surveillance across north Australia, the Torres Strait and through cooperative programmes, Indonesia, East Timor and Papua New Guinea;
- provide national surveillance programmes at high-risk ports of entry for exotic fruit flies and Asian gypsy moth;
- convene and chair Consultative Committees responsible for national response actions for new incursions;
- participate in funding of national response programmes;
- provide information to international trading partners about the plant health status of Australia;
- manage any international trade problems related to outbreaks of pests in Australia; and
- fulfil Australia's obligations under the International Plant Protection Convention (IPPC) and Convention on Biological Diversity (CBD). Under the CBD, contracting Parties have an obligation to prevent the introduction of, control or eradicate those alien species that threaten ecosystems, habitats and species.

The role of the states/territories is to:

- manage conditions for interstate trade of plants and plant products;
- manage any interstate trade problems associated with outbreaks of pests;
- provide general surveillance;
- maintain capacity to diagnose plant pests;
- maintain adequate pest records and collections/disease herbaria; and
- participate in Committee processes and funding of national response programmes.

The role of industry is to:

- provide appropriate control of endemic pests in commercial agriculture;
- meet interstate and international phytosanitary conditions for trade; and
- report suspect exotic pests when detected.

Ministerial Councils and Advisory Committees

The peak government bodies are the Ministerial Councils dealing with primary industries and natural resource management. Plant health issues fall within the scope of the Primary Industries Ministerial Council (PIMC), with the exception of weeds, which are the responsibility of the Natural Resource Management Ministerial Council.

Membership consists of Commonwealth, state and territory Ministers responsible for agriculture and the environment, respectively. Under these are a range of Ministerial advisory committees, such as the Primary Industries Standing Committee (PISC), consisting of Commonwealth and state/territory departmental heads; Primary Industries Health Committee; and technical committees such as the Forest Health Committee (FHC).

These committees advise the Standing Committees and Ministerial Councils on all aspects of response action required for the containment or eradication of exotic pests, including the need for international or interstate quarantine action, as well as legislative, financial, administrative and technical (including research) considerations. Subordinate bodies of the technical committees include:

Forest Health Committee

The FHC provides a forum for dealing with forest health issues, particularly quarantine and incursion management at national level.

The FHC Terms of Reference include:

- preparedness to deal with incursions of exotic pathogens and pests of forests and forest products;
- to undertake a continuing review of the pests and pathogens affecting Australian forests (native, commercial and amenity) and forest products (including imported timber) with particular regard to their incidence and economic and environmental importance;
- to consider and advise the Primary Industry Standing Committee (PISC), Forest and Forest Products Committee (FFHC), other Standing Committees and industry on developments in the fields of forest pathology and forest entomology. This includes matters relating to research, surveillance, diagnostics, extension training and regulatory issues where appropriate, and on all aspects of action required for control, containment or eradication of specific pests and diseases – including the need for new or changed international or interstate quarantine action;
- to consider and advise the PISC, FFHC, other Standing Committees and industry on the prospects and actions required for the integrated management of pests and pathogens of forests and forest products; and
- to assist government through the PISC and FFPC in the development of forest health and plant quarantine policies.

The FHC is comprised of state and territory representatives, CSIRO (and other research providers), AQIS, Biosecurity Australia, OCPPO, Environment Australia, Research Working Group and co-opted members. Representatives from the Plant Health Committee and New Zealand Forest Health are observers.

Regulations involved in invasive species strategies

Recommendations made by the Consultative Committee for response actions are carried out under state legislation, which for QLD is the Plant Protection Act 1989, for VIC is the Plant Health and Plant Products Act 1995 and so forth. Table 4 gives an overview of relevant legislation regarding invasive species and the various different administrative agencies.

Table 4: Australian legislation with regard to invasive species.

Legislation	Administering agency
Quarantine Act 1908	Agriculture, Fisheries and Forestry – Australia
Quarantine Proclamation 1998	Agriculture, Fisheries and Forestry – Australia
Environment Protection and Biodiversity Conservation Amendment (Wildlife Protection Act 1999)	Environment Australia
Plant Diseases Act 1924	New South Wales Agriculture
Plant Protection Act 1989	Queensland Department of Primary Industries
Fruit and Plant Protection Act 1992	Primary Industries and Resources, South Australia
Plant Quarantine Act 1997	Department of Primary Industries, Water and Environment, Tasmania
Plant Health and Plant Products Act 1995	Department of Natural Resources and Environment
Plant Diseases Act 1914	Department of Agriculture, Western Australia
Plant Disease Control Act 1979	Department of Primary Industry and Fisheries, Northern Territory

*There are other relevant acts, such as the state/territory environmental protection legislation. Specific pest responses are carried out under state and territory legislation.

These Acts enable government agencies to:

- enter properties to survey for an exotic pest;
- inspect, treat and take samples of plants or plant products;
- establish quarantine zones;
- restrict the movement of plants, plant products, equipment, vehicles and other sources of contamination;
- issue orders for the destruction of infested/infected plant material; and
- require owners of affected premises to implement quarantine or pest eradication measures.

In the event of a new incursion, it is primarily the state plant protection legislation that will be utilized to respond. The Commonwealth Quarantine Act 1908, Quarantine Proclamation 1998 and Environment

Protection and Biodiversity Conservation Amendment (Wildlife Protection) Act 2001 operate alongside the relevant State Plant Health Acts and have broad coverage over matters of quarantine and environmental protection in Australia. In cases where a state law is inconsistent with a Commonwealth law, however, the Commonwealth law prevails.

Key elements of a biosecurity strategy

The framework for preparing and responding to exotic pests can be seen in Figure 2. This framework includes three major stages that take into account input into the overall outcome of reducing the risk and impact of exotic pests before the pest becomes established (Pre-event), when the pest is detected (Response), and after the pest has been eradicated or managed (Recovery).

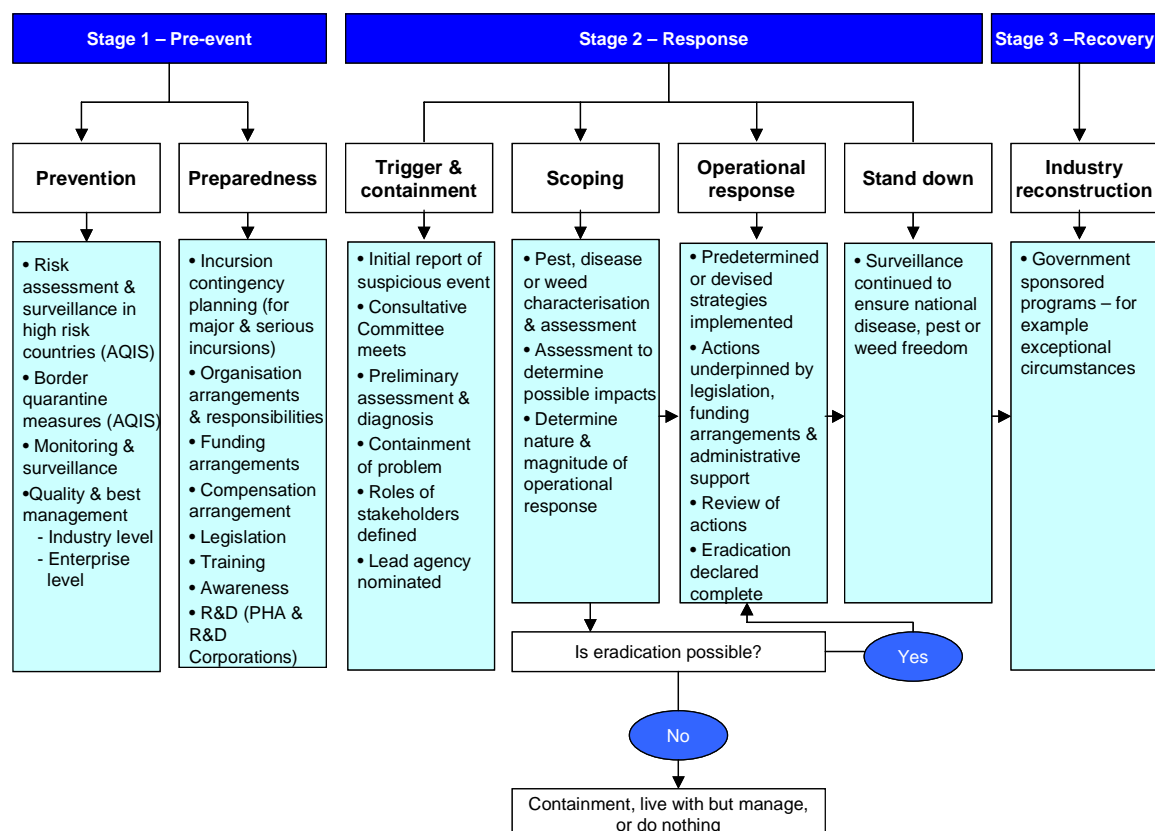


Figure 2: The framework for preparing and responding to exotic pests in Australia

Quarantine activities

Quarantine controls on the entry of plants and plant products at the border, regulated by AQIS, and quarantine policy based on risk assessment, conducted by BA, are designed to identify and minimize the threats to Australian forests and forest industries from incursions of exotic pests. AQIS has been allocated an additional A\$281.4 million (US\$196 million) from 2001-02 to 2004-05, to significantly increase Australia's border protection operations.

Australia is bound by the WTO-SPS Agreement, which sets conditions, based on scientific principles and risk assessment, to protect agricultural industries from exotic pests, and at the same time facilitate trade in agricultural commodities. Approval is subject to BA assessing that applications for entry pose an acceptable level of risk, taking into account matters such as:

- the plant health status of agricultural industries in the country or region from which the commodities are to be sourced;
- the likelihood of pests of concern being transported with commodities and establishing in the importing country;
- potential damage that introduced pests might cause to crops and native flora; and
- the efficacy of phytosanitary treatments that might be used to manage identified risks.

Assessments made by BA in response to applications to access the Australian market are known as Import Risk Assessments (IRAs). In recent years, Australia has improved the transparency of its IRA process and encourages greater input from stakeholders.

Over the last two years, BAs forest health work programme has included: progression of an IRA for five coniferous timber species from three countries, conducting Pest Risk Assessments (PRA) of pine pitch canker and sudden oak death wilt, and risk assessments with regard to imports of thuja logs and oversized kwila timber for construction.

BA is also currently conducting reviews on the importation of *Acacia* and *Casuarina* seed for sowing, in response to advice received from the Forest Germplasm Workshop of January 2002. It continues to progress a coniferous timber IRA consistent with international obligations, and has been involved in further work on a suspended set of draft wood packing guidelines in which the efficacy of proposed treatments with regard to pathogens is now subject to review.

Future forestry related work for BA includes; a review of the species listed as being of forest and amenity significance (which require a two year Post Entry Quarantine), progression of the coniferous timber IRA, further reviews for emergent *Phytophthora* species and nursery stocks, and continuing to provide advice to AQIS on timber imports and exports on an as-needed basis.

Surveillance

The present system for detecting exotic pest incursions in Australia is based on a combination of specific monitoring activities, general surveys across northern Australia, state government and industry awareness programmes and *ad hoc* reporting (from growers, members of the public, etc).

The success of incursion management relies heavily on grower participation in passive or general surveillance to increase the chances of early detection of exotic pests. Currently the AFFA and PHA, have developed a national plant pest hotline telephone reporting system, with associated targeted publicity awareness material, to more effectively capture potential detection information through general surveillance activities.

States have a major role in surveying forest health. Annual surveys of plantations and routine general surveillance of commercial forests is conducted by state forest agencies in NSW, QLD and TAS with other states and territories carrying out various forest surveillance activities. The surveys in native forests target key areas and perceived high-risk zones. In SA, a Forest Health Monitoring Kit has been developed to help staff sample and monitor plantations and identify insect pests and diseases. In WA, a system targeting specific forest sites – known as FORESTCHECK – is carried out.

The Commonwealth, through state government agencies, runs a national trapping programme for Asian gypsy moth. AFFA has produced a field guide to exotic pests of forest and amenity trees and timber to encourage early reporting of suspected outbreaks of these pests.

In addition, during 1999/2000, AFFA funded a trial forest health surveillance programme in QLD. The work was conducted by staff in the Forest Protection Programme of the Queensland Forestry Research Institute (QFRI). Five ports were targeted: shipping and airport surrounds in Brisbane and Cairns; and shipping port surrounds in Gladstone, Townsville and Bundaberg. This was the first serious attempt to systematically survey areas of highest-hazard with respect to forestry quarantine. Although no exotic pests of forestry significance were found, the surveys did demonstrate the capability to detect such pests, if present.

Forestry Tasmania is conducting a trial to develop an effective Port Environ/Urban Surveillance Programme, which uses pheromone trapping for some key insect pests, sentinel sites of key host species and a survey of high risk areas near ports.

The national Asian gypsy moth trapping programme serves as an early warning system to detect incursions of exotic *Lymantrid* species entering through Australian ports. It is funded by AFFA and coordinated by the OCPPO. Ships and shipping containers are seen as likely pathways for entry so the trapping programme is centred in the first ports-of-call. The programme is based on a network of Delta traps on a 1-kilometre grid out to 2 kilometres from port facilities and a 2-kilometre grid from the boundary of the 2-kilometre zone out to 5 kilometres from the port facility centre. Actual trap numbers per port facility vary, with a maximum of 40 traps per port. The surveillance network includes over 450 traps. Field monitoring and servicing of traps is carried out by state agriculture or forestry agencies.

The Northern Australia Quarantine Strategy (NAQS) is a programme of AQIS that is responsible for monitoring and surveillance to provide advanced or early warning of exotic pest threats. The purpose of the programme is to limit the opportunity for exotic pests to establish and remain undetected in remote areas. Surveillance targets are based on pest risk analyses that identified northern Australia as a pathway for entry of exotic pests of major plant host groups.

Exposure of NAQS scientists to exotic pests in the region builds expertise and increases confidence that exotic pests will be detected in regular surveys across northern Australia. The onshore component of the NAQS monitoring and surveillance programme covers a coastal band – 20 kilometres in width – across northern Australia from Broome, in the west, to Cairns, in the east. NAQS activities also extend offshore to East Timor, Papua New Guinea and Indonesia. The initiative includes trapping for exotic fruit flies on the islands of the Torres Strait, as well as a public awareness programme known as Top Watch.

Diagnostics

A decision on whether to eradicate, contain or manage an outbreak of an exotic pest must be made quickly and is dependent on the ability to obtain a rapid and accurate diagnosis of the organism involved. Diagnostic services in Australia are provided via a combination of government laboratories (state agencies and CSIRO), commercial laboratories, universities, and pest and disease specialists who perform diagnostic duties as part of their jobs. A recent assessment of the current status of diagnostic capacity in Australia found that:

- although overall resources allocated to plant pest diagnostics are substantial, resources in certain disciplines, especially nematology and bacteriology, have declined in recent years, potentially compromising national capability in these areas; and
- documented procedures for identifying exotic pests of concern are not generally available and there is little quality control to ensure the delivery of standardized techniques such as those used in veterinary laboratories in Australia.

The OCPPO and PHA have recognized the importance of strengthening diagnostic capacity and are committing resources to the development of national diagnostic standards for priority exotic plant pests as well as a diagnostic network to identify and network domestic and international diagnostic expertise to be used in pest identifications. For forestry, diagnostic protocols being developed include: pine pitch canker (*Fusarium circinatum*), *Eucalyptus* rust (*Puccinia psidii*) and *Bursaphelenchus* spp.

National pest reporting and recording

A sound knowledge of the pest status of Australia's plant industries and native flora is essential if costly false alarms – arising from findings of suspected new invaders – are to be avoided. Clearly, if we don't know what pests are endemic, it is difficult to determine – with any confidence – the status of a newly discovered organism. This is why arthropod and pathogen collections and disease herbaria containing validated and well-curated specimens are critically important. These collections hold information on a pest's distribution, life cycle and host(s) and provide a basis against which to compare unknown organisms and facilitate the accurate identification of suspected exotic pests.

Reference collections holding records of economically important pests are held by numerous organizations throughout Australia. The OCPPO and PHA are managing a project to improve the accessibility of these records through the development of an Australian Plant Pest Database, which links the diverse, geographically scattered databases throughout Australia, so that all of the available data can be accessed from a single point via the internet. Support is also being provided for data entry and some validation of existing records.

Response planning/programmes

In 2000, the national Forest Health Committee released a Generic Forest Incursion Management Plan (GIMP) to facilitate preparedness and response actions to potential new incursions of exotic pathogens or invertebrate pests into Australia. Currently, the PHA, in association with various members, is developing specific industry biosecurity plans that, at this time, do not include forest industries, but may serve as a model for future development of emergency response planning. Key elements to developing appropriate response plans include:

- identification and assessment of pest risks;

- risk mitigation strategies;
- surveillance and diagnostic strategies;
- response procedures and defined roles and responsibilities; and
- termination and post eradication strategies.

Response system for forest pests

The response to a new incursion begins when a suspect exotic plant pest is reported to state and national authorities. There are a number of response phases:

- *notification and initial response*: a grower or member of the public may find a pest, or some unusual symptoms, on plants and report this to the local Department of Agriculture office, or equivalent. Officers will investigate and samples will be taken and sent to diagnostic laboratories. If an exotic pest is suspected, the Chief Quarantine Officer in the state is notified, who will in turn notify the Chief Plant Protection Officer (CPPO) located in AFFA. The CPPO will then notify Plant Health Committee members, other relevant state/Commonwealth agencies and industry. Steps will also be taken to verify the initial identification. This may involve sending samples interstate or overseas.
- *containment and scoping*: state authorities will generally implement a number of containment measures to prevent further spread of an exotic pest beyond the known outbreak site. Depending on the nature of the incursion, areas around the detection site may be immediately quarantined and restrictions may be imposed on the movement of host material from the quarantine area. Surveys and trace backs will be conducted to determine the geographic extent of the outbreak and its severity.
- *determine feasibility of eradication*: The CPPO will convene a Consultative Committee to advise on appropriate response actions. The Consultative Committee will include representatives from the OCPPO, state/territory agencies, Biosecurity Australia and industry. A decision on the feasibility of eradication will consider:
 - biology and mobility of the pest;
 - host range and presence/absence of vectors;
 - extent of the outbreak (is it too widespread?);
 - accessibility of the outbreak site (urban or commercial environment?);
 - likelihood of repeated incursions;
 - availability and effectiveness of control options;
 - sensitivity of monitoring techniques; and
 - cost-benefit analysis of response options.
- *eradication vs. management*: the Consultative Committee will make a recommendation to the relevant Standing Committee on whether an eradication programme should proceed, what this would involve, a budget for response actions during the current financial year, and indicative costs for subsequent years. The Primary Industries Ministerial Council will make the final decision. In cases where the Consultative Committee determines that eradication is not feasible or justifiable, Commonwealth involvement in the outbreak ceases (except when there are implications for international trade), and the states assume responsibility for ongoing management of the pest.

Sources of information

Statistics supplied by ABARE, BRS and AQIS.

National Forest Inventory Australia website link –
<http://www.affa.gov.au/content/output.cfm?ObjectID=C3ABDD30-E8D3-439C-8E37AFE6D01F0C4F&contType=outputs>

National Forest Inventory Australia State of the Forest Report (available from NFIA website)

Research Working Group of Forest and Forest Wood Products Committee

Agriculture, Fisheries and Forestry Australia (AFFA) website link – www.affa.gov.au

The Office of the Chief Plant Protection Officer (OCPPO) website link – www.affa.gov.au/planthealth

Australian Quarantine and Inspection Service (AQIS) website link – www.aqis.gov.au

Appendix 1 – breakdown of pests, processes or agents impacting on forested areas

■ Vertebrate pests

Processes or Agents impacting on forested areas	Process or agents impacting on ecosystem health and vitality in forest areas by state or territory							
	ACT	TAS	NSW	QLD	WA	VIC	NT	SA
Mammals								
Cats	4	1	2	5	3/4			
Deer			1	1		3		1
Dingoes	3		3	3	1	1	1	
Dogs (<i>Canis familiaris</i>)	3		3	3		1	3	
Donkeys			1	1			3	
Foxes (<i>Canis vulpes</i>)	5		4	5	5	3	1	3
Goats (<i>Capra hircus</i>)	5	2	1	3	1	1	3	1
Hares	3		1	3		1		5
Horses	2		1	1		1		
Kangaroos (<i>Macropus</i> spp.)	5		3	3	1	3	3	3
Mice (<i>Mus musculus</i>)	3		3	3	3	1	3	3
Pademelons		4	3	3				
Pigs (<i>Sus scrofa</i>)	5		3	4	3	1	5	1
Possums	3	5	3	3	1	1	3	1
Rabbits (<i>Oryctolagus cuniculus</i>)	5	4	2/4	3	3	3/4	3	2/5
Rats, exotic	3		1	1	1		3	1
Rats, native	1	4	1	3/4	3	3	3	
Wallabies	1	5	3	3/4	3	5	3	3
Amphibians								
Cane toads			1	5				
Fish								
Carp			1					
Birds								
Blackbirds	5		1			1		
Brush turkey				3				
Cockatoos						3		
Indian mynah	3			1				
Parrots					5			
Starlings/sparrows	1		1	4		1		

■ Diseases and pathogens

Processes or Agents impacting on forested areas	Process or agents impacting on ecosystem health and vitality in forest areas by state or territory							
	ACT	TAS	NSW	QLD	WA	VIC	NT	SA
Fungi (<i>Phytophthora</i> spp.)	4	5	3	5	5	5	3	

■ Invertebrate pests

Processes or Agents impacting on forested areas	Process or agents impacting on ecosystem health and vitality in forest areas by state or territory							
	ACT	TAS	NSW	QLD	WA	VIC	NT	SA
Army worms (Noctuids)		1	1	1	1		3	
Autumn gum moth (<i>Mnesampela privata</i>)	1	3	3	1		3		3
Bees	4	3		3	3	3	3	
Beetle, African black			1	1	?			
Beetle, Christmas (<i>Anoplognathus</i> spp.)	3	1	3/4	3		3	3	
Beetle, five-spined bark (<i>Ips grandicollis</i>)	1		1	4	3			4
Beetle, leaf / flea (<i>Chrysomelids</i>)		5	3	4	1	3	3	3
Beetle, longicorn (<i>Cerambycids</i>)				3	3			1
Beetle, white fringe		1	1	3				
Beetle, Monolepta (<i>Monolepta australis</i>)			1		3			
Borers			3		3	4		1
Budworm		1		1	1		3	
Cup moths (<i>Limacodids</i>)			3	3				1
Cut worm				1				
Grasshoppers (<i>Acridids</i>)	1	3	1	5	5	1	3	3
Gumleaf skeletonizer (<i>Uraba lugens</i>)		3	3	3	1	4		1
Gum Tree scale (<i>Eriococcus</i> spp.)			3			4		
Leaf miner	1	3			5	3	3	1
Lerps (<i>Psyllids</i>)	4	3	2/4	3	1	5	3	1
Millipedes	1	3				3	3	
Monterey pine aphid (<i>Essigella californica</i>)			1	3				
Mosquitoes (<i>Culicids</i>)	1	3	1	1/3	3	3	3	
Saw fly (<i>Perga dorsalis</i> , <i>Pergagraptella bella</i>)			3	3	1	3		3
Stick insects (<i>Phasmatids</i>)	1	1	1	3	1	3	3	
Termites (<i>Cryptotermes</i> , <i>Coptotermes</i>)					3	5		
Wasp, European (<i>Vespa germanica</i>)	3	4				1	3	?
Wasp, <i>Sirex</i> (<i>Sirex noctilio</i>)	3	3	3	1		2		5
Weevils (<i>Curculionids</i>)	1	3		3	1	3	3	1
Wingless grasshopper (<i>Phaulacridium vittatum</i>)	1	3	1	1	1	1		3
Other - <i>Eucalyptus</i> leaf beetles (<i>Chrysophtharta</i> spp.)		3						
Other – Spring Beetles (<i>Heteronyx</i> spp.)		3						3

■ Plant pests

Plant Pests impacting on forested areas	Process or agents impacting on ecosystem health and vitality in forest areas by state or territory							
	ACT	TAS	NSW	QLD	WA	VIC	NT	SA
Bathurst burr (<i>Xanthium spinosum</i>)								
Blackberry (<i>Rubus vulgaris</i>)	3/4	4	5	3	3	5		1
Blackberry- (<i>Rubus fruticosus</i> sp. agg.)								
Blue morning glory (<i>Ipomoea indica</i>)								
Blue-bell creeper (<i>Sollya heterophylla</i>)								
Bone seed (<i>Chrysanthemoides monilifera</i>)								
Boxthorn, African (<i>Lycium ferocissimum</i>)								3
Bracken fern (<i>Pteridium esculentum</i>)	1	3		3	–	3	–	5
Broadleaved weeds								
Calliopsis/Coreopsis (<i>Coreopsis lanceolata</i>)								
Cape broom (<i>Teline monspessulana</i>)								
Cape ivy (<i>Delairea odorata</i>)								
Chess or choat (<i>B. secalinus</i>)								
Canadian fleabane (<i>Conza canadensis</i>)								
Cotoneaster (<i>Cotoneaster</i> spp.)								
Crofton weed / Mist-Flower (<i>Ageratina</i> spp.)								
Dodder laurel (<i>Cassytha melantha</i>) / Australian dodder (<i>Cuscuta australis</i>)								
Eucalypt (<i>Eucalyptus</i> spp.)								
Galvanised Burr (<i>Sclerolaena birchii</i>)								
Gorse (<i>Ulex europaeus</i>)								
Grasses, exotic (unidentified Poaceae)	4	1	2	5	4	1	3	4
Grasses, exotic (unidentified)								
Grasses, gamba (<i>Andropogon gayanus</i>)								
Grasses, giant rats tails (<i>Sporobolus</i> spp.)								
Grasses, kikuyu (<i>Pennisetum clandestinum</i>)								
Grasses, native								
Grasses, pampas (<i>Cortaderia</i> spp.)								
Grasses, serrated tussock (<i>Nassella trichotoma</i>)								
Grasses. other								
Great Brome (<i>Bromus diandrus</i>), soft (<i>B. molliformis</i>),								
Groundsel bush (<i>Baccharis halimifolia</i>)								
Horehound (<i>Marrubium vulgare</i>)								
Lantana (<i>Lantana camara</i>)			3	5		1	1	
Madrid (<i>B. madritensis</i>), red (<i>B. rubens</i>),								
Melaleuca (<i>Melaleuca</i> spp.)								
Mimosa (<i>Mimosa</i> spp.)								

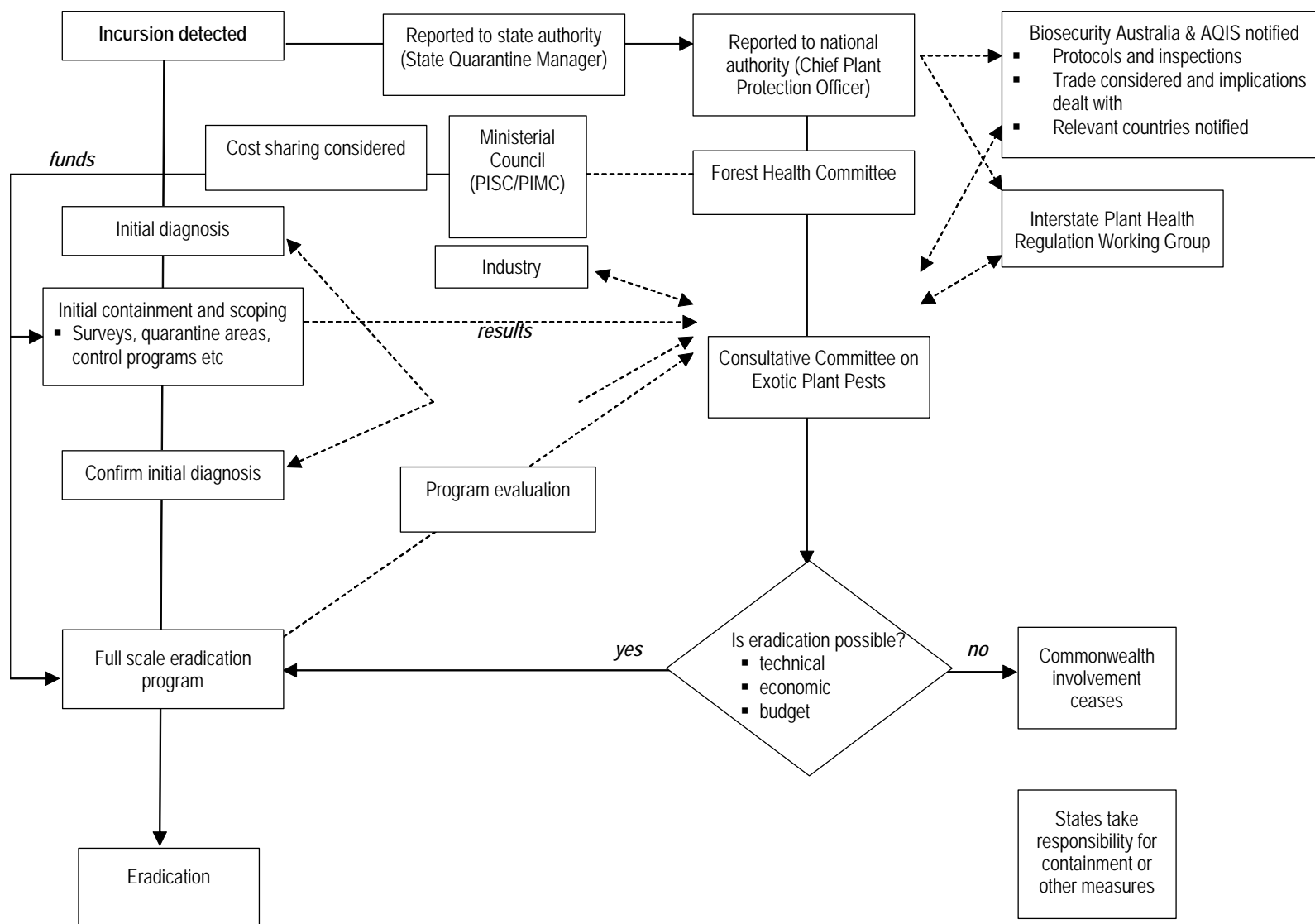
Country reports

Mistletoe								
Noogoora burr (<i>Xanthium occidentale</i>)								
One-leaved Cape tulip (<i>Homeria flaccida</i>)								
Ox-eye daisy (<i>Leucanthemum vulgare</i>)								
Paterson's curse / Salvation Jane (<i>Echium plantagineum</i>)								
Pines (<i>Pinus</i> spp.)								
Prickly pear (<i>Opuntia</i> spp.)								
Ragwort (<i>Senecio jacobaea</i>)								
She-oak (<i>Allocasuarina</i> spp.)								
St John's wort (<i>Hypericum perforatum</i>)								
Stinging nettle / Dwarf nettle (<i>Urtica urens</i> or <i>U. dioica</i>)								
Sweet briar (<i>Rosa rubiginosa</i>)								
Sweet Pittosporum (<i>Pittosporum undulatum</i>)								
Tea tree (<i>Leptospermum</i> spp.)								
Thistle (many spp.)								
Tree of heaven (<i>Ailanthus altissima</i>)								
Vines, creepers – Bridal (<i>Asparagus asparagoides</i>)								
Water hyacinth (<i>Eichhornia crassipes</i>)								
Wattles (<i>Acacia</i> spp.)								
Willow (<i>Salix</i> spp.)								

Problematic
Not Problematic
Not Reported

- 1 = Occurs but is not widespread, has little impact, and requires little or no control.
 2 = Extent and impact are limited but control measures are extensive.
 3 = Widespread or having adverse impacts.
 4 = Widespread and having adverse impacts.
 5 = Very widespread and having severe adverse impacts.

Appendix 2: Generalized model of forest pest incursion management procedure



Cambodia – The *Mimosa pigra* report

Samreth Vanna and Ket Nang

Department of Forestry and Wildlife

Ministry of Agriculture Forestry and Fishery

Introduction

Mimosa pigra is a plant native to South America, although it is now widely distributed throughout the tropics. It was introduced to Thailand in 1947 as a green manure and cover crop. Being prickly, it was thought it would restrict access to water banks and thus reduce erosion. It now covers large areas of standing waters and water banks. Since the 1980s, *Mimosa pigra* has been found growing rapidly in low-lying areas, especially along the Mekong River and areas surrounding Tonle Sap Great Lake. Locally the plant is known as ohyas, Vietnamese thorn, or giant thorn. In Cambodia, it interferes with irrigation systems (sediment accumulation), access to electric power lines, and is a safety hazard along roads. It also grows in fallow rice paddies making reclamation more expensive.

Mimosa pigra is a spreading thorny shrub, usually 2 metres tall, but it occasionally grows up to 6 metres. It forms dense, impenetrable, mono-specific thickets. It establishes along riverbanks and out into the drier floodplains. When it grows along water banks, it affects accessibility to water for stock, irrigation and the use of lakes and rivers for recreation purposes. Pastures are smothered, reducing available grazing area and stock mustering is difficult. In conservation areas, dense growth eliminates most other species and alters the natural habitat. One of the main problems of *Mimosa pigra* is that it forms dense monocultures and suppresses other vegetation, as well as impacting on aquatic habitats, because fish avoid areas infested with *Mimosa pigra*.

Purpose

The purpose of the investigation was to collect information on the distribution of *Mimosa pigra* in order to describe the problems this weed creates for farmers, and to update the knowledge of officials in the various Ministries involved with management of this species.

Methodology

In order to get information on *Mimosa pigra* we have:

- searched for information on the internet;
- prepared questionnaires for interviews with farmers;
- selected farmers to interview; and
- held discussions with representatives from the Ministry of Agriculture.

Results

Cambodia is rich in natural resources, such as inundated forests and fishing grounds. In addition, Cambodian soil is fertile almost all over the country. Unfortunately, over the past 15 years the existence of *Mimosa pigra* has disturbed agricultural work and is causing major concerns among Cambodian farmers. The taskforce members conducted field visits, to interview farmers involved in small-scale agricultural work, in an effort to find out how they handle the problems caused by *Mimosa pigra*.

According to some farmers, there is uncertainty about the origins of this thorny plant, as it was not found in Cambodia until quite recently. The plants have been observed for about the past 15 years. The plants are covered from stem to leaves by dense and hard thorns, making the plant unsuitable for animal fodder. Apparently the only beneficial use of the plant is as fuelwood.

Farmers find it hard to cultivate their crops because *Mimosa* grows considerably faster than agricultural crops. Small *Mimosa* plants grow and migrate rapidly into planted land where crops are developing. Agricultural crops can be overrun within four or five days, if farmers do not meticulously weed their land and ensure the removal of all the *Mimosa* plants – including the roots. Farmers have to spend a considerable amount of time and labour to clear, root out and plough many times to remove all of the roots, stems, stalks and leaves from their land; otherwise the plants will grow again

quickly. When faced with a *Mimosa* infestation some farmers have been forced to leave their land for other vacant land free of the plant, if they do not have adequate labour and financial resources to remove *Mimosa* from their land.

The following steps are taken by most farmers to combat *Mimosa* infestation:

- in the early stages, they clear all the *Mimosa* from their land, as soon as they observe the plant;
- if the plant is mature, they have to cut it all out and pull out all the roots, before it produces flowers and fruits. *Mimosa* plants with ripe fruit should never be burned as this assists in the further spread of this plant;
- it is important to remove all stalks or stems or the plant can sprout again. The roots need to be removed prior to flooding; otherwise they will decay in the soil resulting in additional problems.

There are chemicals available to combat *Mimosa*, however these are expensive and have a negative impact on the environment.

Conclusions and recommendations

Based on the results of our survey, the following conclusions can be made:

- *Mimosa pigra* is a major problem for many farmers in Cambodia. They are worried about it every year;
- *Mimosa pigra* appears to be well adapted to the ecological conditions in Cambodia; and
- eradication of *Mimosa* from infested fields is a time consuming and labourious task.

The following recommendations have been made on the basis of the survey:

- farmers should endeavour to eradicate *Mimosa pigra*, whenever it appears on their land;
- *Mimosa* could be used for fuelwood instead of using trees from the flooded forests. This would help to reduce the occurrence of *Mimosa pigra*;
- The Ministry of Environment and Ministry of Agriculture and Forestry should be responsible for updating knowledge of *Mimosa pigra*, making plans for dealing with the problem, and providing information to farmers; and
- farmers should exchange experiences and information with each other.

Forest Invasive Species: Country Report – P. R. China

Sun Jianghua

Chinese Academy of Sciences

Basic forestry information

In China, total designated forest land covers 263.3 million hectares, although only 163.5 million hectares is actually forested. Natural forest accounts for 118.4 million hectares, while plantation forests cover slightly more than 45 million hectares. Around 52 percent of the forests are coniferous (29.6 percent of forests are of *Pinus* species), and 48 percent of forests are predominantly broadleaved species. Around 62 percent of forests are designated as predominantly timber forests, with 13 percent comprising various shelter protection forests, and the remainder spread among fuelwood and multiple/special purpose forests. Forest land covers around 17 percent of the national land area, with an estimated stocking volume of 12.5 billion cubic metres.

Overall, China is a country with relatively scarce forest resources, due to the low stocking volume in most of its forests and the large portion of pure plantations. China has an average forest area of 0.12 hectares per person and stocking volume of 8.6 m³ per person, which represent 21 percent and 12 percent of the world average, respectively. The forest areas are not evenly distributed throughout the country, with 30.9 percent of forest land cover being found in 11 eastern provinces, which is 1.9 times higher than the national average. Conversely, 12 provinces in the western region only have an average forest cover of 11.99 percent of forest land cover, which is 5 percent less than the national average. Monocultural plantations account for some 90 percent of the national forests, which may result in ecological problems and affect the full ecological and economic potential of the forests.

In 1998, China began the implementation of six major national programmes:

- Natural forest protection project
- Conversion of croplands to forest project
- Three-North and Yangtze river shelterbelt protection forest project
- Desertification control around Beijing area project
- Wildlife conservation and natural reserve construction project, and
- Fast-growing timber plantation project.

Over 10.5 million hectares of trees have been planted to date, some 173 400 hectares of forest have been reserved for the strict protection programme, while the number of natural reserves has reached to 1 405. In addition, over 95 million hectares of forests were protected to some degree as a result of the Natural forest protection project and logging has been reduced to a reasonable level.

General overview of forest invasive species in the country

China is a vast country with rich biodiversity in various forest ecosystems and vast areas of large monospecific plantations. This makes the country vulnerable to invasive species. There are over 8 000 known forest pests in China, including insects, diseases and rodents. Of these pests, there are 5 020 species of insects, 2 918 different types of disease, and 160 species of rodents. Significant accomplishments have been achieved in the management of these major forest pests as a result of national and provincial control projects initiated by the State Forestry Administration. Six national control projects are currently being implemented – three of which are for exotic pests, namely pinewood nematode, red turpentine beetle and fall webworm.

As China's economy continues to expand rapidly, with trade becoming more global, the incidence of invasions has greatly increased. These occur in many forest ecosystems and have caused, or are causing, tremendous loss or damage in terms of economic and ecological values. Half of the most damaging forest pests are exotic pests occurring over an area of 1.3 million hectares and killing over 10 million trees per year. It is estimated that exotic pests result in about 56 billion RMB (US\$6.7 billion) in losses annually, in terms of economic, ecological and social losses. Both the government and the general public are becoming concerned about the threats posed by alien invasive species. It is

recognized that the magnitude of this problem necessitates increased efforts to reduce the incidence and impact of forest pest invasions.

Pinewood nematode, *Bursaphelenchus xylophilus* (Steiner et Buhner)

Pinewood nematode (PWN) is native to North America and has been introduced to Japan, South Korea, Mexico and Portugal. PWN was originally found in Nanjiang in 1982 and has expanded its range since then. It is currently reported in counties in Jiangsu, Guangdong, Hubei and Shandong provinces, in addition to its known distributions in Hong Kong and Taiwan. It is a good example of how an exotic pest can prove costly to the exporting country (the United States of America in this case), as well as the importing countries. Although PWN is causing damage to forests in China, Japan and South Korea, the damage it has caused in the United States of America has been in the loss of exports and quarantine costs.

PWN generally does not damage pines native to North America, but has a very wide range of hosts in China, mainly pines. PWN has been isolated in 49 species of host trees under natural conditions and another 21 species have been infected in trials using artificial inoculation, indicating that there are some 70 potential host species. PWN is also called “pine cancer” in China because there is basically no cure for infected trees. Thus it poses a destructive threat to most pines in its range. Infected pines can be killed within 40 days and most die in 2-3 years following infection. The first signs of attack are red needles and a thinning of the crown, in the autumn, after infestation during summer. The pinewood nematode is not capable of moving from tree to tree on its own. The main pathway for infestation is by transporting infested wood materials, while the main vector for natural spread in China is the sawyer beetle (*Monochamus alternatus*). This beetle is widely distributed in regions south of Hebei Province. The presence of this vector beetle in those regions greatly increases the likelihood of its natural spread. The PWN range has spread steadily, affecting 87 000 hectares and over 40 million pines have been killed to date. The direct economic loss is calculated to be 25 billion RMB (US\$3 billion).

Due to its destructive nature, control of PWN is a high priority for the Chinese Government. PWN is currently ranked as the number one forest pest in the country. A national control project was implemented five years ago, with the direct involvement of the State Forestry Administration and relevant provincial forestry departments. The main measures implemented during this project include:

- timely removal of trees killed by PWN, by a designated well-trained PWN control team;
- chemical treatment of PWN infected logs and stumps. The treatments include: infested trees being covered and fumigated, infected log piles being fumigated with methyl bromide or heat-treated. Fumigated logs are then burned or chipped, or processed for plywood, pulpwood, fibreboard, panelboard or used for producing charcoal;
- control of the vector beetle by bait-trapping, biological control by parasite (*Sclerodema guani*), chemical control including spraying crowns of trees with pesticides during the time of adult flight, to eradicate the beetles before they can infest more trees; and
- replanting PWN infested stands with non-PWN host trees after cutting.

Experience has demonstrated these measures can be effective in bringing PWN under control.

Strict quarantine has also proven to be an effective tool to contain PWN spread, especially regarding the transport of wood materials out of the infested region. Immediate on-site quarantine and treatment measures are taken once a PWN infestation is discovered. Any logs or wood materials coming from a PWN control project can only be utilized locally, after effective PWN treatment, mostly by heat or fumigation. If logs or chips need to be transported out of the quarantine region – for fibreboard production – the State Forestry Administration is the only body authorized to issue transport permits. A special truck is used to transport the chips, which must be accompanied by an inspector along a designated route to the SFA-authorized fibreboard production plant. Quarantine checkpoints have been established, at exits to PWN quarantine regions, to stop any illegal or unprocessed pine wood materials leaving.

Application of these measures as part of an integrated pest management strategy has brought PWN infestations largely under control and has reduced the further spread and loss of pines. The area of the PWN infestations was reduced by some 6 000 hectares in 2002.

Red turpentine beetle, *Dendroctonus valens* (Le Conte)

Red turpentine beetle (RTB) is a common pest in North America; yet, despite the abundance and wide distribution of this beetle, destructive outbreaks have not been extensive or severe. However, since its first outbreak in 1999, in Shanxi Province, this exotic beetle has spread rapidly to the adjacent provinces of Hebei, Henan and Shaanxi, and has infested over 400 000 hectares of Chinese pine (*Pinus tabulaeformis*) stands (usually affecting stands aged 30 years or more) resulting in severe mortality. Nearly 10 million Chinese pines have been killed so far and it also appears to attack other pine species. Several consecutive years of drought have severely stressed its primary host species and contributed to the sudden outbreak. Historical records indicate that the RTB was introduced to China in the early 1980s, when unprocessed logs were imported from the west coast of the United States of America. This has been verified by a collaborative study between the Chinese Academy of Sciences, USDA Forest Service and Texas A&M University. Pines are a major reforestation species in China, and Chinese pine has been widely planted across much of the country, so the potential range and damage by this exotic beetle is overwhelming.

RTB reproduces once a year in China – the females usually bore into tree bark and commence feeding on the phloem. Generally untreated stumps, tree wounds, logging or oleoresin collection will increase RTB attack. The mechanism for beetle attack in China is different from in the United States of America, where the beetle frequently attacks injured or stressed trees. Also, it usually initiates an attack at the ground line and then colonizes a short distance both up and down the bark, i.e. to the upper roots and lower bole. However, in China, RTB attacks healthy trees and it has also been found extensively colonizing roots, where it overwinters. Due to this ability to overwinter in tree roots, and its overlapping generational structure, RTB is hard to effectively control with pesticides.

RTB received considerable attention from the SFA after its initial outbreak. Several teams were sent to the United States of America and a number of research teams from the USDA Forest Service were invited to China to exchange information and conduct joint research on the beetle. As a result of these exchanges, an action plan was developed and implemented. The measures taken to contain this beetle include:

- silvicultural measures to improve stand health, such as removal of fire damaged and stressed trees, thinning, and measures during logging operations to prevent wounding trees. The timing of these operations is important; the removal of stressed or infested trees is usually conducted during RTB dormancy in winter or before adult emergence;
- trapping, using traps baited with host semiochemicals or bait logs have also been experimented with on a large scale and have proven to be effective in reducing RTB populations and, consequently, tree damage. This method has proven to be particularly feasible because the semiochemical-based baits attract both males and females. The release device and traps were developed locally, which makes large-scale use possible. In 2003, some 8 000 traps were placed in RTB infested stands and the preliminary results are encouraging;
- the introduction of a natural predator, *Rhizophagus grandis*, from Europe is being investigated. The first field release was conducted in 2002 and more are being released this year from a laboratory colony, while local natural enemies are also being investigated; and
- in regard to chemical control, fumigation of boles with aluminium phosphide under plastic cover, DDVP or Omethoate injection into newly initiated galleries and spraying insecticides (Phorate, Monocrotophos, Cypermethrin, and Phoxime, etc.) onto boles, during the flight period, are direct control methods that all have been shown to be effective in killing beetles. However, the labour costs and environmental side effects are prohibitive to large-scale use.

International collaboration with RTB's native country has contributed significantly to the effective management of this invasive and destructive species. Especially, the work on an RTB trapping programme conducted with the USDA Forest Service has proven to be effective. Currently joint DNA research is being conducted, in the US and China, to:

- pinpoint RTB's origin in China and its subsequent evolution;
- identify the regional variations of RTB to host semiochemicals; and
- better understand the pathogenicity of RTB associated fungi.

It is hoped that this work will address many of the basic questions related to the mechanism of this invasive species' successful establishment and outbreak.

Fall webworm, *Hyphantria cunea* (Drury)

Fall webworm, *Hyphantria cunea* (Drury), is native to North America, but has since spread to many countries through human activities. It was first recorded in Liaoning Province, China in the 1970s, but has since spread to the eastern coastal provinces and part of Shaanxi Province. It has become a serious invasive pest to agricultural crops, forests and city ornamental trees due to its wide range of hosts. Fall webworm is a typical polyphagous defoliator; its host plants include shrubs, crops, vegetables, orchard trees, conifers and broadleaved trees, but it has a preference for broadleaved trees. A total of 175 species of plants are recorded on its host list in China.

Outbreaks of this moth in China have caused serious damage to local forests, including some valuable ornamental trees. The web formed by its larvae during feeding is a nuisance, especially on city ornamental trees. In most cases, during outbreaks, the feeding larvae defoliate all leaves on a tree, which damages its aesthetic value in cities, while its larvae crawl around, sometime into buildings becoming a nuisance to humans. The cost of controlling the moth is steadily increasing. An estimated 20 million RMB (US\$2.4 million) were spent in control measures in Liaoning Province alone in 1998.

The moth can complete two generations per year – sometimes three in certain ranges – resulting in overlapping generations. It overwinters as pupae and the adult emerges in late-April. Adult moths are very strongly attracted to light and can fly about 100 meters, during which flight the moth pre-selects a host plant for mating and oviposition. Fecundity is very high for this moth, with an average of 800-900 eggs per female. The larval stage lasts about 40 days and has aggregation phenomena. Pupating usually occurs under a roof, in crevices, the corners of walls, rubble, or the crevices of tree trunks. The overwintering generation usually sustains high mortality due low temperatures, disease, predators and parasites – a mortality rate of 70-80 percent has been reported.

There are several ways to conduct damage surveys and detection for the moth. The simplest method involves surveying the webs. Population monitoring is mainly conducted using black light trapping or pheromone trapping.

An effective and cost-efficient management plan has been developed over the past 20 years, since fall webworm's introduction to China. The measures employed in this management plan include:

- strict quarantine procedures specifically targeted at the late instar larval and pupae stages to prevent long distance spread by human activities;
- encouraging the planting of mixed forest stands to restructure the current plantation estate;
- manual removal of webs during the 3-4th instar larval stage; and
- spraying NPV virus during the larval stage and releasing the *Chouioia cunea* parasite during pupae stage. The parasite *Chouioia cunea* has proven to be very effective and has been applied in several epidemic areas.

In 1999, a national control project for the moth was initiated by the SFA to control its further spread and reduce its population around Beijing, Tianjing and Hebei provinces. The main priority of the project is to prevent its expansion into Beijing. The project covers 35 700 hectares of fall webworm infested areas. The main tactics used include black light trapping and pheromone trapping in conjunction with the measures listed above. The use of chemical pesticides has not been allowed during this project. Preliminary results indicate that the infestation has been significantly reduced from some 33 000 hectares prior to the project, to some 7 000 hectares now. The movement of the fall webworm infestation towards Beijing has been pushed back some 20 kilometre in the east to Tianjin.

Japanese pine needle scale, *Hemiberlesia pitysofila* Takagi

Japanese pine needle scale is native to Japan and belongs to the family Diaspididae. It was first reported in Taiwan, and then spread to Macao. From there it spread into Guangdong, China in 1982. It was recorded in Fujian Province, in 2001.

The *Pinus* genus is the host for Japanese pine needle scale, with its primary host being mason pine (*Pinus massoniana*). It attacks saplings and mature trees aged 20-30 years, causing mortality to most of the infested pines. The average loss of volume resulting from attack by this scale is approximately 2.7 cubic meters per hectare, with a reduction in oleoresin production of approximately 900 kilograms per hectare. Two to three years of consecutive attacks usually result in large-scale pine mortality. In Guangdong Province alone, some 180 000 hectares of pines have been killed by Japanese pine needle scale, to date. Currently 1.23 million hectares of pines are infested in both Guangdong and Fujian provinces.

Japanese pine needle scale mainly feeds on the basal sheath of old needles. It also attacks the tender sections of the middle and bottom of the terminal, as well as fresh cones and young needles. Generally only a small portion of the nymphae hatched in the spring feed on the base of needles, while the majority feed on the old terminal sheaths from the previous year. The nymphae hatched after July feed on the current year's terminal. Japanese pine needle scale can produce five generations per year. After settling in a suitable habitat, the immature nymphae live a fixed life on the host. The males can mate several times, with oviposition lasting a long time, but the egg stage is very short, so there is generational overlapping.

Monitoring of this scale mainly relies on random surveying and shoot sampling. The wind-direction side of a pine is selected and examined for the following symptoms: dead branches at the bottom of the trees; yellow top needles; and traces of scales at the base of new needles, the sheath or outside the sheath, at the base of current year's terminal, and among fresh cones.

Guangdong and Fujian provincial governments have made considerable efforts to control the scale and have established a Japanese pine scale control office to coordinate the various control works. Funding for research on this scale has been secured from both the central and provincial governments, and has involved over 100 researchers, including international cooperative projects. A comprehensive control action plan has been implemented, with measures including:

- strengthening quarantine, to stop the import of infected pine seedlings;
- stopping the transport of pine seedlings, branches and logs from epidemic areas;
- planting of broadleaved trees in order to mitigate spread of the scale;
- introduction of the parasite, *Coccobius azumai* from Japan, as well as the utilization of native natural enemies such as *Prospaltella beriosei*, *Encarsia formosa*, ladybug, thrips etc.;
- removal of dying or heavily infested pines and replacement with broadleaved trees to restructure the stand as a long-term solution; and
- strengthening the management of oleoresin collection, in order to prevent excessive collection resulting in over-stressed trees.

All of the above measures have contributed to success in management of the Japanese pine needle scale.

Use of the natural enemy *Coccobius azumai* is considered to be the most effective and environmentally friendly method. This wasp reproduces rapidly with nine to ten generations per year. The parasitism can be as high as 20–30 percent, resulting in a reduction of the average density of female Japanese pine needle scales to below 0.3 - 0.6 per branch of needles. This parasite had been released over an area of some 1 million hectares by 1998. However, the scale population recently resurged due to a lapse in the continuous work on the parasite, partly due to a shortage in the supply of the parasite. The governments of Guangdong and Fujian provinces immediately organized a visit to Japan in May 2002, to collect and reintroduce *Coccobius azumai*, to reinforce the field population of the parasite.

Crofton weed, *Eupatorium adenophorum* Spreng

Eupatorium adenophorum Spreng (Compositae) is a tufty, semi-shrubby, perennial herbaceous plant of about 1–2m in height. It is known, locally in China, as liberation weed, black head weed and evil weed. Its reproductive capacity and ecological adaptive capacity are strong and it grows very fast. It is native to Central America, mainly Mexico, although it is now distributed widely in the United States of America, Australia, New Zealand and many countries of southeastern Asia. *E. adenophorum* was

introduced to southern parts of Yunnan province from Burma in 1940s and has continued to spread from southwest to northeast at a rate of about 20 kilometres per year. It is now diffusely distributed throughout Yunnan, Guizhou, Sichuan, Guangxi and Tibet, and continues to spread towards the north and east of China.

This exotic weed prefers a warm and wet environment, but its ability to adapt to different environmental conditions is very strong. It can grow in environments with temperature ranges from 5°C to 42°C. It grows on dry and barren hills, and can even grow in cracks in stone walls and houses. However, it grows more vigorously in a fecund soil. It has a shallow rooting system spreading horizontally in the topsoil.

E. adenophorum propagates mainly by seed, with each plant producing 30 000–45 000 seeds, and sometimes as many as 100 000 seeds. *E. adenophorum* maintains and spreads its population along rivers and roads, mainly by means of its abundant seed. Wind, flowing water, vehicles, people and livestock are mediums for spreading *E. adenophorum*. Seed germination requires light, but its seedlings can grow in shady environments, which is an advantage to its invasiveness into other plant communities. It is also capable of asexual reproduction. Its root and stem can differentiate an adventitious root, which can then grow in the soil. The root system of *E. adenophorum* excretes an allelopathic substance that restrains the growth and development of other plant species around it. Allelopathy is one of the important reasons why the plant is so highly competitive.

E. adenophorum invades pastures and wild lands suitable for forest. It can have an immense impact on forest regeneration and growth. It poses an increasing threat to livestock, forest regeneration and ecosystems in its range. Its pollen and pappus can cause allergic (anaphylaxis) reactions in some people.

Several research and control projects are currently being implemented on the management and control of this weed. A comprehensive action plan, based on integrated management, has been developed in Yunnan, with the aim of containing its spread and to eradicate it. The integrated management approach being implemented consists of the following control measures:

- *E. adenophorum* can be eradicated in some areas by means of machines or other simple tools. The weed can also be burned after being uprooted and sun-dried. This is the most simple and efficient method, but a very labour-intensive task;
- glyphosate, dicamba and 2,4-D butyl have proven to be effective chemical treatments, but are expensive and contaminate the environment;
- plant species with strong vitality and high growth rates are capable of restraining *E. adenophorum*. Generally, crops, pasture or fast-growing tree species are densely planted after *E. adenophorum* has been pulled out by the roots. *E. adenophorum* cannot invade dense forest, shrublands, well-managed pastures and plantations; and
- *Procecidochares utilis*, *Dihammus argentatus*, and *Cercospora eupatorii* are all natural enemies of the plant that can be used as biological control agents. The combined use of these three natural enemies has proven to be the most effective method of biological control against this weed.

Additional research is being conducted on the utilization of this weed as a raw material for panelboard, for bio-insecticide extraction, as a feedstock after detoxifying, to produce gas by fermentation, as a culture for mushrooms, and as a raw material for essential oil extraction. Progress has been achieved in some of these areas.

Strategies and policies for management of forest pest invasions

Given the tremendous potential impact of forest invasions and current forest programmes in China, the main theme for tackling this problem is prevention and early detection, backed by integrated management. This is in line with national eco-environment development programmes – including the six major forestry projects – to support the country's sustainable development. The problem of alien invasive species has received considerable attention at all levels of government, with the main emphasis on cooperation between the relevant agencies and international collaboration. The establishment of an efficient early warning and detection programme to actively pursue exclusion – with legal and regulatory support to inspection and quarantine – has also been a priority. Extensive

monitoring has also been given priority, as it is essential in any programme where the objective is to prevent the establishment of new invaders.

Intensive basic research on exotic pests – such as good biological information on the pest concerned – that can be used to guide decision-making, monitoring and detection techniques, needs to be developed. The goal is to build an efficient and broad early warning and detection system to achieve exclusion or early detection leading to the eradication of potential invaders. A comprehensive database on forest exotics is being compiled, in collaboration with Chinese Academy of Sciences. This database presently contains information on some 400 species.

Legislation and regulatory procedures regarding quarantine, inspection, and intentional introduction of plants or animals need to be strengthened, with more attention to risk assessment before approval and follow-up monitoring after introduction. Efforts are underway to strengthen on-site quarantine inspection and domestic quarantine for established exotic pests, in order to prevent their further spread. However, new legislation is also required to better combat exotic pests, including restricting the use of alien species in protected areas, while promoting the use of native species in reforestation programmes, and a mandatory requirement for scientific trials and risk assessment prior to large-scale planting of exotic trees.

More than 1 000 forest-pest monitoring and detection centres have been established at county level and a further 8 000 monitoring stations have been set up across the country. These centres and stations can monitor both native and exotic forest pests all year round, to enable early detection.

A number of national control programmes for alien invasive species have been implemented throughout the country. These programmes are starting to yield some positive results.

In order to coordinate the work on forest invasive species, the National Forest Exotics Office and the Identification and Inspection Center for Forest Exotics were established in 2003, under the SFA. Both bodies have appropriate authority and clearly defined functions.

Strengthening the coordination and information sharing between the relevant government agencies for forestry, agriculture, trade, environmental protection and research institutions in dealing with forest invasive species is very important. It is also important to strengthen regional and international cooperation

It is recognized that public awareness plays a key role in combating invasive species, TV, newspapers, internet and other forms of media are being utilized to inform and educate the general public on the impacts of invasive species.

Legislation and regulations on forest invasive species

A series of laws and regulations has been enacted regarding forest invasive species, these include:

- *Implementation details of the Forestry Law* (2001)
- *Notice on the pinewood nematode control by the State Council* (2000)
- *Regulations of forest pest insects and disease control* (1998)
- *Forestry Law of the P.R. China* (1998, revised)
- *Animal and Plant Quarantine Law of the P.R. China* (1991)
- *Plant Quarantine Regulations* (1992, revised)

The State Forestry Administration has also issued a total of 70 regulations, standards or policy documents associated with forest invasive species, an example of which is the *Notice on Further Strengthening Prevention and Management of Forest Invasive Species* (2002). Besides, some local provincial governments have issued local legislation or regulations associated with forest invasive species. For example, *Temporary Management Tactics for Pinewood Nematode* (1989) Jiangsu Province. Similar regulations or acts have also been issued by Anhui Province in 2001 and Guangdong Province in 2002.

Forest invasive species: country report – Fiji

Inoke Wainqolo and Visone Timote

Fijian Forestry Department

Fiji Quarantine Inspection Service

Introduction

Fiji is an archipelago consisting of 320 islands, scattered over 1.3 million square kilometres of the South Pacific Ocean. The islands vary in sizes from 1 million hectares, to tiny islets, and have a total area of 1.83 million hectares. The population of Fiji is concentrated on the two main islands of Viti Levu and Vanua Levu.

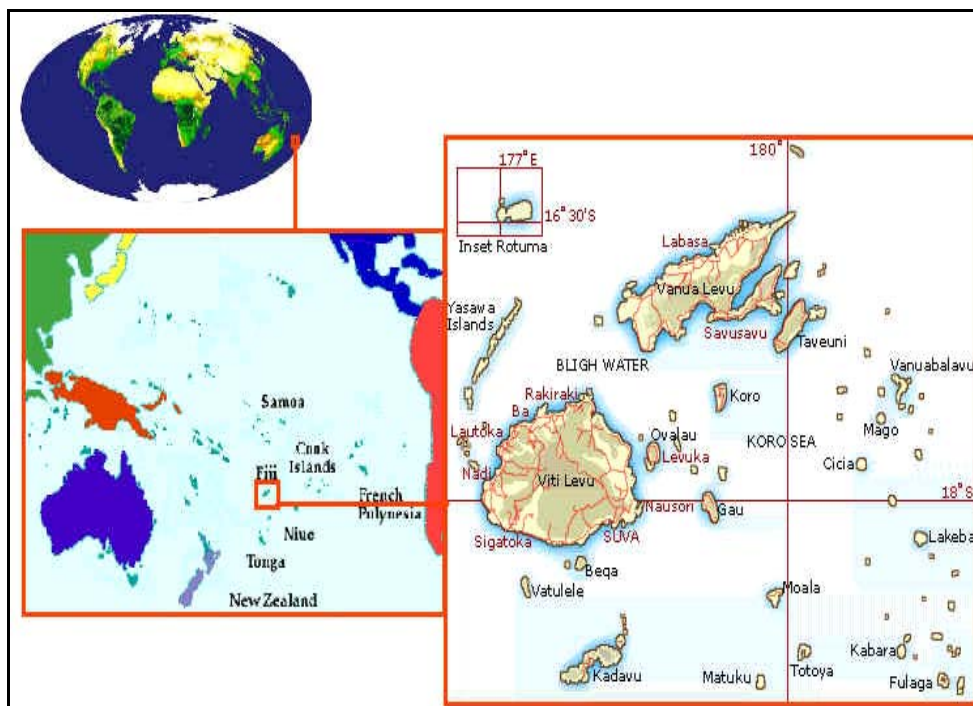


Figure 1: Map of Fiji

The forestry sector is one of the Economic Services sectors of the Republic of Fiji Islands along with agriculture, fisheries, tourism, mineral resources and manufacturing sectors. The forestry sector contributes 2.5 percent of GDP and about F\$50 million (US\$27.6 million) in foreign exchange export earnings, annually. The sector rates as fifth most significant after tourism, sugar, gold and fish. Earnings from the sector have huge potential for growth and expansion with the utilization of the Vanua Levu pine resource and the harvesting, processing and marketing of some 37 500 hectares of mahogany plantations, managed in accordance with environmentally sound and sustainable practices. The sector currently provides direct employment to more than 3 000 people.

The sector functions through mutual trust and cooperation among a diverse group of stakeholders. The most significant “players” are the landowners, who own more than 83 percent of the total land mass and almost the entire natural forest cover. The Native Land Trust Board (NLTB) has statutory powers, as custodians of all customary-owned lands, to deal in native land matters. The pine and hardwood plantations have mainly been established by the government on land, leased from native landowners. The loggers and sawmillers are mostly private individuals or companies who harvest indigenous logs under license and process and market timber products. The Forestry Department is charged with managing a resource it does not own or have full control over. At the same time, the Forestry Department is required to maintain a balance between production and protection and conservation functions of forests.

Quarantine overview

Quarantine has obviously become important on a national, regional and international scale. Fiji becoming a member of the World Trade Organization (WTO), has established bilateral quarantine

agreements with other trading countries. Our obligation is to take into account the principles of plant and animal quarantine whenever making management decisions. The vital role of the Fiji Agriculture Quarantine Division is to provide protection against the entry of unwanted pests, diseases and weeds into Fiji, while at the same time permitting the flow of international trade and to assist in the conservation of flora and fauna.

The Fiji Agriculture Quarantine Division is responsible for the exclusion, from Fiji, of exotic pests and diseases of plants and animals or parts thereof, assessed to be dangerous to agriculture, horticulture, forestry and livestock industries. Due to its relative isolation, Fiji is relatively free of harmful and serious pests and diseases known to occur in other parts of the world. This has only been possible through stringent import quarantine requirements, conditions and strict quarantine awareness and surveillance.

Agriculture quarantine division – border control

Purpose

- To aid safe and efficient production of Fiji's plant and animal industries.
- The conservation of Fiji's flora and fauna in order to contribute to our national economy and social welfare.

Objective

- Protection against entry of unwanted pests and diseases.
- Detect the presence of exotic pests and diseases should they enter and initiate emergency responses.
- Facilitate the safe introduction of animal and plant materials and products.
- Facilitate the safe entry of commercial products.
- Apply sound scientific principles to quarantine decision-making.

Strategy

- Identifying unwanted pests and diseases that threaten national economic and social welfare.
- Assessing risks on basis of biological and other evidence taking into account the need to comply with international trade obligations and at the same time facilitate passenger and cargo movement.
- Formulating and implementing responses to assessed risks.

Produce inspection

Quarantine Officers are responsible for the official visual examination of plants, forestry products and other regulated agricultural related articles to determine if pests and diseases are present and/or to determine compliance with Phytosanitary regulations.

Phytosanitary certificates

International Phytosanitary Certificates are issued by the governments of exporting countries to indicate that consignments of plants, plant products and other agricultural regulated items meet the phytosanitary regulations of the government of the importing country. There are three types of phytosanitary certificates:

- Phytosanitary Certificate for Plant and Plant Products;
- Phytosanitary Certificate for re-export; and
- Phytosanitary Certificate for Regulated Articles (other than plant and plant products).

The certificates are used to indicate conformance with the phytosanitary regulations of the importing country.

Invasive species in Fiji

Despite these strict quarantine measures, Fiji still has some problems with invasive species. Table 1 gives an overview of the most important invasive species.

Table 1: The most important alien invasive species in Fiji

Pests	Impacts
Fruit flies (<i>Bactrocera passiflorea</i> , <i>B. xanthodes</i> , <i>B. kirki</i> , <i>B. obscura</i> , <i>B. distincta</i> , <i>B. gentum</i>)	Significant losses in production and their presence results in quarantine restrictions being imposed on fruits and vegetable export commodities.
Taro Beetle (<i>Papuana huebneri</i>)	A significant loss in production of up to 48 percent in taro beetle infested areas and drastically reduces market value of taro.
Weeds	
African tulip (<i>Spathodea campanulate</i>)	Reduced planting spaces and long, deep rooting system hinders cultivation for arable land use and development.
Animal diseases	
Tuberculosis/Brucellosis on cattle	High costs of meat for consumers due to huge meat imports from New Zealand. A highly dangerous and zoonotic disease for humans in the Pacific region, due to cultural norms (that is slaughtering without a meat inspector).
Animals / birds	
Rats (<i>Rattus rattus</i>), (<i>R. exulans</i>), (<i>R. norvegicus</i>), (<i>R. musculus</i>) Indian mongoose (<i>Rallus philloppensis</i>)	Damage mature coconut groves and destroying one-third of the total potential copra at various stages in its preparation. A recent archeological work on Fiji (Worthy <i>et al.</i> 1999) reveals many extinct species of birds and reptiles due to this invasive species.
Indian myna (<i>Acridotheres tristis</i>) Jungle myna (<i>Acridotheres fuscus</i>) Red-vented bulbul (<i>Pycnonotus cafer</i>)	These invasive birds are known to be very territorial thus taking charge of breeding areas for other wildlife. They are also known to cause havoc at small-scale fruit and vegetable farms, eating fruits and newly emerging seedlings.

Management efforts

Fruit flies (*Bactrocera passiflorea*, *B xanthodes*, *B kirki*, *B obscura*, *B distincta* and *B gentum*)

With the assistance from the Fruit Fly Management Project of the Secretariat of the Pacific Community, together with the Research and Quarantine Divisions of the Ministry of Agriculture, Fiji was able to adopt and use protein and insecticides to attract and kill fruit flies that are present in Fiji. Export farm crops are sprayed with a protein-insecticide mix to attract, and at the same time kill, fruit flies. The presence of fruit flies in the country invariably results in quarantine restrictions being imposed on horticultural products that are destined for export. Export commodities also go through the Hot Treated Forced Air treatment at Nadi before being shipped overseas. The Quarantine Division has also incorporated the use of fruit fly traps in their surveillance and monitoring border control projects around the country, in order to detect any new incursions.

Taro beetle (*Papuana huebneri*)

Awareness campaigns have been held throughout Fiji to educate the general public and farmers on the disastrous impact of taro beetle (*Papuana huebneri*) on taro yields and the importance of not planting or transferring infected planting material from infected areas to non-infected areas. Planting material or "host plants" include plants belonging to following orders: Arales, Zingiberasles, Bromeliales, Pandanales and Solanales. The Secretariat of the Pacific Community, in cooperation with the Research and Quarantine Divisions of the Ministry of Agriculture, Fiji will soon commence with an eradication programme for the beetle.

African tulip (*Spathodea campanulata*)

Initial investigations into the invasive species *Spathodea campanulata* have been undertaken by the Ministry of Forestry over the past few years. These included: chemical control, biological and cultural control and research of the basic wood properties of the species to investigate commercial uses. It was found that a 25 percent solution of TORDON 50D was sufficient to kill the tree. There are currently no known biological control agents, although the Ministry of Forestry is looking at possibilities with various African wildlife ministries and other counterpart agencies, where this species

is known to be invasive. As for cultural control, it is suggested that the trees be cut down, with the complete removal of plant stems, roots and branches, which should be dried before burning. Preliminary tests indicate that the wood of *Spathodea campanulata* can be utilized in non-load bearing applications, such as wall paneling, furniture and in light construction.

Awareness campaigns

There are few specific awareness programmes in place, in reference to individual invasive species. However, at the moment, generic awareness responsibilities and functions are vested in the Fiji Agriculture Quarantine Service to be incorporated in their quarantine awareness programmes. During these generic awareness programmes, specific resource personnel are invited to make presentations in regard to their areas of speciality regarding these invasive pests and diseases.

The production of the awareness materials for the pests and diseases are done in consultation with quarantine, respective pest and disease specialists, and at times with organizations such as FAO, SPC, and other non-governmental organizations.

The main awareness programmes and publications produced include:

- Taro beetle posters and brochures
- Agriculture quarantine in-flight video
- Fruit fly posters and pamphlets
- Agriculture quarantine travellers' guide
- Agriculture quarantine fliers
- Agriculture posters
- Field days and farmers training
- Workshops / training for stakeholders
- Rural radio broadcasting
- Quarantine cinema video bank clip
- Quarantine awareness campaigns
- Quarantine launching programmes

Appendix: Management aspects for the general emergency response plan for plant pest and disease incursions in Fiji.

POSITION	FUNCTIONS AND RESPONSIBILITIES
Chairperson, ERM	<ul style="list-style-type: none"> ➤ Puts the Emergency Response Plan into action. ➤ Overall management of the programme.
Emergency Response Management Committee (ERM)	<ul style="list-style-type: none"> ➤ Discusses recommendations from the Technical Adviser (TA) after delimiting survey and decides on further action. ➤ Appoints Operations Manager and Field Controller. ➤ Quorum (5): Chairperson or Deputy, Chief Quarantine Officer (Plants), representative of affected province or island, representative of private sector and/or government body dealing with the affected commodity, TA.
Head of Quarantine (Deputy Chairperson)	<ul style="list-style-type: none"> ➤ Acts in the absence of the Chairperson. ➤ Commits the resources of the Quarantine Department to the problem.
Director, National Disaster Programme	<ul style="list-style-type: none"> ➤ Commits the resources of the organization to the problem.
Chief Quarantine Officer (Plants)	<ul style="list-style-type: none"> ➤ Alerts Chairperson to a suspected pest incursion. ➤ Reports to ERM during operational phase. ➤ Ensures that all management plans conform to relevant legislation. ➤ Notifies SPC of suspected new pest.
Specialist: ➤ appointed by and reporting to Chief Quarantine Officer (Plants).	<ul style="list-style-type: none"> ➤ Collects samples and organizes identification of samples. ➤ Collects information.
Operations Manager: ➤ appointed by ERM; ➤ located in the area where the new pest is present; ➤ should be in a position of local authority and possess management skills and administrative experience.	<ul style="list-style-type: none"> ➤ Reports to Chief Quarantine Officer (Plants). ➤ Manages day-to-day operations. ➤ Oversees field operations. ➤ Checks resource requirements. ➤ Liaises with provincial authorities. ➤ Selects and appoints the response team(s). ➤ Briefs and trains response team(s) and Field Controller together with Technical Adviser.
Technical Adviser: ➤ appointed by Chairperson; ➤ reports to nobody to make sure that advice remains objective; ➤ located as required; ➤ has to be a recognized expert on the particular pest causing the incursion.	<ul style="list-style-type: none"> ➤ Conducts delimiting survey. ➤ Submits report including response options, recommendations and tentative budgets to ERM. ➤ Briefs and trains response team(s) and Field Controller together with Operations Manager. ➤ Provides technical advice to Chairperson, Chief Quarantine Officer (Plants), ERM, Operations Manager, Field Controller, and operational teams. ➤ Periodically monitors operations.
Financial Controller: ➤ nominated by Head of Quarantine; ➤ reports to Operations Manager.	<ul style="list-style-type: none"> ➤ Responsible for administration and finance.
Field Controller: ➤ appointed by ERM; ➤ located on site full time; ➤ reports to Operations Manager; ➤ should possess agricultural background and management skills.	<ul style="list-style-type: none"> ➤ Logistics. ➤ Day-to-day control of field operations. ➤ Liaises with district staff and stakeholders.
Field Teams: ➤ appointed by Operations Manager; ➤ report to Field Controller.	<ul style="list-style-type: none"> ➤ Practical activities.

Forest invasive species: country report – India

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Introduction

India is considered to be one of the 12 mega-biodiversity countries of the world. It has two important biodiversity hotspots, out of 18 in the world, located in the south and northeast parts of the country. It has a rich biodiversity, with diverse forest ecosystems such as the great moist evergreen forests of the southern tip of the Western Ghats in the south to the evergreen forests of northeast India. The diversity ranges from temperate and high mountain forests of the Himalayas in the North, to the desert and scrub forests in the west. There are dry deciduous and semi-moist deciduous forests in Central India, which transform to coastal forests and mangroves along the coasts and islands. Similarly, it has an extremely rich biodiversity among its wild fauna. India has nearly 64 million hectares of forests, which is nearly 20 percent of the geological area of the country. Five percent of its geographical area has been set aside in the country's protected area network, with nearly 500 wildlife sanctuaries and 89 national parks spread throughout the country. In addition, it has 13 biosphere reserves located in various parts of the country. These biosphere reserves have been developed to facilitate the traditional co-existence of its forests and wildlife with human beings.

Unfortunately, some of these vital lifeforms are put at peril due to invasions by exotic or alien species that have been purposely introduced, or brought in inadvertently, from time-to-time. These invasions can cause extensive damage to natural ecosystems. Specific problems have been recorded in islands such as the Andaman and Nicobar Islands in the Bay of Bengal.

Invasive species

An invasive species is a plant or animal that is, by origin, alien to the local ecosystem. The species grows or reproduces at a speed generally faster than indigenous species. Gradually, this species may become a dominant species and cause economic and ecological stress.

Invasions can occur through two sources – external or internal. Wherever humans have travelled, they have transported other animal and plant species with them. These may be as domesticated animals or plants, or of wild origin. Often these species have been deliberately released. Some of these introduced species become independently established over time, and start invading the habitats of other species.

With increases in international trade and travel – India – like any other country, is becoming increasingly exposed to the dangers of infiltration by potentially dangerous pests and diseases afflicting human beings, animal and/or plants that provide food, fibre and other means of economic and ecological prosperity.

There are several well-authenticated examples of major pests, which have invaded new areas and become established in India. These species, generally, do not have natural predators or enemies to challenge them. Hence they spread rapidly and establish permanently. Some travel as parasites (e.g. rats and mice) and some travel accidentally (e.g. mollusks, birds, insects) through various modes such as ships and planes.

In the past, several pests and pathogens have been introduced through seed materials imported into the country. Many of these pests have since become widespread. Several examples include downy mildew on sunflower, spotted wilt virus on tomato, peanut stripe virus on groundnut, apple scab from Europe, golden nematode and wart disease of potato from Europe, and the bacterial blight of paddy from East Asia. The bunchy top disease of banana was introduced to India from Sri Lanka in 1940. Now it occurs over practically all of Kerala and has been reported in many other states. Appendix 1 (to this paper) gives an overview of the invasive species found in India.

Species such as the giant snail (*Achatina fulica*) (introduced from Japan in many islands), two species of birds, Hava sparrow (*Pedda oryzivora*) and the common pheasant (*Phasianus colchicus*), are examples of animals that have been introduced to India. The bullfrog (*Rana catesbeiana*) has spread to India from Southeast Asia. Various species of tropical ornamental fishes and the caiman crocodile are potential threats to local species.

Lantana (*Lantana camara*), *Ipomoea* (*Ipomoea carena*), *Casia tora* and water hyacinth (*Eichhornia crassipes*) have established permanently as weeds in forests in almost all parts of the country. *Lantana camara* is native to South America, but was introduced to India and has since established itself in the wild. *Lantana* is a fire hazard in deciduous forests because of its ability to burn even when green. In many places, the *Lantana* undergrowth has affected the growth of teak plants, reducing the basal area increment by up to 33 percent. It is also known to harbour injurious insect pests, including malarial mosquitoes. The spread of the species has caused widespread problems, and the Union Government spends thousands of dollars every year to manually eradicate it from national parks and wildlife sanctuaries. However, the problem is far from being tackled satisfactorily. Complete eradication of *Lantana* over large areas is difficult and costly. Various methods, mechanical, cultural, chemical and biological have been tried to check *Lantana*.

Invasive forest insects

There are a number of invasive forest insect species that cause problems in India. The invasiveness of insects is governed by many features. Mayers (1987) suggests that success or failure of introduced insect outbreak densities depends on:

- climatic differences between native and exotic areas;
- quantity of food or taxonomic differences in host plants between exotic and native areas;
- predators and parasitoids in exotic areas;
- reduced genetic variability in the introduced population; and
- competition with native insects.

Exotic insects on exotic tree species

The classical example of an exotic insect invasion on an introduced tree species in India is that of *Heteropsylla cubana* (Homoptera: Psyllidae) invading subabul (*Leucaena leucocephala*). The insect was first reported in Chengalpetu (Tamilnadu), South India, in 1988. By 1990, it had attacked all the *Leucaena* plantations in the country (Singh and Bhandari 1989; Singh, 1988; Misra, 1990).

Pineus laevis sp. (Homoptera: Adelgidae) was first introduced to India in the 1970s. It has caused severe damage to *Pinus patula* plantations in the Nilgiri hills of South India. The damage has been restricted to *Pinus patula*, because only trial plantations had been established. Its further spread has been contained by discontinuing the planting of *P. patula* (Anon, 1977).

Exotic insects on indigenous tree species

Icerya purchasi (Homoptera: Coccidae), the cottony cushion scale, was accidentally introduced into India in 1921. It damages *Acacia decurrens* and *A. dealbata* in addition to numerous other forestry and agricultural plant species. The scale has done serious damage to plants in the Nilgiri hills in South India, and in the Anamallai hills in Tamilnadu, and has since become well established throughout the country. *Rodolia cardinatis* (Coleoptera: Coccinellidae) was introduced for the control of this scale, and it has proven to be a very effective predator (Beeson, 1941). *Quadraspidiotus perniciosus* (Homoptera: Coccidae) (Beeson, 1941) or the San Jose scale is a native of China. It reached India in 1911, and by 1933 it had attained pest status in fruit orchards and plantations of poplars and willows. The San Jose scale also damages species of the following genera: *Aesculus*, *Alnus*, *Betula*, *Celtis*, *Fagus*, *Fraxinus* and *Morus*.

Plant quarantine in India

The Government of India took legislative steps in 1914, in order to protect its agricultural and forest species. In that same year, the Directorate of Plant Protection, Quarantine and Storage was established to implement the new regulations. Plant Quarantine and Fumigation Stations were established at major airports, seaports and land frontier checkpoints across the country.

The most important Acts to control and regulate the export and import of plants, seeds and animals and their products in the country are:

- the Destructive Insects and Pests Act, 1914;
- the Customs Act, 1962; and
- the Foreign Trade (Development and Regulations) Act, 1992.

The Customs Department is the most important organization with regard to the enforcement of Acts relating to international movements of plants, seeds and animals. Customs, in cooperation with the CITES Assistant Management Authorities, the Department of Plant Quarantine and the Department of Animal Quarantine, are the operational organizations that enforce the laws in this regard.

International obligations

India is a member of the International Plant Protection Convention (IPPC). It is also a signatory to the Plant Protection Agreement of the Asia-Pacific Plant Protection Convention (APPPC). The Agreement obliges countries to undertake adequate measures to prevent the spread of pests and diseases.

Strategy to combat the menace

When importing plant germplasm and animal matter, it is of utmost importance that no compromises are made on quarantine. There are 26 quarantine and fumigation stations located at ten airports, nine seaports and seven land frontiers in India. Unfortunately, it takes considerable time to establish a plant or animal quarantine facility when a new airport or seaport is established. As a result, the danger of entry of infected seed or plant material is always heightened with expansions.

The following additional steps need to be taken to improve India's quarantine defences:

- augmentation of technical staff;
- provision of physical infrastructure and essential laboratory equipment;
- creation of regional offices to issue import permits;
- early constitution of a Plant Quarantine Advisory Committee;
- establishment of separate Plant Quarantine Counters in the arrival halls at Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad and Amritsar airports, for effective checking of imported seeds and plant materials and to ensure strict observation of plant quarantine procedures; and
- ensuring that all consignments of seeds and plants are subjected to provisions of Plants, Fruits and Seed (Regulation of Import into India Order, 1984), and accompanied by a phytosanitary certificate with additional declarations.

Conclusions

There has been practically no research carried out on the ecological, environmental or economic impacts of introduced or invasive species in India. Due to impending problems caused by species such as Chital (*Axis axis*), elephants, and the common mynah (*Acridotheras tristis*) in the island ecosystems of the Andaman and Nicobar Islands, some studies have been conducted on these species impacts on the island environments. Such studies have, however, been mainly qualitative in approach.

Although India has been affected by the incursion of many alien invasive species, no systematic studies on the management, control or impacts of these species have been conducted. This is probably due to a lack of sensitivity to the issue, or insufficient political awareness – although, large sums of money are spent by various agencies each year to eradicate some of these invasive species.

A systematic and dedicated approach is required to tackle this growing phenomenon. Some of the steps may be as follows:

- a nationwide assessment survey of invasive species – both plants and animals;
- a combat strategy should be part of the National Forest Policy and National Wildlife Action Plan;
- a boosted Research and Development Programme on invasive species;
- regular coordination meetings among the Customs, Plant Quarantine Department, Animal Quarantine Department and the CITES authorities in the country;
- regular training and workshops for enforcement agencies – especially the Customs Department;
- compulsory and stricter Post-Entry Quarantine (PEQ);
- stricter penalties for violators; and
- strengthening of quarantine facilities and plant quarantine procedures.

Appendix 1 – Pests believed to have been introduced into India

Name	Host	Date of 1st Record	Introduction From
Insect pests			
Fluted scale (<i>Icerya purchasi</i>)	<i>Acacia</i> spp.	1912	Sri Lanka
San Jose scale (<i>Quadraspidiotus perniciosus</i>)	Wild and cultivated plants	1910	Australia
Woolly aphid (<i>Eriosoma lanigerum</i>)	Apple	--	--
Codling moth (<i>Cydia pomonella</i>)	Apple	1919	--
Coffee berry borer (<i>Hypothenemus hampei</i>)	Coffee	1990	Sri Lanka
Diseases			
Leaf disease (<i>Hemileia vastatrix</i>)	Coffee	1879	Sri Lanka
Late blight (<i>Phytophthora infestans</i>)	Potato, tomato	1883	Europe
Rust (<i>Puccinia carthami</i>)	Chrysanthemum	1904	Japan or Europe
Flag smut (<i>Urocystis tritici</i>)	Wheat	1906	Australia
Downy mildew (<i>Plasmopara viticola</i>)	Grapevine	1910	Europe
Downy mildew (<i>Pseudoperonospora cubensis</i>)	Cucurbits	1910	Sri Lanka
Downy mildew (<i>Sclerospora philippinensis</i>)	Maize	1912	Java
Foot rot (<i>Fusarium moniliforme</i>)	Rice	1930	Southeast Asia
Leaf spot (<i>Phyllachora sorghi</i>)	Sorghum	1934	South Africa
Powdery mildew (<i>Oidium heveae</i>)	Rubber	1938	Malaysia
Black shank (<i>Phytophthora parasitica</i>)	Tobacco	1938	Dutch East Indies
Fire blight (<i>Erwinia amylovora</i>)	Pear and other pomes	1940	England
Crown gall and hairy root (<i>Agrobacterium tumefaciens</i> ; <i>A. rhizogene</i>)	Apple and pear	1940	England
Bunchy top (Virus)	Banana	1940	Sri Lanka
Canker (<i>Sphaeropsis malorum</i>)	Apple	1943	Australia
Wart (<i>Synchytrium endobioticum</i>)	Potato	1953	Netherlands
Nematodes			
Cyst nematodes – (<i>Globodera pallida</i> ; <i>G. rostochiensis</i>)	Potato	1961	Scotland
Weeds			
Water hyacinth (<i>Eichhornia crassipes</i>)	--	--	South America
Lantana (<i>Lantana camara</i>)	Potato	--	South America
Others			
Giant African snail (<i>Achatina fulica</i>)	Vegetables	1847	--

The invasion of *Acacia nilotica* in Baluran National Park, East Java, and its control measures

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Introduction

The forests of Indonesia consist mainly of tropical rain forests. According to the forest land use classification by consensus, the TGHK (Tata Guna Hutan Kesepakatan), the total forest area is estimated to be 141.9 million hectares, which is about 74 percent of the total land area of Indonesia. The forest land is classified into four major utilization classes. These are protection forest (29.6 million hectares), conservation and recreation forest (19.2 million hectares), production forest (62.9 million hectares), and conservation forest (30 million hectares) (Ministry of Forestry, 1994). In order to manage its natural resources sustainably, the Indonesian Government, through the Ministry of Forestry (MoF) has gazetted some important areas as conservation areas.

One such area is Baluran National Park, which covers an area of 26 630 hectares, consisting of various different ecosystems ranging from coastal to mountain ecosystems. The park has a number of different vegetation types, such as mangrove, beach forest, deciduous forest, mountain forest and a savannah of 10 000 hectares. This paper looks at the effects of the introduction of *Acacia nilotica* to this national park and some of the measures taken in order to remove the species.

Besides this *Acacia* species, there are other alien invasive plant species that are a potential threat to Indonesia. These include: eceng gondok (*Eichornia crassipes*), klampis air (*Mimosa pigra*), ki rinyuh (*Chromolaena odorata*), jarong (*Stachytarpheta urticaefolia*), tebu rawa (*Hanguana* sp.) and sidagori (*Sida acuta*).

Acacia nilotica in Baluran National Park

Acacia nilotica, a native of Africa, was first introduced to Indonesia in 1850. It is used as fuelwood, cattle feed, the fruit is eaten and the tannins from the bark are used for preserving leather. It was originally planted in the Baluran National Park in 1969, as a firebreak. The tannins in the bark have an allelopathic affect on other vegetation; hence the underlying soil is cleared of undergrowth. *Acacia nilotica* is capable of growing at altitudes of up to 500 metres, can survive extreme temperature conditions such as very dry or flooded areas, and in various soil types.

Acacia nilotica is a very fast-growing species that has various modes of dispersal. The most important dispersal mechanism is through the faeces of herbivores. The species can spread at a rate of some 100-200 hectares per year. Since its introduction, the tree has invaded as much as 70 percent of the savannah area, severely affecting the grassland areas that form an important source of food for several large herbivores in the park.

Control measures

In order to control the spread of *Acacia nilotica*, mechanical measures such as pruning and weeding have been implemented since 1985. However, only 25-40 hectares per year can be cleared by mechanical means. This is only 20 percent of the total target area. This technique has proven to be insufficient in combating the spread of this tree species.

Research on additional control measures has been conducted by the Forest and Nature Conservation Research and Development Centre, Bogor. The research included: soil chemical characteristics in the savannah and the use of chemical control measures.

Based on results of the soil chemical analysis, there has been no significant change in the availability of N, P, K nutrients as a result of the change in vegetation on the savannah. The savannah ecosystem remains a relatively stable ecosystem, from the point of view of nutrient availability (Siregar and Samsedin, 1997).

Research was also conducted on the use of the herbicide 720 Hc in several dosages i.e. 40 cc., 55 cc. and 75 cc. for each stand. All of the treatments killed *Acacia nilotica* (Table 1). There was no significant difference between the three applications of the herbicide, which indicates that the

treatment with 40 cc. is the most efficient dosage. However, the soil at Baluran National Park has high F. reactivity rates in its clay minerals, so the herbicide is immediately absorbed through the surface of the colloids, resulting in the contamination of the soil by toxic materials from the herbicide. So the utilization of herbicides in the control of *Acacia nilotica* needs to be closely monitored.

Table 1: Mortality percentage of *Acacia nilotica* treated with herbicide 720 Hc.

Dosages (cc.)	Diameter class (cm)	Mortality Replication (percent)				Mortality Average (percent)
		1	2	3	4	
40	9	100	100	100	100	100
	10 – 14	100	100	100	100	100
	15	66.66	75	80	75	74.16
55	9	100	100	100	100	100
	10 – 14	100	100	100	100	100
	15	100	66.66	57.14	83.33	76.78
70	9	100	100	100	100	100
	10 – 14	100	100	100	100	100
	15	100	100	100	66.66	91.66

Discussion

The introduction of exotic species into conservation areas is an aspect that needs additional detailed study, especially with regard to the negative impacts. From an ecological point of view, the invasion of exotic species will change the natural ecosystem.

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Forest Invasive Species in Lao PDR

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Introduction

The Lao People's Democratic Republic (Lao PDR) is a land-locked country, located in the centre of the Indochina Peninsula, sharing borders with the People's Republic of China in the north, the Socialist Republic of Viet Nam in the east, the Kingdom of Cambodia in the south, the Kingdom of Thailand in west and Myanmar in the northwest. The total land area of the country is 23.68 million hectares, of which about 70 percent of the total area is hilly and mountainous, mostly in the northern part of the country. The altitudes of the country vary from 300 metres to more than 2 500 metres.

The current population in Lao PDR is 5.2 million (2000 census), with an annual growth rate of 2.5 percent. Lao PDR is a multi-ethnic society. The major ethnic and linguistic groups have been broadly classified as Lao Lum (lowland Lao) 56 percent, Lao Theung (midland Lao) 34 percent and Lao Sung (upland Lao) 10 percent. More than 70 percent of the population lives in rural areas. The majority are subsistence farmers, whom are highly dependent on forest resources for their livelihoods. In terms of socio-economic development, Lao PDR is the least developed country in Southeast Asia, with an average income of US\$380 per year/capita.

Forest situation

Lao PDR has a relatively large forest area per capita, compared with neighbouring countries. However, destruction and degradation of natural forests are clearly evident and are regarded as critical issues for the country. *Degradation* refers to a decline in the quality of forest in terms of species distribution, reduced biodiversity, loss of commercial value, and interference with habitats and food chains. *Destruction* refers to the complete removal of forests and transformation into other land use categories.

Statistics on destruction rates show that forest-covered areas in Lao PDR have been reduced from 16.5 million hectares (70 percent of total land area) in 1965, to about 14 million hectares (60 percent) in 1974 (Myers, 1980) and further down to 12 million hectares in 1981 (FAO, 1990). In 1989, the remaining forested land was approximately 11 million hectares (47 percent) (MAF, 1992).

Forest pests in Lao PDR

Teak (*Tectona grandis* L.) plantations are attacked by a number of insects. Two defoliators, *Hyblaea puera* (popularly known as teak defoliator) and *Eutectona machaeralis* (also known as teak skeletonizer), are the most important invasive species for teak in Lao PDR. Larvae of *H. puera* feed on the entire leaf – leaving only the major veins intact – thus qualifying for the name skeletonizer. Of the two species, *H. puera* is the more serious pest, because it feeds on young leaves during the early part of the growing season, whereas *E. machaeralis* feeds on old leaves not long before natural leaf fall. The outbreak season for *H. puera* occurs in early-May when teak develops new leaves. The warm temperatures enable the insect to complete its life cycle by late-July. The results of a study by Chansomphou (2000) indicated that *H. puera* preferred to attack young teak plantations. The population density of larvae was highest in the top stratum of the tree, although after feeding on leaves the larvae descend to the lower strata and ground for more feeding and pupation. Its life cycle is completed in approximately 15 to 20 days. Male moths live longer than female moths; the average lifespan of an adult male is 13.3 days, while that of a female is 8.8 days. The adult female usually dies after oviposition.

Defoliation does not kill teak trees, but it reduces tree growth. Study results show that natural defoliation by *H. puera* caused an average loss of 44 percent in potential volume increment in 4-9 year old teak plantations, while *E. machaeralis* had no significant impacts on growth. Although it has not yet been possible to quantify the effects in terms of volume loss over an entire rotation (60 years), there are indications that *H. puera* has a substantial impact on wood production.

Management efforts.

The first legislative efforts by the government concerning the protection of flora and fauna are stated in the Forestry Law (1996), Article 43 and 44 as follows:

Article 43: Plant and Wildlife Protection

Plant and wildlife species found in the forest, which are scarce, rare, endangered or have special value, must be protected in the same way as those found inside conservation forest. Forest management agencies, in coordination with local administrative authorities, are to issue specific regulations for this purpose. The export of these kinds of plant or animal species is forbidden, except with special permission from the Ministry of Agriculture and Forestry.

Article 44: The Prevention and Suppression of Disease and Insect Pests

Concerned forest management agencies are responsible to investigate the origins and spread of disease and insect pests and to organize and coordinate protection and control in forest areas for which they are responsible. Concerned agencies must also identify disease free seeds and/or seedlings, develop disease free and protection zones, and establish an organization for certifying the production, distribution and use of disease free plant varieties.

In order to prevent the spread of tree diseases and insect pests the import or movement of infected plants is prohibited. Following the issuance of the Forestry Law, the Ministry of Agriculture and Forestry issued several legal documents relating to monitoring and control of forest invasive species, e.g. Regulation on Long-Term Management of Tree Plantation (Article 8). Although laws and regulations on monitoring and control of removals (import and export) of flora and fauna are in place, actual implementation is still far from satisfactorily due to inadequate technical and financial support.

Institutional arrangements related to invasive species

The Science, Technology and Environment Agency (STEA) has two departments dealing with monitoring and control over the environment. The Department of Environment is responsible for field implementation of environmental impact assessments (EIA). The Environment Research Institute is involved in studies involving the environment. A major role of the STEA is to regulate imports and exports and to provide Certificates of Origin and to ensure that imported/exported species will not have any negative impact on the environment.

The Ministry of Agriculture and Forestry (MAF) is the designated forest management authority. There are several departments and institutions under this ministry:

- Department of Forestry is responsible for conservation of fauna and flora;
- Department of Agriculture is involved with agricultural crops, fertilizers, pesticides, etc;
- Department of Livestock and Fishery is responsible for domestic animals and fish; and
- Agriculture and Forestry Research Institute is responsible for scientific research.

As such, the main invasive species responsibility of MAF lies in monitoring and control of imports and exports and providing the necessary permission for importing and exporting. The Ministry of Finance (Customs Department) – in cooperation with the police – is the enforcement authority. The main responsibility of this authority is to control the import and export of species at international checkpoints.

Conclusions

The Government of Lao PDR is pursuing a policy on conservation and protection of existing natural forests, while stimulating the establishment of tree plantations in order to increase forest cover. The purpose of tree plantations has mainly been for commercial production. Although a number of native tree species have been planted, the introduction of exotic fast-growing tree species is now becoming more fashionable, especially in lowland areas with access roads. Despite the introduction of exotic tree species to Laos, very little research has been conducted on the impact of these introductions.

Defoliators are the main pest species attacking teak plantations throughout the country. Additional collaborative research on the management and control of these pests is needed, particularly with other countries in the region.

The Government of Laos is monitoring the import and export of flora and fauna. However, protection against invasive species is inadequate, due to scarcity of necessary inputs such as staff, funding, technology, information etc. Consequently, there is a need for cooperation with other neighbouring countries and international organizations.

Forest invasive species country paper – Nepal

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Ministry of Forests and Soil Conservation

Plant Quarantine Service

Introduction

Nepal is a land-locked, mountainous country located along the southern slopes of the Himalayas between India and China. Situated at the junction of the Indomalayan and Palaeartic Biogeographic Realms, the land rises dramatically from altitudes of less than 100 metres in the tropical Terai in the south, to the highest point on the earth's surface (8 848 metres) on the edge of the Tibetan plateau, within a distance of less than 150 kilometre. It has an area of some 14.7 million hectares, of which the forest area covers 39.6 percent of the total area. The total population of the country is 23.2 million with an annual growth rate of 2.2 percent (2001 census). The economy is still largely rural and agrarian.

More than 70 percent of the people of Nepal are still largely dependent on forests for goods and services. Forest-trees form an integral part of rural livelihoods in Nepal. Forests dominate not only the landscape, but also the way people live. Forests provide 75 percent of total energy consumed in the country and more than 40 percent of livestock nutrition from fodder (MPFS 1988). Forests also play a dynamic role in the protection of fragile mountains and maintain complex and diverse ecosystems. (Thomson 1995).

Hill forest is the key resource in the Nepalese economy, providing fodder, timber and fuelwood. Its degradation has long been a concern. IDA's Forestry Sector Review of 1988 identified two major problems, which are still relevant today, a) rural energy crisis, and b) the environment deterioration caused by over-utilization of forests. The increasing population is exerting heavy pressure on the forest resources of Nepal, (Table 1). If this trend continues, then the forest condition of the country and species diversity will be badly affected. To counteract this trend, Nepal has established plantations of both exotic and indigenous species.

Table 1: Forest area decline and population growth in the last two decades

	1979	1986	1998
Forest area	43 percent	37.4 percent	29 percent
Population	13.7 million	15 million	21.8 million

(Source: HMGN 1968, 1974, 1998,a and 1998,b)

Invasive species in Nepal

According to the IUCN definition, "Invasive species are alien species that threaten biological diversity". Invasive species include pests, insects and diseases. People are the main source for the introduction of alien species either by accident, deliberate action and/or imports. These species often have a high dispersal ability and adaptability, which enables them to rapidly acclimatize quickly to new habitats. Due to these abilities, invasive species compete with native species for resources such as nutrients, soil moisture, sunlight and space, often resulting in the loss of naturally occurring species.

His Majesty's Government of Nepal (HMGN) became a member of the International Protection Commission for Southeast Asia and the Pacific Region in 1956. In 1972, the Plant Protection Act was passed, which has been enforced throughout the country since 1974.

Probably the most widely distributed invasive species found in Nepal are *Eupatorium adenophorum*, *E. odoratum* and *Lantana camara*. This last species is easily dispersed by birds, which eat the fruit. A more comprehensive overview of invasive species in Nepal is provided in Table 2.

There are a number of other species noted for their invasive nature. *Ageratum houstonianum* is an unwanted species growing as a weed, especially common on marginal agricultural land. *Mikania micrantha* is another weed with similar characteristics. Similarly, water plants like *Eichornia* and *Nelumbius* will cover ponds if not managed.

The systematic documentation of the flora of Nepal is a continuous process. Although thousands of plants have been collected and documented, a substantial number of plants have yet to be identified. It is quite possible that additional invasive species could be identified during this process.

Table 2: Ten most important invasive species in Nepal

SN	Scientific Name	Local name	Origin
1	<i>Eichornia crassipes</i>	Jalkumbhi	South America
2	<i>Eupatorium adhenophorum</i>	Banmara	Mexico
3	<i>Eupatorium odoratum</i>	Banmara	Tropical America
4	<i>Lantana camara</i>	Masinu kanda	Central America
5	<i>Mikania micrantha</i>	**	Tropical America
6	<i>Ipomea carnea</i>	Bastharma	South America
7	<i>Hyptis suaveolens</i>	**	South America
8	<i>Parthenium hysterophorus</i>	**	Tropical America
9	<i>Argemone mexicana</i>	**	Tropical America
10	<i>Ageratum conyzoides</i>	**	South America

Additional threats could come from the various species introduced for Nepal's plantation programme. The most import exotic plantation species include *Pinus patula*, *Leucaena leucocephala* and *Eucalyptus camaldulensis*. The ability of these species to thrive in Nepal, outside plantations, has not been well documented. Other indigenous species used in plantations have been *Pinus roxburgii* and *Dalbergia sissoo*. Infestation by the *Leucaena* psyllid (*Heteropsylla cubana*) and associated die-back in *Leucaena leucocephala* and *Dalbergia sissoo* presented one of the most serious threats to trees in Nepal during the late-1980s.

Documentation, control and other important activities

Many valuable plantation species have been introduced to Nepal. When plantations are established, records should be made of information such as the provenance derived from, when and where the plantation was established, and it should be mapped. This system would provide significant benefits in monitoring and reacting to invasive species infestations. To date, this documenting process has been very poor in the country, and it is therefore essential that a survey be conducted so that the introduction and the distribution of plantation species can be identified and mapped with full details.

Conclusions and recommendations

Nepal is in the early stages of developing a national strategy for the control and management of alien invasive species. The following issues have been identified as requiring additional work in the future:

- the systematic identification of invasive species throughout the country;
- development of a database with information on the species identified as being invasive;
- development of capacity for research, control and management of invasive species; and
- improved coordination among the institutions involved in the control and management of invasive species, including the Department of Forests and the Department of Agriculture.

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A status report on some invasive forest species in Papua New Guinea

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Introduction

Papua New Guinea, the eastern part of the island of New Guinea has a total land area of about 46.4 million hectares, including the islands of the Bismarck Archipelago and Eastern Milne Bay. Located just below the equator, it experiences a humid tropical regime with southeasterly winds in the middle of the year and the northwesterly following soon after. There is distinct wet and dry season associated with these two climatic regimes, although, variations in rainfall do occur, which are closely associated with the local topography. The country is very mountainous but also has vast areas of flat plains, large and long meandering river systems, numerous active volcanoes and about 70 percent of the land is covered with dense forest. The biological diversity is among the richest in the world.

For centuries, man has influenced and modified the vegetation through subsistence farming and hunting. Over the last 40 years, large areas of forests have been cleared by local inhabitants to cultivate food and cash crop plantations. In addition to human influences, natural phenomena such as cyclones, earthquakes, fires and volcanic eruptions have also affected large areas of forests, thus influencing their composition.

Invasive species are common in disturbed forests and modified habitats such as plantations, logged-over areas, shifting cultivation and sites affected by fires. Insects are the most devastating invasive group in both natural and planted forests and these are classified as minor or major pests according to the extent of damage caused to logs, lumber and living trees.

The full extent and status of invasive species affecting natural forests, farmlands, river systems and local plantations in PNG is unknown. This report covers observations and investigations done on selected invasive plant species and major pests and diseases of, particularly, commercial trees in plantations and natural forests of current economic importance.

Invasive plants

Most invasive species are opportunists, ecologically categorized as colonizer or pioneers with the ability to compete and establish successfully in various different environments. Natural and manmade disturbed sites provide opportunities for the increase of invasive species. In disturbed forests, where resources such as light are abundant, the germination of a large number of invasive species is triggered. Trees regenerating in open forest areas initially face severe competition from pioneer plant species. Many of these species are grasses, herbs and shrubs that sprout from dormant seeds.

The invasive plant species selected and presented here are species that appear to be widespread and dominant locally, thus suppressing the development of other local species. Many of the species covered are herbs, shrubs and grasses, the presence of which poses a threat to the regeneration of other plant species, particularly those of economic value. Henty and Pritchard (1988) published a weed species handbook that covers mainly ferns, herbs, shrubs, grasses and sedges that are widely distributed and invade open areas like roadsides, cultivated fields, gardens and pastures. Some of these species are referred to in this paper.

In regrowth forests and fallow gardening sites, *Piper aduncum* (Piperaceae) is a common shrubby weed. This weed is native to Central America and may have entered Papua New Guinea along with shipped logging equipment. It grows to about 7 metres in height and produces numerous small seeds. *P. aduncum* is now widespread and is persistent in many old garden sites where it effectively shuts out other vegetation. The other tree species that has established itself in many coastal provinces is *Spathodea campanulata* (Bignoniaceae). This species is native to Africa and it is referred to as "African tulip". It was introduced as ornamental tree because of its beautiful red flowers. It grows from seeds, cuttings and coppices very aggressively. Because of its regenerative ability, it easily replaces local species over time, wherever it grows. Many examples of such situations can be observed in coastal areas such as the Gazelle area in East New Britain Province and most areas around New Ireland Province.

The leading families with the most weed species are Asteraceae (27), Poaceae (14), Leguminosae (10), Amaranthaceae (9), Cyperaceae (6) and Lamiaceae (6). The common species are: *Cyperus bifax*, *C. brevifolius*, *C. cyperoids*, *C. distans* and *C. rotundus* (Cyperaceae); *Euphorbia geniculata*, *E. heterophylla*, *E. hirta* and *E. thymifolia* (Euphorbiaceae) and *Polygonum barbatum*, *P. nepalense*, *P. orientale* and *P. strigosum* (Polygonaceae).

Asteraceae are most abundant in open areas and are unwanted weeds in pastures and gardens. Species of this family that invade in plantations include, *Eupatorium odoratum*, a naturalized shrub, *Wedelia biflora*, a straggling shrub, and *Youngia japonica*, an introduced perennial herb.

Some grass species are weeds in many places, where they have rapidly colonized open areas – such as cleared sites, after burning. A common weedy grass in Papua New Guinea is *Imperata cylindrica*; an invader of disturbed areas, widely occurring in anthropogenic grasslands and abandoned shifting cultivation sites. Its presence in some plantations that are located in open valleys such as the Markham valley is a threat to cash crops and pastures. It has taken over large open areas in savannah grasslands in the Southern region and many dry areas of the Markham valley where regular burning has occurred. *Imperata*'s success is attributed to production of many small seeds with ability to withstand adverse conditions until germination, and their spread through rhizomes.

Some of the weedy species that have spread very rapidly over the last twenty years included three "nilgras" species: *Mimosa invisa*, *M. pudica* and *M. pigra*. These have localized in many areas, especially along roadsides, in pastures, and opened forest areas. In pastures, they prevent regeneration of palatable species thus limiting livestock grazing areas. The species *Solanum erianthum*, *S. nodiflorum* and *S. torvum* (Solanaceae) also occur in pastures and are regarded as harmful weeds to livestock on grazing lands, though not serious threats to other vegetation. *Merremia peltata* (Convolvulaceae) is a twining, creeping herb with round peltate leaves and a stout stem, often reaching 10-15 metres in height. This species is widespread and is an invader of forest clearings, often suppressing other important vegetation. Its presence and dominance can lead to poor representation of native species regenerating in an area.

Most control measures for individual weeds require chemical use that is not only expensive, but can be environmentally hazardous. However, weeding is still practiced in gardens, and slashing is carried out in plantations to reduce competitive vegetation – regardless of being labor-intensive and time-consuming efforts.

Major insect pests

***Agrilus opulentus* Kerr. (Coleoptera, Fam. Buprestidae)**

Agrilus opulentus is an important pest affecting growth and survival of *Eucalyptus deglupta* and *Syzygium* spp. *A. opulentus* is widely distributed in the mainland of Papua New Guinea and the island of New Britain. The beetle naturally feeds on the cambium of many water gum trees. One of these water gum trees is *Eucalyptus deglupta* (Myrtaceae). The attack on *E. deglupta* is important for two reasons:

- the tree does not recover; and
- the loss of these trees in plantations has adverse impacts on revenues.

According to Mercer (1985), beetle eggs are deposited in crevices in the lower trunks. The hatched larvae bore into the inner bark and feed in a zigzag manner, disrupting translocation. Larvae bore lightly into the sapwood to pupate. Adult beetles emerge and fly to tree crowns, where they mate.

The attack appears to be confined to unhealthy trees under environmental stress with low sap content. Vigorous trees produce copious sap, which is sufficient to drown and kill the larvae. Vigorous infested trees will decline in growth, but initially stressed or suppressed trees gradually die after attack. Mercer (1985) reported that 23-25 percent of five-year old trees lost at least 1 centimetre of diameter at breast height in annual growth increment.

***Lymantria ninayi* B. Br. (Lepidoptera, Fam. Lymentriidae)**

Pinus patula (Pinaceae), originally from Central America, has – despite poor soil conditions – been successfully planted in plantations in the highlands of PNG, where the climate is cooler. Early reports revealed that *Lymantria ninayi*, a species of moth, was present in various locations in the highlands

and damage to *P. patula* trees was also reported by Gray and Wylie (1974). Serious defoliation occurred in the Lapegu Plantations in the Eastern Highlands Province between 1975 and 1978, over an area of 200 hectares. More than 25 percent mortality was recorded (Roberts, 1988). A recent outbreak of *L. ninayi* occurred in 1996, in Faiyantina, affecting 8-10 year old *P. patula* trees. However, a particular group of insect viruses, known as nuclear polyhedroses, was believed to be the main natural agent that brought about an evident crash in *Lymantria ninayi* populations. The control and management of *L. ninayi* is possible with chemical sprays and biological controls, but the chemicals are generally too expensive to obtain.

The females lay their eggs in patches on the bark of trees. After hatching, caterpillars feed on the foliage of the tree, the younger on new needle leaves and older caterpillars on mature leaves (Schneider, 1999).

The moth undergoes a three-stage life cycle. Adult females are flightless, but release pheromones to attract flying males for mating. After mating the female moves down the tree and lays eggs on the underside of branches. Within a period of nine to thirteen days, caterpillars emerge and move to feed on the needles, mostly at night (Mercer, 1985). The caterpillars develop and go into a pupa stage, among bundles of needles. Males emerge first, while females, who usually lack wings, emerge later. The life cycle is about four months, with three generations in a year. *L. ninayi* is spread when the small emerging caterpillar is blown away on strands of silk, while making their way to the tops of trees.

Lymantria ninayi alternatively feeds on local tree species such as *Lithocarpus* spp., *Castanopsis* spp., *Casuarina papuana* and *Casuarina oligodon* present in surrounding natural forests.

***Coptotermes elisae* Desneux (Isoptera, Fam. Rhinotermitidae)**

Araucaria cunninghamii trees from Bulolo plantation have been attacked by *Coptotermes elisae*. This termite is becoming a major problem in second-rotation plantations. The mode of attack is usually via the roots. The termite tunnels through the stem, causing live trees to fall. Trees under stress and those with injuries sustained from thinning are easy targets. The termites are very active in wet periods, when the soil is waterlogged and allows for easy movement to construct galleries. Preventive measures include planting trees in moderately moist sites, and minimizing or avoiding thinning damage. Attempts have been made to locate and destroy queens, but failure to keep up with re-invasion has rendered this exercise impractical as a means of eradicating this pest.

***Mastotermes darwiniensis* Froggat (Isoptera, Fam. Mastotermitidae)**

This species is a subterranean termite that was introduced to Lae, from Australia, among heavy fighting equipment and supplies, sometime during WWII. It has been observed killing live *Araucaria hunsteinii*, *Ficus* spp. *Dracontamelon* dao, and *Mesua* spp. within the vicinity of the Forest Research Institute (FRI). Termites enter from the base of trees and bore multiple tunnels, causing trees to defoliate and die. The same termite is now within the FRI building, causing extensive damage to wooden doors, bookshelves and other materials with cellulose makeup. There are no prescribed eradication measures in place and the institute is struggling with how to deal with this problem, apart from the costs of maintenance to the building. This termite is slowly but surely spreading to reach other parts of Lae.

***Nasutitermes novaumherbridarum* N. and K. Holmgren (Isoptera, Fam. Termitidae)**

This termite is known to attack injured or stressed *E. deglupta* trees in plantations in Madang province. Trees with riddled wood take a comparatively short time to die. Most fall as a result of windthrow.

***Vanapa oerthuri* Pouillande (Coleoptera, Fam. Curculionidae)**

This weevil species is a pest of *A. cunninghamii* plantations in the country. Eggs are deposited under loose bark or in tree wounds. The hatched larvae bore through the cambium causing live trees to die.

Main tree diseases

***Phellinus noxius* (Corner) G.H. Cunn**

Phellinus noxius is a pathogen involved in heart rot disease of *Araucaria cunninghamii* and *Eucalyptus deglupta*. Trees of all ages are vulnerable to attacks from *Phellinus noxius*. A tree may appear healthy from outside appearance, but after felling the disease may be detected. In *Araucaria*

cunninghamii plantations, the fungus is found in debris. Spores are transferred to standing trees through scratched bark and ripped roots. There is no control for the disease except to properly monitor thinning and pruning operations to minimize damage to trees. *Eucalyptus deglupta* in plantations and natural stands is also susceptible to a similar heart rot disease caused by *P. noxius*. The ability of this tree to self-prune by shedding branches makes it easy for fungi to enter through the rotten scars left by fallen branches and spread within the tree. Although *P. noxius* is suspected to be the pathogen responsible for heart rot in *E. deglupta*, other site factors have also been considered as potential causes, but not fully investigated. Muki (1992) suggested low content of polyphenols within the heartwood as a causal factor contributing to low resistance against pathogens. With *E. deglupta*, susceptibility to heart rot is assumed to be genetically inherited and the best approach to contain the problem is to selectively breed resistant trees.

Acacia mangium and *Acacia auriculiformis* are two robust species known to perform better than most tree species on impoverished sites. Both are used as reforestation trees in lowlands and coastal plains. *Acacias* are susceptible to root rot disease, where *Phellinus* and *Ganoderma* are believed to be involved in infection (Muki 1992). Infected and overlapping roots of adjacent trees spread this fungus and ultimately cause trees to fall.

Valsa sp. canker disease

Terminalia brassii occurs naturally on wet soil sites in Bougainville and the Solomon Islands. It has been introduced as a plantation tree to many coastal areas of PNG. The most important disease causing bark necrosis and dieback in *T. brassii* is a canker known as *Valsa* canker. The suspected pathogens are generally identified as being members of the *Cryphonectria* or *Diaporthe* genera, but these deaths may also result from infection by *Valsa eugeniae* from family Diaporthaceaceae (Mercer, 1987). Entry to the cambium is mainly through roots, split bark and hollows in trunks or branches. Symptoms of this disease are bark splits associated with copious black exudates. Incidences of canker disease associated with poor selection of sites were noticed in Gogol, Kerevat and Lae (Mercer, 1985). Trees under environmental stress or in water deficit areas allow the proliferation of this fungus; thus plantation sites must be carefully selected prior to planting as a control measure.

Phytophthora root disease

Pine trees from plantations often suffer from root rot caused by *Phytophthora cryptogea*, and *P. cinnamomi*. Pine trees usually show early chlorosis followed by death. Pathogens are suspected to be present in the soil used at nurseries and are introduced to the field after planting. Fumigating or heating soil prior to tubing the seedlings can control this. *Phytophthora cinnamomi* is suspected of involvement in extensive die back of *Nothofagus* forests in Mt Giluwe, in Southern Highlands province.

Nothofagus occur in montane forests between 1000-3000 metres above sea level and around 750 metres in Kutubu and New Britain. At Mt. Giluwe, in the Southern Highlands, *Nothofagus* is dominant and forms pure stands, with two species, *N. pullei* and *N. grandis* being harvested commercially. Forests appear unhealthy when trees develop dead branches and upper crowns die while standing. Some reports suggest the presence of *Phytophthora cinnamomi* in the soil as partly responsible for the scenario (Ash 1988; Muki 1992). The exact cause remains unresolved with an assumption that multiple factors related to environmental conditions are responsible. Insects and pathogens, definitely contribute to this phenomenon.

Nectria haematococca

Anisoptera thurifera belongs to the Dipterocarpaceae family and is a major commercial tree, naturally occurring in some lowland forests. This species can also be regarded as an invader of logged sites where it surpasses other species as observed in Oomsis, Morobe province. It is a canopy tree, fast-growing and grows gregariously in good straight forms, which are ideal silvicultural characteristics. However *A. thurifera* stands in Oomsis, Morobe province have been invaded by fungus, *Nectria haematococca*, causing canker on trees. A survey by Nalish Sam, in 1995, indicated 63 percent of trees had canker (Nimiago and Nir, 1977). Although trees have no mortality problems at this stage, such a high incidence may have significant negative impacts on future crops.

Quarantine and phytosanitary regulations

The National Agriculture Quarantine Inspection Authority (NAQIA) of Papua New Guinea is the legal institution that administers, manages and monitors the country's laws and regulations on quarantine

and phytosanitary status of imported and exported goods. The most important pieces of enforceable legislation are the Plant Disease and Control Act 1953 and the National Agriculture Quarantine and Inspection Authority Act 1997.

NAQIA maintains an office at all major airports and seaports throughout the country. All importers of food products, agricultural products, supplies and equipment, biological products and equipment, and other general merchandise, are required to declare their goods to the authority for inspection. The authority also undertakes inspections of vessels (ships and aircrafts) on arrival at major ports in PNG and it also inspects all incoming parcels at major post offices. Any materials contaminated with a biological pest or disease are immediately isolated and destroyed. Other materials may be quarantined for a required period before they are released. The authority also maintains close contact with other quarantine services in neighbouring countries and takes necessary steps to prevent pests and diseases from other countries entering Papua New Guinea.

NAQIA also collaborates with the Australian Quarantine and Inspection Services (AQIS) on two regular surveys in PNG:

- the PNG/Indonesia Border Survey for weeds, insect pest and pathogenic diseases; and
- the Coastal Border Survey along the PNG-Australian coastline.

Legislation is mainly focused on restricting the deliberate introduction and spread of invasive species in the country. Laws may be less effective in situations where introduction and spread are accidental. This requires a more vigilant effort from monitoring programmes. Regular surveys and monitoring programmes are carried out for specific pests. For instance, the fruit fly problem in the East New Britain Province, the outbreak of *Locusta migratoria* in the Markham valley, the spread of *Salvinia molesta* along waterways within the Sepik river systems, and the spread of invasive weeds such as *Mimosa pigra* and *Chromolaena odorata*. Posters and information leaflets on these pests and invasive species are periodically produced and distributed for public awareness.

Key institutions involved in invasive species

NAQIA is the legal institution in Papua New Guinea required by law to execute the Plant Disease and Control Act and the National Agriculture and Quarantine Inspection Act. The National Agriculture Research Institute (NARI), the Department of Agriculture and Livestock (DAL) and the Papua New Guinea Forest Research Institute (PNGFRI) are other institutions that participate in assessment surveys, and wherever else their services are required.

Conclusions and recommendations

This report covers some of the common invasive forest species that are known in the forestry and agriculture sector. There are other invasive species considered to be weeds and insect pests that are not mentioned here. On the basis of this report, the following conclusions can be drawn:

- invasive forest species are colonizing natural forests, forest plantations, agricultural lands and river systems;
- most information on invasive forest species in Papua New Guinea was collected in the past. There is no new PNG research undertaken on other species and potential species that may have been introduced recently;
- NAQIA is the legal institution in Papua New Guinea that undertakes quarantine surveillance and ensures that incoming goods and equipments are free of pests and diseases that may be of risk to agricultural and food crops in Papua New Guinea;
- there seems to be very little dialogue among national agencies and institutions such as NAQIA, NARI, PNGFRI and DEC on issues relating to invasive forest species and other potential pests and diseases in general; and
- there are some invasive species that need to be monitored very closely because of their potential threat to the economy and natural forests in Papua New Guinea. These species include *Spathodea campanulata*, *Piper aduncum*, *Mastotermes darwiniensis* and *Phellinus noxius*.

The authors would like to make the following recommendations:

- a national assessment of invasive and potentially invasive species needs to be made to determine the status of their threat to the country;
- an effective communication systems among the local institutions responsible for specific tasks relating to the management, monitoring and eradication of invasive species should be established;
- an Action Plan on how participating institutions can effectively contribute to an “Invasive Species Monitoring Programme” should be developed;
- local resources and sources of funding to enable participating institutions to effectively implement proposed invasive species activities should be identified; and
- local institutions should be aware of which invasive species are in neighbouring countries and devise ways to detect their presence and prepare eradication strategies.

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Country report on forest invasive species in the Philippines

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The natural forest types of the Philippines

The types of forests in the Philippines were first enumerated by Whitford (1911) who recognized mangrove, beach, dipterocarp, molave, pine, montane and mossy forest types. The Palawan Botanical Expedition by Hillebrand AB (1916) recognized within Palawan many types of vegetation, for example, ultramafic and ultrabasic forests, karst limestone forests, riverine forests, semi-evergreen dipterocarp forests, evergreen dipterocarp forests and lake-margin forests. There could be more actual forest types than the number already published. Stereotyping a continuum of unique forest ecosystems into just a few lists may not render justice to the wonders of evolution and the complex Philippine bio-geological history.

However, the latest classification of Philippine ecosystem diversity types in the terrestrial setting (DENR-NBSAP 1997) are the following: (1) lowland evergreen rain forest, (2) lower montane forest, (3) upper montane forest, (4) subalpine forest, (5) pine forest, (6) forest over limestone, (7) forest over ultrabasic soils, (8) semi-deciduous forest, and (9) beach forest.

The lowland evergreen rain forests are located on volcanic soils with even distribution of rainfall and correspond with Whitford's dipterocarp forests excluding the apitong-lauan subtype, which corresponds with semi-deciduous forest. The importance of the members of the Dipterocarpaceae is most notable in lowland evergreen rain forests (Newman *et al*, 1996).

Beyond 1000 metres in altitude, lower montane forests are encountered. In these forests, Fagaceae (the family of oaks) increase in number of species, as do species in families such as Araliaceae, Staphyleaceae, and Lauraceae. Many tree ferns, epiphytes such as orchids, ferns and allies, increase in importance. As elevation is gained, upper montane forest begins to occur (at about 2000 metres). Members of the Ericaceae (e.g. *Rhododendron quadrasiatum*, *Vaccinium myrtoides*, etc.), Myrtaceae (such as *Leptospermum flavescens*) and Theaceae (such as *Eurya*, *Cleyera*, *Schima*, *Adinandra*, and *Camellia* species) families are encountered (Merrill and Merritt, 1910).

In regions with seasonal monsoon climates, the montane forests when disturbed into a gap by fire is readily succeeded by disclimax vegetation dominated by benguet pine (*Pinus insularis*) (Kowal, 1975). In Mindoro Island, only tapulau pine forest exists. Pine forests are perpetuated by fire and therefore also known as fire disclimaxes.

In limestone forests, below 1000 metres, the keystone species are molave (*Vitex parviflora*), lingo-lingo (*Viticipremna philippinensis*), alagao (*Premna odorata*), and batete (*Kingiodendron alternifolium*).

Beach forests above the intertidal zone vary depending upon the substrate (Merrill, 1945). Beach forests exist as *Casuarina* subtype or *Barringtonia* subtype. In one extreme, on sand dunes, pure stands of agoho (*Casuarina equisetifolia*) would be characteristic. At the other extreme, on rocky shores, is mixed vegetation of the *Barringtonia* subtype.

Forests on ultrabasic soils (Hillebrand Forestry AB, 1916) are not as dense and tall as the mixed dipterocarp forests, simply because they develop on unhealthy serpentine and basic soils. This type of forest features hardwoods such as mancono (*Xanthostemon verdugonianum*), bagoadlau (*X. philippinensis*), malabayabas (*Tristaniopsis decorticata*), *Brackenridgea palustris*, mountain agoho (*Gymnostoma rumphiana*), and *Scaevola micrantha*.

The introduction of exotic species

Merrill's "Enumeration of Philippine flowering plants" (1921-26) and subsequent revisions in the "Flora Malesiana" (1954-present) are good references to determine which species are indigenous and exotic (Rojo, 1999). Exotic species are indicated with asterisks.

Prehistoric introduction of trees (probably by Malayo-Polynesian settlers) were first noted and may have included common agricultural tree crops such as the katurai (**Sesbania grandiflora*), malunggai (**Moringa oleifera*), mango (**Mangifera indica*), nangka (**Artocarpus heterophyllus*), breadfruit (**A. altilis*), santol (**Sandoricum koetjape*), rambutan (**Nephelium lappaceum*), karamai (**Cicca*

(*Phyllanthus acida*), bignai (*Antidesma bunius*), kamias (*Averrhoa bilimbi*), balimbing (*A. carambola*), duhat (*Syzygium jambolana*) and other *Syzygium* spp., kawayan kiling (*Bambusa vulgaris*), kawayan tinik (*B. spinosa*) and many others. Most of these are Indo-Malayan in origin. A few escaped into the wild like the bignai, duhat and santol. However, these have not grown and established themselves as persistent gregarious stands.

The Spanish regime, through the Acapulco trade, brought additional exotic tree species, mostly agricultural crops such as the *Anona* spp. (atis, cherimoya, guyabano, anonas), biriba (*Rollinia deliciosa*), zapote (*Diospyros digyna*), cacao (*Theobroma cacao*), siniguelas (*Spondias purpurea*), chico (*Manilkara sapota*), tiesa (*Pouteria campechiana*), cashew (*Anacardium occidentale*), avocado (*Persea americana*), kamatchile (*Pithecellobium dulce*) and datiles (*Muntingia calabura*). Woody trees such as the monkey-pod tree (*Samanea saman*), *ipil-ipil (*Leucaena leucocephala*), kakawate (*Gliricidia sepium*) and kalachuchi (*Plumiera rubra*) were also introduced. Coffee (*Coffea* spp.) was introduced by the Spanish from Africa. Some of these escaped into the field, for example ipil-ipil, datiles, and kamatchile. Of the tropical American exotic trees, ipil-ipil may be singled-out as bio-invasive, as the species forms pure stands in open areas. Kamatchile and datiles have been dispersed but their numbers are limited, compared with ipil-ipil.

During the American regime, more exotic tree species found their way to the Philippines as Caguioa (1953) recounts:

“After the Spanish-American war, plants have been introduced into the Philippines generally by exchange between the governments of foreign countries and the Philippine Government, through the Bureau of Forestry and Bureau of Plant Industry and by purchase from foreign countries by private citizens. Introduced plants came into the Philippines during the Spanish regime, the Philippines introduced plant materials from Central American countries through missionaries and others who came to the Philippines by way of galleon from Mexico to the Orient, and from the neighbouring countries or islands through traders and travellers who came to visit this country by water transportation. During the first half of the present century, many countries in both the western and the eastern hemisphere have exchanged planting materials with the Philippines.”

Exotic species were added as a result of the agricultural and forestry schools that were opened (Buenaventura, 1958). In 1910, the School of Forestry site consisted of grass and brush at the base of Mount Makiling. Laguna, Luzon and American administrators initiated the reforestation of the school grounds mainly by planting indigenous tree species, as well as the tropical American species mahogany (*Swietenia* spp.), rubber (*Hevea brasiliensis*), and ipil-ipil (*Leucaena leucocephala*). Then other exotics followed such as kakawate, palosanto (*Triplaris cumingiana*), Anchoan dilaw (*Cassia spectabilis*), golden shower (*C. fistula*), and teak (*Tectona grandis*). Note that they also introduced dipterocarps from other parts of the country to enrich the native Makiling dipterocarps, namely, white lauan (*Shorea contorta*), bagtikan (*Parashorea malaanonan*) and guijo (*Shorea guiso*) (Brown, 1919). African tulip (*Spathodea campanulata*) was introduced in 1925 to the Forestry School campus (Anonymous, 1930) and it has since spread deep in natural stands.

Ponce (1933) documented the introduction of the American mahoganies. Small leaf mahogany (*Swietenia mahogani*) was introduced as early as 1911, and by batches in 1913, 1914, 1920 and 1922, from tropical America. Large leaf mahogany (*S. macrophylla*) was first planted in Manila in 1907, then at the Forestry School at Mt. Makiling in 1913. Lizardo (1960) reviewed the introduction of *Eucalyptus* in the Philippines. Spanish friars introduced (*Eucalyptus globulus*) at Alcala, Cagayan as early as 1851 and in 1939, the first trial plantings for *E. robusta* were initiated. Other plantings were *E. rostrata* in 1918, *E. tereticornis* 1910, *E. citriodora* 1936, *E. viminalis* 1918, *E. pulverulenta* 1916, and *E. saligna* 1947. The paper mulberry (*Broussonetia papyrifera*) was introduced in 1935 to augment bast fibre-producing tree crops at the Makiling Forestry School campus and – as did coronitas (*Lantana camara*) from Hawaii – escaped to become serious pests. Both species invade young secondary forests, thickets, orchards and farms. These two species and mahogany have spread throughout the Philippine archipelago.

Post-war introduction of exotics continues and planting them has almost become synonymous with reforestation. Yemane (*Gmelina arborea*) was introduced in 1960 and planted in Minglanilla, Cebu by the Bureau of Forestry (Binua and Arias, 1966). Mangium (*Acacia mangium*) was introduced in 1960 from Sabah. The Philippines Forestry Statistics (1984) record that out of a total 52 487 seedlings produced by the Philippines Government forest agency, 82.4 percent (43 234 seedlings) of seedlings were exotics. These were distributed across giant ipil-ipil (41 percent), large leaf mahogany

(33 percent), yemane (17 percent), teak (4 percent), and others (5 percent). Seedlings of indigenous tree species contributed 17.6 percent.

Current foresters' notion of reforestation

Based on the forest definition by American mentors as artificial or natural, Tamesis and Sulit (1937) define "reforestation" as the restoration of an area to forest either by artificial or natural means and "afforestation" applies to the planting of a forest on land that has not previously borne forest. They mention planting exotics in Bukidnon including chinchona, large leaf mahogany, **Araucaria bidwillii*, **Pinus massoniana*, Anchoan dilaw, **Adenanthera microsperma*, **Thuja orientalis*, black wattle (**Acacia decurrens*), and **Cryptomeria japonica*. In Baguio, **Eucalyptus* spp. and Alder (**Alnus* spp.) were planted. Tamesis and Sulit cite that good reforestation species are of:

- economic value;
- rapid growth for short cutting cycle;
- fire and other damage causes are resisted by species; and
- easy to grow and propagate.

There is also the mindset among foresters that artificial forests are as ecological as the natural forest they replace. For example, Domingo (1983) wrote during the First ASEAN Congress,

"... when we convert a dipterocarp forest to pulpwood plantation, what we are doing is just transferring the jungle regrowth onto a tree species of our choice for pulpwood. Substituting the economically unnecessary but ecologically necessary jungle regrowth with an economically important pulpwood plantation does not change, it might even enhance, the normal ecological pattern. The same ecological benefits that the jungle regrowth provides can be provided by the plantation..."

In short, this goes in line with most foresters' pragmatism that if the natural forest is gone or nearly gone, enrichment planting with fast-growing commercial exotic tree species is better than restoring natural forests for two reasons. One, because a return of investment at the earliest possible time is provided by the artificial forest, and two, artificial forests also provide the same environmental services as natural forests, particularly, on watershed function and carbon-sequestration. Other foresters also claim that analogue forests and agroforest zones can also be as rich in floral diversity as or even richer than are natural forest ecosystems. Thus, during the ASEAN Regional Centre for Biodiversity Conservation (ARCBC) Symposium-Workshop on Facing the Challenge of Sustaining Biodiversity Conservation in Mt. Makiling, Gruezo (2000) reports

"...Comparison of floral diversity in these four zones (Mossy forest zone, Dipterocarp mid-montane forest zone, Grassland zone and Agroforestry Zone) reveals that the agroforestry zone had the highest diversity value using the Shannon-Weiner formula, with $H' = 4.2869$ followed by the dipterocarp-mid-montane forest zone, $H' = 3.8913$, ...".

Man can cram many exotic crops including their exotic weeds in one place, then make statements to the effect that agro-ecosystems are more diverse than natural forest ecosystems.

Bio-invasive species and natural forests

As far back as the pre-war period, exotic trees have been used in reforestation. Projects of the Reforestation Administration used exotic species as showcases, e.g. reforestation at Minglanilla in Cebu, the Nasiping Reforestation Project in Cagayan, Paraiso reforestation in Ilocos Norte, Canlaon reforestation in Negros, and Impalutao reforestation in Bukidnon. The reforestation projects of the Bureau of Forestry were well spread throughout the archipelago. Seedlings from these projects found their way into national parks and for this reason mahogany can be found in most of the country's nature parks. However, no studies have yet been done on the rate of bio-invasion of these nature reserves and parks. The planting of exotics in the Integrated Protected Area System (IPAS) of the Philippines has now been prohibited under the present DENR's PAWB (Park and Wildlife Bureau). No definite policies are in place yet on what to do with mature exotic trees, should they become bio-invasive. This issue is now being seriously considered by the College of Forestry and Natural Resources, for the Makiling Forest reserve.

Because there was a law requiring replanting of logged-over dipterocarp forests during the 1960s to 1980s, many timberlands have had been reforested with exotic trees, among them mahogany, yemane, mangium, bagras and teak. Of these tree species, only mahogany is a potential bio-invasive species in the logged-over forest and is threatening to out compete the indigenous dipterocarp and non-dipterocarp tree species.

Mahogany is successful at invading natural forests due to the following attributes of the species. The fruit of mahogany is a capsule and contains an average of 62 winged seeds (Anonymous, 1930). The number of seeds a mahogany mother tree can disperse is considerable. Assuming 50 capsules, 3000 seeds can be blown away from the mother tree. The seeds can be blown some 20 to 40 meters from the mother tree. The seeds, being recalcitrant, germinate in less than a month. Mahogany seeds contain food reserves and germinate hypogeal. This means that even if the initial light is relatively poor, the young mahogany plant develops even without initial photosynthesis. The first young leaves of mahogany are scale leaves and not green. True photosynthetic leaves come later and are adapted to sun-flecked shade and partial shade. Hardened mahogany seedlings can tolerate open fields as long as soil moisture is not limiting. The leaves of mahogany are rarely attacked by herbivores. Thus, a mahogany plantation is like a "green desert" to wildlife. Dipterocarps fruit and seed irregularly in intervals of four to five years and therefore stand no chance competing with mahogany.

When mother trees shed their leaves during the months of February, they form a thick litter mat. Dry mahogany leaves are red and can be very rich in tannin. The leaves are intact during the whole length of the dry season. This litter mat could be one reason why very few seedlings are recruited under the mahogany plantation, including their own seedlings. Dispersed recalcitrant seeds rest on top of the litter mat instead of reaching the moist soil and hence die due to desiccation.

They may also be allelopathic (Thinley, 2002). Extracts from the leaves of mahogany were shown to retard the growth of narra (*Pterocarpus indicus*) test seedlings. Recruits increase away from the mahogany plantation and this increase is proportional to the competition offered by mahogany wildlings (Alvarez, 2001; Castillo, 2001). The importance of mahogany seedlings is negatively correlated with the Shannon-Weiner Diversity Indices of quadrats positioned from the mahogany plantation and away from it. In other words, diversity of the quadrats decreases as the importance of mahogany increases.

While mahogany invades regenerating dipterocarp forests and may give the dipterocarps a hard time in competition, the paper mulberry (*Broussonetia papyrifera*) also gives indigenous gap and pioneer tree species very keen competition. Ocular observation shows that where paper mulberry forms pure stand thickets, the usual indigenous pioneer tree species such as anabiong (*Trema orientalis*), binunga (*Macaranga tanarius*), alim (*Melanolepis multiglandulosus*), banato (*Mallotus philippinensis*), tibig (*Ficus nota*), hauili (*F. septica*), isis (*F. ulmifolia*), sablot (*Litsea sebifera*), paguringon (*Cratoxylon sumatranum*), and malapapaya (*Polyscias nodosa*) are not present.

The combination of mahogany and paper mulberry is therefore a big blow for the ecological succession of the landscape, at the gap and building-up phases. This can be a serious problem for Assisted Natural Regeneration (ANR) practitioners. Other important bio-invasive species in the general landscape of rural Philippine settings are hagonoy (*Chromolaena odorata*) and coronitas (*Lantana camara*). These two species retard the succession process in open grasslands, where they can become very gregarious, thus offering no ground for indigenous gap species. Where paper mulberry cannot establish, the equally important bio-invasive species ipil-ipil (*Leucaena leucocephala*) can usurp steep bare slopes and form pure stands of ipil-ipil. At the back of beaches and along beaches, two exotic mimosoid legumes also form gregarious thickets of aroma (*Acacia farnesiana*) and mesquite aroma (*Prosopis juliflorae*), respectively.

In the gaps of lower and upper montane forests of the Cordillera Highlands, the prolific and gregarious alders *Alnus maritima* and *A. nepalensis* also tend to form pure stands and these could also potentially be bio-invasive species in these parts of the country.

Recommendations

Tree plantations and natural forest stands should be distant and dispersal of bio-invasive propagules should be avoided. Bio-invasive species that have very long dispersal abilities and with allelopathic properties should be checked and banned in all successional stages of natural forests, for example paper mulberry and mahogany. Dispersal radius of suspect bio-invasive exotic tree species should be

studied, so that plantations that are safe from becoming sources of bio-invasive species may be designed.

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Status of forest invasive species in Sri Lanka

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Introduction

Sri Lanka has a land area of about 6.5 million hectares. Sri Lanka is a small but biologically diverse country that is recognized as a biodiversity hotspot of global importance for plants. Its varied topography and tropical conditions have given rise to this high level of biodiversity. There are many plant and animal species endemic to the country. Much of the diversity is found in the wet zone located in the southwest parts of the country. Human threats to biodiversity are greatest in this part of the country, due to the dense human population. It has been noted in the past that bio-invasions can have serious negative impacts on the function of these ecosystems. The direct economic consequences are more prominent in the agricultural sector, while the indirect economic consequences will be the loss of biodiversity. The agricultural sector has suffered a lot in the past from intentional or unintentional introductions of alien pests and diseases, including weed species. However, in more recent times attention has been given to the introduction of invasive species and their impacts on biodiversity in the country.

General overview of forest types in the country

According to the forest cover map prepared in 1992, Sri Lanka's closed natural forest cover was 23.9 percent of the total land area, which amounts to about 1.5 million hectares. Including sparse forests, the total natural forest cover is 30.9 percent of the land cover, which is around two million hectares. The average rate of deforestation during the past few decades, both planned and unplanned, has been around 42 000 hectares per year (Bandaratillake, 2001). The major natural forest ecosystems and their extent are presented in Table 1.

Table 1: Natural forests in Sri Lanka, 1992

Forest type	Total area (hectares)	Percentage of total land area	Bio-climatic zone
Closed canopy montane	3 108	0.05	Montane zone
Sub montane	68 616	1.04	Submontane zone
Lowland rain	141 506	2.14	Low/mid country wet
Moist monsoon	243 886	3.69	Low/mid country intermediate
Dry monsoon	1 090 981	16.49	Low country dry
Riverine	22 435	0.34	Low country wet and dry
Mangrove	8 688	0.13	Coastal areas, lagoons
Subtotal	1 579 220	23.88	
Open canopy sparse	464 076	7.01	Low country dry and arid
Total	2 043 296	30.89	

The forests in the montane and submontane areas occur at high elevations, located in the central parts of the country. In the montane zone, the height of the canopy is low. The trees are of poor form with dense, spreading, flat-topped crowns. The forest is not of commercial value, rather it is left undisturbed, to serve as protection forest preventing soil erosion and flash flooding in the catchment areas. The genera in both zones include *Syzygium*, *Calophyllum*, *Gordonia*, *Michelia*, etc. Lowland rain forests are rich in biodiversity and represent tropical rain forests that receive a well-distributed rainfall throughout the year. As a result, they develop multi-storey canopy structure with dense understorey. Climbers and epiphytes are prevalent in these forests. Common genera include *Dipterocarpus*, *Mesua*, *Doona*, *Shorea*, *Camptosperma*, *Vitex*, *Wormia*, *Chetocarpus*, *Anisophyllea*, etc. Moist monsoon forests are in the intermediate zone areas, which form a transition zone between the dry and the wet areas. Dry monsoon forests cover a large area of two-thirds of the country. In these forest areas, there is a pronounced moisture deficit period of about four months. Some of the timbers produced in these forests are highly priced. The major genera include *Manilkara*, *Drypetes*, *Chloroxylon*, *Berrya*, *Diospyros*, etc. Riverine forests are small in extent and distributed along major rivers in low lying areas. Mangrove forests are comparatively small, but play an important ecological role stabilizing the estuaries and lagoons and providing shelter and breeding grounds for fish, crustaceans and other marine life.

Importance and relevance of forest invasive species issues in the country

Invasive species are generally exotic or alien species having the ability to compete with and replace native species in natural habitats, thereby threatening native biological diversity. They have special characteristics that enable them to spread rapidly and aggressively and compete with native flora and fauna, to form a dense population that interferes with the natural development of biotic communities.

In order to protect biodiversity in the country, Sri Lanka became a signatory to the Convention on Biological Diversity in 1992 and ratified it in 1994. The Ministry of Forestry and Environment was identified as the focal point for activities related to biological diversity. The introduction of alien invasive species – intentionally or unintentionally – can cause a tremendous negative impact on biodiversity in a country like Sri Lanka. A large number of species extinctions can occur through the introduction of invasive species. In addition, some invasive species can contribute to degradation of catchment areas and irrigation systems, incurring severe economic losses. Intentional introductions include deliberate introductions for use in agriculture, forestry, horticulture, fisheries, aquaculture, landscaping, zoos, pet trade, etc. Unintentional introductions include accidental introductions of species through transport, trade, travel, tourism, etc. In Sri Lanka, alien invasive species are particularly important due to following factors (IUCN, 2000):

- geographically separated small size and island nature of the country;
- developing status;
- greater diversity of habitats;
- high levels of species endemism in the southwest parts of the country;
- current highly threatened status of many endemic species and their habitats; and
- increased degradation and fragmentation of natural habitats due to development activities.

As some invasions have the potential to become irreversible, the prevention of new introductions is of primary importance, followed by the management of already established species that may pose a conservation threat.

Most significant forest invasive species in the country

The most significant invasive species and their mode and source of introduction, distribution and affected habitats/ecosystems are presented in Table 2 and Table 3.

Table 2: Invasive fauna in forest ecosystems in Sri Lanka

Species	Mode/source of introduction	Distribution	Affected habitats/ecosystems
<i>Bubalus bubalis</i> (Domestic / feral buffalo)	Deliberate; animal husbandry	Island-wide	Forests
<i>Oncorhynchus mykiss</i> (Rainbow trout)	Deliberate; sport fishery	Montane zone	Streams
<i>Chitala chitala</i> (Clown knife fish)	Negligence; ornamental fish trade	Lowland wet zone	Ponds, slow-flowing rivers, marshes
<i>Hypostomus plecostomus</i> (Plectosomus catfish)	Negligence; ornamental fish trade	Lowland wet zone	Ponds, slow-flowing rivers, marshes
<i>Clarias batrachus</i> (Walking cat fish)	Negligence; ornamental fish trade	Lowland wet zone	Marshes, streams
<i>Gambusia affinis</i> (Mosquito fish)	Deliberate; mosquito control	Lowland wet zone	Marshes, ditches, streams
<i>Poecilia reticulata</i> (Guppy)	Deliberate; mosquito control	Lowland wet zone	Marshes, ditches, streams
<i>Oreochromis mossambicus</i> (Tilapia)	Deliberate; commercial fishery	Island-wide	Rivers, marshes, lagoons and estuaries

Table 3: Invasive flora in forest ecosystems of Sri Lanka

Species	Mode/source of introduction	Distribution	Affected habitats/ecosystems
<i>Wedelia triloba</i> (runner)	Negligence; ornamental plants	Wet and intermediate zone	Forest edges
<i>Mikania micrantha</i> (wine)	Negligence; ornamental plants	Montane zone	Montane forests
<i>Opuntia stricta</i> (shrub)	Negligence; ornamental plants	Arid zone	Thorn scrublands
<i>Lantana camara</i> (shrub)	Negligence; ornamental plants	Island-wide	Scrublands, degraded open forests
<i>Ulex europaeus</i> (shrub)	Negligence; ornamental plant	Montane zone	Montane forests, wet patana grasslands
<i>Eupatorium riparium</i> (shrub)	Negligence; ornamental plants	Montane zone	Montane forests
<i>Clidemia hirta</i> (shrub)	Unknown	Lowland wet zone	Rain forests
<i>Eupatorium odoratum</i> (shrub)	Negligence; ornamental plants	Lowland dry and wet zone	Forest edges and pathways
<i>Mikania calvescens</i> (shrub)	Negligence; ornamental plant	Submontane zone	Disturbed forests
<i>Dillenia sufruticosa</i> (shrub)	Negligence; horticulturists	Lowland wet zone, Riparian areas	Marshes, low lying areas
<i>Millingtonia hortens</i> (shrub)	Negligence; ornamental plant	Southern dry and intermediate zone	Disturbed forests and scrublands
<i>Prosopis juliflora</i> (small tree)	Deliberate; afforestation	Arid zone	Thorn scrublands
<i>Annona glabra</i> (small tree / shrubs)	Unknown	Lowland wet zone	Coastal lagoons, marshes
<i>Swietenia macrophylla</i> (large tree)	Deliberate; forestry/ timber	Lowland wet zone	Disturbed forests
<i>Leucaena leucocephala</i> (small tree)	Deliberate; fodder plant, soil rehabilitation	Intermediate zone	Dry mixed evergreen forests
<i>Psidium littorale</i> (treelet)	Negligence; ornamental plants	Montane zone	Montane forests
<i>Myroxylon balsamum</i> (tree)	Deliberate; forestry	Wet and Intermediate zone	Forest edges
<i>Alstonia macrophylla</i> (tree)	Deliberate; forestry	Wet and Intermediate zones	Secondary forests
<i>Mimosa pigra</i> (small tree)	Unknown	Mid country wet and intermediate zones	Wastelands, along river banks
<i>Imperata cylindrica</i> (grass)	Unknown	Island-wide	Disturbed forests and scrublands
<i>Panicum maximum</i> (grass)	Deliberate; fodder	Island-wide	Disturbed forests and scrublands
<i>Bambusa bambos</i> (bamboo)	Unknown	Mid country areas	Disturbed forests and scrublands
<i>Ochlandra stridula</i> (bamboo)	Unknown	Wet zone	Disturbed forests
<i>Acrostichum aureum</i> (fern)	Unknown	Lagoon areas	Mangrove forests
<i>Najas marina</i> (submerged plant)	Unknown	Coastal areas	Lagoons and estuaries

Source: Bambaradeniya *et al.* (1999) and authors' own observations

Biology and life history of the most significant invasive species

Grasses

Imperata cylindrica, Graminae

Imperata is a rapidly spreading, noxious perennial weed in agricultural, forest and wastelands. Once this weed colonizes the land its subsequent propagation takes place by stolons. It poses serious problems to many agricultural crops and forest seedlings in plantation establishment. It is found in most parts of the country. It grows year round and up to 1 metre in height. Propagation is by wind

dispersal of seeds and by underground stem parts. Manual control is very difficult and chemical control is fairly successful.

***Panicum maximum* (Guinea grass), Graminae**

Guinea grass is a ubiquitous perennial weed. It poses a major problem in agriculture and forestry plantation establishment. It has spread to most parts of the country including natural ecosystems, abandoned or degraded lands, forest plantations, etc. When growth is uncontrolled, it can grow up to about 2 metres in height, shading out and out-competing natural or planted seedlings in forests and retarding their establishment and growth. Taller stands can block the access of humans and vehicles. Its faster spread, both by seeds and underground stem parts, threatens natural ecosystems by replacing native plants. In addition, it creates a fire hazard in dry periods, which can also replace natural vegetation in an area. When Guinea grass is burned it re-sprouts and grows rapidly, dominating the area. Its control is extremely difficult unless long-term control measures are taken. Cattle-grazing is somewhat effective in controlling this grass, although this does not eradicate it.

Shrubs

***Lantana camara*, Verbanaceae**

Lantana camara is a plant introduced to Sri Lanka in 1926 through the Royal Botanic gardens of Sri Lanka. Currently a major weed found throughout the country, it has invaded natural ecosystems particularly when open conditions are prevalent. This species is commonly found in dense stands along roadsides and abandoned lands. It is a fast-spreading, thicket-forming, perennial shrub and is somewhat shade tolerant. The weed has invaded the Udawalawe National Park, which is a leading elephant sanctuary of the island, significantly reducing the grazing lands available for the elephants. It has also spread in forest plantations and degraded natural forests interfering with natural regeneration. The spread is influenced by birds eating the fruits. Manual methods are somewhat successful in controlling this grass.

***Prosopis juliflora* (Mesquite), Fabaceae**

Mesquite was first introduced to Sri Lanka in 1880 and is currently found spreading rapidly in the coastal belts of Southern and Western provinces in the country. It was introduced in the early 1950s to Southern province to improve the saline soils and as ground cover. The species has now become invasive and is a serious threat to natural habitats. This species has severely affected the Bundala National Park, the only wetland in Sri Lanka listed under the Ramsar Convention, affecting all types of vegetation, except sand dunes. It invades disturbed open areas and gradually encroaches on forest interiors. The most seriously invaded vegetation is lagoon marsh, where more than 75 percent of vegetation has been replaced by this species. Some positive aspects have also been observed in this species: it reduces erosion around lagoons, provides resting, feeding and nesting places for the birds and provides fodder for cattle, elephants, birds and monkeys in periods of drought (Seneviratne and Agama, 2001).

***Ulex europaeus* (Gorse), Fabaceae**

This species was introduced to Sri Lanka in 1888 and has invaded natural ecosystems in the hill country of Sri Lanka. It is a prickly evergreen shrub with profuse yellow flowers. It reproduces by re-sprouting from stumps and by seed. Heavy seed production and long seed viability make it troublesome to control. It is confined to high altitude areas in the country. The biodiversity of the Horton Plains, a nature reserve, has been significantly affected due to the spread of this invasive plant. Several attempts have been made by community organizations to eradicate this weed by uprooting and burning, however, these efforts have only been marginally successful.

Trees

***Myroxylon balsamum*, Fabaceae**

First reported in the 1920s, *Myroxylon* has recently been identified as colonizing natural and semi-natural habitats in some parts of the country. It has been planted as a shade tree along roadsides, as windbreaks and in plantations. It has been reported to damage the composition, structure and functions of natural ecosystems. In certain forests, it has developed into mono-specific stands, for example, in Udawattakele Nature Reserve and in some mixed mahogany forests.

Specific efforts to manage and control invasive species

At present, the identification and prioritization of species is done on an *ad hoc* basis. There is a lack of proper institutional and legal frameworks to deal with invasive species. Furthermore, there is no coordination among various government institutions that are directly or indirectly involved in dealing with alien invasive species. Currently, there are no concerted efforts to manage invasive species in Sri Lanka, except several isolated attempts to control such species.

To deal with this situation, the Biodiversity Secretariat of the Ministry of Environment and Natural Resources organized a national workshop on Alien Invasive Species (AIS) of Sri Lanka in October 1999. Some of the important recommendations in this workshop are given below:

- develop a national strategy/action plan and a comprehensive set of clear guidelines to prevent the introduction, eradicate and mitigate the impacts of AIS;
- conduct a comprehensive capacity building and awareness programme;
- establish a national database, prepare a national action plan on AIS, and prepare a national weed strategy;
- review existing legislation and regulations on quarantine practices, plant protection and other relevant Acts and ordinances to avoid the introduction of potential invasive species;
- make additional funds available for research, awareness and control measures on AIS;
- develop technologies to enable the use of weeds for productive purposes; and
- appoint two separate taskforces for alien invasive flora and fauna.

A follow-up workshop was held in September 2000 to make an in-depth analysis of the problem. It recommended the development of a national invasive species action plan (NISAP) to overcome the problems of AIS (Marambe, 2000). The workshop participants identified strategies to be included in the NISAP.

Certain invasive species have the potential to be utilized in various ways. For example, water plants such as *Eichornia*, *Salvinia*, *Hydrilla* species and grasses such as *Imperata* and *Panicum* have the potential to be used as compost manure and mulch. Some are useful in making bio-gas. Species such as *Colocasia* and *Tithonia* can be used as organic manure in agricultural fields. *Dillenia* and *Clusia* species can be used as good fuelwood sources. Natural forest invasive species such as mahogany and *Alstonia* are good timber species and used widely in local markets.

For prevention, eradication and control of alien invaders, Bambaradeniya (2000) suggested the following actions:

1. Coordination, policy and legislative initiatives:
 - establish a coordinating body, which could oversee all aspects and issues pertaining to invasive species;
 - address the gaps and conflicts in policies and legislation; and
 - develop new policies as appropriate.
2. Actions to prevent future detrimental introductions:
 - collect data on alien invasive fauna and flora in other parts of the world;
 - train personnel to detect alien biota;
 - adoption of strict quarantine procedures;
 - strengthening of the current legislation; and
 - conduct awareness-building programmes.

3. Actions to control/eradicate established invaders:

- initiate active scientific research on the management and control of alien invasive species;
- adoption of control measures, supported by scientific research; and
- regular monitoring of natural ecosystems infested by AIS to determine the status of invaders.

Assessment of costs associated with specific pest and disease incursions

In the case of forestry, no assessments have been carried out with regard to the costs of damage caused by the alien invasive species. In general, no special pest or disease invasions have been recorded in the past, except some common pests found in teak and mahogany.

Forest health, quarantine and sanitary / phytosanitary regulations and procedures

In Sri Lanka, the legal basis for plant protection and plant quarantine (Plant Protection Ordinance) dates as far back as 1924. Plant quarantine ordinance is enacted by the Department of Agriculture in Sri Lanka. It makes provisions against the introduction of weeds, pests and diseases and for the sanitation of plants in the country. The ordinance has been progressively amended in 1956 and 1981. However, several devastating pests have established themselves in the country during the last decade. Therefore the ordinance was totally revised in 1999 to make adequate provisions to cope with current trends in the movement of flora and fauna, as a result of the increase in international trade and traffic. The plant protection ordinance of Sri Lanka aims to prevent the introduction of exotic pests including insects, diseases and weeds, but places less emphasis on plant species that can have serious negative effects on biodiversity of natural habitats.

The Fauna and Flora Act was amended in 1964, and again in 1970. It makes provisions for the establishment and maintenance of national reserves, national parks and jungle corridors.

The policy on imports of seed and planting material was revised by the Department of Agriculture in 1991, and the New Seed Act was formulated in 1999.

Key institutions involved with invasive species

In Sri Lanka, there are several institutions involved with alien invasive species – mainly those involved with biodiversity conservation. These are listed below:

1. Ministry of Environment and Natural Resources
2. Forest Department
3. Agriculture Department
4. University of Peradeniya
5. University of Sri Jayawardanapura
6. IUCN, Sri Lanka
7. National Science Foundation

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Invasive species in the United States of America – 2003

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Scope of problem

The threat of aquatic and terrestrial invasive species⁴ is one of the greatest natural resources concerns in the United States of America. Their prevention and control is operationally critical to meeting the stewardship mission of the USDA Forest Service. Thousands of species of invasive plants, invertebrates, fishes, diseases, birds, and mammals threaten ecosystem function, economic stability, and human health. Second only to direct habitat destruction, invasive species are the greatest threat to native biodiversity and native communities, nutrient cycling, hydrology, and natural fire regimes. Direct and indirect impacts of invasive species have contributed to the decline of approximately 46 percent of all listed threatened and endangered species. Public recreational opportunities and experiences have been severely degraded by rapid infestations of invasive species, in many cases hampering access, reducing recreational quality and enjoyment and decreasing the aesthetic values of public use areas.

Nationally, invasive species cost Americans over US\$137 billion each year, with a large portion of the impacts affecting public lands and agriculture. As the largest land managing agency within the Department of Agriculture, the Forest Service has a significant role in battling these insidious invaders and has stepped forward to work collaboratively at the local, state and national levels. The economic threats from invasive species to Forest Service timber and other production operations are significant and cannot be marginalized, and the linkage between the spread of invasive species and increased wildfire frequency and intensity has been well documented. It has been estimated that invasive plants occupy nearly 133 million acres (53.8 million hectares) of national forests and rangelands, other federal ownerships, state, tribal and private lands, and are spreading at a rate of nearly 1.7 million acres (688 000 hectares) per year. It is estimated that annual losses associated with invasive plants total US\$13 billion. Insect and disease problems continue to increase and plague millions of acres of private, state, and national forests in nearly every region of the nation.

Due to the broad range of pathways for invasive species to enter and become established within our nation's forests and rangelands, the rate of new infestations is growing exponentially. Also, due to overstocking of many forested areas, the threat of infestations by insects, pathogens and invasive plants is greatly enhanced. It is estimated that 70 million acres (28.3 million hectares) of the nation's forests are threatened by infestations of insects and disease mortality, including 21 million acres (8.5 million hectares) by western bark beetles. Compliance with the requirements of the National Environmental Policy Act governing agency actions, and subsequent appeals and litigation have slowed the USDA Forest Service efforts in completing many projects designed to improve forest health.

Introduction

America's forests cover 747 million acres (302 million hectares), of which 20 percent are on National Forest System lands, 49 percent are owned by non-industrial landowners, 8 percent by states, 13 percent by other federal agencies and 10 percent by industrial landowners (Figure 1). This forest land is an invaluable asset to the American people, providing water, recreation, wildlife habitat, and future timber. Maintaining the health and sustainability of natural resources is a national security issue and the United States Department of Agriculture (USDA) Forest Service remains committed to the protection of these resources. America's forests continue to face many catastrophic risks, including fires, invasive species and fragmentation.

The Forest Service definition of a healthy, sustainable forest is:

a condition wherein a forest has the capacity, across the landscape, for renewal, for recovery from a wide range of disturbances, and for retention of its ecological resiliency while meeting current and future needs of people for desired levels of values, uses, products, and services.

⁴ Definition of Invasives Species: An invasive species is defined as a species that is 1) non-native to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health (Executive Order 13112).

The USDA Forest Service works collaboratively with state foresters, state departments of agriculture, and other USDA agencies, including the Animal and Plant Health Inspection Service (APHIS) to protect America's forests from native and introduced insects, pathogens and invasive plants. The FHP programme provides services to federal, state, tribal, and private managers of forest lands. Services include technical information and assistance in management and control of forest insects, diseases, and invasive plants; forest health monitoring; technology development; and pesticide use.

This report provides a summary of current forest ecosystem health issues in America's forests. There are three general areas of concern:

- non-native invasive insects and pathogens;
- invasive plants; and
- outbreaks of native insects.

Non-native invasive insects and pathogens

Global trade and travel are causing an unprecedented movement of animals, plants and micro-organisms across continents and oceans. All too often, these non-native species are invasive and can cause impacts that are extremely costly to both the U.S. economy and environment. When brought into new ecosystems, non-native invasive species have no natural enemies and can cause extensive damage. Nearly 50 percent of the plants and animals on the federal endangered species list have been negatively impacted by non-native invasive plants, animals, insects and microbes. These species threaten biodiversity and have caused catastrophic damage to agriculture, forest products, recreation and natural resources across North America. Examples include yellow star thistle, leafy spurge, gypsy moth, American chestnut blight and white pine blister rust.

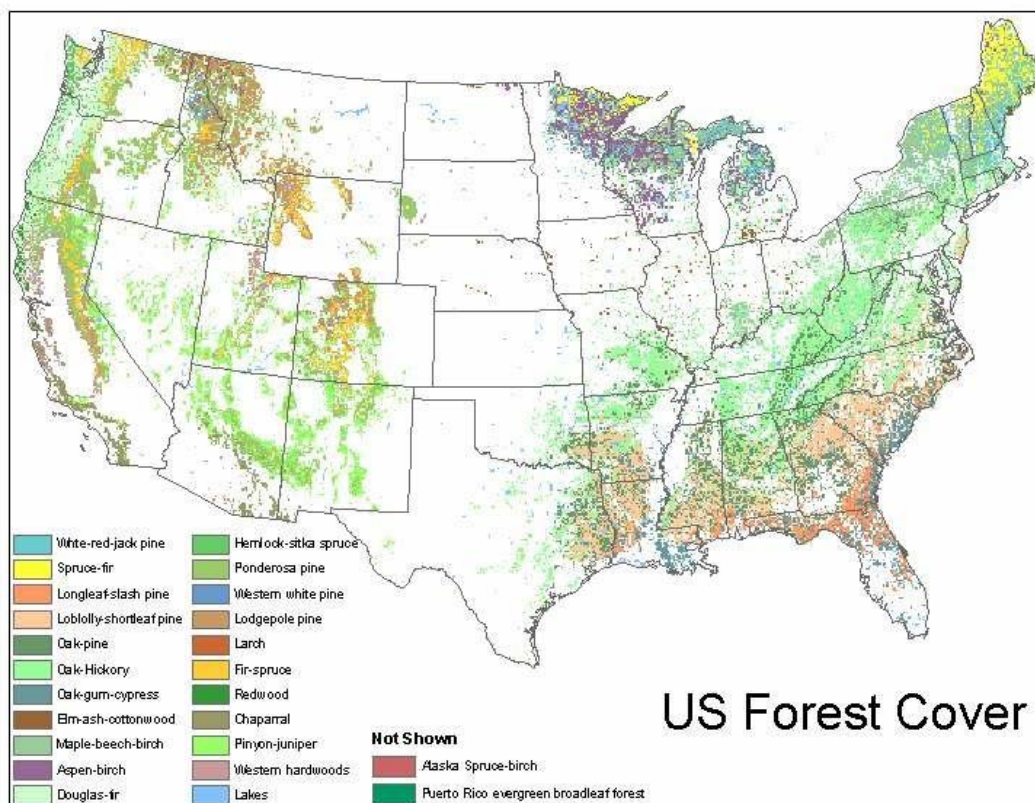


Figure 1: United States of America forest cover types

In February 1999, the President issued *Executive Order 13112 on Invasive Species*, establishing the National Invasive Species Council. The council provides, for the first time, a coordinated effort by its 10 member departments. In October 2001, the council completed a management plan, *Meeting the Invasive Species Challenge*, to address the Executive Order. The plan is designed to raise public awareness and control the introduction and spread of non-native invasive pests. According to the plan, the economic cost of invasive species is estimated at US\$137 billion every year.

The USDA Forest Service alone spends more than US\$40 million annually to control the introduction and spread of non-native species and approximately US\$40 million for native species. The control efforts include refining, developing and deploying a broad array of technologies to minimize the impacts of invasive species. Technology includes remote sensing, computer modeling, mechanical treatments, bio-pesticides, biological controls and conventional pesticides. The USDA Forest Service and APHIS have started an early detection and rapid response programme to detect and promptly eradicate any new invasive species. Invasive pests are dealt with as aggressively as possible, within budget constraints, before they become well established.

Selected examples of major invasive insects affecting U.S. forests

Emerald ash borer

The invasive emerald ash borer, a recently introduced pest, is threatening ash trees (*Fraxinas* spp.) in North American forests, urban plantings and shelterbelts. Critical, time-sensitive research is needed on the borer's basic biology, ecology and management. At the present time, information is insufficient to support ongoing detection efforts and to develop effective strategies for containing the infestation, reducing beetle density, or eradicating this pest.

In 2002, the emerald ash borer (*Agilus planipennis*) was discovered in dead and dying ash in a 5-county region around Detroit, Michigan and in neighbouring Windsor, Ontario, Canada. In August 2003, Forest Service research confirmed its presence in Toledo, Ohio. The borer, which was introduced into Michigan about five years ago, is native to China, Korea, Japan and other Asian countries.

A recent federal and state survey of ash in southwest Michigan determined that the outbreak covers over 2000 square miles (518 000 hectares). In southwest Michigan, 49.1 percent of the trees surveyed, and an estimated 5.2 million ash trees, are dead or declining. The State of Michigan has quarantined movement of ash trees and ash wood products from the five counties around Detroit to reduce the chances of transporting emerald ash borer outside the currently infested area.

In Michigan, only ash has been attacked – in Asia, elm, walnut and chestnut may be attacked. The borer may have a major impact on forests across the United States of America. Ash is a major component of natural and urban forests in the east and central United States of America and urban areas in the west. The potential value loss in nine major urban centres is estimated at US\$20-60 billion for 30-60 million ash trees. Losing urban ash is also critical, because ash has been the primary replacement tree for American elm.

Information on biology, detection and control of emerald ash borer is limited to less than a paragraph in the Chinese literature. Currently, infestations are detected by visually examining each tree for exit holes left by emerging adults. "Control" is limited to removal and destruction of infested trees, although preliminary tests conducted this year indicate that tree injections or aphids may work. More research is necessary to obtain information on the basic biology and ecology of emerald ash borer and tools for assessing ecosystem risk, detection and control that managers must have to formulate effective management strategies.

The Undersecretary of Natural Resources and Environment at USDA and Chief of the Forest Service are aware of the urgency of the problem and the need for emergency research funds to obtain vital information. APHIS and the Forest Service are planning to submit a request to the Secretary for authority to use Commodity Credit Corporation (CCC) emergency funds.

Scolytus schevyrewi

Scolytus schevyrewi is native to eastern Russia, China and Korea. The beetle was first collected in rapid detection bark beetle pheromone traps set in Aurora, Colorado (a suburb of Denver) and Ogden, Utah, starting in late April 2003. It is considered very invasive. Dr James LeBonte, Oregon Department of Agriculture, first identified the beetle as new to the United States of America. At this time, there is no common name for this beetle and it is currently not known how damaging this insect can potentially be.

APHIS has increased its detection effort for this bark beetle in Colorado, Utah, and several adjacent states. The Forest Health Protection (FHP) rapid detection group along with staff of other FHP offices in the West and the Colorado State Forest Service are assisting APHIS.

In Colorado, *S. schevyrewi* has been collected all along the Front Range from Pueblo to Fort Collins and has been found in Durango in the southwest and in Lamar, a town in southeastern Colorado. In Utah, the bark beetle has been found in Ogden, Salt Lake City, and in eastern Utah. The beetle was found in samples of fresh wood from American elm, rock elm and Siberian elm.

The biology of *S. schevyrewi* is similar to that of *S. multistriatus*. The beetle completes a generation in about two months (fresh attacks in late-April and early-May in the Denver area, and brood emergence by early-July). The USDA Forest Service expects that *S. schevyrewi* will complete two to three generations per year in the Denver area. The literature suggests that the beetle has a feeding period on branch junctions like that of *S. multistriatus*. The egg galleries are very similar between these two bark beetle species.

Sudden oak death

Sudden oak death (SOD) – a disease caused by *Phytophthora ramorum*, a newly discovered pathogen of uncertain origin – has killed thousands of trees in coastal, mixed evergreen forests and urban-wildland interfaces in California and southern Oregon. It kills a range of tree species – including coast live oak, California black oak, shreve oak, tan oak, and madrone – and infects several other plant species including rhododendron, manzanita, California bay laurel, buckeye, evergreen huckleberry, and big leaf maple. The disease degrades ecological processes and watershed functions, and lowers forest productivity. It reduces aesthetic, recreational and economic values and leaves forests susceptible to invasive plant infestations. Dead trees add fuel to an already high fire risk.

There is presently insufficient knowledge of how the disease spreads and its biology. It is known to be spreading rapidly and has been found in nursery stock (particularly rhododendrons) in a few ornamental nurseries, raising concerns that it could be transported to and infect the extensive, susceptible oak forests of the Eastern United States of America. The oak-hardwood forest is the largest forest type in the United States of America.

The USDA Forest Service has spent over US\$5 million to research, monitor, manage, and educate the public about SOD. The USDA Forest Service is also working closely with APHIS to assist in implementing quarantine and to regulate the transportation of wood, bark, and nursery stock that might harbor the SOD pathogen.

California and Oregon implemented state regulations, prior to the release of federal regulations, to prevent the spread of this disease. The states are coordinating their respective regulations with APHIS. The USDA Forest Service (through the California Oak Mortality Taskforce, a public-private coalition) is leading federal, state, and local partners in implementing effective SOD research, monitoring, management and education programmes to protect the nation's oak forests.

In 2000, USDA Forest Service provided funds to help investigate the cause of this disease. Investigations led to the discovery that the primary cause of SOD is a previously undescribed species of *Phytophthora*. In 2001, the USDA Forest Service provided additional funds to determine the extent and severity of SOD in oaks and other native plants in California and Oregon. The funds were also used to develop diagnostic and survey methodologies for the SOD pathogen, evaluate fungicide treatments and other management strategies, and assess the fire risk and other ecosystem effects of accelerated oak mortality. The USDA Forest Service continues to support cooperative efforts in 2002 to monitor the disease development and spread. Forest health monitoring surveys detected the pathogen in southwestern Oregon. In the autumn of 2001, the Oregon Department of Forestry attempted to eradicate the pathogen. Monitoring efforts to determine the effectiveness of the eradication treatment are underway.

White pine blister rust

White pine blister rust (WPBR), an introduced fungus from Asia, has decimated several species of native white pines across the American West and Canada. Native white pines are an integral part of the natural biodiversity of western forests. The ecological and economic impacts have been most acute on the two largest commercial species – western white pine and sugar pine. WPBR entered North America through the east and west coasts on European nursery stock around 1910. In the west, it quickly spread from Vancouver, British Columbia, Canada, south through the Cascades and Sierra Nevada, and east into the Rocky Mountain States of Idaho, Montana, Colorado, Wyoming, and New Mexico. The pest has also inflicted severe ecological damage in high-altitude whitebark and limber

pine forests. In susceptible stands, WPBR can kill over 95 percent of mature trees, effectively altering a forest ecosystem forever. Strategies for control include:

- restoration of white pine forests through development and planting of white pines, which are genetically resistant to WPBR. More than 8 000 acres (3 237 hectares) of forest lands have been planted with resistant seed from seed orchards and proven resistant seed trees;
- restoration of white pines through deployment of silviculturally integrated practices, such as pruning the infected plantation trees and planting in low hazard areas; and
- extensive ongoing resistance-breeding programmes, run by the USDA Forest Service, that began in the 1950s. These breeding programmes continue to discover and develop WPBR-resistant varieties of white pines. These programmes saved the western white pine and sugar pine from extinction. In California, a total of 1 329 proven resistant seed trees have been identified, and two seed orchards have been established. In the Pacific Northwest, the resistance-breeding programme supports 40 seed orchards. The Rocky Mountain region has identified more than 3 100 trees and planted 96 255 acres (38 953 hectares) with WPBR-resistant white pine seedlings.

Gypsy moth

Since 1930, gypsy moth has defoliated more than 80 million acres (32 million hectares) of forests in the eastern United States of America, with most of this damage occurring during the past 20 years. A hardwood defoliator native to Europe and Asia, gypsy moth arrived in the United States of America in the 1800s, established itself in the oak forests of southern New England, and then spread south and west across 19 states. Occasionally, it appears in western forests, but has been successfully eradicated each time. Unfortunately, gypsy moth is now a permanent resident of eastern forests.

During outbreaks, moth populations often outpace the few natural enemies, parasites, predators, and pathogens that attack them. The gypsy moth feeds on the delicate first flush of leaves in the spring. It prefers oaks, but it will feed on 500 species of woody plants. The attacked trees become highly susceptible to secondary attacks from other insects and pathogens, often resulting in death. The deaths alter the forest ecosystem dramatically; usually dead oaks are replaced not with more oaks, but with other species that do not produce as much mast for wildlife. In response to this pest, the USDA Forest Service adopted the following strategies:

- implementing programmes and providing technical and financial assistance to states and other federal agencies to suppress and slow the spread of gypsy moth in the East; and
- detecting and eradicating – along with APHIS, state governments, and other federal agencies – localized introductions of gypsy moth in the West.

A gypsy moth virus and aerial treatments with biological and chemical insecticides conducted over 460 000 acres (186 155 hectares) in 2001 have effectively suppressed or slowed the spread of gypsy moth in nine northeastern states. The USDA Forest Service's gypsy moth slow-the-spread programme slows the southwesterly spread of the insect by 60 percent through concentrated monitoring and by using environmentally benign mating disruption techniques. After discovering adult gypsy moths in pheromone traps in seven western states in 2000, steps were taken that eradicated the pest from these states. The USDA Forest Service and many other cooperators continue to develop new controls and delivery methods to use against this pest.

Hemlock woolly adelgid

The hemlock woolly adelgid (HWA) is one of the most serious forest pests threatening eastern forests. The insect defoliates eastern hemlock; trees can die within four years of infestation. Native to China and Japan and introduced to the American Northwest in the 1920s, it has spread quickly across the northern United States of America. Fortunately, western hemlock proved resistant to HWA. Unfortunately, eastern hemlock is highly susceptible to HWA. Beginning in the 1950s, the pest began a destructive march north and south through eastern forests. Today, it infests nearly half of the hemlock forests across 11 states from Massachusetts to South Carolina, and as far west as the southwest tip of West Virginia.

Eastern hemlock is a pivotal species in eastern forest ecosystems. It is especially important along streams and creeks, where its shade helps control water temperatures – thereby helping to sustain

aquatic ecosystems. Eastern hemlock spans the eastern United States of America from Maine, west to northern Wisconsin, and south along the Appalachians to north Georgia. The span also includes small pockets in Indiana and Mississippi. To arrest the pest's advance, the USDA Forest Service has:

- implemented spray programmes on individual trees wherever practical and environmentally safe, such as in non-riparian settings;
- identified, developed, and released HWA-specific biological control agents; and
- developed an integrated plan to address the problem, as funding permits.

The USDA Forest Service identified a number of pathogens and predators native to the United States of America that would attack HWA. The most effective to date is the Japanese ladybird beetle (*Pseudoscymnus tsugae*). This predator attacks only HWA, will feed on all stages (egg to adult) of HWA and, in sufficient numbers, will consume up to 97 percent of a HWA population. Since 1999, the USDA Forest Service has raised and released over half-a-million beetles in nine states. Additional research, development, and subsequent management actions are expected to reduce the impacts of this destructive pest.

Invasive plants

Thousands of invasive plant species have been introduced in the United States of America. About 1 400 are recognized as pests that pose significant threats to the biodiversity of forest and grassland ecosystems. Federal natural resource agencies list 94 species of exotic plants as noxious weeds, and many more appear on state lists. Experts estimate that well over 100 million acres (40 million hectares) are infested with invasive plants, and that as much as 20 million additional acres (8.1 million hectares) are being added every year. An estimated 3.6 million acres of National Forest System lands are infested.

Many of the invasive plants are not native to the United States of America. Therefore, they have no natural enemies to limit their reproduction and spread. Although rangelands are the primary targets of many invasive plants, they are showing up everywhere – in forests, parks, preserves, wilderness areas, wildlife refuges, croplands and urban spaces. Invasive plants threaten two-thirds of the habitat of all threatened and endangered species.

Two federally coordinated efforts are:

- the Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW) – comprised of 17 federal agencies with a common goal to develop biologically sound techniques to manage invasive plants on all lands; and
- the National Fire Plan – focused on rehabilitating and restoring forests and rangelands, specifically reducing the spread of noxious weeds.

In 2001, the USDA Forest Service spent over US\$27 million in implementing provisions of the National Fire Plan to prevent and control the spread of noxious weeds on more than 145 000 acres (58 000 hectares) of National Forest System lands. Part of these funds, US\$3.5 million, was allocated to Idaho and Montana to protect approximately 93 000 acres (37 635 hectares) of state and private lands from invasive weeds.

The USDA Forest Service and its cooperators are conducting extensive research and development on biological control agents for use against many invasive plants, such as mile-a-minute weed, a major problem in five northeastern states. Biological control agents are showing some success in slowing the spread of invasive plants, such as leafy spurge in the West.

Selected examples of invasive plants affecting U.S. forests

Leafy spurge

Leafy spurge is a classic non-native, invasive plant. Arriving in North America from Eurasia in the 1890s, it now infests over 2.5 million acres (1.01 million hectares) of rangeland in southern Canada and the northern United States of America. At maturity, it can reach heights of 7 feet (2 meters). Leafy spurge can kill cattle and horses, and its sap can cause irritation to the eyes, mouths, and digestive systems of all domestic and wild grazing animals, except goats and sheep. The sap can also cause blistering, severe dermatitis and permanent blindness among humans. Seedpods explode when

touched, scattering seeds up to 15 feet. It has a nutrient-storing taproot system that can reach soil depths of 20 feet (6.1 meters). Pulling the plant actually encourages it to spread.

Although conventional herbicides are effective against leafy spurge, they have a limited use. Due to this limited use, the USDA Agricultural Research Service, in cooperation with APHIS, developed and evaluated integrated approaches to managing leafy spurge. Now a cooperator, the USDA Forest Service, is researching and applying several biological control agents to suppress the pest's spread, including:

- grazing goats and sheep;
- fungal controls that kill the plant by causing root rot; and
- flea beetles that feed specifically on leafy spurge.

Of these three, the flea beetles appear to be most effective against this pest, especially when used as an integral part of a pest management approach that includes grazing by sheep and goats and use of conventional herbicides, wherever possible. Imported from Asia, beetle populations have been established in Montana, the Dakotas, and Wyoming. Adult insects weaken the plants by attacking leaves and stems, and the larvae feed upon the roots. The USDA Forest Service and other cooperators are refining laboratory techniques so that the beetles can be mass-produced.

Mile-a-minute weed

Mile-a-minute weed is a prickly, annual vine that, true to its name, grows very rapidly and overpowers virtually all vegetation in its path. Originally from Asia, it first appeared on the west coast in the 1890s. In 1946, it was found in nurseries in Pennsylvania. It has spread to New York, Ohio, Maryland, New Jersey, Virginia, West Virginia, Delaware, and the District of Columbia. Seeds are spread by birds and rodents and are carried in rivers and streams. The plant is an excellent climber and easily overpowers, engulfs, and displaces much of the native flora in its path. It invades nurseries, forest openings, railroads, utility rights-of-way, roadsides, and riverbanks. It also threatens forest regeneration and recreational activities. In short, mile-a-minute weed is degrading plant diversity in North America.

Controlling the spread of mile-a-minute weed presents a tremendous challenge to forest and rangeland managers. The USDA Forest Service and its cooperators are working diligently to identify and apply effective biological controls to use against this non-native pest, including:

- identifying over 20 varieties of fungi that attack and/or kill the weed. Additional tests on the fungi are planned; and
- evaluating three insects from China known to attack the weed. One of the insects in particular – a weevil – shows promise for future release.

Outbreaks of native insects

Although native insects don't fall into the definition of invasives species, they are an important damaging agent in the United States of America. Examples including southern pine beetle and western bark beetles are causing significant mortality.

Native insects such as bark beetles, in the West, and southern pine beetle, in the South, act as "agents of change" in coniferous forests. At the endemic level, they play a critical role in the development, aging, and rebirth of entire forests. At the landscape level, insect-caused mortality contributes to structural and mosaic diversity within ecosystems. Insects can also cause major disturbances within U.S. forests. For example, tree mortality due to bark beetle outbreaks can be extensive, affecting thousands of acres.

Certain circumstances can exert uncommon stress on forests and predispose them to extraordinary insect outbreaks and damage. These circumstances include drought, overstocking, and large areas of aging forest. During the last decade, several of these circumstances have arisen simultaneously, causing extensive tree mortality. In turn, that mortality has threatened wildlife, endangered and threatened species habitat, and degraded recreational quality. The increased mortality has contributed to considerable fuel accumulation, which in turn increases the risk of catastrophic fires.

In 2001, the USDA Forest Service spent about US\$10 million to suppress and prevent bark beetle outbreaks. The USDA Forest Service has developed management plans to address the problem in an integrated manner and will implement these long-term plans as funding permits.

Southern pine beetle

Southern pine beetle (SPB) (*Dendroctonus frontalis*) is the most destructive forest pest in the South. Over 90 million acres (36 million hectares) of southern forests are at a moderate-to-high risk of SPB infestation. In 2001, due to a combination of a mild winter and a prolonged drought, the South experienced its most severe and prolonged SPB outbreak in history. SPB infested tens of thousands of acres and caused over US\$200 million in damages. A single SPB “spot” (outbreak) can spread very quickly and cover up to 1 000 acres in one season. The situation has been especially dire in Alabama, where more than 25 000 SPB spots have been detected. In the Southern Appalachian Mountains, SPB has killed thousands of acres of pines. It has killed more than 70 percent of the pine forest habitat of the red cockaded woodpecker, a federally listed endangered species, in the Daniel Boone National Forest in southern Kentucky. In response, the USDA Forest Service has:

- stepped up its funding of programmes to detect, suppress, and prevent SPB infestation and restore southern pine forests; and
- modernized and improved computer modeling and tracking technology – including the Southern Pine Beetle Information System (SPBIS), which enables national forest field staffs to quickly log information about SPB spots and schedule, execute, and monitor treatments on those spots.

In 2001, the USDA Forest Service doubled its financial commitment from the previous year and provided over US\$13 million to fund SPB suppression projects on federal, state, and private lands across the South. A comprehensive plan focusing on prevention and restoration has been developed and will be implemented as funding permits.

Mountain pine beetle in Colorado

The native mountain pine beetle (MPB) (*Dendroctonus ponderosae*) kills more pines in the American West than any other bark beetle. A regional assessment conducted by USDA Forest Service staff of the forests around the wildland-urban interface near Vail found that almost all of the 34 000 acres (13 759 hectares) of lodgepole pine in the area were at moderate to high risk of MPB infestation because of tree age, density and drought.

Vail, Colorado, the site of the 1999 World Alpine Ski Championships, is a world-class recreation setting. Vail also has some of the most valuable real estate in the United States of America. Among Vail’s natural treasures is the nearby White River National Forest – a large, and mostly wild, expanse of forest land. Increases in MPB infestations among Vail’s lodgepole pine forests started in 1996. Increases in MPB infestation were also detected in the forest around the Steamboat Springs area. The management of these outbreaks highlighted the importance of early communication and better understanding of science-based management methods to implement suppression and restoration practices within the wildland-urban interface. Sensitive to community concerns, while recognizing the urgent need to address the growing MPB problem, the USDA Forest Service:

- initiated a cooperative effort to address landowner and public concerns with the Colorado State Forest Service, the Town of Vail, and the ski area management company, Vail Associates; and
- devised and implemented a comprehensive plan to address the MPB problem.

Since 1997, the USDA Forest Service has provided technical assistance through the Colorado State Forest Service. This assistance has helped implement prevention and suppression programmes on private property, within the White River National Forest, and on property owned by the Town of Vail. The USDA Forest Service has also conducted programmes to peel and remove bark from beetle-infested trees in isolated locations, conducted field trials to identify and deploy pheromones effective against MPB, and applied insecticides to select individual trees. In April 2002, the USDA Forest Service published a “*Western bark beetle report: a plan to protect and restore Western forests*”, which addresses the prevention, suppression and restoration needs related to bark beetle outbreaks.

The USDA Forest Service is an active member of the Bark Beetle Information Taskforce that helps residents of Routt County and surrounding areas understand the potential effects of bark beetles on national forests and state and private lands. The taskforce was formed in 1999 to provide the public with information about bark beetles and potential tree mortality so that they can make informed decisions about protecting their private property and provide meaningful input on proposed actions on public lands.

Risk map

A risk map for insect and disease potential within the United States of America is presented in Figure 2. It depicts where USDA Forest Service scientists predict mortality will occur over the next 15 years. Areas in dark gray will experience at least 25 percent mortality over and above normal levels (under 1 percent per year) due to the actions of insects and pathogens. It is a coarse-filtered map and, with other data, is used to plan where treatments will take place. Based upon our definition of risk, it depicts about 70 million acres (28 million hectares) at risk out of a total of 749 million acres (303 million hectares) of forest land in the United States of America. Four pests are responsible for 66 percent of the risk acres: gypsy moth in the East, southern pine beetle in the South, root disease in the Interior West and bark beetles in the West.

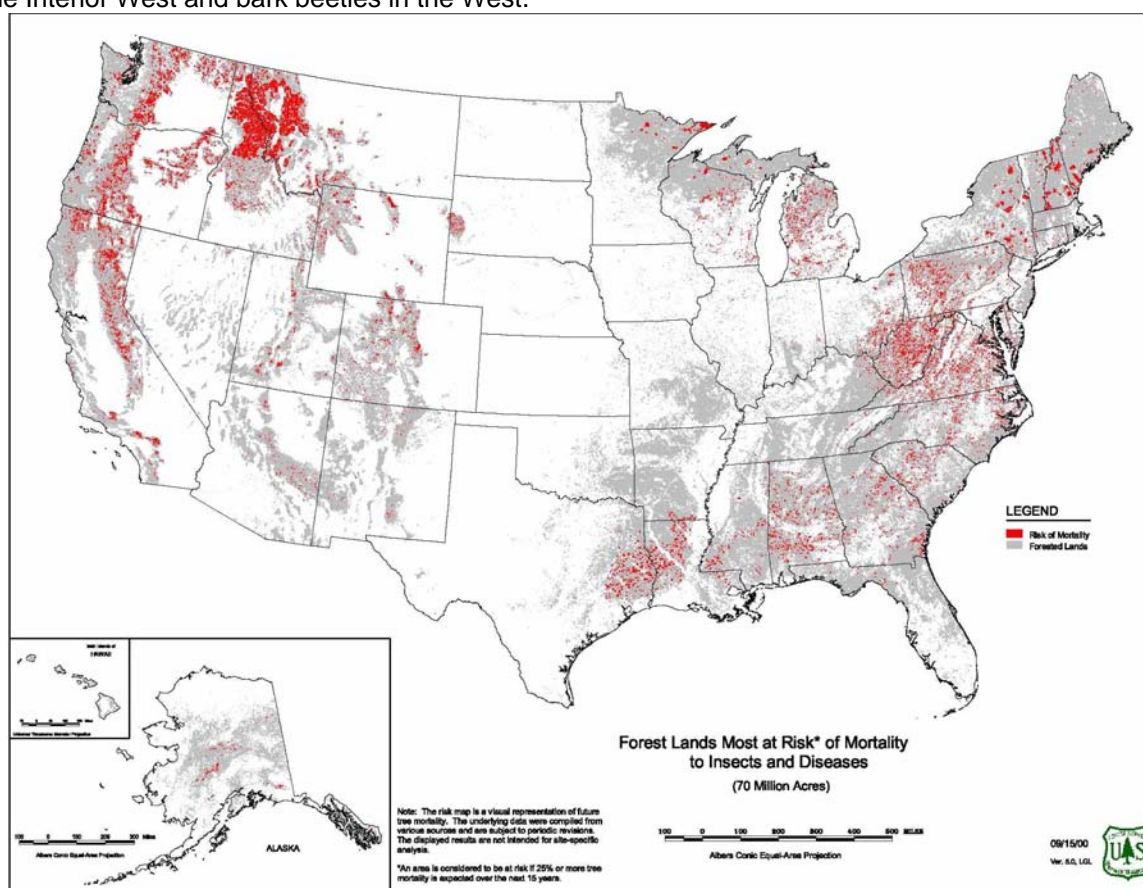


Figure 2: Risk map

Forest Service budget for 2004

The budget for combating invasive species is presented in Table 1. The figures are in thousands of dollars and include both native and non-native invasive species.

Table 1: USDA Forest Service 2004 budget for combating invasive species

Forest Service programmes	2001 Actual	2002 Current Estimate	FY2003 President's Budget	FY2004 President's Budget
Forest and rangeland research	13 183	10 034	7 940	14 540
International programmes	575	575	575	575
State and private forestry				
▪ Forest health	20600	40 121	45 000	59 152
▪ Pest mgmt. emergency	12 472	0	0	0
▪ Emerging pest and pathogen fund	0	0	11 968	1
Total Forest Service	54 830	61 130	81 683	95 535

Country report on the forestry invasive species situation in Vanuatu

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Introduction

Invasive plant and animal species are a global concern because of their ability to interrupt biological and ecological balances and cause havoc to receiving environments. Despite the relatively long history of introduction of exotic species into the Pacific Islands, it was not until recently that efforts have been made to address them. This is true for Vanuatu, particularly with regard to invasive species that impact on forests.

This report presents the forestry invasive species situation in Vanuatu. The report begins with a general overview of forest types in the country. This is followed by a list and description of the most significant forest invasive species. Following this, mention is made of the importance and relevance accorded to forest invasive species issues in Vanuatu. The final section discusses efforts to manage and control invasive species, highlighting the key institutions or bodies involved – and the laws, policies and mechanisms employed – in addressing the threat posed by these species. No attempt is made to quantify the costs involved in management and control of these species, because of the lack of information on costs. The report concludes that increased efforts need to be made to strengthen the management and control measures required. Emphasis should be on forging an integrated approach, one also backed with much-needed external assistance.

Forest Types

Data from a forest inventory conducted from 1990 to 1993, show that around 70 percent of Vanuatu is covered by woody vegetation, half of which is closed forests with the remainder being discontinuous shrubs, secondary forest and thickets of low trees. Vanuatu has in excess of thirty forest types. These can be put into three major groups in terms of land area occupied:

- thickets – occupying more than 433 000 hectares (35 percent) of Vanuatu's land area;
- mid-height forests totalling of 205 307 hectares (16 percent); and
- low forest covering 234 089 hectares (19 percent).

The remaining land area is mostly man-made vegetation or bare ground (more than 20 percent), grassland and scrub.

Commercially exploitable forest is estimated to be about 35 percent of forest cover, and 10 percent of the total land area is covered by primary forests. Major areas of native forests occur on the larger islands of Santo, Malekula, Erromango and Efate, with smaller areas on other islands. There is immense pressure on some timber species on the larger islands, where harvesting is concentrated. In 1998, for instance, 92 percent of logs harvested were of just two species, *Endospermum medullosum* (whitewood or basswood), and *Antiaris toxicaria* (known in Vanuatu, as milk tree). Many landowners are not keen on reforestation or afforestation and have used their logged forest lands for alternative activities like commercial agriculture. Natural regeneration is not yet a priority.

The plantation forest estate is small, with currently some 1 000 hectares planted. As part of its national forest policy (NFP) the Department of Forests (DoF) is targeting the establishment of 20 000 hectares of planted trees in the next 20 years. Many smallholders – and a few foreign investors – are actively engaged in tree planting. Negotiations are continuing with several companies, to encourage investment in commercial timber plantations. Discussions have also been held lately, about the possibility of engaging in wood-energy plantations. Among the trees encouraged for planting by the DoF are *Endospermum medullosum* (whitewood or basswood), *Pinus caribaea* (pine), *Agathis macrophylla* (kauri) and *Santalum austro-caledonicum* (sandalwood). Fruit/timber trees such as *Terminalia catappa* (tavoia or Indian almond) and several others are encouraged, to increase economic and other gains from forest resources. These local supply plantations are located throughout Vanuatu and range in age from 12 to 25 years.

The forests of Vanuatu are less complex, in terms of biodiversity, compared with forests in larger countries. Human activities are already rapidly diminishing and altering the forest cover and biodiversity, so that the threat posed by invasive species aggravates an already very worrying situation. It is difficult to quantify the invasive-induced threat confronting Vanuatu, whether it is to forests alone or all the country's ecosystems.

For forests and other vegetation in Vanuatu, the challenge brought about by invasive species is real and immense. The DoF, other government agencies, and regional and international entities are mobilizing resources in efforts to make sustainable management and conservation of forests a reality. However, invasive species add dimensions to the challenges of sustainable forestry. Aside from traditional forest management concerns, such as declining forest cover and imbalance between utilization and reforestation, alien species are increasingly becoming a concern, posing problems that require additional resources and even new strategies to address. Furthermore, given that some 28 percent of Vanuatu is already under man-made vegetation or bare ground, grassland and shrubs, the chances for the spread of invasive plant species into these vegetation types is greatly enhanced. This is because many invasive species tend to thrive in disturbed forests. If thickets, which already occupy more than 35 percent of land area, are also considered as prone to domination by invasive plants like *Miremia peltata* (big lif rop), then invasive species are indeed worthy of serious attention nationally.

Significant forest invasive species

Invasive species that impact on the forests and related biodiversity of Vanuatu are numerous. A number of points need to be noted prior to enumerating and describing the impacts and significance of these species. First, in compiling this report, it was not possible to establish if any of the fungi and diseases that threaten sustainable forestry and biodiversity in Vanuatu are alien or indigenous. Second, it is difficult to list these species in any priority because of the variations in their impacts and the limited understanding of the extent of their impacts on forests. Third, some invasive species are yet to register observable impacts on the forests, and their distribution is yet to be ascertained.

Invasive plants

Of all invasive plants in Vanuatu, perhaps the most widely cited pest is *Cordia alliodora* (Ecuador laurel or salmwood). Introduced as a forestry tree to Vanuatu in the 1970s, this species has now become dominant and is considered a serious pest in locations where it was planted. Planting trials were initiated on the islands of Santo, Vanua Lava, Mota Lava, Ureparapara, Malekula, Ambae, Maewo, Pentecost, Efate, Epi and Eromango. These are the major islands of Vanuatu.

The introduction of this Central American tree is a classic example of an aid programme gone wrong, especially now that there is no lucrative market to sell the 800 hectares of stock planted. *Cordia alliodora* was introduced with the best intentions, but failed to live up to expectations for various reasons, probably linked to climatic differences between Central America and Vanuatu. It is becoming a nuisance as it slowly penetrates natural forests. It is a species that is multiplying at a faster rate than it is being harvested. Communities on a number of islands, particularly, Eromango and Maewo, have made formal complaints. *Cordia alliodora* is widely distributed meaning that if unchecked it could trigger an immense biodiversity problem.

Another invasive plant species that is common, particularly in the drier parts of certain islands, is *Leucaena leucocephala* (kasis). Also known as the "conflict tree", this species was widely promoted as, among other things, a leguminous (nitrogen fixating) tree, cattle feed and fuel-wood source. *Leucaena leucocephala* can form dense monospecific thickets and is very difficult to eradicate once established, rendering extensive areas unusable and inaccessible. This plant is very competitive, has a high rate of regeneration, and is threatening native plants in some areas.

Merremia peltata (big lif rop) is a vigorous creeping vine that may have been introduced to the islands during World War II, by the American army, for camouflage purposes. It is a real threat to forests because it strangles vegetation. *Merremia peltata* kills forests on sites disturbed by man, and where the canopy is naturally opened as a result of factors like dying trees and the impacts of cyclones. It is one of the most important weeds of plantation forestry and is also found in natural and semi-natural environments. This vine is one of two major species threatening natural regeneration in logged or disturbed areas. It prefers disturbed habitats and openings, including forest gaps and margins.

Probably the second most invasive creeping vine that threatens forests in Vanuatu is *Mikania micrantha* (also called mile-a-minute weed or American rope, and sometimes confused with *Polygonum perfoliatum*). This is a perennial, twining plant that is rampant and fast spreading. It grows best where fertility, organic matter, soil moisture, and humidity are all high. It damages or kills other plants by cutting out light and smothering them. The plant is believed to have been intentionally introduced by the American army during World War II. Like *Merremia peltata* it grows very fast in disturbed forests and natural openings. Forest regeneration is difficult where this plant is established.

A number of other invasive plants are worthy of mentioning here, even though their impacts are less apparent in Vanuatu. These include *Acacia farnesiana* and *Coccinia grandis* (ivy or scarlet gourd), which is a smothering vine that climbs over trees and forms a dense cover that completely shades and destroys the forest underneath. Another is *Mimosa invisa*, a giant plant covered with thorns. This is becoming a problem in Vanuatu, particularly in disturbed areas such as pasture. It moves into nearby forests, where it interferes with regeneration at the forest edges and forms dense tangles that are difficult to walk through.

Also noteworthy is *Clidemia hirta* (Koster's curse), which is a very serious weed of the forest understory in Vanuatu. Another nuisance species is *Lantana camara*, which is particularly common in pasture areas, but nevertheless interferes with the growth of more desirable trees. One of the activities that aids in the spread of *Lantana camara* is the movement of logging equipment in the forest. *Lantana* is a pioneer weed that grows in newly disturbed areas. Another plant with similar impacts is *Psidium guajava* (guava or kuava). Mixed with species such as *Mimosa invisa* this plant is a complete barrier to the natural expansion of forests. Birds and other animals disperse seeds of *Psidium guajava*. Its growth is vigorous, particularly in the low plains used for grazing or in other disturbed areas.

Invasive animals and insects

Invasive animal species are also upsetting the natural balance in the forests. Many have impacts that are yet to be fully understood, as far as forests or trees are concerned, although it is already clear that some are causing immense destruction to forest biodiversity. One major pest is *Acridotheres tristis* (Indian mynah). This bird may have been introduced in the 1970s. It is fast becoming a dominant species on many islands. Commonly seen on cattle ranches, the bird is now an agricultural pest and reduces biodiversity by competing for nesting hollows, destroying chicks and eggs, and evicting small mammals. A study of its impacts on the forest in Vanuatu could yield very interesting and discouraging results. By displacing and preying on other birds and species, *Acridotheres tristis* is bound to have negative impacts on the forest and biodiversity.

Another invasive pest is *Achatina fulica* (the giant African snail). This is a major agricultural and garden pest, but it also feeds on trees and leaves. It has been observed to feed on the bark of certain trees like *Dendrocnide latifolia* and tissues or shoots of young seedlings. It is also a vector (as are many snail species) of several human pathogens and parasites. It lays hundreds of eggs and multiplies at an alarming rate. In Vanuatu, droughts and prolonged dry conditions have killed large numbers of snails and slowed the extent of damage. *Achatina fulica* is found on a number of major islands.

In dealing with snails, Vanuatu has also become a victim of biological control gone wrong, with the introduction of *Euglandina rosea* (rosy wolf snail or cannibal snail). This species was introduced as a biological control agent for *Achatina fulica*. It has been discovered, however, that although *Euglandina rosea* has indeed attacked the *Achatina fulica*, there is worrying evidence that this cannibal snail has caused the extinction of numerous native snails in other countries. The cannibal snail prefers preying on smaller snails, especially if the shell can be swallowed whole, suggesting that a component of its feeding behaviour is dictated by calcium demands. This means Vanuatu risks losing most, if not all, of its native snail species. The impacts of this alien species on the vegetation of Vanuatu perhaps begins with the destabilizing of snail and other species populations that are important to natural systems on which healthy forests depend. Combined with *Achatina fulica*, invasive snails are serious forest pests in Vanuatu.

Another species of concern in Vanuatu is *Wasmannia auropunctata* (also known as cocoa tree-ant). Considered to be perhaps the greatest ant species threat in the Pacific, the little fire ant is blamed for reducing species diversity, reducing overall abundance of flying and tree-dwelling insects, and eliminating arachnid populations. Quarantine authorities have indicated that this species is currently

confined to an island in the Banks group. Though its impacts on forests are yet to be fully understood, it is likely that *Wasmannia auropunctata* will alter many of the natural process that determine the kind of forest and related biodiversity of the islands. Given that invasive ants are capable of killing crabs, Vanuatu can expect *Wasmannia auropunctata* to be a major threat to its many crab species, including the famous *Birgus latro* (coconut crab), which is already heavily exploited by humans.

Given the spread of ants globally, Vanuatu also needs to be aware of the possible introduction of other ants such as *Anoplolepis gracilipes* (yellow crazy ant). Apart from the potential to devastate human surroundings this species is also known to decimate endemic species, rapidly degrade native communities, and alter ecosystem processes. It interferes with and preys on species of reptiles, birds and mammals both on the forest floor and canopy. This species has caused extensive canopy dieback on Christmas Island and is capable of changing the structure of forests as a result of its impacts on native species⁵. The impact of sooty mould, which kills trees and shrubs, is increased where *Anoplolepis gracilipes* is established. Some claim this species is already present in Vanuatu, but local authorities refute this claim. *Solenopsis invicta* (red imported fire ant) is also a potential threat.

Importance and relevance of invasive species

The threats and nuisance posed by invasive species in Vanuatu have been a concern for a good number of years, perhaps beginning in the late-1970s and early-1980s. But, some invasive species were introduced to the islands much earlier. This is particularly true for a number of plant species like *Merremia peltata* and *Mikania micrantha* that now threaten forests and make sustainable forestry activities increasingly difficult. Despite the realization of the growing problem caused by invasive species, until recently, little was done to manage or control the spread of these species. It would also be correct to say that very little knowledge existed on these invasive species and the dangers they pose.

It was only during the latter part of the 1990s that invasive species were given increased attention. Though these are now gaining increasing importance in the country, one could only wish that efforts to address them had come earlier, and been backed with more technical and financial resources. Vanuatu, like many other island countries, now accords alien invasive species much greater relevance, but this relevance is very much belated. Through a number of studies, the National Biodiversity Strategy And Action Plan (NBSAP) project implemented by the Environment Unit has brought the issue of invasive species to the attention of a wider audience. The studies, among other things, noted the impacts invasive species are having on the environment at large. The results of the assessment were documented in the country's National Biodiversity Conservation Strategy for further action (see below).

That more is being understood, said and done about invasive species in Vanuatu is not disputed. However, a number of other issues provide essential background to building on appreciation of the importance and relevance accorded to matters of invasive species. First, invasive species did not take priority (to a large extent this is still a problem) in government agencies until the late-1990s and early-2000. Second, because of the tradition of the sectoral approach employed by government agencies in the management of resources, the invasive problem, which cuts across sectors, has been more of a concern to the Vanuatu Quarantine and Inspection Service (VQIS) than others, although the work of the VQIS does not specifically address forest invasive species. Third, Vanuatu has limited resources and capacity in terms of expertise and finances, meaning the importance of invasive issues nationally is to a large extent driven by essential input from external entities. Fourth, the tendency in resource management has, for a long time, focused on the commercial value of resources. Threats to these resources, particularly as posed by invasive species and diseases, are seldom identified or addressed. This is especially true in forestry. Fifth, the understanding of invasive species by decision-makers is minimal and corresponds with seemingly limited political will given to the subject. Finally, island communities have little knowledge about invasive species. Put simply, for many years the majority of people did not know what an "invasive species" is. Many still think they are native and cause no detrimental impacts. More recently, many more communities are learning about these unwanted species.

⁵ See Earth crash. Earth spirit. Healing ourselves and dying planet. www.eces.org/index.php/368?page_nbr=2 - 11k

Management and control measures

Plant Protection Act

Efforts are being made to manage and control forest invasive species. It is appropriate to note two phases or levels to this management and control regime. The first are measures implemented by the VQIS through the Plant Protection Act of 1997. This legislation provides for the exclusion and effective management of plant pests and facilitates exports of plant produce. The Act provides mechanisms to deter any entry of unwanted organisms (including invasive species) that may affect the environment and natural resources, agriculture, humans, control of pests and diseases; and for the eradication of exotic pests and diseases.

Phytosanitary measures

Imports: The VQIS only issues import permits for approved products from approved countries, after a risk analysis has been carried out on the product. This includes the pest list associated with the product, effects on the environment, effects on agriculture, and consulting stakeholders. Stakeholders usually include relevant government departments and industries. All products are approved on a no risk or minimum risk basis. Strict guidelines controlling imports of plants or plant products are currently in place because some plants that have been approved for import by relevant departments have become invasive.

Import certification: all approved imports of plants and plant products are documented with specific requirements for each country. The specific requirements are issued with the import permit when an application for a permit to import is lodged.

Border control: quarantine posts have been established on the main islands of Vanuatu to control the entry of unwanted pests and diseases as well as imports of plants and plant products. Controls on existing entry pathways have been quite effective.

Quarantine inspections: all approved imports of plant and plant products are inspected at the border. Goods that meet import requirements are released, while those that do not meet standards are either destroyed or reshipped. All illegal imports are dealt with under the Act and offenders are prosecuted.

Plant protection services

Surveying Vanuatu

Like most least-developed countries, Vanuatu has very limited plant protection resources. The isolated nature of the islands allows for very little surveying and monitoring. Most of the monitoring systems in place are for specifically targeted pests and are implemented by the Plant Protection Service of the VQIS. Regional institutions conduct the survey and documentation of general pests and plant diseases, with assistance from local counterparts. These are not carried out on a regular basis.

Monitoring

Monitoring of pests and diseases is carried out by the Plant Protection Service, with the assistance of rural communities. Monitoring of pests and diseases in the islands is expensive and, to mitigate costs, the VQIS has set up an awareness campaign under which targeted pests are documented and this information is disseminated to rural communities. Rural communities are advised to report any unusual plants, pest, and diseases to the local authorities or the quarantine office.

Control measures

Vanuatu has undertaken several control operations for specific pests and diseases, but with very little success. The control measures that Vanuatu has used include: mechanical control, chemical control and the introduction of bio-control agents. A good example of a biological control agent introduced to control *Achatina fulica* is the predator snail *Euglandina rosea*. The predator snail has become invasive and is attacking native snails. Mechanical control is usually done by farmers to control weeds. Chemical control was employed in an attempt to control *Wasmannia auropunctata*, but it has proven very costly. All flights and ships from Banks and Torres are sprayed and checked to prevent the further spread of *Wasmannia auropunctata*. Awareness-raising is also a major activity.

Eradication measures

There are currently no eradication programmes for established pests and diseases. Vanuatu needs assistance for the implementation of such programmes. This also applies to invasive species of plants that are well established in Vanuatu.

Emergency diseases and pest response

Vanuatu is very vulnerable to the effects of an introduction of diseases, pests, or invasive plants and animals. An emergency disease and pest response system is in place to complement and be part of a total detection/protection system. This system starts at the border, through routine surveillance, and carries into response activation to control and/or eradicate a disease or pest before it becomes established.

Forestry and environmental management and conservation acts

The second level of the management regime can be categorized as that executed by the DoF and the Environment Unit. The Forestry Act of 2001 makes provision for the protection, development and sustainable management of forests and the regulation of the forestry industry in Vanuatu. It notes as one of the principles of forestry administration the protection of the diversity of forests and forest ecosystems in Vanuatu. The Act, however, says nothing about the control or management of forest invasive species. Part VI of the Act talks about the protection of the environment, but focuses on conservation *per se*. One of the cited dangers to forests is fire. Alien species are not acknowledged. Furthermore, although the Act calls for rehabilitation of forests, this is not because invasive species are more likely to occur in logged areas hence interfering with forest regeneration. The only control measure recommended by the DoF for the management of *Cordia alliodora* is to use the plant as fuel-wood. Even at the level of the DoF, a sense of urgency in relation to invasive species has developed only recently. The Department has still to give invasive species the policy priority, strategies and resources required.

The Environmental Management and Conservation Act of 2002 provides for the conservation, sustainable development and management of the environment of Vanuatu. The Act defines foreign organisms as all stages of any life form that are not endemic to Vanuatu. However, this is almost all that the law says with regard to invasive species. The Act deals mostly with biodiversity in general and has little focus on invasive species.

Other measures and initiatives

Forest and environmental instruments

Vanuatu is party to a number of international and regional environment-related instruments and initiatives. There are also a number of other national instruments. These need not all be enumerated here. Vanuatu signed the Convention on Biological Diversity (CBD) in 1993 and therefore agrees to “try to prevent the introduction of, control or eradicate, those alien species that threaten ecosystems, habitats or species”⁶ and prepare a *National Biodiversity Strategy And Action Plan* (NBSAP) as noted above. An Act to ratify the CBD was also passed to effect the implementation of this convention. Nevertheless, there is a need for additional instruments to ensure that Vanuatu fully meets its obligations under the treaty.

The country’s constitution states that every person has among other fundamental duties “to protect Vanuatu and to safeguard the national wealth, resources and environment in the interests of the present and future generation”⁷. A national conservation strategy was adopted in 1994, but this document says nothing about invasive species. A national forest policy (nfp) adopted in 1997 does not address the management of invasive species either. It acknowledges that vines compete with natural regeneration, but fails to note that two of the greatest vine threats are invasive. The code of logging practice (COLP) does not say anything about invasive species, but could be helpful in the control of invasive species because of its emphasis on limiting forest opening. The only national instrument to say anything much on unwanted species is the *Prevention of the Spread of Noxious Weeds Regulation* of 1966. This is, however, outdated and does not prevent the transmission of such weeds on trucks, heavy equipment and by other means. Another relevant ordinance is the *Wild Bird*

⁶ Convention on Biological Diversity

⁷ Constitution of the Republic of Vanuatu

Protection Regulation of 1962. This is unfortunately also outdated and not effectively applied. It fails to address the current need to protect wildlife, endangered species and habitats.

Vanuatu's NBSAP is now complete and is, in many ways, the first policy and strategy document that gives high priority to the management of introduced species. The document notes the need to develop an administrative system to prevent adverse impacts of organisms that are potentially invasive, and also called for communities and implementing organizations/stakeholders to find opportunities to manage and eradicate species that are already threatening Vanuatu's biodiversity (Environment Unit, 1999: 21-22)⁸. A number of priorities, responsible agencies and required activities are noted. The provisions in the document are, however, inadequate, as far as the involvement and role of the DoF is concerned. In other words, the NBSAP cannot be translated into detailed activities to be implemented by the DoF. Given the immense need for knowledge about an enormous diversity of species that impact on the forests, it might perhaps be more appropriate to have policies and other instruments on the management and control of forest invasive species.

In August 2002, the first ever consultation involving a number of key groups in relation to invasive species was organized at the national level. The government institutions and stakeholders involved included the Environment Unit, government ministries including the departments of Forestry, Fisheries, Agriculture, and Attorney General, the VQIS, and a farm association. This is an integrated approach that partially stems from NBSAP research findings on invasive species. This group comprises the key institutions currently involved with invasive species management. The meeting noted a need to review existing policies/laws to identify their consistency or otherwise with respect to invasive species, so that the management and control of these species is provided for. The review should enable stakeholders to decide whether to work under existing laws or if there is a need to have a new law on invasive species. A policy on invasive species that identifies the roles of every institution or stakeholder is seen as essential. A review of these instruments is now underway. Vanuatu also benefited from a workshop on invasive species conducted by the South Pacific Regional Environment Programme (SPREP) and its partners. Given these efforts, more people are becoming aware of invasive species and their impacts.

Conclusion

The forests of Vanuatu – and the biodiversity of which they are a part – are becoming increasingly invaded and threatened by alien species. These species include both plants and animals. This scenario calls for concerted new efforts on the part of the DoF and stakeholders. Vanuatu has a number of instruments for environmental management. These are nevertheless fragmented and underdeveloped, while some are outdated – and more often than not, legislation is neither applied nor enforced (Environment Unit, 1998: 9)⁹. The VQIS already has an elaborate pest and disease management and control system in place. The Forestry Act and NFP are generally devoid of provisions on invasive species. Consequently, the DoF has done little to address the crisis brought about as a result of the introduction of invasive species.

A common weakness in existing instruments is their lack of emphasis on new environmental issues, particularly the challenge posed by invasive species. The review of instruments that have bearing on invasive species is a step in the right direction. The DoF may have to develop its own instruments and be a leading implementing agency in addressing the invasive problem in forests.

It is recommended that – given the crosscutting and multi-sectoral nature of the problem and coupled with limited resources, expertise and capacity – an integrated approach with the assistance of regional and international bodies and governments would be the best option. Work begun by the relevant government agencies and stakeholders must be continued and backed by political will. The commitment of donors in terms of expertise and finance is a necessity and therefore called for. This is not only to aid in the development of the required management and control instruments, but also in actual ground implementation. The need for research into invasive species to scientifically describe the severity of their impacts and future threat to the forests is an activity to be considered seriously. The inclusion of forest invasive species in a revised NFP or the development of a policy entirely on invasive species has to be considered. Forest health surveillance should become an integral aspect of a new NFP because of the common problems addressed. There may be a need for an instrument that governs the introduction of plants and animals for biological control purposes. Government, through its agencies and stakeholders will, among other things, need to increasingly raise awareness about invasive species and work with communities. This is to develop a long-term, cheaper and sustainable approach to effectively addressing the impacts of invasive species on the forest resources of Vanuatu.

⁸ Environment Unit, 1999. National Biodiversity Conservation Strategy. Environment Unit, Port Vila.

⁹ Environment Unit, 1998. Vanuatu National Report to the Conference of the Parties, Environment Unit, Port Vila.

Forest invasive species and their impacts on afforestation in Viet Nam

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Introduction

Over the past few decades, there has been a steady expansion of forest plantations across the country. According to data collected during 1999 by the Ministry of Agriculture and Rural Development, it is estimated that 1 471 394 hectares of forest plantations have been established in Viet Nam, of which there are about 288 073 hectares of *Acacia*, 348 000 hectares of *Eucalyptus*, 218 056 hectares of pines, 100 000 hectares of *Melaleuca* and about 500 000 hectares of other exotic and native species plantations. Products from plantations play a very important role in supplying raw materials for industry and are gradually replacing forest products harvested from natural forests. Plantations are now regarded as a means to meet wood requirements without putting excess pressure on natural forests.

However, there is a fear that a catastrophic outbreak of pests and diseases may occur suddenly and that weed species may invade plantations during the rainy season, affecting tree growth and the quality of plantations. Outbreaks of diseases and insect pests occur in as much as 20 000 hectares of plantations annually.

Surveys of diseases, insect pests and weeds and their importance to the trees have been implemented several times, on different scales, by various institutions including: the Forest Science Institute of Viet Nam, the Forest Science Sub-Institute of Viet Nam, the Forest Inventory and Planning Institute and the Forest Protection Department. Table 1 lists the most important plantations species in Viet Nam.

Table 1: Tree species investigated.

Species	Abbreviation
<i>Acacia auriculiformis</i>	Aa
<i>Acacia mangium</i>	Am
<i>Acacia hybrid</i>	Ah
<i>Eucalyptus camaldulensis</i>	Ec
<i>Eucalyptus spp.</i>	Epp
<i>Eucalyptus tereticornis</i>	Et
<i>Eucalyptus urophylla</i>	Eu
<i>Casuarina equisetifolia</i>	Cas
<i>Cinnamomum cassia</i>	Cin
<i>Dendrocalamus membranaceus</i>	Den
<i>Manglietia glauca</i>	Mg
<i>Melaleuca spp.</i>	Mela
<i>Pinus merkusii</i>	Pme
<i>Pinus kesiya</i>	Pk
<i>Pinus caribaea</i>	Pca
<i>Pinus massoniana</i>	Pma
<i>Styrax tonkinensis</i>	St
<i>Tectona grandis</i>	Tec

Status of forest invasive species in Viet Nam

Forest invasive insect pests

The most important insect pest species are listed in alphabetically in Table 2, with an indication of the species that are affected by these insects. There are 19 main invasive insect species associated with large-scale monocultural forest plantations in Viet Nam. The most important is a species of leaf feeding caterpillar *Dendrolimus punstatus*, which invades plantations of *Pinus merkusii* and *P. massoniana*. Six species of insects, such as *Anomis fulvida*, *Pteroma plagiophleps* and *Speiredonia retorta* are considered to be important and widespread invasive species and their outbreaks occur widely in plantations. The other species are considered important invasive species and outbreaks have occurred locally in plantations.

Table 2: The major forest invasive insects

Species	Family	Principal trees attacked
<i>Anomis fulvida</i> (Guennee)	Noctuidae	Am
<i>Arbela baibarana</i> (Mats)	Cossidae	Cin
<i>Aristobia approximator</i> (Thoms.)	Cerambycidae	Ec, Et
<i>Culcula paterinaria</i> (Brem. Et Grey)	Geometridae	Cin
<i>Cyrtotrachelus longimanus</i> (Fabr.)	Curcunionidae	Den
<i>Dendrolimus punctatus</i> (Walker)	Lasiocampidae	Pme, Pma
<i>Dioryctria abietella</i> (Denis Schif)	Pyraliidae	Pme, Pma
<i>Dioryctria sylvestrella</i>	Pyralidae	Pca
<i>Erthesina fullo</i> (Thunberg)	Pentatomidae	Cin
<i>Eutectona machaeralis</i> (Walker)	Pyralidae	Tec
<i>Fentonia</i> sp.	Notodontidae	St
<i>Macrotermes</i> sp.	Termitidae	Pk, Pme, Pma, Epp, Am, Aa, Ah
<i>Microtermes</i> sp.	Termitidae	Am, Aa, Ah, Epp
<i>Nesodiprion biremis</i> (Konow)	Diprionidae	Pme, Pma
<i>Odontotermes</i> sp.	Termitidae	Am, Ah, Aa, Epp, Mg, Cin, Tec
<i>Pteroma plagiophleps</i> (Hampson.)	Psychidae	Am
<i>Shizocera</i> sp.	Agridae	Mg
<i>Speiredonia retorta</i> (L.)	Noctuidae	Am
<i>Zeuzera coffeae</i> (Nieth)	Cossidae	Cas, Mela

The main pathogens attacking forest plantations

The major pathogens affecting plantations in Viet Nam are listed alphabetically in Table 3. Nine main species have infected large-scale monocultural plantations in Viet Nam. Three of these species *Cryptosporiopsis eucalypti*, *Cylindrocladium quinqueseptatum* and *Corticium salmonicolor* are the most important exotic species affecting *Eucalyptus* and *Acacia* plantations. The other species are considered to be important species to both exotic and indigenous species plantations.

Table 3: Major pathogens to forest plantations

Species	Family	Principal trees attacked
<i>Botryosphaeria dothidae</i>	Botryosphaeriaceae	Ah, Ec
<i>Corticium salmonicolor</i> B. Broome	Corticaceae	Am, Ah, Ec, Eh
<i>Cronartium</i> sp.	Melampsoraceae	Pk
<i>Cryptosporiopsis eucalypti</i>	Melanconiaceae	Epp
<i>Cylindrocladium quinqueseptatum</i>	Moniliaceae	Epp
<i>Ganoderma</i> spp.	Ganodermataceae	Am, Aa, Ah
<i>Phaeophleospora destructans</i>	Dematiaceae	Eu, FA
<i>Ralstonia solanacearum</i> Smit	Pseudomonaceae	Eu, Cas
Unidentified		Cin

Invasive weeds in forest plantations

The main invasive weeds in Viet Nam are listed in Table 4. There were six main weeds, of which two species, blady grass and feather pennisetum, are very widespread and important in *Acacia* and *Eucalyptus* plantations.

Table 4: Major weeds to forest plantations

Species	Family	Principal trees attacked
<i>Eleocharis acicularis</i> (L.) R. & Sch.	Cyperaceae	Mela
<i>Eupatorium odoratum</i> Linn.	Asteraceae	Am, Aa, Ah, Epp, Pme, Pma, Pk, Pca, Mg, St
<i>Imperata cylindrica</i> (L.) P. Beauv.	Poaceae	Am, Aa, Ah, Epp, Pme, Pma, Pk, Pca, Mg, St
<i>Mimosa pudica</i> Linn.	Mimosaceae	Am, Aa, Ah, Epp, Pme, Pma, Pk, Pca, Mg, St
<i>Mimosa pigra</i> L.	Fabaceae	Mela
<i>Pennisetum polystachion</i> (L.) Schult	Poaceae	Am, Aa, Ah, Epp

Impacts of invasive species to plantations

Acacia plantations

Acacia spp. plantations have been planted throughout the country for the production of pulp for paper and medium density fiberboard. In general, *Acacia* plantations are remarkably free of insect pests. Insects commonly found feeding on the foliage include several species of bagworms, curculionid beetles and some hairy caterpillars. However, outbreaks of insect pests in *Acacia mangium* plantations occasionally occur on a large-scale. Bagworm (*Pteroma plagiophleps*) (Lepidoptera, Psychidae) has caused damage to *Acacia mangium* in Hoa Binh and Ha Tay provinces (northern Viet Nam) in 2000 and 2001, respectively. Other leaf-eating insects, *Anomis fulvida* (Lepidoptera, Noctuidae) and *Speiredonia retorta* (Lepidoptera, Noctuidae) have infested thousands of hectares of 2-10 year-old *Acacia mangium* plantations in Tuyen Quang, Phu Tho, and Thai Nguyen provinces in 2001 and in 2002. In addition, *Odontotermes* sp., *Microtermes* sp. and *Macrotermes* sp. (Isoptera, Termitidae) killed 10-50 percent of planted saplings aged less than one year in several locations of the central highlands and mountainous areas.

Measures for controlling insect pests attacking *Acacia* plantations have been implemented. Chemical compounds are the main means of controlling these insect pests. The chemical control measures have been partially successful, but are expensive to implement and have a considerable negative impact on the environment. There are currently no effective measures for controlling termites.

Diseases associated with *Acacia* plantations were investigated at a number of locations in Viet Nam. The most important disease is the pink disease caused by the fungal pathogen *Corticium salmonicolor* (Aphyllophorales, Corticiaceae). This disease occurs in locations with high rainfall, of more than 1 800 mm per year, which includes most of Viet Nam. It attacks plantations aged more than three years. Disease incidence is regarded as very high in southeast Viet Nam, ranging from 10-40 percent depending on species/provenance or clones.

Stem canker associated with *Acacia* hybrids has shown a tendency to develop into outbreaks in the central highlands (Kon Tum province). One thousand hectares of 2-3 year-old *Acacia* hybrid plantations were infected by *Botryosphaeria dothidae* (Dothideales, Botryosphaeriaceae), with disease incidence ranging from 10-30 percent.

Heart rot disease occurs in *Acacia* plantations in high rainfall areas, especially in the north and southeast of Viet Nam. Pathogens were identified to be *Ganoderma* spp. The disease incidence with advanced decay and hollows was 20-30 percent.

There are currently no measures for controlling these diseases. It seems to be impossible to spray chemical compounds because of the high costs involved and the potential for environmental pollution. Screening for provenances or clones showing disease resistance, from progeny trials, has been implemented for several years, however, the results from this work have yet to be published.

Weeds are considered to be very important invasive species in *Acacia* plantations aged less than two years. The dominant weeds are blady grass (*Imperata cylindrica*) and feather pennisetum (*Pennisetum polystachion*). These two species affected growth of plantations. Two other species *Mimosa pudica* and *Eupatorium odoratum* are distributed widely and considered to be important weed species.

Eucalyptus plantations

In Viet Nam, a few species of lepidopteran caterpillars have been found to feed on Eucalyptus leaves, although outbreaks are rare. The cerambycid borer (*Aristobia approximata*) (Coleoptera, Cerambycidae) caused severe damage to thousands of hectares of *Eucalyptus camaldulensis* and *Eucalyptus tereticornis* plantations in the Mekong delta. The most common insect pests are subterranean termites including *Odontotermes* sp., *Microtermes* sp. and *Macrotermes* sp. (Isoptera, Termitidae) that attack the roots of young transplants and kill 10-60 percent of saplings aged less than one year. Measures for controlling insect pests attacking *Eucalyptus* plantations have not yet been implemented. There are currently no effective measures for controlling termites.

Diseases associated with *Eucalyptus* plantations have been investigated throughout Viet Nam. The most important and widespread diseases have been leaf blight disease caused by the fungal pathogen *Cylindrocladium quinqueseptatum* and leaf spot disease caused by the fungal pathogen

Cryptosporiopsis eucalypti. Disease incidence for the first disease was regarded as very high in southeast and central Viet Nam, ranging from 10-90 percent depending on species/provenance or clones.

Leaf spot disease is caused by *Phaeophleospora destructans* and is associated with *E. urophylla* and some hybrid clones. It was first found in Viet Nam in 2001. The disease incidence is 10-60 percent in Phu Tho and Gia Lai provinces. Disease incidence of the bacterial wilt disease caused by *Ralstonia solanacearum* Smit, associated with *Eucalyptus urophylla* plantations is 10-30 percent in the northern provinces.

There are currently no measures for controlling these diseases. Research on provenances or clones showing disease resistance from progeny trials continues to be implemented. The results of this work have not yet been published.

The most important weeds in *Eucalyptus* plantations are *Imperata cylindrica* and *Pennisetum polystachion*. These two species affect the growth of the plantations. Two other species *Mimosa pudica* and *Eupatorium odoratum* are widely distributed and considered to be important species.

Pine plantations

Outbreaks of the caterpillar *Dendrolimus punctatus* (Lepidoptera, Lasiocampidae) have occurred frequently on a large scale in *Pinus merkusii* and *P. massoniana* plantations in the whole country. Sawfly *Nesodiprion biremis* (Lepidoptera, Diprionidae) has caused considerable damage to *Pinus kesyia* and *P. massoniana* in the central highlands of Viet Nam. These two species have severely affected resin productivity in Viet Nam. Other shoot borer pests *Dioryctria abietella* (Lepidoptera, Pyralidae) and *Dioryctria sylvestrella* (Lepidoptera, Pyralidae) attacked *Pinus merkusii*, *P. massoniana* and *P. caribaea* in some northern provinces. *Macrotermes* sp. attacks the roots of young transplants and killed 10-30 percent saplings aged less than one year in several mountainous areas.

Chemical measures have been implemented by growers to manage these pests. However, these control measures are costly and cause significant environmental pollution.

White blister rust *Cronatium* sp. is associated with *Pinus kesyia* in Lam Dong and Gia Lai provinces. Disease incidence is rather high in young plantations in some locations. Identification of species and the implementation of control measures are yet to be done.

Impacts of weeds on *Melaleuca leucadendra* and *M. cajuputi* plantations

Mimosa pigra is quickly becoming one of the most serious species threats to *Melaleuca* plantations in the freshwater wetland areas of the Tram Chim National Park and U Minh Thuong Nature Reserve. At present, the U Minh Thuong Nature Reserve and Tram Chim National Park in the Cuu Long (Mekong) river delta are endangered by *Mimosa*. *Mimosa* plants were first observed at Tram Chim in 1985. By 1999, some 150 hectares were infested. A distribution map drawn up by the HCM Natural Science College in June 2000 showed an infested area of 490 hectares. The map also predicted that a further 4 600 hectares, or 60 percent of the park's land area, is highly susceptible to *Mimosa* invasion. At present this species has also developed at other locations such as Tri An lake, Cat Tien Natural Park, and Hoa Binh lake.

A *Mimosa* control experiment showed that cutting stems, burning off, and a combination of the two, were ineffective measures to eradicate the plant from Tram Chim National Park. The experiment found that the plants resprouted quickly after cutting and that burning helped to trigger the spread and germination of *Mimosa* seeds. The most successful control method was cutting the *Mimosa* plants during the flood season. The Tram Chim wetlands are subject to between four and six months of flooding each year. The experiment cut the stems when the floodwater was about 30 cm above the soil surface. Four months after the treatment, when floodwater was still 60 to 80 cm above soil surface, none of the treated plants had resprouted and 75-90 percent of the roots had died.

Other plantations

Outbreaks of the leaf-feeding caterpillar, *Fentonia* sp. (Lepidoptera, Notodontidae), have occurred annually in *Styrax tonkinensis* plantations causing different levels of damage. In 2001, an outbreak of *Fentonia* sp. occurred, affecting about 2 100 hectares of 3-5 year old plantations. Chemical compounds were applied to control this insect. Outbreaks of sawfly (*Shizocera* sp.) (Hymenoptera, Agridae) have caused considerable damage to *Manglietia glauca* plantations in northern Viet Nam.

Eutectona machaeralis (Lepidoptera, Pyralidae) attacked *Tectona grandis* plantations in several provinces, and caused considerable damage. Some insect pests such as: *Culcula paterinaria* (Lepidoptera, Geometridae), *Arbela baibarana* (Lepidoptera, Cossidae) and *Erthesina fullo* (Hemiptera, Pentatomidae) are important species affecting *Cinnamomum cassia* plantations, in some provinces. *Cyrtotrachelus longimanus* Fabr. (Coleoptera, Curcunionidae) feeds on young bamboo shoots of *Dendrocalamus membranaceus* causing considerable damage in Thanh Hoa and Hoa Binh provinces.

Conclusions and discussions

At present, the Vietnamese Government is in the process of implementing a programme for the reforestation of 5 million hectares, by the year 2010. This means that the area of forest plantations will increase rapidly in Viet Nam. Research on planting species, natural enemies, insect pests, diseases and weeds in forest plantations and policy related to forest development and forest protection must be conducted.

Outbreaks of diseases and insect pests affect as much as 20 000 hectares of plantations annually. The narrow genetic base of introduced planting stock increases the risk of pest outbreaks. No systematic research on insect pests, diseases and other forest invasive species has been conducted. Plant quarantine and avoidance of natural enemies to planting trees have not been sufficiently investigated, resulting in high costs to combat the pests.

At present, chemical control methods are the most commonly applied management techniques. Other control methods are rarely applied. Screening for disease resistance or insect pest resistant tree varieties commenced several years ago, but there are currently no published results from this.

There is a need for capacity building in the area of invasive species through on the job training. Additional extension activities are required to promote the use of IPM among farmers in Viet Nam.

There is a direct need for basic information on important insect pests, pathogens, weeds etc. This should be obtained by means of an intensive research programme.

Appendix 1: Programme

SUNDAY 17 AUGUST			
9:00 – 9:30 a.m.	Opening Addresses.	Mr Zhu Lieke, Deputy Administrator, Chinese State Forestry Administration. Mr Kong Chui Zhu, Vice-Governor, Province of Yunnan. Mr Zhang Zhong Xin, President, Yunnan Branch of Chinese Academy of Sciences. Mr Patrick B. Durst, Senior Forestry Officer, Regional Office for Asia and the Pacific, Food and Agriculture Organization. Mr Jerome Beatty, Deputy Director, USDA Forest Service, Forest Health Protection. Mr Daniel Baskaran, Executive Secretary, Asia-Pacific Association of Forest Research Institutions (APAFRI).	Chaired by Mr Wei Diansheng
9:30 – 10:00 a.m.	Group Photo	Lobby	
10:20 – 11:05 a.m.	Global perspective on forest invasive species.	Ms Sally Campbell, Biologist Team Leader, USDA Forest Service, PNW Research Station.	Chaired by Mr Patrick Durst
11:05 – 11:50 a.m.	Forest invasive species and China.	Mr Wei Diansheng, Director-General, Department of Silviculture, State Forestry Administration.	
1:10 – 1:50 p.m.	Basic science and nature of the problem.	Mr Zhang Runzhi, Institute of Zoology, Chinese Academy of Sciences.	Chaired by Mr Daniel Baskaran
1:50 – 2:30 p.m.	Pest risk assessments and incursion pathways.	Mr Allan Bullard, Director, Forest Health Technology Enterprise Team, USDA Forest Service.	
2:30 – 3:10 p.m.	FAO activities in relation to invasive species.	Mr Simmathiri Appanah, NFP Adviser, Food and Agriculture Organization of the United Nations.	
3:30 – 4:10 p.m.	Ecological and economic impacts of invasive species incursions.	Mr Chris Baddeley, Team Leader Biosecurity Policy, New Zealand Ministry of Agriculture and Forestry.	Chaired by Mr Gary Man
4:10 – 4:50 p.m.	Using the IPPC to manage invasive alien species affecting forests.	Mr Greg Stubbings, National Manager of the Forestry Section, Plant Health and Production Division, Canadian Food Inspection Agency.	
4:50 – 5:30 p.m.	Discussion and wrap-up	Overview Report of Day's Proceedings (Mr Robert Kiapranis, PNG Forest Research Institute) Comments and Discussion	
MONDAY 18 AUGUST			
8:30 – 9:05 a.m.	Key issues in developing an invasive species biosecurity strategy for Australia.	Mr Michael Cole, Department of Agriculture, Fisheries and Forestry, Australia.	Chaired by Mr Sun Jianghua
9:05 – 9:40 a.m.	Managing invasive species threats to oil-palm and rubber.	Mr Ho Haw Leng, Director of Crop Protection and Quarantine Services, Department of Agriculture, Malaysia.	
9:40 – 10:15 a.m.	When good trees turn bad: the unintended spread of introduced plantation tree species in India.	Mr Kavileveetil Sankaran, Scientist, Kerala Forest Research Institute.	

10:35 – 11:10 a.m.	Acacias and their invasiveness in secondary/disturbed forests in the wet tropics.	Mr Daniel Baskaran, Executive Secretary, Asia-Pacific Association of Forest Research Institutions (APAFRI).	Chaired by Mr Wu Jian
11:10 – 11:45 a.m.	Pine wood nematode (<i>Bursaphelenchus xylophilis</i>) and other forest pathogens in Japan.	Mr Shigeru Kaneko, Director, Kansai Research Center, Forestry and Forest Products Research Institute, Japan.	
11:45 a.m. – 12:20 p.m.	Assisted Natural Regeneration – Countering the impact of <i>Imperata</i> grass infestations in the Philippines.	Peter Walpole, Executive Director, Environmental Science for Social Change (ESSC).	
1:30 – 4:00 p.m.	Group Discussion: Knowledge and information gaps in relation to invasive species. Group 1. Knowledge and information on incursion pathways and risks. Groups 2 and 3 Knowledge and information on invasive species impacts and specific means of combating.	Moderators Ms Sally Campbell Peter Walpole/Mr Chris Baddeley Ms Wang Xiaohua/Mr You Dekang	Chair: Mr Heok-Choh Sim
4:30 – 5:30 p.m.	Discussion and wrap up	Rapporteurs reports Group Discussion Housekeeping	
TUESDAY 19 AUGUST			
STONE FOREST FIELD TRIP			
9:00 – 9:30 a.m.	Crofton Weed Site		
10:00 – 11:00 a.m.	Pine shoot beetle site		
1:00 – 4:00 p.m.	Tour of Stone Forest		
8:30 p.m.	Return to hotel		
WEDNESDAY 20 AUGUST			
8:30 – 10:30 a.m.	Panel discussion-“Where to now on invasive species in Asia and the Pacific?”	Moderator: Mr Simmathiri Appanah, Forestry Officer, Food and Agriculture Organization of the United Nations. Panel members: Mr Michael Cole, Department of Agriculture, Fisheries and Forestry, Australia. Mr Sun Jianghua, Researcher, Entomologist, Institute of Zoology, Chinese Academy of Sciences. Mr Gary Man, Asia-Pacific Program Manager, International Programs, USDA Forest Service. Mr Shekhar Kumar Niraj, Regional Deputy Director, Wildlife Preservation, Ministry of Environment and Forests, India. Mr Allan Bullard, Director, Forest Health Technology Enterprise Team, USDA Forest Service.	

11:00-11:30 a.m.	Closing ceremony Closing remarks	<p>Mr Wei Diansheng, Director-General, Chinese State Forestry Administration.</p> <p>Mr Lu Yonglong, Deputy Director-General, Bureau of Comprehensive Policy, Chinese Academy of Sciences.</p> <p>Mr Patrick B. Durst, Senior Forestry Officer, Regional Office for Asia and the Pacific, Food and Agriculture Organization.</p>	Chaired by Mr Leng Hua, Director- General, Yunnan Provincial Forestry Department
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Appendix 2: List of participants

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Invasive species have a long history of causing damage to forests in Asia and the Pacific, and a variety of infestations are currently having significant impacts in a number of countries. The damage caused by invasive species imposes enormous costs on the forests of the region in terms of ecological destruction, economic losses and detrimental social effects.

To begin to address the challenges of forest invasive species, the Asia-Pacific Forestry Commission convened the Asia-Pacific Forest Invasive Species Conference, 17-23 August 2003, in Yunnan Province, China. The conference provided opportunities to share experiences and knowledge relating to the threats of invasive species to forests and forest products - and to develop proposals for regional cooperation and action in addressing invasive species problems.

This publication provides an overview of the results of the workshop and includes a summary of the technical presentations, as well as papers describing country initiatives related to invasive species.



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