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Minimising impacts of fungal disease of eucalypts in South-East Asia

IMPACT ASSESSMENT SERIES **49**

Australian Government
Australian Centre for International Agricultural Research

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Minimising impacts of fungal disease of eucalypts in South-East Asia

Hayden Fisher and Jenny Gordon
Centre for International Economics, Canberra and Sydney

July 2007

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The Research Program Manager
Policy Linkages and Impact Assessment Program
ACIAR
GPO Box 1571
Canberra ACT 2601
Australia

tel +612 62170500
email <aciar@aciar.gov.au>

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Foreword

A range of *Eucalyptus* species is grown in large areas throughout the world. This has been happening for over a century. In the past 30–40 years, however, the area grown in plantations and smallholder lots has increased substantially. Because of Australia's knowledge and expertise in many areas of research on these species, the Australian Centre for International Agricultural Research (ACIAR) has continued to fund a range of projects in this important area.

Part of the reason for the popularity of eucalypts has been a relative freedom from pests and diseases when they are introduced into new environments. Nevertheless, as greater numbers and areas of trees are planted, the risks will increase that pests and, especially, diseases will be introduced, or that local pathogens will adapt to attack the trees.

In the 1980s, there was a severe leaf blight epidemic in south-eastern and central Vietnam that markedly reduced growth rates and deformed the crowns and main stems of trees. This threatened the future of eucalypt plantations. Subsequently, less severe symptoms were also observed in Thailand and northern Queensland.

The project assessed in this study increased knowledge about leaf blight disease; developed effective screening methods for selecting resistant trees; devised management strategies based on resistant species, provenances or clones; and established within-country expertise in all areas. It focused on Vietnam and Thailand.

The study found that, as an outcome of the project, there is now genetic material with enhanced disease resistance available to growers in all countries. There is also capacity in both Vietnam and Thailand to effectively manage any disease outbreak.

High-risk regions were identified through climatic modelling, so surveillance is now more effective. In addition, information on the importance of disease management has been provided to growers, especially those in the plantation sector.

Adoption has been substantial, through certification of the new plant material in Vietnam and collaboration with private plantation companies in Thailand.

The impact-assessment analysis shows that the return on investment has been very high, with a net present value of benefits of over A$65 million, a benefit:cost ratio of 30:1 and an internal rate of return of 23%.

Peter Core
Director
ACIAR

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Contents

Tables

Boxes

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The following people were consulted as part of this impact assessment: Dr Ken Old, Mrs Krisna Pongpanich, Dr Vitoon Langviriyasaeng, Dr Nguyen Hoang Nghia, Mr Hoang Lien Song and Dr John Fryer.

The report also benefited from comments from Dr Jeff Davis, ACIAR.

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Summary

From 1996 to 2000, ACIAR funded project FST/1994/041, 'Minimising disease impacts on eucalypts in South-East Asia', in collaboration with CSIRO Forestry and Forest Products. In broad terms, the project aimed to minimise disease impacts in eucalypts in Vietnam and Thailand by: increasing knowledge of leaf blight aetiology and epidemiology; developing effective screening methods for selection of resistant trees; developing management strategies based on resistant species, provenances or clones; and establishing within-country expertise through training, and extension and adoption of disease-management practices.

The partner-country collaborators were the Forest Science Institute of Vietnam (FSIV) and the Royal Forest Department (RFD) in Thailand. The total budget for the project was around A$1.7 million. An extension project costing around 2.5 billion Vietnamese dong, funded by the Vietnamese Ministry of Agriculture and Rural Development (MARD), has also been included as an input in this impact assessment. The overall inputs into the project are therefore estimated at around A$1.9 million.

As a direct result of the research project, genetic material with enhanced disease resistance is now available to growers in both Thailand and Vietnam. The capacity of the FSIV and RFD to manage disease outbreaks has also been developed considerably. The main pathogens in the region have been identified and assessed for potential impact, and screening methods have been developed. Climatic modelling identified high-risk regions. The skills and knowledge of key staff in partner countries were developed through formal training and collaboration with Australian researchers. In addition, the project resulted in greater knowledge about the pathogens present in Australia; pathogens that were not previously known to be here have since been detected and identified.

Information on the importance of disease management was disseminated to growers through various workshops. In Vietnam, a number of clones with enhanced disease resistance have received certification from MARD, which should ensure a high rate of adoption. In Thailand, the research was conducted in collaboration with private plantation companies.

As a direct result of the ACIAR project, growers are now planting genetic material with enhanced disease resistance. In Thailand, nearly all plantation companies have changed their selection practices to include resistance to disease as a major selection trait for clones to be released to farmers. In Vietnam, the importance of disease management for plantation forestry has been recognised by MARD, and this has resulted in further research in the area.

The project is estimated to have delivered significant benefits to both Vietnam and Thailand. The benefits to Australia are less tangible and have not been quantified as part of this impact assessment. The internal rate of return on the project is estimated at around 23%. The estimated net present value of the project is around A$65 million, assuming a discount rate of 5%. The benefit:cost ratio is estimated at about 30:1. These estimates are, however, sensitive to the assumptions made about the probability of fungal disease occurring in the absence of the research.

Fungal diseases can significantly reduce the productivity of plantation forests. This project has highlighted the importance of disease management and selecting disease-resistant clones for forestry plantations. As a result of the project, the FSIV and the RFD have been better placed to deal with the outbreaks that have occurred, as well as any future outbreaks.

Figure 1 maps the impacts of the research done in project FST/1994/041.

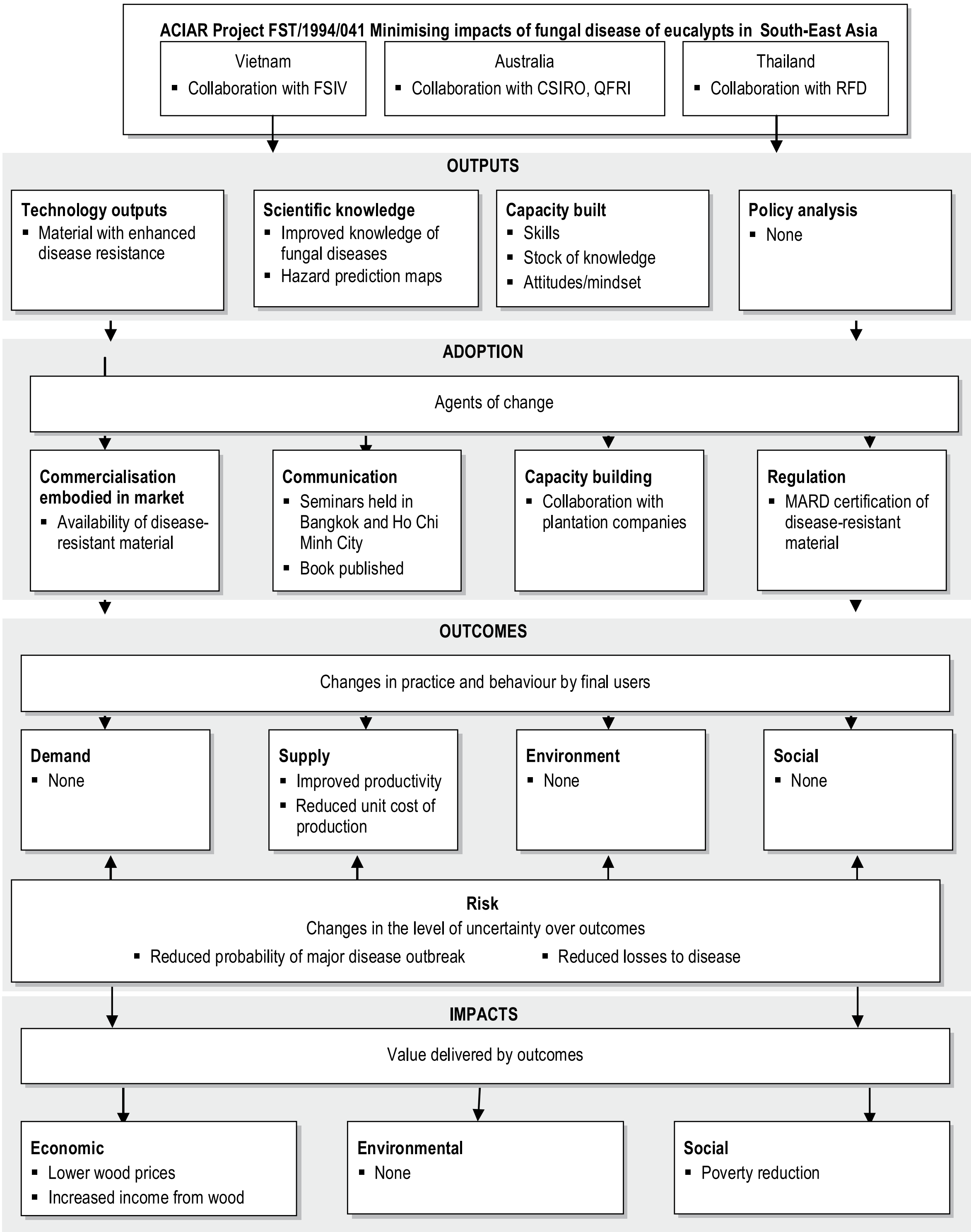

Figure 1. Mapping of research impacts. Data source: Centre for International Economics

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1 Introduction

Background

Eucalypts are common plantation species in tropical and subtropical regions, including Vietnam and Thailand. They are also planted informally on farms, around homesteads, and along canals and roadsides. Eucalypts are a good alternative to native species because of their adaptability and rapid growth, even on seasonally dry, infertile and degraded sites (Harwood 2006). Eucalypts can be used for industrial pulpwood, sawlogs, poles and fuelwood. According to the Ministry of Agriculture and Rural Development (MARD), eucalypt plantations in Vietnam cover around 348,000 hectares, and make up a large share of the estimated equivalent of 700,000 hectares of scattered plantings (Ha Huy Thinh 2004). However, many sawmills prefer to saw wood from acacias. Consequently, most wood produced from eucalypt plantations tends to be used for pulpwood. In Thailand, eucalypt plantations cover around 480,000 hectares and are largely used for pulp or woodchips (Luangviriyasaeng 2003).

Some provenances of *Eucalyptus camaldulensis*, in particular, are vulnerable to fungal diseases under certain climatic conditions. In the late 1980s, there was a severe outbreak of leaf blight disease in south-eastern and central Vietnam. The disease severely reduced growth rates, and deformed the crowns and main stems of affected trees (CSIRO 1995). A similar syndrome occurred in localised areas of northern Queensland in 1989, while less severe symptoms were also observed in Thailand.

The research project

Objectives of the research

In broad terms, the project aimed to minimise disease impacts in eucalypts by: increasing knowledge of leaf blight aetiology and epidemiology; developing effective screening methods for selection of resistant trees; developing management strategies based on resistant species, provenances or clones; and establishing within-country expertise through training, and extension and adoption of disease management practices.

More specifically, the project was divided into three subprojects, each with a number of detailed objectives (Keane and Lee Su See 1999). These are outlined below.

Subproject 1: Aetiology, epidemiology and screening methods

This subproject aimed:

- to survey the incidence of leaf and stem blight of eucalypts in trials in community and commercial plantings in Vietnam, Thailand and northern Queensland
- to identify the main pathogens, including other species of *Cylindrocladium*
- to develop reference collections of cultures and herbarium specimens in all three countries
- to develop screening methods for testing the susceptibility of species, provenances and clones to the major pathogens

- to determine environmental optima for the growth of these fungi and infection of susceptible hosts, through literature search and experimentation
- to investigate the influence of defoliation on the susceptibility of eucalypts to invasion by canker-inducing fungi
- to test for resistance and assess impacts of pathogens on a range of provenances of *E. camaldulensis*
- to survey a range of tree species for disease problems and pathogenic fungi.

Subproject 2: Tree improvement

This subproject aimed:

- to supply seed of selected provenances of *E. camaldulensis* with enhanced resistance to fungal disease
- to estimate heritability to fungal disease by controlled crossing and testing susceptibility of progeny arrays
- to test susceptibility of clones of selected genotypes of *E. camaldulensis* across the climatic gradient in south-eastern Vietnam to provide information on site × genotype interactions.
- to test clonal selections for susceptibility to a range of isolates of *Cylindrocladium quinqueseptatum* leaf blight (CqLB) and other leaf pathogens to determine tree genotype × fungal species or genotype interactions.

Subproject 3: Prediction of regions of high disease hazard

This subproject aimed:

- to review the information on climatic factors affecting severity of CqLB
- to collate information provided by Vietnamese and Thai collaborators on the present extent and severity of CqLB infections
- to conduct bioclimatic analysis of these data to provide a profile of the climatic requirements of CqLB
- to use existing climatic mapping programs for Vietnam and Thailand to map areas at risk of CqLB
- to use a climatic mapping program for South-East Asia to identify other areas in the region which may be at risk
- to use the PLANTGRO[1] program to predict disease risk at selected sites across Vietnam
- to use a simulated mapping program for Thailand to predict CqLB risk across Thailand.

Approach to the research

CSIRO Forestry and Forest Products was commissioned to undertake the project. The Queensland Forestry Research Institute (Department of Primary Industries) also provided glasshouse facilities, collected pathogenic fungi and participated in the evaluation of trials and presentation of workshops in Vietnam. The partner-country collaborators were the Forest Science Institute of Vietnam (FSIV) and the Royal Forest Department (RFD) in Thailand.

Costs of the research

The project was scheduled to run from January 1996 to December 1999, but was subsequently extended until December 2000. When measuring the cost of the project, it is important to consider all sources of funding, not just ACIAR. Other sources of funding included CSIRO, FSIV and RFD. Following the completion of the ACIAR-funded project, MARD provided funding of around Vietnamese dong (VND) 2.5 billion for an extension project, which ran for 5 years from 2001 to 2005. This project continued and extended the research work started under the ACIAR project and culminated in nine disease-resistant clones receiving certification from MARD. As the MARD-funded research was a direct result of the ACIAR project and was critical to the development of disease-resistant clones, this funding has also been included as an input. MARD has also committed to funding a second extension project from 2006 to 2010. However, this has not been included as an input. Inputs into project FST/1994/041 from all parties are shown in Table 1.

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1 The PLANTGRO model was originally developed to predict plant growth using a number of soil and climatic variables. The project aimed to modify the model to assess disease risk.

Table 1. Project funding budget (nominal terms)

	ACIAR funding (A$)	**CSIRO funding** (A$)	**Other Australian collaborators** (A$)	**Thailand and Vietnam partners** (A$)	**Total funding** (A$)
1995–96	106,630	71,400	13,100	13,000	204,130
1996–97	196,711	142,800	34,400	10,800	384,711
1997–98	174,051	142,800	26,200	10,800	353,851
1998–99	158,671	142,800	26,200	10,800	338,471
1999–2000	101,645	142,800	13,100	10,800	268,345
2000–01	35,448	71,400	–	–	106,848
Total	773,156	714,000	113,000	56,200	1,656,356

Source: ACIAR project FST/1994/041 proposal

2 Research outputs and adoption

Research outputs

The key output produced as a direct result of the ACIAR-funded research was the development of genetic material with enhanced disease resistance, which is now available to growers in both Vietnam and Thailand. Screening methods for testing susceptibility of seedlings to various diseases were also developed.

The project also built the capacity to manage fungal diseases in eucalypt plantations within the partner countries in a number of important ways. The identification of the main eucalypt pathogens in the region, and an assessment of their capacity to severely reduce growth of plantations, were key contributions of the project (Old 2001). This included the identification of three important new pathogens: *Coniothyrium zuluense* and *Cryphonectria cubensis* in Vietnam and *Phaeophleospora destructans* in Thailand.

Climatic modelling also raised awareness about those areas that are susceptible to CqLB. This highlighted the importance of planting disease-resistant species, provenances or clones in those areas (Old 2001).

The development of the knowledge and skills of key staff within the FSIV and the RFD was central to building the capacity to manage fungal diseases in partner countries. Before the project, forest pathology skills in both Vietnam and Thailand were limited (Old 2005). The project was able to build the knowledge and skills through a combination of formal training and collaboration with the Australian researchers. The FSIV and the RFD now have the capacity to provide advice to growers in the event of a major disease outbreak. The skills are also applicable beyond this particular project. In Vietnam, for example, the capacity built through the project has been utilised in examining diseases affecting acacia plantations.

The project also increased knowledge about the pathogens present in Australia; pathogens that were not previously known to be here have since been detected and identified.

Adoption

Applicability of the research

There are a number of potentially serious pathogens present in Vietnam and Thailand, while others could emerge in the future. The research is therefore applicable for eucalypt growers throughout both Vietnam and Thailand. In Vietnam, CqLB affects mainly south-eastern and central Vietnam; in particular, the provinces of Ho Chi Minh, Song Be, Dong Nai and Binh Thuan.

In Vietnam, the importance of disease management in forestry plantations has been recognised by MARD. As a direct result of the ACIAR project, MARD is investing around VND5.5 billion over 10 years in two further research projects into fungal diseases. The scope has been extended to include diseases affecting acacias.

Cylindrocladium quinqueseptatum leaf blight is not a serious problem in Thailand. However, climatic modelling indicated that most of Thailand is vulnerable to *Cryptosporiopsis eucalypti*. In 2000, a major outbreak of *Phaeophleospora destructans,* which was first identified through the project, severely affected around 100,000 hectares of eucalypt plantations, equivalent to about 20% of the total plantation area. The research is clearly highly relevant to eucalypt plantations throughout the country.

Pathways to adoption

Vietnam

During the life of the ACIAR project, information relating to fungal diseases in eucalypts was disseminated to key stakeholders through various workshops. The main technical workshop was held in Ho Chi Minh City (HCMC) in 1999. Participants, who included industry representatives, were made aware of the potential for serious disease impacts in plantations to limit production.

After the project's completion, Dr Nguyen Hoang Nghia, the project leader in Vietnam, organised a workshop in Ho Chi Minh City for provincial forestry department staff in central and southern Vietnam (Old 2005). The workshop was attended by staff from Thua Thien Hue, Da Nang, Bin Phuc, Bin Dung and Dong Nai provinces. Representatives from Vietnam Tree Improvement Enterprise Hanoi and HCMC, Southern Paper Company and FSIV also attended. Dr Nghia has published a book on tree improvement and selection for disease resistance.

Genetic material with enhanced disease resistance was certified by MARD and made available to growers in 2005. Under MARD regulations, nurseries must be licensed and can legally sell only material from approved sources. While these regulations may not completely eliminate plantings of unimproved genetic material immediately, they will ensure widespread adoption of the material with enhanced disease resistance.

The estimated adoption profile is shown in Figure 2. Nearly all plantings after 2005 will have enhanced disease resistance and it is expected that 100% adoption will eventually be achieved. As the benefits from planting material with enhanced disease resistance are not realised until harvest, the benefits flowing to Vietnam are lagged a full average rotation after adoption.

Thailand

In Thailand, much of the research was conducted in partnership with private plantation companies such as the Siam Pulp and Paper Co. Old (2005) notes that adoption has tended to be higher in those companies that cooperated with RFD and CSIRO. This collaboration with final users was therefore a key pathway to adoption.

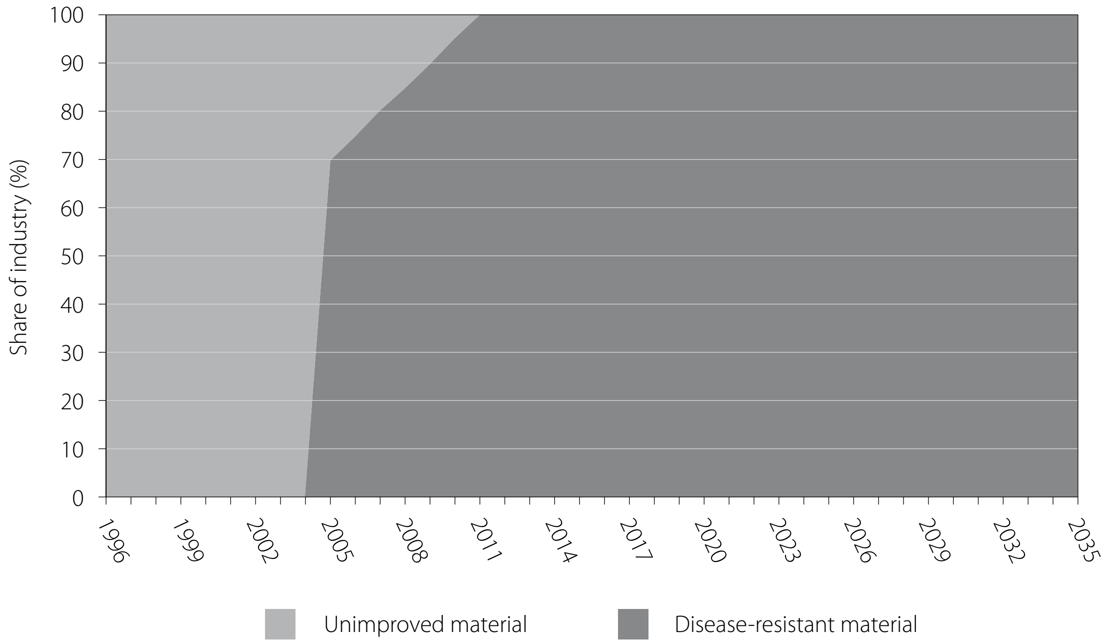

Figure 2. Adoption profile for Vietnam. Data source: Centre for International Economics' estimates based on consultation with researchers

Following the major outbreak of *Phaeophleospora destructans* in 2000, a major technical workshop was held in Bangkok. The workshop was attended by more than 50 representatives from government and major plantation companies. Old (2005) notes that virtually all companies in Thailand have now included resistance to disease as a major selection trait for clones to be released to farmers. Mrs Krisna Pongpanich, the project leader in Thailand, has also given a number of lectures to staff from plantation companies.

Adoption is reported to have been extremely fast, with 100% uptake achieved in the first few years following the workshop (Figure 3). The benefits flowing to Thailand have been lagged a full average rotation after adoption, reflecting the fact that the benefits from planting disease-resistant material are not realised until harvest.

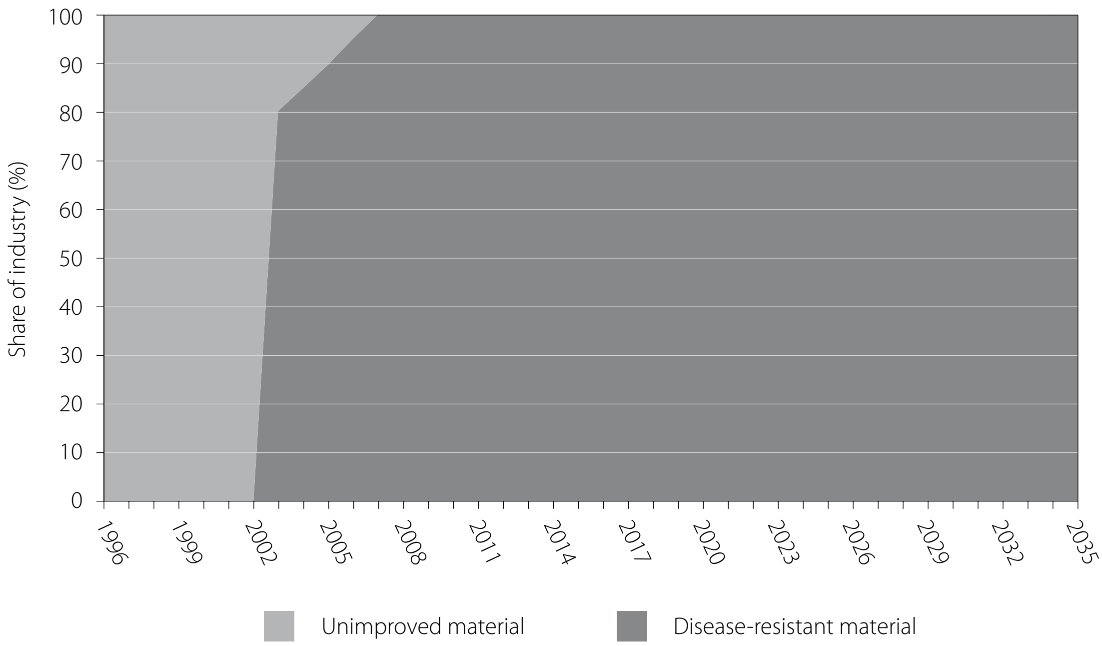

Figure 3. Adoption profile for Thailand. Data source: Centre for International Economics' estimates based on consultation with researchers

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3 Research outcomes

Changes in practice, products or policy

Genetic material with enhanced disease resistance is now available to growers as a direct result of the ACIAR project. In Vietnam, planting of this improved material is enforced by policy; disease-resistant clones have been certified by MARD. In Thailand, the project has caused virtually all plantation companies to change their selection practices, with the resistance to disease now included as a major selection trait for clones to be released to farmers (Old 2005).

The capacity built through the ACIAR project has also influenced the domestic research agenda in Vietnam. The skills developed by FSIV staff are now being used on further disease-management projects funded by MARD. This demonstrates that MARD is now more aware of the importance of disease management in plantation forestry.

Unit cost of production

To assess the economic impacts of the project, it is important to understand how adoption of the research outputs affects the unit cost of production. Planting material with enhanced disease resistance reduces the probability of the tree being affected by fungal diseases. This reduces losses in the volume of wood production and lowers the unit cost of production. Fungal diseases change both the amount of wood harvested and the costs incurred.

Wood yields

Wood yields vary widely, depending on many factors, including quality of seed, location, climatic conditions, extent of silviculture and length of rotation. The rotation length largely depends on the end use. As eucalypts have generally been found to be less suitable for sawing than acacias, most eucalypt plantations tend to be used for pulpwood. On average, rotations for pulpwood are estimated to be around 7–10 years in Vietnam. Annual increments for eucalypt species in Vietnam can vary between 5 and 40 m^3/ha/year but, on average, the mean annual increment over a 9-year rotation is estimated to be around 7 m^3/ha/year.

In Thailand, eucalypt logs are largely sold to pulp or chip mills. The average rotation is estimated to be around 5 years, with a mean annual increment of 13 m^3/ha/year over this rotation (Luangviriyasaeng 2003). Assuming no major outbreaks of fungal disease, typical per-hectare yields on eucalypt plantations in Vietnam and Thailand are shown in Table 2.

The presence of fungal pathogens, which have the potential to severely reduce growth rates, is an important factor affecting the productivity of eucalypt plantations.

There are some outbreaks of fungal diseases in eucalypts in Thailand and Vietnam every year. However, the severity depends on climatic conditions in ways that are not fully understood. The effects of disease in years where the incidence of fungal disease is relatively low are reflected in the relatively low productivity of eucalypt plantations in the region. From time to time, however, a major outbreak of fungal disease occurs that has a major effect on wood yields.

The effect of fungal diseases on wood yields depends on when the tree is affected. In general, if the disease occurs in the first 2 years, the seedling is replanted. If the disease occurs in subsequent years, some output may be salvageable. In some cases, a tree affected by the disease may survive until it is due for harvest, but with slower growth rates after infection. Alternatively, diseased trees may be harvested immediately to help prevent the disease from spreading. To simplify the analysis, it is assumed that, from the third year onwards, a hectare of trees affected by the disease is harvested immediately and some wood is salvageable for sale. The volume of wood salvaged is assumed to be equivalent to the mean annual increment for each year of normal growth. So if, for example, the disease occurs in the fourth year, the tree is harvested immediately, with the volume of wood harvested equal to three times the mean annual increment. These assumptions are summarised in Box 1.

The probability of a particular tree developing the disease in any given year is calculated by multiplying the probability of a disease outbreak in that year by the conditional probability of a particular tree developing the disease in the event of the outbreak.

The project made a significant contribution to understanding the various fungal pathogens present in Vietnam and Thailand, and the areas that are susceptible. But there is still not a detailed understanding of the conditions that cause higher incidences of disease in a particular year and how often they are likely to occur. It has, however, been established that the likelihood of disease depends on climatic conditions, and the probability of the disease occurring is much higher in years that are wetter than average. Given the limitations in the understanding of conditions that contribute to a higher incidence of disease, it is difficult to predict the frequency with which major disease outbreaks would have occurred in the absence of the research. Researchers indicated that major disease outbreaks are unlikely to occur every year. However, once a pathogen is present, it is virtually impossible to get rid of it. Consequently, major disease outbreaks are likely to occur increasingly frequently as new pathogens emerge. In Thailand, those farmers that did not plant disease-resistant material have continued to have problems with disease. This suggests that major disease outbreaks could occur as often as every second year on average. The probability of a major outbreak in any given year is therefore 0.50.

Box 1. Key assumptions about the impacts of fungal disease

The effect of fungal diseases on growth rates depends on the disease and its severity. The impact on wood yields depends on when the disease occurs. For this impact assessment, the following assumptions are made in relation to the effect of the disease.

- If the disease occurs in the first or second year, the area is replanted.
- If the disease occurs in later years, the trees are harvested immediately.
- When disease-affected trees are harvested early, it is assumed that they have grown normally until the disease occurred. and that some saleable wood is salvageable. Therefore, the yield at harvest of a hectare of trees affected by the disease is equivalent to the mean annual increment (over a full rotation) multiplied by the years of normal growth. If the disease occurs in the fourth year, for example, it is assumed that the tree has grown normally for the first three years. The yield at harvest is therefore the mean annual increment times three.

Table 2. Eucalypt wood yields (assuming no major outbreak of disease)

	Average rotation length (years)	**Mean annual increment** (m^3/ha/year)	**Yield at harvest** (m^3/ha)
Vietnam	9	7	63
Thailand	5	13	65

Sources: Luangviriyasaeng (2003) and Centre for International Economics' estimates based on consultation with researchers

As regards the probability of a tree being affected by the disease in the event of a major outbreak, past experience has shown that, in Vietnam, up to 40,000 hectares have been affected by disease if climatic conditions are unfavourable. This is close to 10% of the total area planted to eucalypts. In Thailand, around 20% of total eucalypt plantations were affected in the major disease outbreak of 2000. In the absence of more comprehensive information, this provides a reasonable guide to the probability of a tree being affected by the disease in the event of a major outbreak.

The probability of the disease occurring in a particular year is estimated to be 0.05 (0.50 × 0.10) in Vietnam and 0.10 (0.50 × 0.20) in Thailand. The effect of varying this assumption on the overall impact assessment is examined in Chapter 4. From this information, the probability of the disease occurring in each year of the rotations can then be assigned. These probabilities are shown in Table 3.

The volume of wood harvested depends on when the disease occurs. The expected harvest (Table 4) is given by the probability-weighted average of all possible outcomes. In Vietnam, the presence of fungal diseases reduces the expected harvest from eucalypt plantations to 49 m^3/ha, given the assumptions made about the impact of disease. In Thailand, the expected harvest is around 47 m^3/ha.

Production costs

Like the volume of wood harvested, the costs incurred for each hectare planted also vary depending on if and when the fungal disease occurs. Clearly, once the tree has been harvested no further costs are incurred. The first step is to establish the costs involved in planting and maintaining eucalypt plantations in Vietnam and Thailand.

As production in the forestry industry occurs in rotations lasting several years, many of the costs are incurred in periods different to that in which the benefits are received. The time value of money must therefore be taken into account. The most appropriate measure of the cost of production is the future value of the costs incurred, i.e. their value at the time of harvest. The future value of costs at harvest are estimated assuming a cost of capital of 10%.

Vietnam

The estimated costs involved in planting and maintaining a eucalypt plantation in Vietnam are shown in Table 5. The costs are compared for planting unimproved genetic material and disease-resistant material. The key difference is the cost of the seedlings. Unimproved seedlings cost around VND200, while improved material costs around VND300 each. The

Table 3. Probability of disease occurring in each year of rotation

	Vietnam	**Thailand**
First year	0.050	0.100
Second year	0.048	0.090
Third year	0.045	0.081
Fourth year	0.043	0.073
Fifth year	0.041	0.066
Sixth year	0.039	n.a.
Seventh year	0.037	n.a.
Eighth year	0.035	n.a.
Ninth year	0.033	n.a.
No disease during rotation	0.630	0.590
Total	1.000	1.000

Source: Centre for International Economics' estimates based on consultations with researchers estimates shown in Table 5 assume 1,500 seedlings are planted per hectare. Harvesting and transportation costs have been excluded.

Thailand

As in Vietnam, the key difference between the cost of planting unimproved genetic material and material with enhanced disease resistance is in the seedling price (Table 6). An unimproved seedling costs around 1 baht, while disease-resistant seedlings cost around 3 baht and sometimes up to 4.5 baht each.

Expected cost

The actual costs incurred on a hectare of eucalypt plantation depend on if and when a fungal disease occurs. The expected cost is the probability-weighted average of all possible outcomes.

Vietnam

The estimated future value of the costs associated with a hectare of eucalypt plantation (at the time of harvest) in Vietnam is shown in Table 7. Weighting each possible outcome by its probability gives an expected cost of VND18.8 million per hectare.

Thailand

The estimated future value of the costs associated with a hectare of eucalypt plantation (at the time of harvest) in Thailand is shown in Table 8. Weighting each possible outcome by its probability gives an expected cost of 22,286 baht per hectare.

Change in the unit cost of production as a result of the research

The benefits from the adoption of the research outputs depend on what would have happened in the absence of the research. It seems clear that, in the absence of the research, fungal diseases would have continued to be a major problem for eucalypt plantations.

Drawing all the above information together, the expected unit cost of production can be estimated by dividing the expected cost of a hectare of eucalypts by the expected harvest. To estimate the change in the unit cost of production as a result of the research project, the unit cost of production with the research project is compared with the cost in the absence of the research. This is shown in Table 9. The unit cost of production is estimated to be VND28,578 per m^3 lower in Vietnam and 18 baht per m^3 lower in Thailand as a result of the research project.

Table 4. Expected wood volume (m^3/ha) harvested

	Years of normal growth	Vietnam yield at harvest[a]	Thailand yield at harvest[b]
Disease in first year	–	–	–
Disease in second year	1	–	–
Disease in third year	2	14	26
Disease in fourth year	3	21	39
Disease in fifth year	4	28	52
Disease in sixth year	5	35	n.a.
Disease in seventh year	6	42	n.a.
Disease in eighth year	7	49	n.a.
Disease in ninth year	8	54	n.a.
No disease during rotation	9	63	65
Expected harvest		48.8	46.7

[a] The mean annual increment in Vietnam is assumed to be 7.

[b] The mean annual increment in Thailand is assumed to be 13.

Source: Centre for International Economics' estimates based on consultation with researchers

Table 5. Estimated eucalypt plantation costs in Vietnam

	Unimproved material ('000 VND[a]/ha)	**Improved material** ('000 VND/ha)
First-year costs		
Labour[b]	3,750	3,750
Seedlings	300	450
Transport of seedlings	25	25
Fertiliser	750	750
Technical advice	200	200
Management	600	600
Total first-year costs	*5,625*	*5,775*
Second-year costs		
Labour[c]	1,500	1,500
Technical advice	400	400
Management	250	250
Total second-year costs	*2,150*	*2,150*
Third-year costs		
Labour[d]	600	600
Technical advice	400	400
Management	120	120
Total third-year costs	*1,120*	*1,120*
Fourth (and later)-year costs		
Labour	500	500
Total fourth (and later)-year costs	*500*	*500*
Future value of costs at harvest of a full rotation[e]	22,089	22,411

[a] VND = Vietnamese dong

[b] Includes labour used for clearing the land, digging and filling holes, transporting seedlings, establishing firebreaks, pest and disease protection, monitoring and replanting dead seedlings.

[c] Includes labour for monitoring and evaluation, protection and weeding. Weeding is completed twice in the second year; the first time involves weeding and grass cutting, while the second involves only grass cutting.

[d] Includes labour used for protection, monitoring and evaluation, and weeding. Weeding is completed only once in the third year, and involves only grass cutting.

[e] Assumes a cost of capital of 10%.

Source: Centre for International Economics' estimates based on information provided by the Forest Science Institute of Vietnam

Table 6. Estimated eucalypt plantation costs in Thailand

	Unimproved material (baht/ha)	**Improved material** (baht/ha)
First-year costs		
Seedlings	1,688	5,063
Land preparation	2,188	2,188
Planting	1,375	900
Fertiliser	1,813	1813
Weeding	1,875	1,875
Ploughing	750	750
Fire protection	125	125
Total first-year costs	*9,814*	*12,714*
Second-year costs		
Fertiliser	1,751	1,751
Ploughing	750	750
Cutting wire plant	125	125
Herbicide	875	875
Fire protection	125	125
Total second-year costs	*3,626*	*3,626*
Third-year costs		
Fertilising	1,563	1,563
Ploughing	750	750
Cutting wire plant	125	125
Herbicide	875	875
Fire protection	125	125
Total third-year costs	*3,438*	*3,438*
Fourth-year costs		
Ploughing	750	750
Cutting wire plant	125	125
Herbicide	875	875
Fire protection	125	125
Total fourth-year costs	*1,875*	*1,875*
Fifth-year costs		
Fire protection[a]	125	125
Total fifth-year costs	*125*	*125*
Future value of costs at harvest over full rotation[b]	**25,542**	**29,788**

[a] Excludes cutting and transportation costs

[b] Assuming a cost of capital of 10%

Source: Centre for International Economics' estimates based on information provided by the Royal Forest Department

From: Fisher, H. and Gordon, J. *Minimising impacts of fungal disease of eucalypts in South-East Asia*. ACIAR Impact Assessment Series Report No. 49, July 2007.

Table 7. Future value of costs ('000 VND[a]) under different disease scenarios in Vietnam

Cost incurred	Disease in first year	Disease in second year	Disease in third year	Disease in fourth year	Disease in fifth year	Disease in sixth year	Disease in seventh year	Disease in eighth year	Disease in ninth year	No disease	Probability-weighted average
First year	5,625	6,188	6,806	7,487	8,236	9,059	9,965	10,962	12,058	12,058	
Second year	–	2,150	2,365	2,602	2,862	3,148	3,463	3,809	4,190	4,190	
Third year	–	–	1,120	1,232	1,355	1,491	1,640	1,804	1,984	1,984	
Fourth year	–	–	–	500	550	605	666	732	805	805	
Fifth year	–	–	–	–	500	550	605	666	732	732	
Sixth year	–	–	–	–	–	500	550	605	666	666	
Seventh year	–	–	–	–	–	–	500	550	605	605	
Eighth year	–	–	–	–	–	–	–	500	550	550	
Ninth year	–	–	–	–	–	–	–	–	500	500	
Total	**5,625**	**8,338**	**10,291**	**11,820**	**13,502**	**15,353**	**17,388**	**19,627**	**22,089**	**22,089**	**18,771**

[a] VND = Vietnamese dong

Source: Centre for International Economics' estimates

Table 8. Future value of costs (baht) under different disease scenarios in Thailand

Cost incurred	Disease in first year	Disease in second year	Disease in third year	Disease in fourth year	Disease in fifth year	No disease in rotation	Probability-weighted average
First year	9,814	10,795	11,875	13,062	14,369	14,369	
Second year	–	3,626	3.989	4,387	4,826	4,826	
Third year	–	–	3,438	3,782	4,160	4,160	
Fourth year	–	–	–	1,875	2,063	2,063	
Fifth year	–	–	–	–	125	125	
Total	9,814	14,421	19,302	23,107	25,542	25,542	22,286

Source: Centre for International Economics' estimates

Table 9. Unit cost of production

	Expected cost	Expected harvest	Expected unit cost	Reduction in unit cost
Vietnam	('000 VND[a]/ha)	(m^3/ha)	(VND/m^3)	(VND/m^3)
Without ACIAR research	18,771	49	384,307	
With ACIAR research	22,410	63	355,729	28,578
Thailand	(baht/ha)	(m^3/ha)	(baht/m^3)	(baht/m^3)
Without ACIAR research	22,286	47	477	
With ACIAR research	29,788	65	458	18

[a] VND = Vietnamese dong

Source: Centre for International Economics' estimates

4 Impact assessment

Benefits from the research

This impact assessment focuses on the economic benefits of minimising the impacts of disease in eucalypts. Reducing losses to disease reduces the unit cost of production, which can benefit both producers and consumers.

Approach to estimation

The best approach to estimate the benefits resulting from the ACIAR-funded research is an economic-surplus analysis. The economic-surplus framework captures the benefits flowing to both consumers and producers.

While many forestry products are tradeable, the market for unprocessed pulpwood can be modelled as a closed market. High transport costs mean that it is rarely feasible to import unprocessed pulpwood from neighbouring countries. Consequently, there is likely to be little competition from imported pulpwood at domestic pulp and chip mills.

Using a standard static supply and demand model, the effect of the research can be represented as a downward shift in the supply curve (Figure 4), which can be approximated by the change in the unit cost of production. This downward shift in the supply curve increases consumer surplus by the area $(b+c+d)$ in Figure 4, and producer surplus by the area $(e+f-b)$. Economic surplus increases by the shaded area $(c+d+e+f)$.

This change in economic surplus is given by:

$$\Delta ES = \Delta S \times q_0 + 0.5 \times \Delta S \times \Delta Q \quad (1)$$

where

- ΔES is the change in economic surplus
- ΔS is the shift in the supply curve, approximated by the change in the unit cost of production
- q_0 is the quantity produced under the counterfactual scenario
- ΔQ is the increase in the quantity producers are willing to produce as a result of the lower cost of production.

The change in consumer surplus is given by:

$$\Delta CS = \Delta P \times q_0 + 0.5 \times \Delta P \times \Delta Q \quad (2)$$

where

- ΔCS is the change in consumer surplus
- ΔP is the change in prices.

Therefore, the change in producer surplus is given by:

$$\Delta PS = \Delta ES - \Delta CS \quad (3)$$

The supply curve captures the opportunity cost of alternative uses of resources. As a result of the increase in productivity, fewer resources are required to produce the same quantity of wood. This initial quantity can be estimated from the total area planted. The most recent estimates of total plantings are shown in Table 10. An estimate of the area harvested annually can be obtained by dividing the total area harvested by the average rotation length; this assumes that plantings are staggered evenly, so that the same quantity is harvested every year. The estimated area harvested annually can then be multiplied by the expected yield at harvest.

As the initial price of wood exceeds the cost of producing an additional unit, some of the resources freed up by the increase in productivity will be used to increase the quantity of wood produced, as long as there is demand for the additional output. The upward-sloping supply curve implies that the cost of producing each additional unit of wood increases. The elasticity of supply for pulpwood in Vietnam and Thailand is unknown. The global forest products model (Zhu et al. 1998) uses an elasticity of supply of 0.8 for developing countries. While this is relatively low, it seems a reasonable estimate given that Australian tree species are generally grown on degraded land with few alternative uses.

To encourage customers to purchase the additional wood produced, it is necessary for producers to lower the price. The elasticity of demand for a variety of forest products is estimated to range between around –0.2 and –0.6 (Zhu et al. 1998). Using –0.4, the midpoint of this range, implies that demand is relatively inelastic. Again, this is a reasonable assumption given that there are few close substitutes for pulpwood available in Vietnam and Thailand. Furthermore, high transport costs mean that it is cheaper for local mills to use locally produced inputs rather than imports. While these elasticity assumptions appear somewhat arbitrary, it makes little difference to the end result. This is because the area $(d+f)$ (Figure 4) is typically small relative to the area $(c+e)$, so long as plausible assumptions are made in relation to the elasticities of supply and demand. The effect of varying the elasticity assumptions is tested in the sensitivity analysis below.

The standard supply and demand model is static; that is, it measures the change in economic surplus in a particular period. However, benefit–cost analysis must measure the benefits over a long period. Consequently, the change in economic surplus must be estimated in each period. The shift in the supply curve in each period is determined by the proportion of producers who adopt the new technology in each period.

The net present value of the change in economic surplus arising from planting improved genetic material that arose as a direct result of the ACIAR-funded research over time is then calculated.

Box 2 outlines the major assumptions used in modelling the costs and benefits attributable to the ACIAR research.

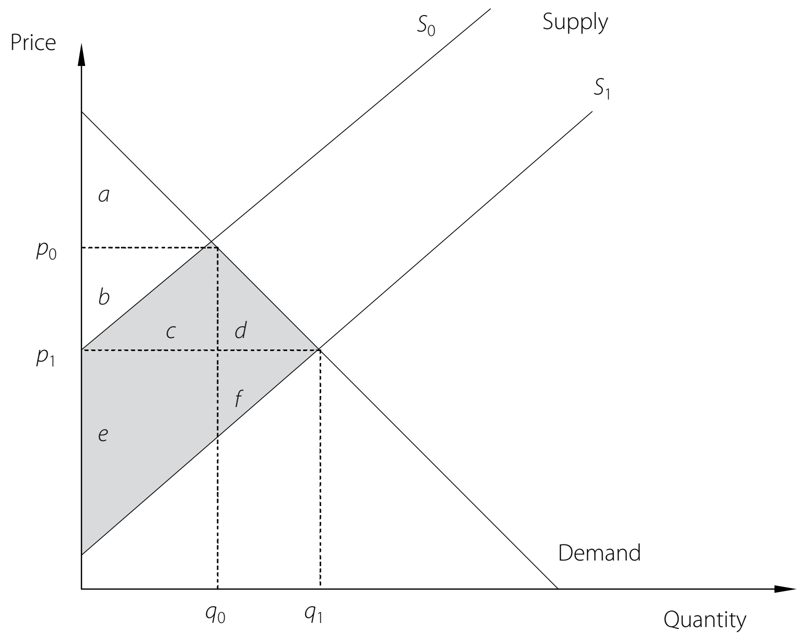

Figure 4. Change in economic surplus. Data source: Centre for International Economics

Box 2. Major assumptions used in modelling

- In the absence of the research projects, unimproved material would have continued to be planted.
- The supply and demand curves are linear.
- Adoption of the research outputs results in a vertical, parallel shift in the supply curve.
- The elasticity of demand at the initial equilibrium is –0.4.
- The elasticity of supply at the initial equilibrium is 0.8.
- Demand is constant.
- There are no quality improvements from using improved genetic material.

Environmental benefits

There are several environmental benefits from planting eucalypts on degraded land. These include: salvage of waterlogged land; reduced soil erosion; protection of crops and livestock from wind; and providing a nurse crop that allows for the regeneration of native vegetation (Davidson and Huoran Wang 2004). Furthermore, more-productive plantation forests reduce the reliance on native forests. However, it is not clear that reduced incidence of disease significantly enhances these benefits. Consequently, for the purposes of this impact assessment, it is assumed that the improved genetic material had no significant environmental benefits.

Social benefits

An important benefit not captured by the reduction in the expected unit cost of production is reduction in risk associated with a lower incidence of disease. In Thailand, for example, plantations supply seedlings to farmers, and there is often a contract between the plantation and the farmer. But losses incurred through disease are borne entirely by the farmer. Consequently, the risk associated with disease is worn by small farmers, the group least able to bear it.

A further flow-on effect from reduced incidence of disease is a more stable supply of wood and, therefore, more stable prices. In Thailand, the major disease outbreak in 2000 restricted the supply of wood in subsequent years and pushed prices higher. But this was followed by a surge in supply as the large area replanted in the aftermath of the disease outbreak was ready for harvest. This surge in supply depressed prices.

Stable sources of income are extremely important for rural communities. The research project will result in more stable incomes for poor farmers. The value of reduced uncertainty in income is not easy to measure and is dependent on access to alternative sources of income, so will vary by region as well as household characteristics.

Benefit estimates

The estimated benefits from the ACIAR-funded research and the subsequent extension project in Vietnam, over the 40-year period from 1996 to 2035, are shown in Table 11. Following Gordon and Davis (2007), benefits in subsequent years are converted to an annuity value. The benefits are also converted to Australian dollars using the average annual exchange rates from the IMF's world economic outlook database.[2] For future years,

Table 10. Estimated annual harvest

	Estimated plantings (ha)	**Average rotation length** (years)	**Area harvested annually** (ha)	**Estimated annual harvest** (m^3)
Vietnam	348,000	9	38,667	1,888,647
Thailand	480,000	5	96,000	4,487,296

Sources: Ha Huy Thinh (2004), Luangviriyasaeng (2003) and Centre for International Economics' estimates

2 < http://www.imf.org/external/pubs/ft/weo/2007/01/data/index.aspx>

Table 11. Benefits from ACIAR project

	Vietnam (VND million)	**Vietnam** (A$ '000)	**Thailand** (baht '000)	**Thailand** (A$ '000)	**Total** (A$ '000)	**Present value**[a] (A$ '000)
1996	–	–	–	–	–	–
1997	–	–	–	–	–	–
1998	–	–	–	–	–	–
1999	–	–	–	–	–	–
2000	–	–	–	–	–	–
2001	–	–	–	–	–	–
2002	–	–	–	–	–	–
2003	–	–	–	–	–	–
2004	–	–	–	–	–	–
2005	–	–	–	–	–	–
2006	–	–	–	–	–	–
2007	–	–	–	–	–	–
2008	–	–	66,488	2,329	2,329	1,297
2009	–	–	70,650	2,475	2,475	1,312
2010	–	–	74,814	2,620	2,620	1,323
2011	–	–	78,978	2,766	2,766	1,331
2012	–	–	83,144	2,912	2,912	1,334
2013	–	–	83,144	2,912	2,912	1,271
2014	37,949	2,959	83,144	2,912	5,871	2,440
2015	40,673	3,171	83,144	2,912	6,083	2,407
2016	43,398	3,384	83,144	2,912	6,296	2,373
2017	46,125	3,596	83,144	2,912	6,509	2,336
2018	48,854	3,809	83,144	2,912	6,721	2,298
2019	51,584	4,022	83,144	2,912	6,934	2,258
2020	54,316	4,235	83,144	2,912	7,147	2,216
2021	54,316	4,235	83,144	2,912	7,147	2,111
2022	54,316	4,235	83,144	2,912	7,147	2,010
2023	54,316	4,235	83,144	2,912	7,147	1,914
2024	54,316	4,235	83,144	2,912	7,147	1,823
2025	54,316	4,235	83,144	2,912	7,147	1,736
2026	54,316	4,235	83,144	2,912	7,147	1,654
2027	54,316	4,235	83,144	2,912	7,147	1,575

Table 11. (continued)

	Vietnam (VND million)	**Vietnam** (A$ '000)	**Thailand** (baht '000)	**Thailand** (A$ '000)	**Total** (A$ '000)	**Present value[a]** (A$ '000)
2028	54,316	4,235	83,144	2,912	7,147	1,500
2029	54,316	4,235	83,144	2,912	7,147	1,429
2030	54,316	4,235	83,144	2,912	7,147	1,361
2031	54,316	4,235	83,144	2,912	7,147	1,296
2032	54,316	4,235	83,144	2,912	7,147	1,234
2033	54,316	4,235	83,144	2,912	7,147	1,175
2034	54,316	4,235	83,144	2,912	7,147	1,119
2035	54,316	84,700	83,144	58,244	142,944	21,320

[a] Assumes discount rate of 5%

Source: Centre for International Economics' estimates

the exchange rates are assumed to remain constant at 12,825 Vietnamese dong per Australian dollar and 28.6 Thai baht per Australian dollar, as per the IMF's 2007 forecast. The last column shows the present value of the future benefits, discounted at an annual rate of 5%.

Benefit–cost and the rate of return

Costs

The project budget was presented in terms of Australian financial years from July to June (Table 1). This is converted to calendar years by assuming that funds were spent evenly throughout the year (Table 12). The costs of the first MARD-funded project have been included as an input, because this followed on from the work began under the ACIAR project and was critical in making genetic material with enhanced disease resistance available to growers. The nominal research costs are then converted to real 2006 dollars using the Australian GDP deflator. Finally, the present value is calculated assuming a discount rate of 5%.

Results

The project has delivered significant benefits to both Vietnam and Thailand. Assuming that the probability of a major outbreak of fungal disease in any year is 0.05 in Vietnam and 0.10 in Thailand, the internal rate of return on the project was around 23% (Table 13). Using a discount rate of 5%, the net present value of the project was around A$65 million, with the benefits relatively evenly shared between Vietnam and Thailand. In present value terms, the project generated around A$30 of benefit for every dollar spent. The net present value and the benefit:cost ratio are highly sensitive to the discount rate used. This is largely a result of the, often substantial, lag between the period in which the costs are incurred and the periods in which the benefits are realised.

Sensitivity of estimates

The results presented in Table 13 are dependent on many assumptions that have been made. In this section, some of these key parameters are varied and the impact on the estimated internal rate of return is examined. Table 14 summarises the results of this analysis. The impact on the internal rate of return is examined because the net present value and the benefit:cost ratio are themselves sensitive to the discount rate used.

Since there is no reliable information on the probability of a tree being affected by a fungal disease in any particular year, this is the key uncertainty surrounding the results. The internal rate of return on the project is relatively more sensitive to varying the probability assumption in Thailand. This is partly because the cost of material with enhanced disease resistance is higher, relative to the cost of unimproved material. Consequently, if the probability of a tree being affected by disease falls below around 0.09, there is no benefit from planting enhanced genetic material in Thailand.

The high rate of adoption, however, suggests that there are significant benefits from planting material with enhanced disease resistance.

The internal rate of return on the project is relatively insensitive to a range of other assumptions, including the mean annual increments, the average rotation length and the elasticity of supply and demand. The internal rate of return is somewhat sensitive to the assumed cost of capital.

Table 12. Research costs

	Nominal research costs (A$)	**Australian GDP deflator** (in 2006 = 100)	**Real research costs**[a] (A$ 2006)	**Present value**[b] (A$)
1996	396,486	76.0	521,433	521,433
1997	369,281	77.0	479,485	456,653
1998	346,161	77.4	447,098	405,531
1999	303,408	77.8	389,834	336,753
2000	241,001	81.1	297,334	244,617
2001	65,239	84.3	77,420	60,661
2002	60,195	86.4	69,652	51,975
2003	49,440	89.2	55,454	39,410
2004	43,113	92.2	46,785	31,666
2005	41,294	96.3	42,874	27,637

[a] Using GDP deflator.

[b] Assuming discount rate of 5%.

Sources: ACIAR project documents, International Monetary Fund, Centre for International Economics

Table 13. Summary measures

	1% discount rate	**5% discount rate**	**10% discount rate**
Present value of benefits to Vietnam (A$m)	121.2	34.6	8.6
Present value of benefits to Thailand (A$m)	99.7	32.8	10.4
Present value of total benefits (A$m)	221.0	67.5	19.0
Present value of costs (A$m)	2.5	2.3	2.1
Net present value (A$m)	218.5	65.2	17.0
Benefit:cost ratio	88.7	29.5	9.2
Internal rate of return (%)	23.0	23.0	23.0

Source: Centre for International Economics' estimates

Distributional implications

Impact on poverty

A key advantage of the economic surplus methodology is it allows determination of the likely distribution of benefits between producers and consumers. Looking again at Figure 4, the increase in consumer surplus is given by area ($b+c+d$), while the increase in producer surplus is given by area ($f+g-b$). Assuming 100% adoption of material with enhanced disease resistance, this implies that around two-thirds of the benefits are captured by consumers. The large share captured by consumers is largely because demand for wood is assumed to be relatively inelastic. The ultimate beneficiaries of the price reduction depend on whether the lower prices are passed down the supply chain.

The remaining benefits flow to those producers who plant disease-resistant material. This will include many small-scale producers. The project is therefore likely to make some contribution to increasing incomes and reducing poverty in rural communities.

While the assumptions made about the elasticity of supply and demand have little impact on the overall benefits, they do affect the estimated distribution of the benefits. This is shown in Table 15.

Lessons

Fungal diseases can significantly reduce the productivity of plantation forests. This project has highlighted the importance of disease management and of selecting disease-resistant clones for forestry plantations. As a result of the project, the FSIV and the RFD have been better placed to deal with the outbreaks that have occurred, and are in an improved position to handle any future outbreaks.

The project also shows that research that improves the productivity of plantation forests can have significant benefits despite the often long lags before these benefits are realised.

Table 14. Sensitivity analysis

	Current assumption	**Alternative assumption (low)**	**Alternative assumption (high)**	**Internal rate of return (low)** (%)	**Internal rate of return (high)** (%)
Probability of disease (Vietnam)	0.05	0.01	0.10	20.5	24.6
Probability of disease (Thailand)	0.10	0.05	0.15	16.4	31.1
Mean annual increment (Vietnam)	7	5	9	23.0	23.0
Mean annual increment (Thailand)	13	10	16	23.0	23.0
Average rotation length (Vietnam)	9	5	13	21.3	22.8
Average rotation length (Thailand)	5	3	7	16.4	30.7
Elasticity of supply	0.8	0.5	1.1	23.0	23.0
Elasticity of demand	–0.4	–0.1	–0.7	23.0	23.0
Cost of capital	10%	5%	15%	28.9	14.0

Source: Centre for International Economics' estimates

Table 15. Sensitivity of distribution of benefits

	Share of benefits to consumers (%)	**Share of benefits to producers** (%)
Elasticity of supply		
Elasticity of supply = 0.8 (current)	66.7	33.3
Elasticity of supply = 0.5 (low alternative)	55.6	44.4
Elasticity of supply = 1.1 (high alternative)	73.3	26.7
Elasticity of demand		
Elasticity of demand = −0.4 (current)	66.7	33.3
Elasticity of demand = −0.1 (low alternative)	88.9	11.1
Elasticity of demand = −0.7 (high alternative)	53.3	46.7

Source: Centre for International Economics' estimates

Literature consulted

CSIRO 1995. Minimising disease impacts on eucalypts in South-East Asia. ACIAR project FST/1994/041 summary. CSIRO: Canberra.

— various dates. Minimising disease impacts on eucalypts in South-East Asia. Annual progress reports on ACIAR project FST/1994/041. CSIRO: Canberra.

Davidson J. and Huoran Wang 2004. Domestication of Australian trees for reforestation and agroforestry systems in developing countries. Review report. ACIAR: Canberra.

Gordon J. and Davis J. 2007. ACIAR impact assessment: guidelines for practitioners. [May 2007 working draft of a manuscript to be published as a report in the ACIAR Impact Assessment Series.] ACIAR: Canberra.

Ha Huy Thinh 2004. Country report on domestication of key Australian tree species. Unpublished report presented to the 'Domesticating Australian trees' project termination meeting, Bangkok, Thailand, October 2004.

Harwood C.E. 2006. Australian contributions to the development of improved forest germplasm for tropical countries. Paper presented to Institute of Foresters Australia conference, Mt Gambier, May 2006. Published on IFA website to IFA members.

Keane P. and Lee Su See 1999. Minimising disease impacts on eucalypts in South-East Asia. Review of project FST/1994/041. ACIAR: Canberra.

Luangviriyasaeng V. 2003. Eucalypt planting in Thailand. In 'Eucalypts in Asia', ed. by J. Turnbull. ACIAR Proceedings No. 111, 29–31.

Old K.M. 2001. Minimising disease impacts on eucalypts in South-East Asia. Final report on ACIAR project FST/1994/041. CSIRO Forestry and Forest Products: Canberra.

—2005. Minimising disease impacts on eucalypts in Southeast Asia (FST/1994/041). Pp. 47–54 in 'Adoption of ACIAR project outputs: studies of projects completed in 2000–2001', ed. by V. McWaters, S. Hearn and R. Taylor. ACIAR: Canberra.

Zhu S., Tomberlin D. and Buongiorno J. 1998. Global forest products consumption, production, trade and prices: global forest products model projections to 2010. Working Paper No. GFPOS/WP/01, Forestry Policy and Planning Division, Food and Agriculture Organization of the United Nations, Rome.

From: Fisher, H. and Gordon, J. *Minimising impacts of fungal disease of eucalypts in South-East Asia*. ACIAR Impact Assessment Series Report No. 49, July 2007.

IMPACT ASSESSMENT SERIES

No.	Author(s) and year of publication	Title	ACIAR project numbers
1	Centre for International Economics (1998)	Control of Newcastle disease in village chickens	8334, 8717 and 93/222
2	George, P.S. (1998)	Increased efficiency of straw utilisation by cattle and buffalo	8203, 8601 and 8817
3	Centre for International Economics (1998)	Establishment of a protected area in Vanuatu	9020
4	Watson, A.S. (1998)	Raw wool production and marketing in China	8811
5	Collins, D.J. and Collins, B.A. (1998)	Fruit fly in Malaysia and Thailand 1985–1993	8343 and 8919
6	Ryan, J.G. (1998)	Pigeon pea improvement	8201 and 8567
7	Centre for International Economics (1998)	Reducing fish losses due to epizootic ulcerative syndrome—an ex ante evaluation	9130
8	McKenney, D.W. (1998)	Australian tree species selection in China	8457 and 8848
9	ACIL Consulting (1998)	Sulfur test KCL–40 and growth of the Australian canola industry	8328 and 8804
10	AACM International (1998)	Conservation tillage and controlled traffic	9209
11	Chudleigh, P. (1998)	Post-harvest R&D concerning tropical fruits	8356 and 8844
12	Waterhouse, D., Dillon, B. and Vincent, D. (1999)	Biological control of the banana skipper in Papua New Guinea	8802-C
13	Chudleigh, P. (1999)	Breeding and quality analysis of rapeseed	CS1/1984/069 and CS1/1988/039
14	McLeod, R., Isvilanonda, S. and Wattanutchariya, S. (1999)	Improved drying of high moisture grains	PHT/1983/008, PHT/1986/008 and PHT/1990/008
15	Chudleigh, P. (1999)	Use and management of grain protectants in China and Australia	PHT/1990/035
16	McLeod, R. (2001)	Control of footrot in small ruminants of Nepal	AS2/1991/017 and AS2/1996/021
17	Tisdell, C. and Wilson, C. (2001)	Breeding and feeding pigs in Australia and Vietnam AS2/1994/023	
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