From: Fisher, H. and Gordon, J., *Improved Australian tree species for Vietnam*. ACIAR Impact Assessment Series Report No. 47, July 2007

Improved Australian tree species for Vietnam

IMPACT ASSESSMENT SERIES **47**





Australian Government
Australian Centre for International Agricultural Research

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Improved Australian tree species for Vietnam

Hayden Fisher and Jenny Gordon
Centre for International Economics, Canberra

July 2007

Australian Government
Australian Centre for International Agricultural Research

The Australian Centre for International Agricultural Research (ACIAR) operates as part of Australia's international development cooperation program, with a mission to achieve more-productive and sustainable agricultural systems, for the benefit of developing countries and Australia. It commissions collaborative research between Australian and developing-country researchers in areas where Australia has special research competence. It also administers Australia's contribution to the International Agricultural Research Centres.

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Fisher, H. and Gordon, J., *Improved Australian tree species for Vietnam*. ACIAR Impact Assessment Series Report No. 47, July 2007.

This report may be downloaded and printed from <www.aciar.gov.au>.

ISSN 1832-1879
ISBN 1 86320 544 6 (print)
ISBN 1 86320 545 4 (online)

Editing and design by Clarus Design
Printing by Elect Printing

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Foreword

Australian tree species are being used extensively throughout the world because of their rapid growth and adaptability to many (harsh) environments. While there is often some concern about extensive use of these 'exotic' species, there are many cases where they have resulted in substantial benefits for developing countries and effective replacements for degraded native forests.

From its earliest days, the Australian Centre for International Agricultural Research (ACIAR) has had projects researching the growth of these tree species in various countries and environments.

One important area has been to support the collection of information about the wide range of species available and the diversity of material within individual species. Even where a particular species has been grown for some time, capture of the wide range of genetic material that is available within even individual subspecies can yield substantial improvements in productivity and product quality.

This study looks at the impact on Vietnam of some of these research activities. It shows that, through adaptation, significant improvements in productivity can be achieved by selecting tree provenances that are best suited to specific environments. This is doubly highlighted in the outcomes of the research reported here, which combined optimal provenance selection with the introduction of improved methods of establishing seed-production areas, seedling-seed orchards and clonal-seed orchards.

Very high levels of adoption were found, assisted by new Government of Vietnam licensing of nurseries and certification regulations for seed.

The returns on the research investment are shown to be very high, with estimates of the net present value of benefits of around A$129 million and a benefit:cost ratio of 79:1. These values are consistent with those measured in other countries for this area of forestry research.

Peter Core
Director
ACIAR

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Acknowledgments

The authors thank the researchers involved in the 'Seeds of Australian trees and domestication of Australian trees' projects for their help in preparing this report. Staff in ACIAR's Vietnam office were very helpful in arranging meetings.

The following people were consulted as part of this impact assessment: Mr Stephen Midgley; Dr Chris Harwood; Professor Le Dinh Kha; Dr Ha Huy Thinh; Mr Phi Hai Hong; Dr John Fryer; and Mr Hoang Lien Son and other staff in the Forestry Economic Research Division of the Forest Science Institute of Vietnam.

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

Preface

The ACIAR-funded 'Seeds of Australian trees' (FST/1993/118) and 'Domestication of Australian trees for reforestation and agroforestry systems in developing countries' (FST/1998/096) projects aimed to contribute to the economic, social and environmental wellbeing of people in developing countries by establishing and domesticating Australian tree species.

While these were multi-country research projects, the focus of this report is on their impacts in Vietnam, one of the main beneficiaries of the projects. The impact assessment was undertaken in conjunction with a training program on impact assessment for the Forest Science Institute of Vietnam (FSIV), conducted in March 2007.

Estimating the economic benefits of these projects is a difficult exercise. The 'Seeds of Australian trees' (SAT) and 'Domestication of Australian trees' (DAT) projects affected nearly all aspects of Vietnam's forestry and forest-products industries. It involved research into many species, each of which has multiple end uses. Furthermore, forestry yields are dependent on a variety of location-specific factors such as climate, gradient, and soil quality, as well as the level of silviculture applied and the quality of the genetic material planted. Consequently, forestry yields are highly variable, which is difficult to capture in the context of impact assessment. In the absence of official data, this impact assessment relies on a mix of scientific evidence and the judgments of researchers involved in the project. It therefore provides a broad overview of the possible impacts of the SAT and DAT projects, rather than a micro-level analysis.

The SAT and DAT projects have made an important contribution to a broader effort in the area of forestry research in Vietnam. This broader program has included other projects funded by ACIAR, projects funded by other aid organisations such as the Australian Agency for International Development (AusAID) and the Swedish International Development Agency, and Vietnam's own domestically funded forestry-research program.

A key contribution of the SAT and DAT projects has been the provision of better-quality genetic material and assistance with the establishment of research trials, seed-production areas and seed orchards. The project has also had a significant capacity-building component, in terms of both the skills and knowledge developed by Vietnamese collaborators, and in providing the source material for subsequent research.

Telling the full story of the development of Australian trees in Vietnam and the successful research collaborations between CSIRO and various Vietnamese research institutions is beyond the scope of this report. Our brief is to focus on the incremental impacts of the SAT and DAT projects. The quantitative analysis focuses on the direct economic impacts of the improved genetic material provided and the seed-production areas and seed orchards established under these projects. The importance of the capacity-building aspects is acknowledged in a qualitative sense, but the benefits flowing from the subsequent research using the skills and facilities developed under SAT and DAT are not included in the quantitative analysis. This can be a very important and high-return area of benefit. This has been illustrated and quantified in several recent reports in the Impact Assessment Series (IAS). It is a complex area and, to some extent, the benefits have been captured in a previous IAS report on hybrid acacia in Vietnam (Van Bueren 2004).

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Summary

From 1993 to 1999, ACIAR funded the 'Seeds of Australian trees' (SAT) project in collaboration with CSIRO Forestry and Forest Products. This followed on from a similar project funded by AIDAB (now AusAID) from 1983 to 1992. From 2000 to 2004, the project continued as ACIAR project FST/1998/023, 'Domestication of Australian trees for reforestation and agroforestry systems in developing countries' (DAT). While the projects involved a number of developing countries, this impact assessment focuses on the benefits to Vietnam. The total ACIAR investment in the project amounted to nearly A$6 million, with a further A$3.9 million from CSIRO Forestry and Forest Products in in-kind contributions. It is estimated that around 15%, or about $1.5 million, can be allocated to the research activities in Vietnam; Vietnamese collaborators are estimated to have contributed a further $164,000 to the project.

The principal collaborator in Vietnam was the Forest Science Institute of Vietnam. Under the SAT and DAT projects, a significant quantity of high-quality seed was provided, and advice and assistance were given in establishing research trials. A key contribution was the support provided in establishing seed-production areas, seedling-seed orchards and clonal-seed orchards of various species.

The research has resulted in a greater understanding of the best species and provenances to plant in various conditions. The seed-production areas and seed orchards also provide a sustainable domestic source of improved-quality seed. New regulations introduced by the Ministry of Agriculture and Rural Development (MARD) require that nurseries be licensed and that new plantings use material from certified sources.

The research into tree improvement has resulted in many plantations and farmers planting improved genetic material. This has increased the productivity of forestry plantations, reducing the unit cost of wood production.

It is estimated that the SAT and DAT projects have delivered significant benefits to Vietnam. The internal rate of return on the project is estimated to be around 32%. Assuming a discount rate of 5%, the net present value of the project is around $129 million, implying a benefit:cost ratio of 79:1. Around two-thirds of these benefits are estimated to flow to consumers, through lower prices. The remaining benefits go to those producers who plant better-quality genetic material. Given the new MARD regulations, this will include a large number of smallholder farmers, an outcome that will contribute to higher household incomes. Use of improved genetic material for scattered plantings would deliver additional benefits for rural communities. However, these benefits have not been quantified.

The project shows that research into improving the productivity of forestry plantations can provide a high return on investment, despite the often long lags before the benefits are realised. Improving productivity is likely to be a key to meeting increasing regional demand for forestry products. The SAT and DAT projects also show that introducing new species can provide immediate benefits. However, there are further significant productivity benefits to be gained from ongoing research into the domestication of these species.

Figure 1 summarises the approach taken in the impact assessment.

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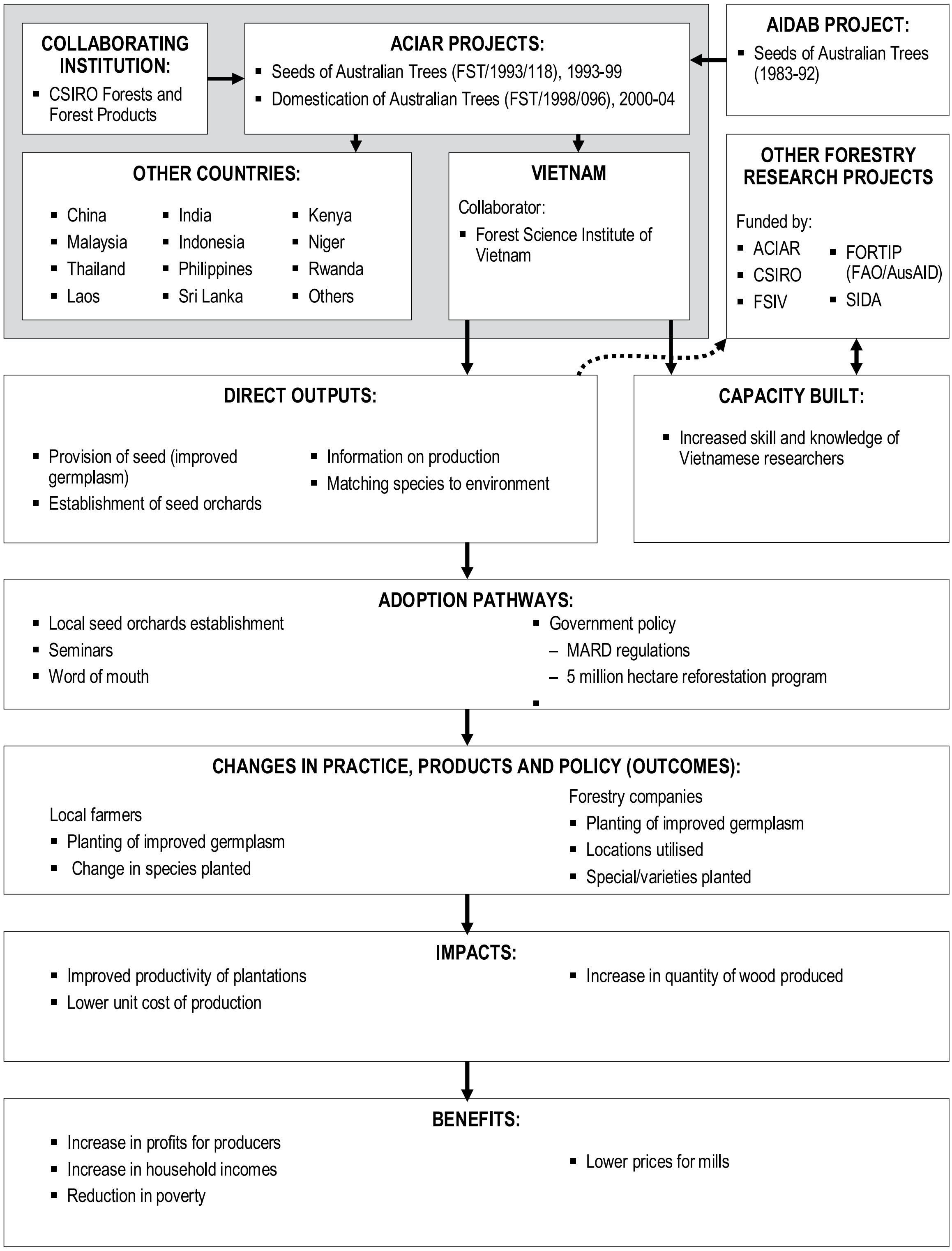

Figure 1. Summary of approach to impact assessment

1 Introduction

Background

Plantation forestry is becoming increasingly important to Vietnam's forestry and forest-products industries. The Government of Vietnam actively promotes the expansion of plantation forests to offset the loss of natural forest cover. Natural forest cover has declined over recent decades as a result of land clearing and over-exploitation for timber and fuelwood (Van Bueren 2004). Timber extraction from many natural forests is now banned (Food and Agriculture Organization of the United Nations website). During the 1990s, the government spent US$213 million protecting existing forests and establishing an estimated 638,000 hectares of plantation forest. The '5 million hectare reforestation program' replaced 'Program 327' in 1998. The program aims to establish 2 million hectares of production forest by 2010.

Australian trees in Vietnam

Australian trees are common plantation species in tropical and subtropical regions, including Vietnam. They are also planted informally on farms, around homesteads, and along canals and roadsides (Harwood 2006). Australian trees are a good alternative to native species because of their adaptability and rapid growth, even on seasonally dry, infertile and degraded sites (Harwood 2006). Australian trees can be used for industrial pulpwood, sawlogs, poles and fuelwood. According to the Ministry of Agriculture and Rural Development (Ha Huy Thinh 2004), Australian trees account for more than half of the total area of forestry plantations in Vietnam (Table 1). In addition, there is an estimated equivalent of 700,000 hectares of scattered plantings.

Domestication of Australian species

Domestication of species can be defined as bringing the wild genetic resources into sustainable cultivation for human use (Harwood 2006). Full tree domestication includes identification and characterisation of germplasm resources; the capture, selection and management of genetic resources; and the regeneration and sustainable cultivation of the species in managed ecosystems (Midgley and Turnbull 2003). In Vietnam, the domestication of Australian trees has been evolving since the introduction of eucalypts in the 1930s. Acacia species were first introduced in the 1960s. The current status of tree domestication programs in Vietnam is shown in Table 2.

Table 2 shows that the domestication process is much further advanced for eucalypt and acacia species than for melaleucas and casuarinas. *Melaleuca* species grow relatively quickly in the acid sulfate soils in the Mekong Delta (CSIRO 1998). However, melaleuca wood has fewer end uses than that from eucalypt and acacia species. It is unsuitable for sawing and has recently been found to be too acidic to make acceptable pulp. This impact assessment therefore focuses on the benefits provided by research into acacias and eucalypts, where most of the research has been directed.

Contribution of ACIAR-funded projects

The original SAT project began in 1983 and was funded by AIDAB (now AusAID), with the intention of facilitating seed distribution to developing countries covered by AIDAB's programs (Drielsma et al. 1997). The first phase of SAT (1983–88) aimed to assist developing countries by providing germplasm and advising on the establishment of research trials to evaluate which species and provenances were most likely to produce the required ecologically sustainable outputs under local conditions.

In the second phase (1988–92), activities were expanded to cover all developing countries, but with a special emphasis on the least-developed ones. There was also a focus on a larger range of end uses of trees, in addition to timber production. While Vietnam did not officially receive Australian aid until 1993, it did receive some Australian seed and assistance via CSIRO's Australian Tree Seed Centre and via international agencies during this earlier period.

Table 1. Plantings of Australian trees in Vietnam, 2001

	Plantations (ha)	Share of plantation estate (%)
Eucalypts	348,000	23.7
Acacias	228,100	15.5
Casuarinas	50,000	7.8
Melaleucas	114,850	3.4
Key Australian species	740,950	50.4
Total plantation	1,471,400	100.0

Source: MARD (2002) referred to in Ha Huy Thinh (2004)

Table 2. Status of tree domestication programs in Vietnam

Activity	*Eucalyptus*	*Acacia*	*Casuarina*	*Melaleuca*
Key species identified for major planting regions	Yes	Yes	Yes	Yes
Superior provenances of key species identified	Yes	Yes	No	Yes
Seed production areas based on best provenances now delivering seed	Yes	Yes	No	Yes
Progeny trials of key species established	Yes	Yes	No	No
Seedling-seed orchards yielding seed	Yes[a]	Yes[a]	No	No
Functioning national or regional tree seed centre	No	No	No	No
Clonal seed orchards based on index-selected material established	Yes	Yes	No	No
Clonal forestry operational with key species	Yes	Yes	No	No
Outgrower schemes for farmers to use clones	No	Yes	No	No
Clonal forestry with interspecific hybrids	No	Yes	No	No
Second generation breeding population (progeny trials)	Yes	No	No	No
Well-documented genetic improvement strategies	Yes[a]	Yes[a]	No	No
Wood quality incorporated into improvement objectives	Yes[a]	Yes[a]	No	No
Controlled pollination used for key species/hybrids	Yes	Yes	No	No
Genetic gain trials testing improved seed/clones established	Yes	Yes	No	No

[a] Impact not yet major
Source: Harwood (2006)

Following the completion of the second phase, the project was continued by ACIAR. During 1993–98, the SAT program was managed as project FST/1993/118, 'Seeds of Australian trees'. The project was subsequently extended to December 1999.

From 2000 to 2004, the program was continued as ACIAR project FST/1998/096, 'Domestication of Australian trees'. It was felt that failure to use the best germplasm, poor species/site/end-use matching and careless use of local land races of poor genetic quality had reduced the benefits that plantings of Australian trees were providing (CSIRO 1998).

This report focuses on the impact the two ACIAR-funded projects had in Vietnam, one of the main beneficiaries from the projects. Domestication of Australian species in Vietnam is an ongoing and evolving process. It has involved collaboration and funding from key forestry research organisations in Vietnam, principally the Forest Science Institute of Vietnam (FSIV), and a number of international aid organisations, including ACIAR, AusAID, the Swedish International Development Agency and the United Nations' Forestry Tree Improvement Program. A key challenge in this impact assessment was to identify the incremental impacts that the ACIAR-funded SAT and DAT projects had in the context of this broader research program. This impact assessment estimates only the *additional* contribution arising from the SAT and DAT projects. It should be noted that this is only a small portion of the total value of the broader research program. Estimating the impact of the whole of what has been a long and highly fruitful collaboration between Australian and Vietnamese researchers is beyond the scope of

Table 3. Project costs (A$, nominal terms)—FST/1993/118 and FST/1998/096

	ACIAR funding	CSIRO funding	Vietnam share[a]	Other funding[b]	Total
Seeds of Australian trees (FST/1993/118)					
1993–94	598,087	315,779	137,080	15,231	152,311
1994–95	600,159	354,693	143,228	15,914	159,142
1995–96	600,531	360,254	144,118	16,013	160,131
1996–97	599,715	364,177	144,584	16,065	160,649
1997–98	599,589	366,476	144,910	16,101	161,011
1998–99	499,973	366,476	129,967	14,441	144,408
1999–2000	210,779	169,772	57,083	6,343	63,425
Subtotal	**3,708,833**	**2,297,626**	**900,969**	**100,108**	**1,001,077**
Domestication of Australian trees (FST/1998/096)					
1999–2000	210,779	169,772	57,083	6,343	63,425
2000–01	452,778	342,299	119,262	13,251	132,513
2001–02	487,188	350,154	125,601	13,956	139,557
2002–03	467,679	358,225	123,886	13,765	137,651
2003–04	481,037	366,672	127,156	14,128	141,285
2004–05	135,600	–	20,340	2,260	22,600
Subtotal	**2,235,061**	**1,587,122**	**573,327**	**63,703**	**637,031**
Total	**5,943,894**	**3,884,748**	**1,474,296**	**163,811**	**1,638,107**

[a] Assuming that 15% of the total budget was spent on Vietnam

[b] It is estimated that the contribution of Vietnam to the project was around 10% of the total budget.

Sources: 'Seeds of Australian trees' project, various six-monthly reports. and FST/1998/096 project budget, parts D and G this report. The contribution this collaboration has made to the Vietnamese forestry industry was recognised by the Government of Vietnam when the key Australian researchers (who were also involved in the SAT and DAT projects)—Mr Stephen Midgley, Dr Chris Harwood and Mr Khongsak Pinyopusarerk—were presented with medals in 1996.

Objectives of the ACIAR projects

According to project documents, the objectives of the SAT project were:

- provision of certified seed of proven and promising Australian species
- provision of up-to-date information on selection, improvement, silviculture, utilisation and management
- provision of training courses for knowledge and technology transfer to recipients.

The aim of DAT was to support more effective domestication and use of Australian tree species in the poorer developing countries, targeting South-East Asia, south Asia, China and certain African countries.

Approach to the research

CSIRO Forestry and Forest Products was commissioned to undertake the research in collaboration with various scientists from forestry organisations in developing countries. The principal collaborator in Vietnam was the Research Centre for Forest Tree Improvement of the FSIV.

Costs of the research

ACIAR's total contribution to the two projects amounted to nearly A$6 million, with a further A$3.9 million provided by CSIRO in in-kind contributions. Since only the benefits accruing to Vietnam are considered for the purposes of this report, only that portion of the total cost that relates to Vietnam should be included on the cost side of the analysis. Therefore, a proportion of the total funding provided by ACIAR and CSIRO needs to be allocated to Vietnam. Researchers estimate that 10–20% of the total budget was spent on Vietnam. Allocating 15% of the total cost of the project to Vietnam—the mid-point of this estimated range—would seem reasonable. This is broadly consistent with the share of total seed provided to Vietnam under the projects. In addition to the contributions of ACIAR and CSIRO, it is estimated that Vietnamese collaborators contributed approximately 10% of the total funding for the project in Vietnam. The estimated nominal project costs are shown in Table 3.

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2 Research outputs and adoption

Research outputs

The SAT and DAT projects made a significant contribution to a number of important outputs.

- The information provided through requests and the research trials established under the SAT and DAT projects significantly increased the knowledge of the best species and provenances to plant in particular environments. Information was also provided on silviculture, utilisation and management of Australian trees.
- The seed provided to Vietnam under the projects widened the genetic base of Australian trees in the country. Inbreeding had been a major cause of productivity decline in Australian trees species in many developing countries.
- The SAT and DAT projects assisted with the establishment of seed-production areas, seedling-seed orchards and clonal-seed orchards. These seed-production areas and seed orchards are providing Vietnam with a domestically produced source of high-quality seed, which is crucial to the sustainability of the productivity improvements achieved.
- Formal training and collaboration with Australian researchers significantly increased the knowledge and skills of Vietnamese researchers.

Seed and information

Providing seed and information to collaborators in developing countries was an important focus of the SAT and DAT projects. Information on selection, improvement, silviculture, utilisation and management of Australian trees, in the form of detailed responses to questions, distribution of scientific and technical papers, and advisory visits, was critical in improving knowledge and establishing successful research trials. A significant quantity of high-quality seed was also provided from the Australian Tree Seed Centre to Vietnamese collaborators, principally to the Research Centre for Forest Tree Improvement. Inbreeding resulting from narrow introduction was a key factor behind the declining productivity of Australian tree species in a number of developing countries. Widening the genetic base was therefore critical. A wider range of provenances was also introduced, resulting in better matching of the best provenances to particular sites.

Seed orchards and seed-production areas

The SAT and DAT projects assisted with the establishment of seed orchards and seed-production areas (SPAs) of various *Acacia*, *Eucalyptus* and *Melaleuca* species. These SPAs and seed orchards have increased the availability of improved genetic material. The SPAs and seed orchards also provide high-quality source material for research and therefore increase the capacity for future research.

A SPA is a plantation raised from a known suitable provenance (or exotic seed source) of a species, selectively thinned and specially managed for seed production (Harwood, no date). Selective thinning removes inferior trees and enables retained superior trees to produce heavy, branching crowns that increase seed production. Under the SAT project, a number of SPAs from a genetic base of identified best natural provenances were established.

A seedling-seed orchard (SSO) is developed by selectively thinning a progeny trial which tests many different families of a species (Harwood n.d.). Inferior trees are removed in two or more selective thinnings. A number of progeny trials and SSOs of all key species were established under SAT and DAT.

In SSOs and SPAs, the best 10% or so of trees are selected to be seed producers (the best 1 in 10 trees are selected). In clonal seed orchards, trees are selected at an intensity of 1 in 100 or 1 in 1,000 trees (Harwood n.d.). This gives more genetic gain than from seedling-seed orchards. A number of genetic-gain trials and clonal-seed orchards (CSOs) were established under DAT. A clonal-seed orchard brings together several genetically identical individual trees (ramets) from each of 15 or more selected superior clones. The seed-production areas and seed orchards established under SAT and DAT are shown in Table 4.

Training

Capacity building was a major focus of the SAT and DAT projects. From project documentation, it was estimated that around 20% of the projects' total budget was spent on formal training. In addition to formal training, capacity was also built through learning by doing, in the course of collaboration with CSIRO scientists. Formal training was provided to Vietnamese collaborators, as follows:

- Mr Phi Quang Dien, from the Research Centre for Forest Tree Improvement, undertook a professional attachment with the Queensland Forest Research Institute for one month. He learned about practical control-pollination in *Pinus caribea*. These techniques are applicable to indigenous pines in Vietnam.
- Mr Ha Huy Thinh and Mr Luu Bu Thinh successfully completed a seven-week training course in tree-seed technology and seed-orchard management. The course incorporated seed testing, storage and collection.
- A short course in experimental design and analysis was conducted at the Research Centre for Tree Improvement in July 1994.
- A paper entitled 'Genetic improvement of *Acacia* and *Eucalyptus* in Vietnam' was delivered to the Project Technical Workshop, Forest-Based Development of the Long Xuyen Quadrangle, held on 3–5 August 1995.
- SAT contributed A$30,000 towards the cost of a conference on 'Tree improvement for sustainable tropical forestry'. The conference was attended by Dr Nguyen Nghia and Dr Hoang Chuong from Vietnam.

Table 4. Areas (ha) of seed production areas and seed orchards established under the 'Seeds of Australian trees' and 'Domestication of Australian trees' projects

	Seed-production areas	Seedling-seed orchards[a]	Clonal-seed orchards
Acacia auriculiformis	5.0	3.0	4.0
A. mangium	9.0	3.0	3.0
A. crassicarpa	2.0	9.0	–
Eucalyptus urophylla	6.0	6.0	
E. camaldulensis	–	–	3.5
E. tereticornis	–	6.0	–
E. pellitta	–	4.0	–
Melaleuca leucadendra	–	2.0	–
M. cajuputi	–	1.2	–
M. viridiflora	–	7.0	–

[a] Excludes the seedling-seed orchard established in Chon Thanh in 1996, which was subsequently cleared in 2001, due to industrial rezoning.

Source: Ha Huy Thinh (2004)

- A 6-day training course on seed technology was given in Vietnam. The emphasis was on developing competency in analysing assessment data from progeny trials and seed orchards, and using the information to successfully develop seed production in seed orchards and selection of superior trees. The course was attended by 17 Vietnamese participants from 6 forestry organisations.
- Mr Nguyen Viet Cuong from the FSIV undertook a professional attachment with the isozyme laboratory at the Australian Tree Seed Centre for 6 weeks. His attachment focused on learning techniques and analysis that can be applied to his work in Vietnam.
- Six-week professional training attachment of Mr Phi Hai Hong and Mr Nguyen Tranh from the Research Centre for Forest Tree Improvement. Analysed growth data from progeny trials, which will be used for the development of these trials into seedling-seed orchards.
- Mr Tran Duc Vuong from the Research Centre for Forest Tree Improvement received 4 weeks of training in starch-gel electrophoresis.
- A training course on seed-orchard management, safe seed collection and processing was conducted in Vietnam in April 2004. There were 11 Vietnamese participants.

The extensive formal training provided under SAT and DAT demonstrates the significant capacity-building aspects of the project. Utilisation of this capacity is likely to provide significant future benefits as the domestication process continues. However, formally estimating the capacity-building impacts requires mapping these skills to how they have been, and will be, utilised and the consequent research outputs and their impacts. To some degree, the project drew on the skills developed in previous research projects to enhance the effectiveness of the research and technology transfer that is assessed in this report.

Adoption

Applicability of the research

There is significant demand for unprocessed wood from pulp and saw mills in Vietnam. The paper industry remains protected by tariffs on many products, resulting in strong demand for domestically produced pulpwood. Vietnam's burgeoning furniture export industry underpins demand for solid wood products.

The productivity of Vietnamese plantations tends to be relatively low, owing to climatic conditions and because many plantations are established on land of steeper gradient that is unsuitable for rice or other higher-value use. Furthermore, inbreeding has caused a deterioration of the genetic quality in many unmanaged land races of key Australian species (Harwood 2006). This has resulted in declines in productivity of plantations based on informally collected seed. Research that improves the productivity of plantations is therefore highly applicable in Vietnam. As the research covered a broad range of species, suitable for a variety of environments, it is relevant throughout the country. Improving the productivity of forestry plantations is a key to meeting growing demand for forest products in Vietnam and the region more broadly.

Pathways to adoption

For the SAT and DAT projects to deliver economic benefits, improved genetic material must be planted by final users. In March 1999, a 2-week study of tree-seed supply and management systems in Vietnam was undertaken with researchers from the FSIV and the Central Forest Seed Company. The study found that there was no clear division of tasks among different stakeholders. Duplication was common. The report recommended that, to enhance the adoption of genetically improved seed and planting material, there was a need to:

- raise awareness of the value of improved material
- quantify the demand and supply of all major plantation species
- identify the best routes for deployment.

The availability of high-quality seed is a key barrier to adoption in many developing countries. Harwood (2006) notes that the availability of improved planting stock has often not kept up with the identification of superior varieties. While Vietnam continues to import high-quality seed from Australia, this can be costly in large quantities and limits adoption, particularly by poor small-scale farmers. Domestic production of improved genetic material is therefore important for lowering costs to maximise adoption and maintain the sustainability of the productivity improvements achieved through the domestication process so far. The SPAs and seed orchards established under SAT and DAT are therefore an important pathway to adoption.

Adoption profile

Adoption of improved genetic material has also been supported by government policy. In 2004, new regulations were introduced, preventing farmers from planting genetic material that has not been approved by MARD. This is expected to ensure high rates of adoption, even among smallholder farmers. The timing of the Government of Vietnam's five million hectare reforestation program was ideal for adoption of these superior Australian species rather than other species in the expansion of plantations and farm trees.

Plantings of improved genetic material are estimated to be already quite extensive. Due to unfortunate circumstances, specific data on plantings of each variety were not available, although some of these data have been collected for some areas. The adoption profile presented here is based on a variety of factors, including the observations of researchers and the principle that, since only a proportion of the plantations are harvested in any given year, adoption must occur gradually.

It should also be noted that while adoption refers to planting of improved genetic material, the benefits from adoption are not realised until harvest. Consequently, there is a significant lag between adoption and the flow of benefits. The benefits profile presented in Chapter 4 has therefore been lagged a full rotation from the adoption profile shown below.

Acacia adoption profile

The main acacia species in Vietnam are *Acacia auriculiformis*, *A. mangium,* a hybrid of those two species and, to a lesser extent, *A. crassicarpa*. *Acacia auriculiformis* is a major species in central and southern Vietnam, but it grows too slowly in the north to be a viable plantation species (Harwood et al 2006). *Acacia mangium* is grown largely in the north.

It is estimated that there are between 300,000 and 400,000 hectares of acacia plantations in Vietnam (Midgley 2006). Plantings of the acacia hybrid species have increased rapidly since its release in 1996 (Van Bueren 2004). The hybrid species is estimated to account for around 60% of total acacia plantings. Since the research into the hybrid species was not funded under the SAT and DAT projects, it is not appropriate to include the benefits of the acacia hybrid in an assessment of the SAT and DAT projects. An impact assessment of ACIAR's contribution to the research into the acacia hybrid has already been undertaken (Van Bueren 2004). ACIAR's contribution to the project was found to have brought forward the introduction of acacia hybrids by 4 years. The net present value of those benefits was estimated to be $152 million.

The SAT and DAT projects have, however, provided source material for the hybrid species. They have therefore made some contribution to improving the productivity of the hybrid species. Plantings of the hybrid species are therefore reflected in the adoption profile as plantings of improved provenances, since that is the contribution made by the SAT and DAT projects towards improvement in the hybrid species. The benefits measured are those that would have arisen if the improved material had not in turn been replaced by the even better hybrids.

Van Bueren (2004) assumed that the hybrids will completely replace the traditional acacia species once hybrid seedlings (grown from cuttings) become widely available. Yet there are still significant plantings of traditional acacia species throughout Vietnam. It is estimated that *A. mangium* makes up around 15–20% of total acacia plantations, *A. auriculiformis* around 10–15% and *A. crassicarpa* around 10%. There is emerging evidence suggesting that traditional acacia species continue to have a future in Vietnam. Recent genetic-gain trials have found that improved quality *A. mangium* outperformed the hybrid species in some conditions. In these trials, the hybrid species showed signs of nutrient deficiency that was not present in the *Acacia mangium* (Harwood et al. 2007). Recent surveys also found that, in some conditions, the acacia hybrid is vulnerable to insects, is easily broken in half at age four to five and is empty at the core (Nguyen Nghia Bien et al. 2006). Also, some sawmills prefer to saw *A. auriculiformis* because it is denser and has a more attractive grain for furniture making (Harwood et al. 2006). All this suggests that the acacia hybrid is unlikely to completely replace traditional acacia species. It is therefore assumed that the share of each species in total acacia plantings will remain broadly constant in the future.

According to Harwood et al. (2006), use of elite seed from SPAs or seed orchards is the recommended method of mass propagation for *A. mangium* and *A. crassicarpa*. This is reflected in the adoption profile for acacias shown in Figure 2. Mass clonal propagation is recommended for *A. auriculiformis*. However, according to the DAT review report (Davidson and Huoran Wang 2004), the project did not play a major role in the development of clonal forestry. These benefits cannot therefore be attributed to DAT. In the adoption profile (Figure 2), it is assumed that plantings of *A. auriculiformis* are propagated from seed from SPAs and seed orchards, the approach recommended by Harwood et al. (2006) where clonal propagation is not available. Plantings of unimproved germplasm are phased out shortly after the implementation of the MARD regulations requiring that nurseries sell only seedlings from improved genetic material.

Eucalyptus adoption profile

It is estimated that 60% of eucalypt plantings are hybrids propagated from selected clones. According to the DAT project review (Davidson and Huoran Wang 2004), DAT did not make a major contribution to this outcome. Nevertheless, the research trials conducted under SAT and DAT would have played a significant role in the selection of the best clones. The development of clones can therefore be considered an incremental improvement on the research undertaken as part of SAT and DAT. Under these circumstances, it is not appropriate to treat this as disadoption of DAT technology.

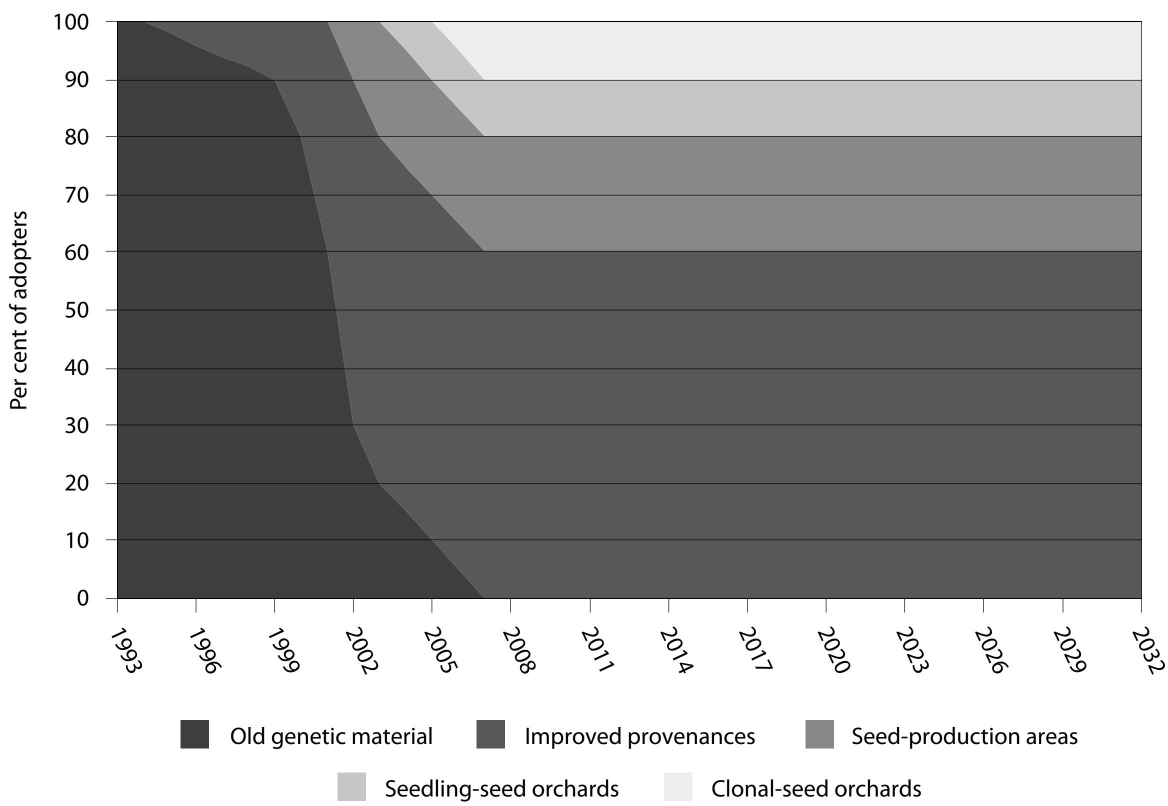

Figure 2. Acacia adoption profile. Source: Centre for International Economics' estimates

Consequently, the clones are assumed to be improved provenances under the adoption profile shown in Figure 3. The incremental improvements attributable to the SAT and DAT research are therefore captured by this impact assessment, but not the subsequent improvements.

Of the traditional eucalyptus species, it is estimated that *E. urophylla* accounts for around 20% of total eucalyptus plantations, *E. camaldulensis* around 10%, *E. tereticornis* around 5% and other eucalypt species the remaining 5%.

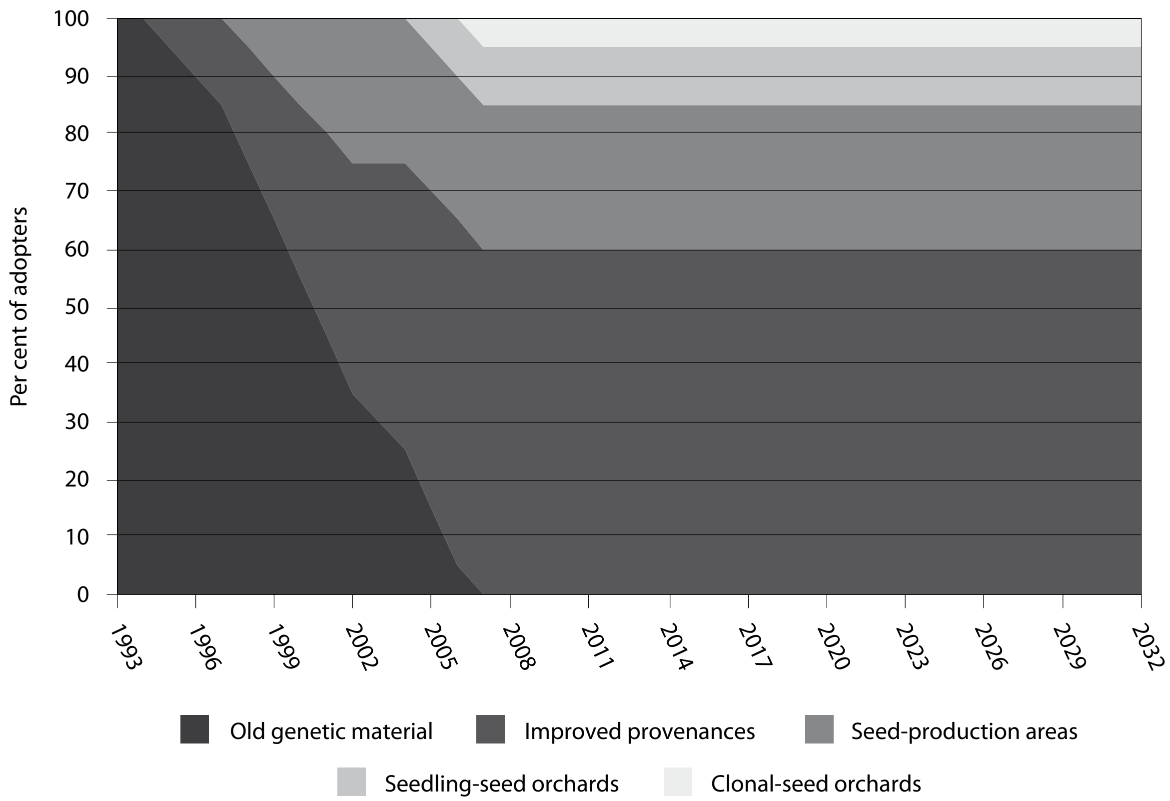

Figure 3. Eucalypt adoption profile. Source: Centre for International Economics' estimates

3 Research outcomes

Changes in practice, products or policy

As a direct result of the SAT and DAT projects, plantations and farmers in Vietnam are now planting improved genetic material. This has enhanced the productivity of plantation forests and therefore reduced the unit cost of wood production.

Another key change directly attributable to the SAT and DAT projects is the improved seed-production practices within Vietnam. Previously, unmanaged seed production resulted in a deterioration of the genetic stock. Improved seed-production practices and a broader genetic base provided by the projects should ensure the sustainability of the productivity improvements.

Wood yields

Wood yields vary widely and depend on many factors, including the quality of seed, location, climatic conditions and the extent of silviculture. Annual increments for acacia and eucalypt species can vary between 5 and 40 m^3/ha/year. Fully capturing these variations would involve analysing each individual farm. This is clearly not feasible, so some averaging is required to make the task manageable. A key distinction is between acacias and eucalypts. Although performance varies between species, within each genus the variation is less significant when the most appropriate species is matched to each site. Disaggregation by end use captures the effect of different rotation lengths. While acacia and eucalyptus wood has many more end uses than as just sawlogs and pulp wood, this disaggregation at least captures the distinction between the shorter and longer rotation lengths. On average, it is estimated that acacia plantations are on 7-year rotations for pulpwood and 10-year rotations for sawlogs. This is broadly consistent with the estimates of Midgley (2006).

As formal data are not available, the wood yield estimates shown in Tables 5 and 6 are based on estimates of productivity improvements likely to be achieved from using the higher-quality genetic material.

Eucalypts tend to be on longer rotations and grow at a slightly slower rate. It is estimated that eucalypt plantations are on 9-year rotations for pulpwood and 12-year rotations for sawlogs. The main traditional eucalypt species grown in Vietnam are *E. urophylla*, grown mainly in the north and *E. camaldulensis*, grown mainly in the south. *Eucalyptus pellita* is a minor species, but its plantings are increasing in area.

Production costs

The costs involved in establishing and maintaining a forestry plantation can also vary widely depending on many site-specific factors. The plantation costs shown in Table 7 are based on a plantation in the north of Vietnam. Plantation costs tend to be slightly lower in southern areas, where conditions are more conducive to plantation forestry. Nevertheless, the northern costs will form the basis of the analysis. It should be noted that harvesting and transport costs are excluded. Many farmers sell their trees standing to traders who bear the harvesting and transportation costs. The per hectare cost of establishing and maintaining acacia and eucalypt plantations is broadly similar. Most costs are independent of the quality of the material planted. The key difference is the cost of the material itself. Higher-quality genetic material generally sells for a higher price and this is reflected in the cost estimates presented in Table 7.

Unit cost of acacia-wood production

The nominal production costs for each hectare over a rotation increase slightly for higher-quality seedlings (Table 8). This is a direct result of the higher costs of the improved seedlings. However, the nominal production costs per cubic metre of production fall, as the productivity improvements more than offset the higher production costs.

Table 5. Acacia wood yields

	Mean annual increment[a] (m^3/ha/year)	Yield at harvest pulpwood[b] (m^3/ha)	Yield at harvest sawlogs[c] (m^3/ha)
Unimproved germplasm	8.0	56	80
Identified provenances (+10%)	8.8	62	88
Seed from seed-production areas (+12%)	9.0	63	90
Seed from seedling-seed orchards (+15%)	9.2	64	92
Seed from clonal-seed orchards (+20%)	9.6	67	96
Clone (+25%)	10.0	70	100

[a] As growth rates through time are not linear, the mean annual increment is likely to vary with rotation length. However, for this exercise it is assumed to be the same.
[b] The average rotation for pulpwood is assumed to be 7 years.
[c] The average rotation for sawlogs is assumed to be 10 years.
Source: Centre for International Economics' estimates based on consultation with researchers

Table 6. Eucalyptus wood yields

	Mean annual increment[a] (m^3/ha/year)	Yield at harvest pulpwood[b] (m^3/ha)	Yield at harvest sawlogs[c] (m^3/ha)
Unimproved germplasm	7.0	63	84
Identified provenances (+10%)	7.7	69	92
Seed from seed-production areas (+12%)	7.8	71	94
Seed from seedling-seed orchards (+15%)	8.1	72	97
Seed from clonal-seed orchards (+20%)	8.4	76	101
Clone (+25%)	8.8	79	105

[a] As growth rates through time are not linear, the mean annual increment is likely to vary with rotation length. However, for this exercise it is assumed to be the same.
[b] The average rotation for pulpwood is assumed to be 9 years.
[c] The average rotation for sawlogs is assumed to be 12 years.
Source: Centre for International Economics' estimates based on consultation with researchers

Nominal production costs over the rotation are, nevertheless, not the most appropriate measure of the cost of production. This is because forestry involves multiple year rotations, so the benefits are received several years after most of the costs have been incurred. The time value of money must therefore be taken into account.

Assuming a cost of capital of 10%, the future value of the costs at harvest is significantly higher than the nominal costs over the rotation. Importantly, however, the unit cost of production still falls as productivity improves.

Table 7. Plantation costs ('000 VND[a]/ha)

	Old genetic material	Identified provenance	Seed production areas	Seedling-seed orchards	Clonal seed orchard	Clone
First-year costs						
Labour[b]	3,750	3,750	3,750	3,750	3,750	3,750
Seedlings	320	320	370	400	450	500
Transport of seedlings	25	25	25	25	25	25
Fertiliser	750	750	750	750	750	750
Technical advice	200	200	200	200	200	200
Management	600	600	600	600	600	600
Total first-year costs	**5,645**	**5,645**	**5,695**	**5,725**	**5,775**	**5,825**
Second-year costs						
Labour[c]	1,500	1,500	1,500	1,500	1,500	1,500
Technical advice	400	400	400	400	400	400
Management	250	250	250	250	250	250
Total second-year costs	**2,150**	**2,150**	**2,150**	**2,150**	**2,150**	**2,150**
Third-year costs						
Labour[d]	600	600	600	600	600	600
Technical advice	400	400	400	400	400	400
Management	120	120	120	120	120	120
Total third-year costs	**1,120**	**1,120**	**1,120**	**1,120**	**1,120**	**1,120**
Fourth (and later) year costs						
Labour	500	500	500	500	500	500
Fourth (and later) year costs	**500**	**500**	**500**	**500**	**500**	**500**

[a] Vietnam dong

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

[c] This 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 time involves only grass cutting.

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

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

Unit cost of eucalypt-wood production

Production costs for eucalypt wood (Table 9) are slightly higher than those for acacias, owing to the longer rotation length. However, as with acacias, the unit cost of production falls with higher-quality seed.

What would happen in the absence of the research?

The benefits from the adoption of the research outputs depend on what would have happened in the absence of these research projects. Most of the main Australian species were already widely grown in Vietnam before the SAT and DAT projects. The counterfactual scenario is assumed to be that these trees would continue to have been grown with the low rates of productivity. While scientific research into tree improvement was already occurring, a key contribution of SAT and DAT was the provision of improved genetic material. It is unlikely that research would have yielded significant benefits using inferior genetic material. Indeed, inbreeding is likely to have resulted in further degradation of the genetic base.

It is important to emphasise that this report is not assessing the impact of Australian trees in Vietnam per se. Rather, it is assessing the incremental improvements in productivity that directly resulted from the SAT and DAT projects.

In measuring the reduction in the unit cost of production from planting better-quality genetic material, it must be compared to the counterfactual scenario; that is, the unit cost of production using unimproved genetic material (Table 10).

Table 8. Acacia-wood production costs

	Nominal production costs over rotation VND[b] ('000)/ha	Nominal unit cost of production VND/m^3	Future value of costs at harvest[a] VND ('000)/ha	Future value of costs per unit [a] VND/m^3
Pulpwood				
Unimproved genetic material	10,915	194,911	17,423	311,131
Identified provenances	10,915	177,192	17,423	282,847
Seed from seed-production areas (SPAs)	10,965	174,825	17,512	279,208
Seed from seedling-seed orchards (SSOs)	10,995	170,730	17,565	272,750
Seed from clonal-seed orchards (CSOs)	11,045	164,360	17,654	262,703
Clone	11,095	158,500	17,742	253,460
Sawlogs				
Unimproved genetic material	11,815	147,688	23,431	292,884
Identified provenances	11,815	134,261	23,431	266,258
Seed from SPAs	11,865	132,422	23,549	262,819
Seed from SSOs	11,895	129,293	23,619	256,732
Seed from CSOs	11,945	124,427	23,737	247,263
Clone	11,995	119,950	23,855	238,551

[a] Assuming the cost of capital is 10%
[b] VND = Vietnam dong
Source: Centre for International Economics' estimates based on consultation with researchers

Table 9. Eucalypt-wood production costs

	Nominal production costs over rotation VND[b] ('000)/ha	Nominal unit cost of production VND/m^3	Future value of costs at harvest[a] VND ('000)/ha	Future value of costs per unit[a] VND/m^3
Pulpwood				
Unimproved genetic material	11,915	189,127	22,132	351,306
Identified provenances	11,915	171,934	22,132	319,369
Seed from seed-production areas (SPAs)	11,965	169,572	22,239	315,185
Seed from seedling-seed orchards (SSOs)	11,995	165,562	22,304	307,850
Seed from clonal-seed orchards (CSOs)	12,045	159,325	22,411	296,441
Clone	12,095	153,587	22,518	285,944
Sawlogs				
Unimproved genetic material	13,415	159,702	31,113	370,393
Identified provenances	13,415	145,184	31,113	336,721
Seed from SPAs	13,465	143,123	31,256	332,225
Seed from SSOs	13,495	139,700	31,341	324,444
Seed from CSOs	13,545	134,375	31,484	312,341
Clone	13,595	129,476	31,627	301,206

[a] Assuming the cost of capital is 10%
[b] VND = Vietnam dong
Source: Centre for International Economics' estimates based on consultation with researchers

Table 10. Reduction in unit cost (in Vietnam dong/m^3) of production

	Acacia pulpwood	Acacia sawlogs	Eucalypt pulpwood	Eucalypt sawlogs
Unimproved genetic material	–	–	–	–
Identified provenances	28,285	26,626	31,937	33,672
Seed from seed-production areas	31,923	30,065	36,121	38,169
Seed from seedling-seed orchards	38,382	36,152	43,456	45,949
Seed from clonal-seed orchards	48,428	45,621	54,865	58,053
Clone	57,671	54,332	65,361	69,188

Source: Centre for International Economics' estimates

4 Impact assessment

Benefits from the research

This impact assessment focuses on the economic benefits that flow from more productive forestry plantations. More productive plantation forests reduce the unit cost of production, which can benefit both plantations and tree farmers, firms further down the value chain 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 forestry products are tradeable, it is appropriate to model the market for unprocessed pulpwood and sawlogs as a closed market, as high transport costs, in most areas, effectively exclude competition from imports. In areas near to ports there is considerable competition from imports and a significant quantity of sawlogs and sawn wood is imported into Vietnam (Midgley 2006), to meet demand from Vietnam's burgeoning furniture export industry. This is, however, a relatively small share of the total harvest and, for the domestic producers who compete with imports, their fall in unit costs translates into higher profits and not lower prices as elsewhere in the country.

Using a standard static supply and demand model, the productivity improvements resulting from the research can be represented as a downward shift in the supply curve (Figure 4). The downward shift in the supply curve 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 $(b+c+d)$ 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:

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

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.

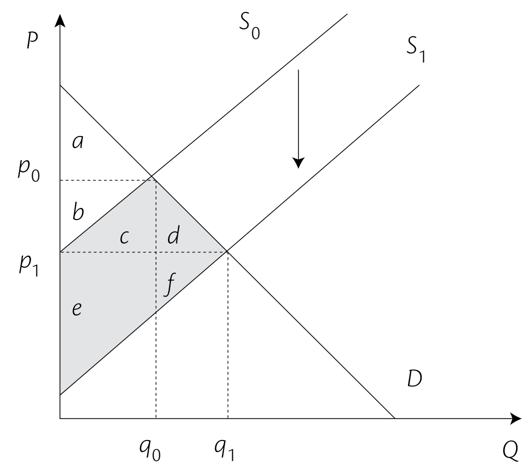

Figure 4. Change in economic surplus

The change in consumer surplus is given by:

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

where

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

Therefore, the change in producer surplus is given by:

$\Delta PS = \Delta ES - \Delta CS$

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 11.
It is estimated that around 70% of acacias are used for pulp and around 30% for sawlogs. As eucalypts are less suitable for sawing, around 85% is estimated to be used for pulp and only 15% for sawlogs. An estimate of the area harvested annually can be obtained by dividing by the average rotation length; this assumes that plantings are staggered evenly, so that an even quantity is harvested every year.

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 wood in Vietnam is unknown. The global forest products model (GFPM; 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 that has few alternative uses.

To encourage customers to purchase the additional wood produced, producers must 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 the midpoint of this range of –0.4, implies that demand is relatively inelastic. Again, this is a reasonable assumption, given that wood has few close substitutes available in Vietnam for most end uses. Furthermore, high transport costs mean 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 $(d+f)$ 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.

Table 11. Estimated annual harvest

	Estimated plantings (ha)	Average rotation length (years)	Area harvested annually (ha)	Estimated annual harvest (m^3)
Acacias				
Pulp (70%)	245,000	7	35,000	2,205,000
Sawlogs (30%)	105,000	10	10,500	882,000
Total[a]	350,000			
Eucalypts				
Pulp (85%)	295,800	9	32,867	2,070,600
Sawlogs (15%)	52,200	12	4,350	365,400
Total[b]	348,000			

[a] From Midgley (2006)
[b] From MARD (2002), referred to in Ha Huy Thinh (2004)
Source: Centre for International Economics' estimates

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.

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

Environmental benefits

A range of environmental benefits result from planting Australian trees on degraded land. These include: salvage of waterlogged land, less soil erosion, protection of crops and livestock from wind, and providing a nurse crop that allows for the regeneration of native vegetation (CSIRO 1998). Furthermore, more productive plantation forests reduce the reliance on native forests.

Box 1. Major assumptions used in modelling

This box outlines the major assumptions used in modelling the costs and benefits attributable to the SAT and DAT projects.

- 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.

Since Australian trees were introduced to Vietnam well before the SAT and DAT projects were established, these environmental benefits cannot be attributed to these projects. Nor can the reduced exploitation of native forests, since harvesting of many native forests is now banned. It is also not clear that improved genetic material enhances the environmental benefits of planting Australian trees on degraded lands. Consequently, for the purposes of this impact assessment, it is assumed that the improved genetic material brought no significant environmental benefits.

Social benefits

Boosting incomes is the key to lifting rural communities out of poverty. This can be considered a social benefit, over and above the increase in incomes measured as an economic benefit. The highly aggregated nature of this study makes it difficult to assess the overall impacts on poverty reduction, but they are likely to be substantial. The new regulations should help to ensure that the benefits of improved-quality seed reach small-scale farmers. However, it should be noted that adoption amongst small farmers is likely to be slower than for the larger plantations. In these circumstances, non-adopters lose if the reduced production costs of adopters flow through to lower prices.

An important social benefit is the potential for improved-quality seed to increase the productivity of scattered plantings. Scattered plantings provide most of the fuelwood for rural communities (Le Dinh Kha et al. 2003) and can also be used for poles for construction. It is estimated that, in addition to formal plantations, there are 700,000 hectares of informal plantings of Australian tree species (Ha Huy Thinh 2004).

There could be significant benefits for rural communities from planting improved quality seed. However, it is difficult to quantify the benefits, partly because the final products are sometimes used for the growers' own use. Consequently, these potential benefits have not been quantified in this impact assessment.

Benefit estimates

The estimated benefits from the ACIAR-funded research over the 40-year period from 1993 to 2032 are shown in Table 12. 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 rate from the 'World economic outlook' database of the International Monetary Fund (IMF). The future exchange rate is assumed to remain constant at 12,825 Vietnamese dong per Australian dollar, as per the IMF's 2007 forecast. The last column in Table 12 shows the present value of the future benefits, discounted at an annual rate of 5%.

Benefit–cost and the rate of return

Research costs

In Table 3, the project budget was presented in terms of Australian financial years (1 July – 30 June). In Table 13, these are converted to calendar years by assuming that funds were spent evenly throughout the year. The nominal research costs are then converted to real 2006 dollars using the Australian GDP deflator, obtained from the IMF database. Finally, the present value is calculated assuming a discount rate of 5%.

Results

Owing to the lack of quality data and the complexity of the project, there is significant uncertainty surrounding the estimates. Nevertheless, it is highly likely that the SAT and DAT projects generated significant benefits for Vietnam (Table 14). The internal rate of return on the project is around 32%. Assuming a 5% discount rate, the net present value of the benefits flowing from the projects is around $128.7 million, while the benefit:cost ratio is around 79:1. The net present value and benefit:cost ratio are highly sensitive to the chosen discount rate because of the long lag before the benefits are realised. This is largely due to the nature of forestry.

Sensitivity of estimates

The results presented in Table 14 are dependent on the many assumptions that have been made. In this section, we vary some of these key parameters and examine the impact on the estimated benefit:cost ratio, assuming a 5% discount rate.

Table 15 shows that the benefit:cost ratios on the SAT and DAT projects are relatively insensitive to the assumption on the share of wood used for pulp and sawlogs or on the elasticity of supply and demand. The estimates are a little more sensitive to the assumption about average rotation length and mean annual increment over the rotation, and are relatively sensitive to the estimates relating to the improvements in productivity that can be expected from using higher-quality seed, the cost of capital and the allocation of research costs to Vietnam. Nevertheless, so long as the assumptions used are reasonable, the broad conclusion is unchanged: the project produced significant benefits for Vietnam.

The benefit:cost ratio is also sensitive to the adoption profile. Due to the lack of data and because many of the benefits from the project will accrue in the future, this is an area of significant uncertainty.

To examine the sensitivity of the adoption profile, and to explore the benefits associated with full adoption, the benefit:cost ratios for various full adoption scenarios are calculated (Table 16). First, we assume that all plantings from 2000 onwards use improved genetic material. The second scenario implies 100% of plantings from 2005 onwards use improved material. The table shows the benefit:cost ratio is sensitive to the timing of adoption, owing to the discounting process. This highlights the importance of early adoption. Nevertheless, the broad picture remains that the project has delivered significant benefits to Vietnam under all reasonable adoption scenarios.

Distributional implications

Impact on poverty

A key advantage of the economic surplus methodology is that it allows us to determine the likely distribution of benefits between producers and consumers. Referring again to Figure 4, the increase in consumer surplus is given by area $(b + c + d)$, while the increase in producers surplus is given by area $(f + g - b)$. Given the assumptions made about the elasticities of supply and demand, around two-thirds of the benefits are estimated to be captured by consumers and the remaining third by producers. The exception to this split is in the areas where there is import competition (where the furniture producers target the export market). In these areas the benefits will largely be captured by the wood producers.

Table 12. Benefits from ACIAR-funded research on improved Australian tree species for Vietnam

	Acacias VND[b] million	Eucalypts VND million	Total VND million	Total A$'000	Present value[a] A$'000
1993	–	–	–	–	–
1994	–	–	–	–	–
1995	–	–	–	–	–
1996	–	–	–	–	–
1997	–	–	–	–	–
1998	–	–	–	–	–
1999	–	–	–	–	–
2000	–	–	–	–	–
2001	–	–	–	–	–
2002	1,248	–	1,248	150	97
2003	2,495	–	2,495	247	151
2004	3,743	3,308	7,051	608	355
2005	5,462	6,618	12,079	998	555
2006	7,180	9,930	17,110	1,400	742
2007	13,899	17,611	31,510	2,457	1,241
2008	26,889	25,304	52,193	4,069	1,957
2009	47,008	33,007	80,015	6,239	2,858
2010	56,466	41,420	97,886	7,632	3,330
2011	65,448	49,845	115,293	8,989	3,735
2012	77,102	54,501	131,603	10,261	4,061
2013	85,172	59,161	144,333	11,254	4,241
2014	92,187	68,378	160,565	12,519	4,494
2015	93,790	76,908	170,698	13,309	4,550
2016	95,814	83,293	179,106	13,965	4,547
2017	97,838	84,757	182,595	14,237	4,414
2018	97,838	86,222	184,060	14,351	4,238
2019	97,838	87,291	185,129	14,434	4,060
2020	97,838	87,291	185,129	14,434	3,866
2021	97,838	87,291	185,129	14,434	3,682
2022	97,838	87,291	185,129	14,434	3,507
2023	97,838	87,291	185,129	14,434	3,340
2024	97,838	87,291	185,129	14,434	3,181
2025	97,838	87,291	185,129	14,434	3,029
2026	97,838	87,291	185,129	14,434	2,885
2027	97,838	87,291	185,129	14,434	2,748
2028	97,838	87,291	185,129	14,434	2,617
2029	97,838	87,291	185,129	14,434	2,492
2030	97,838	87,291	185,129	14,434	2,374
2031	97,838	87,291	185,129	14,434	2,261
2032	1,956,770	1,745,816	3,702,586	288,688	43,057

[a] Assumes discount rate of 5%

[b] VND = Vietnam dong

Source: Centre for International Economics' estimates

Note that the analysis does not consider the breakdown between growers, the harvesters and transport industry and the mill. Volume constraints at any point of the value chain tend to result in the agent with the constraint being able to capture a higher share of the benefit while the constraint remains. Given the small scale and highly competitive nature of many of the agents along all points of the value chain, benefits are more likely to be fairly evenly distributed among producers than captured by one point on the value chain.

The SAT and DAT projects are therefore likely to make some contribution to increasing incomes and reducing poverty in rural communities. Where improved genetic material is used for scattered plantings, there is also likely to be benefits for rural communities. However, these benefits have not been quantified. The benefits largely depend on the relative scarcity of wood in these communities for domestic uses. This varies widely across communities, and so benefits would also be highly variable, and greatest where wood was in short supply relative to potential domestic uses.

Table 13. Research costs

	Nominal research costs (A$)	Australian GDP deflator (2006 = 100)	Real research costs[a] (A$ – 2006)	Present value[b] (A$)
1993	76,155	72.6	104,919	104,919
1994	155,726	73.1	212,894	202,756
1995	159,636	74.5	214,325	194,400
1996	160,390	76.0	210,935	182,213
1997	160,830	77.0	208,826	171,802
1998	152,709	77.4	197,238	154,541
1999	135,629	77.8	174,263	130,038
2000	129,682	81.1	159,994	113,705
2001	136,035	84.3	161,435	109,266
2002	138,604	86.4	160,379	103,382
2003	139,468	89.2	156,434	96,037
2004	93,242	92.2	101,184	59,160

[a] Using GDP deflator
[b] Assuming a discount rate of 5%
Sources: ACIAR project documents, Interntional Monetary Fund, Centre for International Economics

Table 14. Summary measures

	Present value of benefits A$m	Present value of costs A$m	Net present value A$m	Benefit:cost ratio	Internal rate of return %
l%	432.4	2.0	430.5	220.6	32.2
5%	128.7	1.6	127.0	79.3	32.2
10%	34.7	1.3	33.4	26.3	32.2

Source: Centre for International Economics' estimates

Table 15. Sensitivity analysis

	Current assumption	Alternative assumption (low)	Alternative assumption (high)	Benefit:cost ratio (low)	Benefit:cost ratio (high)
Share of acacia used for pulpwood	70%	60%	80%	78.2	80.5
Share of eucalypt used for pulpwood	85%	75%	95%	79.0	79.7
Elasticity of demand	–0.4	–0.1	–0.7	79.0	79.5
Elasticity of supply	0.8	0.5	1.1	79.2	79.4
Average rotation for acacia pulp	7	5	9	96.1	71.9
Average rotation for acacia sawlogs	10	8	12	81.7	77.9
Average rotation for eucalyptus pulp	9	7	11	72.5	87.4
Average rotation for eucalyptus sawlogs	12	10	14	77.4	81.2
Mean annual increment for unimproved acacias	8	6	10	93.6	70.7
Mean annual increment for unimproved eucalypts	7	5	9	67.2	91.4
Improvement from improved seed	10–25%	Half	Double	40.8	145.8
Cost of capital	10%	1%	20%	63.1	112.0
Share of project allocated to Vietnam	15%	10%	20%	119.0	59.5

Source: Centre for International Economics' estimates

Table 16. Sensitivity of adoption assumptions

	Adoption from 2000 (%)	Benefit:cost ratio	Adoption from 2005 (%)	Benefit:cost ratio
Unimproved genetic material	–	–	–	–
Identified provenances	100	76.2	100	58.9
Seed from seed-production areas	100	86.2	100	66.6
Seed from seedling-seed orchards	100	103.8	100	80.2
Seed from clonal-seed orchards	100	131.3	100	101.4
Clone	100	156.7	100	121.0

Source: Centre for International Economics' estimates

Lessons

Although the magnitude of the benefits is highly sensitive to various assumptions, it is nevertheless clear that the projects resulted in significant benefits to Vietnam. These benefits were both direct and, in terms of building the capacity of the Vietnamese collaborators, indirect. This suggests that research into improving the productivity of forestry can provide a high return on investment, despite the often long lags between doing the research and the benefits flowing to developing countries. The sensitivity analysis also highlights the importance of ensuring that research outputs are adopted early. The quality of the science does not ensure the success of a project; projects can result in benefits only if the outputs are adopted by final users.

Another important lesson from these projects is that introducing new species can have immediate benefits. However, ongoing research into the domestication of exotic species can improve productivity and increase these benefits significantly.

Attribution of benefits to the SAT and DAT projects was another difficult issue, as these projects were significant contributors to a broader tree-improvement research program. It may be appropriate to undertake a more detailed impact assessment of the broader Australian tree-research program when better quality data become available. Nevertheless, the results are quite plausible. Varying a range of the assumptions does alter the magnitude of the benefits but, under all scenarios examined, the project appears to have delivered significant benefits to Vietnam.

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From: Fisher, H. and Gordon, J., *Improved Australian tree species for Vietnam*.
ACIAR Impact Assessment Series Report No. 47, July 2007

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