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Eucalypt tree improvement in China

IMPACT ASSESSMENT SERIES 30

EUCALYPT TREE IMPROVEMENT IN CHINA

Martin van Bueren
Centre for International Economics
Canberra & Sydney

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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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Foreword

ACIAR's impact assessment reports provide information on project impacts which helps to guide future research activities. While the main focus of these commissioned reports is on measuring the dollar returns to agricultural research, emphasis is also given to analysing the impacts of projects on poverty reduction.

Over the last 20 years ACIAR has funded seven projects related to the development of high-yielding eucalypt plantations in China. In total, about A$12 million has been invested in these projects since 1985, equivalent to A$18.2 million in today's dollars. The ACIAR-funded work has been a catalyst for an active and ongoing eucalypt research program in China.

Today, China boasts a thriving eucalypt plantation industry. The new species and hybrids being planted are achieving average wood yields almost three times that of the traditional species. The development of these high-yielding species coincides with a series of beneficial policy reforms in the forestry sector and a booming domestic economy, which is stimulating strong demand for industrial wood.

The ACIAR-funded projects played a central role in delivering the productivity improvements that now underpin this industry. Furthermore, the development of high-yielding trees has been partly responsible for the rapid expansion in plantation area.

The investments made by ACIAR and its collaborators account for 78% of total research costs, suggesting a significant proportion of the $1.3 billion benefit may be attributable to these projects.

This benefit–cost study estimates the net economic benefits of all seven ACIAR-funded projects as a package. Some of the benefits have already been realised, with up to two rotations of higher-yielding trees having been harvested to date. The benefits are expected to extend into the future as the area of commercial plantations continues to grow and the Chinese make further yield improvements through breeding and better management techniques.

ACIAR's contribution to forestry research in China has been the subject of two previous impact assessments. Since these analyses were conducted, more is known about the adoption of high-yielding eucalypts and the impact that this has had on China's wood industry. The industry has expanded more rapidly than assumed by the previous studies.

This assessment updates the previous evaluations and investigates the impact that plantations have had on reducing poverty.

The report is number 30 in ACIAR's Impact Assessment Series and is also available for free download at <www.aciar.gov.au>.

Peter Core
Director
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Abbreviations

BCR	benefit–cost ratio
CERC	China Eucalypt Research Centre
IRR	internal rate of return
MAI	mean annual increment
MDF	medium-density fibreboard
NPV	net present value
R&D	research and development
RITF	Research Institute of Tropical Forestry
SOFEs	state-owned forest enterprises

Details of projects evaluated

ACIAR projects FST/1990/044 and FST/1994/025	Increasing productivity of eucalypt plantations in China by inoculation with ectomycorrhizas and nutrient application Ectomycorrhizal fungi for eucalypt plantations in China
Collaborating organisations	Australia: CSIRO Forestry and Forest Products (CFFP); Murdoch University (MU) China: Research Institute of Tropical Forestry (RITF); Chinese Academy of Forestry (CAF); Chuxiong District Forest Research Institute (CDFRI); Gaoyao Forest Bureau (GFB); Kunming Institute of Botany (KIB); Xinhui Forest Bureau (XFB) Philippines: University of the Philippines, Los Baños (UPLB)
Project leaders	Dr Nicholas Malajczuk, Mr Michael Brundett (CFFP); Mr Gong Mingqin (CAF); Professor Reynaldo de la Cruz (UPLB)
Linked projects	FST/1987/036, FST/1988/008, FST/1988/009, FST/1988/048
Duration of ACIAR projects	1 January 1991–31 December 1994 1 January 1996–31 December 1999
Total ACIAR funding	A$1,976,003
Project objectives	• To continue work begun in an earlier project • To collect the fungi from under target eucalypt species in Australia, and develop a program for inoculating eucalypt seedlings in nurseries in China • To investigate which nutrient deficiencies most limit the growth of eucalypts in China and devise procedures to correct these deficiencies • To match the fungi to important plantation eucalypts in a range of climatic and soil situations
ACIAR projects FST/1984/057 and FST/1988/048	Introduction and cultivation experiments for Australian broad-leaved tree species
Collaborating organisations	Australia: CFFP China: RITF; CAF; Research Institute of Forestry; Chinese Academy of Forestry (CAFB)
Project leaders	Mr Alan Brown (CFFP); Mr Bai Jiayu (CAF); Mr Wang Huo-ran (CAFB)
Linked project(s)	FST/1983/063, FST/1983/020, FST/1983/057, FST/1984/058, FST/1986/030, FST/1987/036, FST/1988/008, FST/1988/009, FST/1988/049
Duration of project	3 October 1985–1 July 1989 1 July 1989–30 June 1993
Total ACIAR funding	A$1,033,940
Project objective	To continue to explore the potential of Australian trees to fulfil China's forest products needs especially through the introduction of more productive germplasm
ACIAR project FST/1987/036	Increasing productivity of casuarina and eucalyptus plantations in southern China by inoculation with selected symbiotic micro-organisms
Collaborating organisations	Australia: CSIRO Division of Soils (CS) China: RITF; CAF
Project leaders	Dr Paul Reddell (CS); Mr Bai Jiayu (CAF)
Linked project(s)	FST/1984/057, FST/1983/020, FST/1983/031
Duration of project	1 January 1988–31 December 1990
Total ACIAR funding	A$671,649
Project objectives	To select symbiotic micro-organisms for the two genera effective on different soil types To develop appropriate inoculation technologies under a range of environmental conditions and transfer the relevant technology and selected micro-organisms to collaborating scientists in developing countries

ACIAR project FST/1996/125	Development of germplasm and production systems for cold-tolerant eucalypts for use in cool regions of southern China and Australia
Collaborating organisations	Australia: CFFP; Centre for Forest Tree Technology (CFTT); Forestry Tasmania (FT) China: China Eucalypt Research Centre (CERC); Fujian Forestry Department (FFD); Guangxi Forest Research Institute (GFRI); Yunnan Academy of Forestry (YAF)
Project leaders	Dr John Doran (CFFP); Mr Yang Minsheng (CERC)
Linked project(s)	FOG/1989/025, FST/1984/057, FST/1988/048, FST/1990/044, FST/1991/027, FST/1992/027, FST/1993/118, FST/1994/025, FST/1997/077, LWR1/1993/003
Duration of project	1 January 1999–31 December 2004
Total ACIAR funding	A$1,184,385
Project objective	To improve the use of eucalypts in the degraded cool highlands of southern central China by testing provenances and developing suitable seed orchard techniques to help establish more productive local plantations there
ACIAR project FST/1997/077	Eucalypts and groundwater: managing plantations to avoid resource depletion and environmental detriment in China and Australia
Collaborating organisations	Australia: Department of Natural Resources and Environment (DNRE); CSIRO Land and Water (CLW); University of Melbourne (UM) China: RITF; CAF; South China Institute of Botany (SCIB); CERC
Project leaders	Dr Jim Morris (DNRE); Mr Bai Jiayu (CAF)
Linked project(s)	FST/1984/057, FST/1988/048, FST/1990/044, FST/1991/027, FST1992/027, FST/1998/016, FST/1994/025, FST/1995/106, FST/1996/125, LWR21/1992/022, LWR2/1996/216
Duration of project	1 July 1999–30 June 2003
Total ACIAR funding	A$999,235
Project objective	To contribute to the development of optimally productive, sustainable, socially beneficial forest tree plantations in China and Australia.

Summary

Over the past 20 years, ACIAR has funded seven projects on the development of plantations of high-yielding eucalypt (genus *Eucalyptus*) trees in China. These projects have focused on three main areas: genetic improvement; silviculture (with an emphasis on ectomycorrhizas); and investigations of the sustainability of eucalypt plantations. Approximately A$12 million has been invested in these projects since 1985, equivalent to A$18.2 million in today's dollars. The research and development (R&D) was carried out by CSIRO Forestry and Forest Products, the Victorian Department of Sustainability and Environment (formerly the Department of Natural Resources and Environment) and Murdoch University, in collaboration with the Chinese Academy of Forestry. The ACIAR-funded work has been the catalyst for an active and ongoing eucalypt research program in China.

Extensive areas of eucalypts were established in southern China in the 1950s and 1970s using poor, unimproved genetic stock. The plantations were established by state-owned forest farms and little attention was paid to site selection, fertiliser or management. The poor performance of these trees prompted Australian scientists to investigate the potential for introducing better-yielding trees and cultivation techniques. ACIAR's first involvement with China was in 1985, when it funded a project that, over eight years, introduced over 100 eucalypt species for selection trials. This project provided China with a valuable gene base for breeding and selection. Australian scientists helped the Chinese with setting up trials and establishing a breeding plan. Other ACIAR-funded projects have developed cultivation techniques, nutrient guidelines, introduced mycorrhizal fungi for improving tree growth and examined the water requirements of eucalypts.

Today, China boasts a thriving eucalypt plantation industry, with about 1.5 million ha of trees planted to date. This is about double the area of Australia's eucalypt plantations. On average, the new species being planted for commercial production are achieving wood yields of 20 m^3/ha/year, almost three times that of the traditional species. The development of these high-yielding species coincides with a series of beneficial policy reforms in the forestry sector and a booming domestic economy, which is stimulating strong demand for industrial wood. The combination of these factors is encouraging foreign companies to invest in plantations and processing facilities—primarily paper mills and

fibreboard factories. Over the past three years, plantation area has grown, on average, by 88,000 ha each year.

The ACIAR-funded projects played a central role in delivering the productivity improvements that now underpin this industry. Furthermore, the development of high-yielding trees has been partly responsible for prompting the rapid expansion in plantation area. The total research effort in China, including China's own projects, is estimated to generate a net present value (NPV) of A$1.3 billion over a 30-year period (1985 to 2015). Benefits exceed research costs by a ratio of 57 to 1. The research yields an internal rate of return (IRR) of 40%. Sensitivity analysis indicates that NPV returns may range from A$669 million to A$2148 million, reflecting the uncertainty associated with key parameters.

Clearly, not all these benefits are attributable to the ACIAR-funded research. However, the investments made by ACIAR and its collaborators account for 78% of total research costs, suggesting a significant proportion of benefits may be attributable to these projects.

While no hard data are available, the R&D has almost certainly made a considerable contribution to improving the living standards of rural people in southern China. Many households are benefiting directly from the higher yields, and there has been increased adoption of short-rotation eucalypts as a cash crop over the past few years. For others, eucalypts are providing new employment opportunities off-farm. There is no evidence to suggest that households are being displaced from their land or marginalised by plantation companies. Indeed, in some provinces companies are leasing land from households, thus providing an alternative source of income for these households. Furthermore, a proportion of plantation revenue is being redistributed through the tax system to help fund public infrastructure development.

1 Introduction

Eucalypt plantation forestry has become a major economic activity in China's southern provinces. China now boasts a plantation area of almost 1.5 million ha, approximately double the area of Australia's eucalypt plantations. Eucalypts (genus *Eucalyptus*) were first introduced into China in about 1890 and were originally planted as ornamentals and roadside shade trees. It was not until the 1950s that extensive areas of plantations were established by state forest farms for the purposes of supplying mining timbers (pitwood), poles for construction and fuel wood. Government-sponsored planting programs during the 1970s and 1980s increased the plantation estate to about 600,000 ha. The productivity of these plantations was low—only 5 to 8 m^3/ha/year—as trees from unimproved genetic stock were planted on infertile soils with little or no fertiliser (McKenney et al. 1991). Today, after 20 years of research and breeding, newly established commercial plantations have substantially greater growth rates, in the order of 20 m^3/ha/year. Several projects funded by ACIAR have played a central role in achieving this outcome.

Australia's research collaboration with the Chinese began in 1981 with an afforestation project at Dongmen State Forest Farm in Guangxi Province. This Australian Agency for International Development (AusAID)[1]-funded project demonstrated the potential for substantial yield improvements through the introduction of new species and provenances of eucalypts and the application of fertiliser. This initial work set the scene for a series of ACIAR-funded projects that was carried out in collaboration with the Research Institute of Tropical Forestry (RITF) of the Chinese Academy of Forestry.

1.1 The ACIAR-funded projects

Over the past 20 years, ACIAR has funded seven projects in China that relate to eucalypt breeding, silviculture and propagation. In total, about A$12 million (in nominal terms) has been invested by ACIAR and its collaborators on these projects. As summarised in Table 1, three main types of research have been undertaken:

- Genetic selection and tree improvement.
  Two projects, operating from 1985 to 1992, laid the foundation for eucalypt improvement and breeding in China. These projects

[1] Formerly the Australian International Development Assistance Bureau (AIDAB).

introduced over 100 species/200 provenances, and established 40 ha of seed orchards and 1400 ha of eucalypt research plantations. More recently, ACIAR funded a project that examined the potential for cold-tolerant eucalypts as commercial species in cooler, temperate regions of China.

- Ectomycorrhiza research.
  Three projects have examined the potential for mycorrhizal fungi to improve the productivity of eucalypts on infertile soils. These fungi are capable of colonising roots and developing a symbiotic relationship whereby the fungi assist the plant to take up nutrients. Significant tree growth responses have been demonstrated in trials where inoculations were successful.

- Eucalypt sustainability research.
  The most recent collaborative work with China has focused on investigating whether high-yielding eucalypt plantations are sustainable. This work arose from concerns that plantations could lead to disease and insect problems, soil erosion, groundwater depletion and declining soil fertility. The results of this work have been used to develop management techniques to avoid these problems.

A detailed examination of the outputs of these research activities is provided in Chapter 3.

Table 1. ACIAR-funded eucalypt projects in China

Project number	Title	Timing
FST/1984/057	Introduction and cultivation experiments for Australian broad-leaved tree species	1985–1989
FST/1988/048	Phase II follow-on from FST/1984/057	1989–1992
FST/1987/036	Ectomycorrhiza research	1988–1990
FST/1990/044	Increasing productivity of eucalypt plantations in China by inoculation with ectomycorrhizas and nutrient application	1991–1994
FST/1994/025	Follow-on project to FST/1990/044	1996–1998
FST/1996/125	Development of germplasm and production systems for cold-tolerant eucalypts for use in cool regions of southern China and Australia	1999–2003
FST/1997/077	Eucalypts and water: managing forest plantations in China and Australia for sustained productivity and environmental benefits	1997–2003

Source: ACIAR project database

1.2 This impact assessment

This benefit–cost study estimates the net economic benefits of all seven ACIAR-funded projects as a package. A 30-year time horizon is adopted for the analysis, from 1985 to 2015. Some of the benefits have already been realised, with up to two rotations of the higher-yielding trees having been harvested to date. But the benefits are expected to extend into the future as the area of commercial plantations continues to grow and the Chinese make further yield improvements through breeding and better management techniques. These benefits are accounted for by extending the analysis by a further 11 years. The scope of the study is limited to benefits accruing to China. Spill-over benefits and costs to other countries are not examined.

ACIAR's contribution to forestry research in China has been the subject of two previous impact assessments. In 1991 and 1998, economic evaluations estimated the benefits from selecting Australian trees for cultivation in China (McKenney et al. 1991; McKenney 1998). However, those studies looked at not only eucalypts, but also acacias and casuarinas. Also, the studies were partial in the sense that they did not include the research on mycorrhizas or plantation sustainability. Furthermore, since these analyses were conducted, more is known about the adoption of high-yielding eucalypts and the impact that this has had on China's pulpwood industry. The industry has expanded more rapidly than was assumed by the previous studies.

This assessment updates the previous evaluations and investigates the impact that plantations have had on reducing poverty. While a detailed analysis of poverty reduction is beyond the scope of the study, observations of the spatial distribution of plantations, combined with information about plantation ownership structures, are used to infer what benefits are being received by the poorer households in rural China.

2 China's eucalypt forest industry

Each year China harvests approximately 3.5 million cubic metres (m^3) of eucalypt wood with an estimated gross value of A$105 million. While significant in absolute terms, eucalypt wood production is small relative to China's total forest resources. China has 31 million ha of forest plantations, of which eucalypts constitute only some 4–5% (FAO 2004). Introduced and native pines are the dominant plantation species (Table 2).

Table 2. China's forest resources—2000

	Area ('000 ha)
Plantation forest	
Acacia	129
Eucalypts	1 334
Teak	24
Casuarina	601
Pines (native and introduced)	29 476
Total plantations	31 564
Economic forests[a]	22 066
Natural forest	100 000
Total forest	153 630

[a] Includes rubber, orchards and bamboo.
Source: <www.fao.org/forestry>

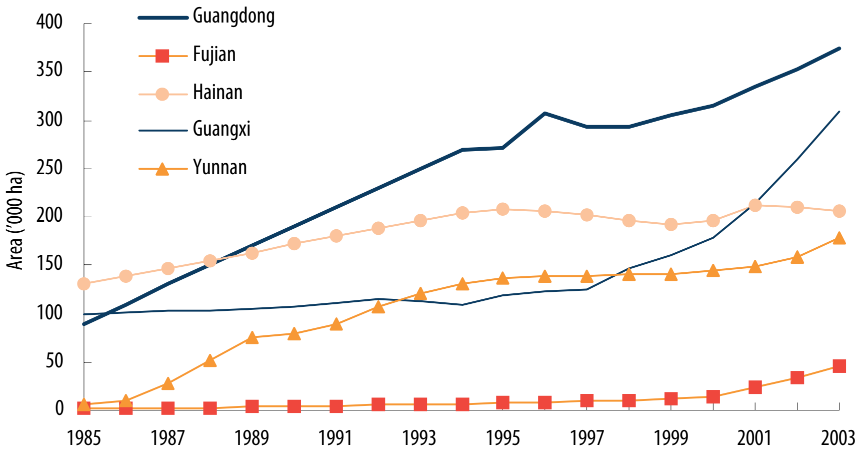
However, in the tropical to subtropical southern regions of the country, eucalypts are becoming the species of choice for fast-growing pulpwood production. Eucalypts are gradually replacing less-productive pines in these regions. Due to the advances made in breeding, eucalypts are higher yielding, produce a higher-quality writing-grade paper and are more disease resistant.

Five provinces in southern China account for over 80% of China's eucalypt plantation area, or 1.11 million ha. It is these provinces that are the focus of this impact assessment, principally because most of the commercial plantations are located here. The majority of plantations are grown in Guangdong and Guangxi provinces. Hainan and Yunnan provinces are also significant eucalypt-producing regions. These provinces each account for 15–20% of total eucalypt area. More recently, Fujian Province in the south east of the country has developed 45,000 ha of eucalypts, which account for 4% of total area. Hainan Province has by far the greatest density of eucalypt plantations per square kilometre of province area.

Figure 1 shows the development of eucalypt plantations in each province over the past 20 years. In some provinces, the area of plantations has more than tripled. Government-funded planting programs in the early 1980s were responsible for establishing the initial areas of eucalypt plantations in Hainan, Guangdong and Guangxi. It is estimated that up to 300,000 ha of eucalypts were planted under the Ministry of Forestry's 'Fast Growing and High Yielding Forest Plantations' program. Commercial plantation forestry received a further boost from 1990 to 1997 under the World Bank's 'National Afforestation Project', which provided China with a loan of US$328 million for commercial plantation establishment. Approximately 1.4 million ha of plantations—some of which were eucalypts—were developed across 16 provinces. A subsequent World Bank project (the 'Forest Resource Development and Protection Project') provided a further loan of US$200 million to help China plant an additional 620,000 ha, of which 38,500 ha were eucalypts (Wang and Wilson 2001).

Since the late 1990s, most of the large commercial eucalypt plantations have been funded by private companies, such as Asia Pulp and Paper, which have taken advantage of institutional reforms to China's forest sector. Eucalypts are also being used for non-commercial purposes; for example, to protect watersheds, provide farm shelter and fuel wood and stabilise soil. Various government programs have been directed towards these ends.

Figure 1. Cumulative area of eucalypts established in China's southern provinces



2.1 China's wood production and markets

In the context of China's overall forest industry, eucalypts account for a small—yet increasing—proportion of total wood production. Eucalypts account for less than 5% of the 320 million m^3 of wood produced each year. Much of China's wood (60%) is used for domestic fuel (Table 3). Most of the remaining production is industrial roundwood, which accounts for 91 million m^3. Industrial wood is used for manufacturing pulp, construction and mining timbers (pitwood). A relatively small proportion of raw material is processed into sawn timber, artificial board and plywood.

Wood production has fallen over the past 6 years, mainly due to government-imposed bans on logging of natural forests (Figure 2). At the same time, China's booming economy has stimulated higher demand for wood products. Consequently, timber imports—in particular softwood logs—have risen steeply since 1997 to fill the gap between demand and supply. However, imports still constitute only a small share of domestic consumption. China's wood demand is largely met from domestic sources. Owing to falling domestic production, exports are minimal. Woodchip and plywood exports are beginning to emerge as plantations mature.

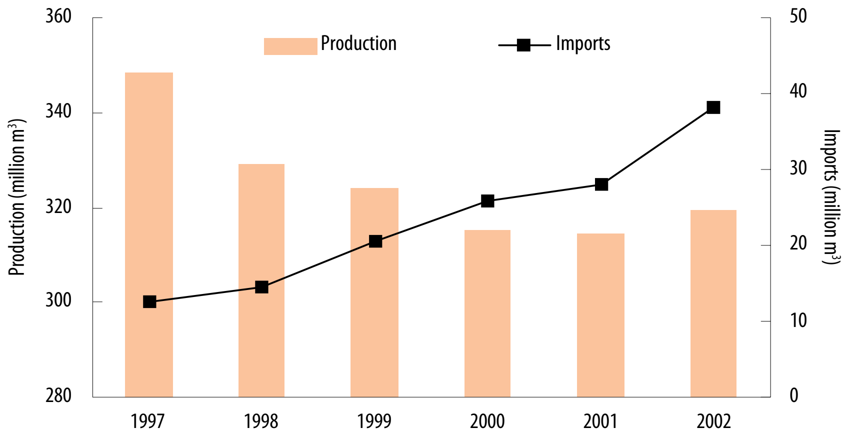
Table 3. Breakdown of China's wood production, imports and production—2002

	Production (million m^3)	Imports (million m^3)	Exports (million m^3)
Industrial roundwood[a]	91.3	24.3	0.03
Wood fuel	190.9	0	0
Wood residues	5.3	0	0
Sawnwood	8.5	7.7	0.5
Woodchips	2.0	0.1	2.0
Veneer	0.9	0.72	0.08
Plywood	11.4	1.59	2.0
Particle board	3.7	0.89	0
Fibreboard	7.7	2.25	0
Other	0	0.56	0
Total	321.6	38.11	4.61

[a] Includes pulp logs, pitwood and poles for construction.
Source: Production statistics from FAO online <www.fao.org>. Import statistics from Xiufang et al. (2004)

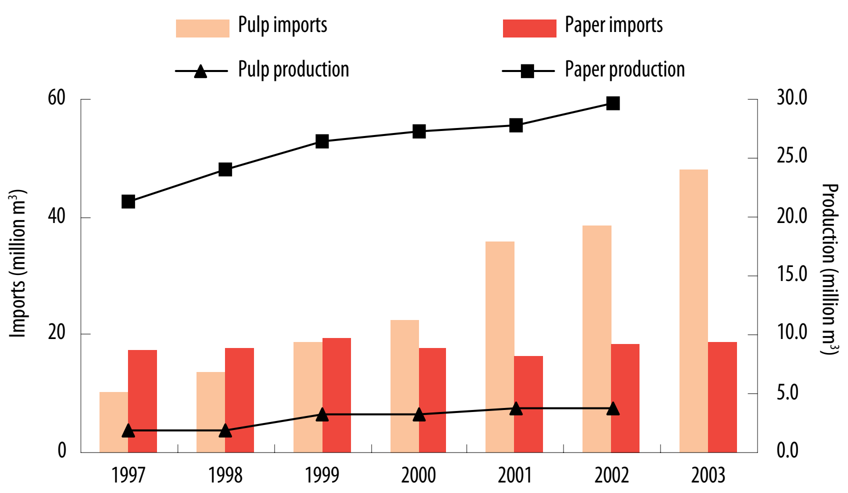
Demand for paper has grown considerably over the past decade, in line with China's growing economy, and this trend is forecast to continue (Figure 2). Instead of increasing its paper imports, China has responded to this demand by constructing new pulp and paper mills. However, domestic wood production is not sufficient to meet the raw material requirements of these mills. The gap is being made up by importing pulp and using other fibre to manufacture pulp (Figure 3). There is scope for eucalypt plantations to replace these pulp imports, provided eucalypt pulp logs can be produced at a price that is commercially competitive with imported pulp.

Figure 2. China's production and imports—wood products.[a]
Note different scales of vertical axes.



[a] Includes fuel wood
Source: Production statistics from FAO online <www.fao.org>. Import statistics from Xiufang et al. (2004)

Figure 3. China's production and imports—paper and pulp



Source: Production statistics from FAO online <www.fao.org>. Import statistics from Xiufang et al. (2004)

2.2 Forest policy reforms

Over the past 25 years, China's forest sector has experienced considerable liberalisation and institutional change. These reforms have been partly responsible for the observed increase in eucalypt plantation area. Other factors influencing forestry have been China's growing economy and consequent strong demand for industrial wood, particularly pulpwood, and various government incentives promoting private investment in plantations.

2.2.1 *Plantation ownership and land reforms*

Before 1981, China's forests—including natural forests and plantations—were administered in two broad categories: state-owned forests and collective forests. They remain officially classified within these same two categories, although forests in the latter classification have been separated into several categories of private ownership (Hyde et al. 2003).

One of the first significant policy reforms, commencing in 1978, was the 'decollectivisation' of forest land held in common by agricultural collectives. By 1984, almost 60% of collective forest land had been transferred to 57 million households (Xu and Hyde 2002). Various forms of private forest enterprises have emerged since, including rural forest cooperatives, shareholding groups, joint venture firms and private forest farms. In particular, township and village enterprises have become common. About 90% of the country's paper mills are owned by township and village enterprises. It is now estimated that of the 31 million ha of plantations, 73% is privately owned.

The other 27% of plantation area remains under state ownership and is managed by state-owned forest enterprises (SOFEs). These enterprises receive financial assistance from central government and are subject to the management guidelines of the State Forest Administration. SOFEs have also been exposed to reforms, albeit more gradually. Since 1985 the SOFEs have been given more autonomy in their day-to-day management, many state forest farms have been sold to private operators and most remaining SOFEs are no longer involved in wood processing. Compared with the private sector, the area of plantation developed by SOFEs has been less, and plantations have tended to be dependent on the financial support of central government (Xu and Hyde 2002).

2.2.2 *Private plantation investment*

The Chinese Government has an objective of increasing the national forest cover by 26% by 2050. As at 2001, about 17% of the country was forested. The target of 26% will require an additional 100 million ha of afforestation, or 2 million ha per annum. Forest cover in China is currently expanding at a rate of 1.5 million ha each year, of which about 90,000 ha (or 6%) is eucalypts.

In an effort to close the gap between domestic wood production and consumption, about 30% of this additional forest is to be used for commercial purposes (Yainshet 2002). The planned expansion in commercial plantation forest is intended to be achieved largely through foreign investment. Numerous policies have been introduced over the past decade, some of which have made conditions more favourable for private plantation investment. Reforms include:

- government auctions of barren wasteland for the purposes of afforestation. These auctions commenced in 1993 and have allowed private individuals and firms to purchase additional land for plantations.
- reduced government log price setting and intervention in timber markets. The government now accounts for less than 10% of timber purchases (Xu and Hyde 2002). However, it still regulates timber harvesting and shipments. For example, in Hainan Province, to ensure that the province's paper mill has sufficient supplies of raw material, there are government controls on woodchip exports.
- a ban on logging natural forests in 18 provinces. This was introduced in 1998 (under the Natural Forest Protection Program), and has reduced China's industrial wood production by 15% and increased its demand for raw wood material from plantations and log imports.
- introduction of a variety of government incentives to encourage the development of commercial plantations. Incentives are aimed at attracting foreign investment. Among the incentives are low-interest loans for tree planting, 50-year leases on land for establishing plantations and tax-free income from tree thinnings. The government is also allowing private forestry on public land.
- a reduction in forestry taxes and other fees of up to 20%. Before 2002, taxes on wood harvest revenue were in the order of 33–35% (Xu Daping 2003). Some provinces now levy taxes on plantation area rather than on wood sales. This has removed the disincentive for plantation growers to invest in productivity improvements.

- a government requirement that foreign-owned paper companies establish their own wood resources in China. This policy is aimed at encouraging private plantation investment.

In addition to these reforms, China made several reductions to its import tariffs on wood and wood products in the lead up to its accession to the World Trade Organization in 2001. As at 2001, tariffs on imported logs and woodchips were 1%, 1–5% for sawn wood and a zero tariff on pulp. However, tariffs of 4–7.5% are still in place for processed wood products such as plywood, veneer and paper products (APEC 2001). Over time, these tariffs are expected to be reduced further in line with World Trade Organization rules. Lower import tariffs could place downward pressure on domestic raw wood prices as imports of processed wood compete with local production. China will need to maintain ongoing improvements in production efficiency, including improved plantation productivity, if it is to compete with lower-priced imports.

2.3 Eucalypt wood products

Eucalypt plantations are harvested for pulpwood, artificial fibreboard, sawlogs, roundwood, veneer, fuel wood and oil. However, detailed statistics on the volume of wood going into each end product are not available. It is anticipated that, as the new high-yielding plantations mature, some 50–60% will be used for pulp and paper production. The other 40–50% will be used for plywood, medium density fibreboard (MDF) and sawn timber (Xu Daping 2003). At present, it is estimated that most of the wood is being used for domestic pulp production, export woodchips and MDF. In 2003, about 560,000 tonnes of eucalypt woodchips were exported from Guangdong and Guangxi provinces. Less than 15% of production is used for sawn timber. Residues and leaf litter are used for fuel wood.

Eucalypt oil and veneer are produced in relatively small quantities. Oil production is primarily confined to the cooler, temperate regions of Yunnan Province, where up to 85% of eucalypt plantations (150,000 ha) are used for oil. Oil is produced on-site by farmers using basic distilling equipment. There is no central processing plant. The oil is used for medicinal purposes. About 30% is used domestically and the remaining 70% is exported, mainly to Japan. Exports amount to about 1000 tonnes/year (Minsheng 2003). Veneer wood is produced in small mills located in Guangdong and Fujian provinces, owned and operated by private individuals or households. The veneer is largely used for boat-building. The product sells for 1000 Yuan (A$178)/$m^3$ (a square bale).

Mills purchase eucalypt logs for 310 Yuan (A$55)/tonne, which is a premium to the pulp-log price of 250–280 Yuan (A$45 –50)/tonne.

2.4 Eucalypt plantation development in each province

Table 4 summarises the current status of eucalypt plantations in each of the five provinces where eucalypts are grown. All of the provinces are using high-yielding eucalypt clones or selections from China's tree improvement program. New plantations are being established at a rate of between 3500 ha and 43,000 ha per annum, depending on province. At present, the fastest expansion is occurring in Guangxi Province.

Most of the provinces are using tropical or subtropical species of eucalypts, which were introduced by ACIAR-funded projects in the 1980s. The Chinese have made subsequent releases of improved planting stock from their breeding/selection program. The dominant species are *Eucalyptus urophylla* and hybrids of *E. urophylla, E. tereticornis* and *E. grandis*. Cooler-climate species are being grown in Yunnan and in the northern part of Fujian Province. Yunnan's plantations are mostly (80%) based on *E. globulus* and *E. maideni*, both of which are suited to cool, temperate regions. These species are predominantly used for oil production. Other cool-climate species, such as *E. nitens* and *E. smithii*, make up about 5% of the area grown in Yunnan. Subtropical species make up the remaining 15%. They include *E. grandis* and *E. grandis* × *E. urophylla* hybrid clone, both of which are used for pulpwood production. In the north-western mountainous regions of Fujian Province, the cold-tolerant species *E. saligna* and *E. dunnii* are being adopted. These species were released for commercial use in 1998 and were the product of ACIAR-funded project FST/1996/125.

Plantations are being established on a variety of land types, including barren land, degraded plantation forests and former agricultural land. However, in the main, eucalypts are planted on land with relatively low rental values, as the returns from tree growing are not competitive with agriculture on flat, fertile land. Depending on province and land type, the rental values for land vary widely. Plantation growers pay annual rents of up to 1800 Yuan/ha for flat land in Guangdong and Guangxi provinces. But rents of only 100 Yuan/ha are paid for mountainous land, reflecting the lower profitability of crops that can be grown on this land.

Table 4. Plantation statistics for each province in China in which eucalypts are grown—2004

		Hainan	Guangdong	Guangxi	Yunnan	Fujian
Area of province	km^2	34 000	197 000	236 000	394 000	121 400
Area of eucalypt plantations	ha	207 000	373 000	308 600	178 000	45 000
Main species being planted		*E. urophylla* *E. urophylla* clone	*E. urophylla* *E. urophylla* clone	*E. urophylla* clone	*E. grandis* x *E. urophylla* clone *E. grandis* *E. globulus*, *maideni*, *smithii*, *nitens*	*E. urophylla* *E. urophylla* clone
Rate of new plantation development[a]	ha/year	3500	20 000	43 000	11 500	11 000
Ownership						
• state	%	30	10	17	20	60
• collectives and households	%	10	5	47	25	25
• private company	%	60	85	36	55	15
Year of first investment by private plantation companies		1996	1996	1998	2000	Yet to invest
Target area planned for 2010	ha	NA	490 000	358 000	200 000	70 000
Land being used for plantations		Mostly degraded native timber plantations	65% on barren mountainous land; 35% on flat land	85% on degraded native timber plantations; 15% on barren land	90% on barren land; 10% on agricultural land	90% on degraded pine forest; 5% on barren land; 5% on agricultural land
Land rental value	Yuan/ha/year	Average of 500	1200–1800 on flat land; 100 on mountainous land	900–1200 on flat land; 75–450 on mountainous land	120 for industrial plantations; 300 for oil tree plantations	30 – 150
Annual volume harvested	m^3	215 000	2 170 000	570 000	210 000	163 800
Main products		Pulp & paper	Pulp & paper, MDF[b], veneer and export woodchips (500,000 t)	Pulp & paper and 60,000 t export woodchips	Pulp & paper; oil, MDF and pitwood	Veneer and MDF
Factories		Asia Pulp & Paper	Jing Feng (200,000 t pulp) 3 MDF mills in Zhangjiang (250,000 t chips)	Feng Huang (300,000 t pulp) Gao Feng (200,000 t pulp) Huo Zhou (100,000 t pulp)	Jingge mill (150,000 t pulp)	1 Veneer factory and 1 MDF factory

[a] Average planting rate over the three years 2001 to 2003.
[b] Medium-density fibreboard
Source: RITF workshop 23–25 May 2004

In most of the provinces, the bulk of plantations are owned by private companies, households and village collectives. Typically, only 10–30% of plantations, by area, are state-owned. The exception is Fujian Province, where approximately 60% of eucalypt plantations are under public ownership. The land-reform process has been slower in this province. The privately owned plantations to date have been established by households and village collectives. Plantation companies are yet to invest in Fujian. In the other provinces, considerable foreign investment has helped to establish trees, with the first companies investing in about 1996. In Hainan, Guangdong and Guangxi, new paper mills have been built, or are being planned. These mills will provide an outlet and ready market for the increasing volumes of feed-stock being produced in these provinces.

3 Eucalypt research in China

Over the past 20 years China has maintained an active, ongoing program of eucalypt selection, breeding and silviculture research. ACIAR was an important catalyst for this research when it funded projects in the mid 1980s that introduced new germplasm to the country and imparted breeding techniques and skills to Chinese scientists. In more recent years, China has embarked on a wider array of R&D projects that seek to further improve eucalypt productivity. This chapter identifies the main outputs of each ACIAR-funded project and summarises the contributions made by these projects to China's research program.

3.1 Research chronology

Table 5 provides a brief summary of eucalypt R&D in China since 1980. It is clear from the summary that the ACIAR-funded projects have made a significant contribution to eucalypt research over the past 20 years. Efforts to improve the productivity of eucalypts began in the early 1980s with the initiation of the China–Australia Afforestation Project at Dongmen Forest Farm supported by AusAID. This was soon followed by ACIAR-funded project FST/1984/057. Over an eight-year period, the ACIAR-funded work helped to establish a substantial gene base which the Chinese could use as a foundation for breeding and selecting improved trees. In the early to mid 1990s, silvicultural research was carried out, including fertiliser trials, planting density experiments, different cultivation treatments and a series of ACIAR-funded projects that investigated the potential for mycorrhizal fungi to improve nutrient uptake.

In 1992, the Chinese set up the China Eucalypt Research Centre (CERC) with the help of CSIRO Forestry and Forest Products. This centre has taken on the role of coordinating eucalypt research in China and promoting new R&D relating to eucalypt production and sustainability. Current activities include the investigation of practices for developing high-value (large diameter) eucalypts, sawlog processing technology and advanced genetic engineering research. Another emerging area of research is the development of integrated management systems for maintaining the long-term sustainability of eucalypt plantations. ACIAR continues to support China by helping to organise and fund colloquia such as the 'Eucalypts in Asia' conference held in Zhanjiang in 2003.

Table 5. Chronology of eucalyptus research in China

Date	Research projects and events
1981	China–Australia Afforestation Project at Dongmen State Forest Farm, Guangxi. Introduced 110 species/350 provenances/1100 families.
1985	ACIAR-funded project FST/1984/057 commenced. Further new introductions of eucalypt species and provenances over a period of 8 years. Established substantial gene base comprising 1400 ha of plantations and 40 ha of seed orchard.
1991	Ectomycorrhiza research commenced with assistance from ACIAR projects FST/1990/044 and FST/1994/025.
1991	Commencement of World Bank Loan Project—'Research and extension of cultivation technology on fast-growing and high yielding *Eucalyptus*'. (1996–2001).
1992	China Eucalypt Research Centre (CERC) was established in Zhanjiang City. The main task of CERC is collaboration with research groups and undertaking research projects of national relevance to the Chinese eucalypt industry. CERC, in collaboration with RITF and forest bureaus, continues an active breeding, selection and silviculture program.
1996	Commencement of a National Key Project—'Improved variety selection and cultivation technology on *Eucalyptus* species for pulpwood' (1996–2000).
1997	Commencement of State Science Fund Project—'Construction of genetic linkage maps of *E. urophylla* and *E. tereticornis* (1997–2000)
1999	Commencement of research on selecting, breeding and cultivating cold-tolerant eucalypts for cooler regions of south-central China. Assisted by ACIAR project FST/1996/125.
1999	Commenced research on interactions between eucalypts and water. Funded by ACIAR project FST/1997/077.
2003 (in progress)	• Introduction of high-value eucalypt species (CERC) • The cultivation technology of large diameter eucalypts (CERC) • Improved and diversified use of tropical plantation timbers in China (ITTO funded project) • Gene transfer and molecular marker technology for eucalypt improvement (RITF)

Source: Based on information in Minsheng (2003).

3.2 Genetic selection and tree improvement

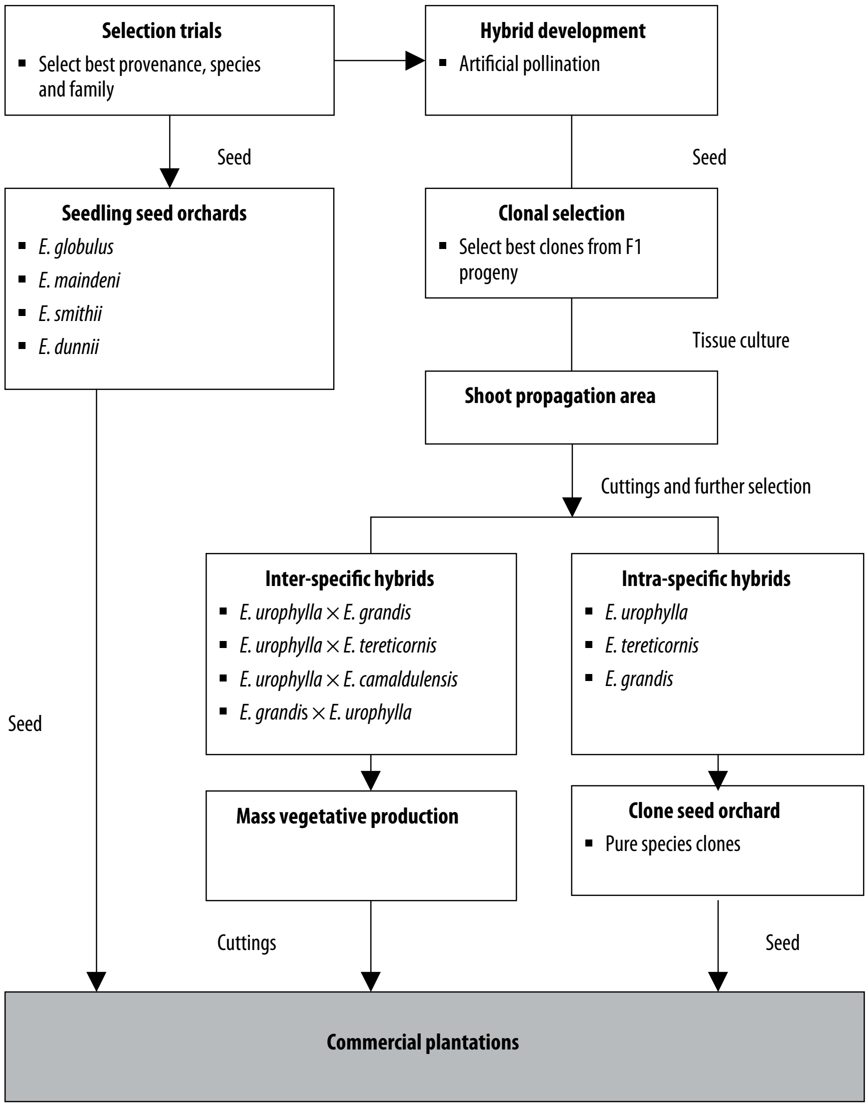
The genetic improvement of trees through selection and breeding involves a lengthy process of scientifically controlled trials. Figure 4 outlines the process used in China to develop high-yielding trees for commercial use. There are at least three distinct steps. First is the introduction of new germplasm and the establishment of field trials at different locations to test the performance of different eucalypt species, families and provenances. ACIAR-funded projects FST/1984/057 and FST/1988/048 were instrumental in setting up about 20 trials in Yunnan, Fujian, Guangdong and Hainan provinces. In total, approximately 1400 ha of experimental plantation was established, comprising over 100 species and 200 provenances of new introductions.

A second step in the improvement process is to select the best-performing trees from the trial sites and establish seed orchards for commercial seed production or for developing a genetic base for breeding. The ACIAR projects established 40 ha of seed orchards. At minimum it takes 2–3 years before trees begin producing seed. In China, improved seed was first available for commercial use in 1991. From 1992 to 2000, high-yielding species such as *E. urophylla* and *E. grandis* × *E. urophylla*, introduced and selected by the ACIAR-funded projects, were the main species used in commercial plantings.

Further genetic advances are possible through a program of controlled breeding. This is the third step in the process. Breeding involves the controlled pollination of trees, using a breeding plan that assigns weights to particular genetic traits, such as harvest volume, pulp yield and disease resistance. During the 1990s, the Chinese began a program of hybrid breeding with the support of ACIAR. Hybridisation involves selecting parent trees with desirable characteristics, then producing hybrid seed from these trees through artificial pollination. The seed is then used to propagate hybrid clones. The best clones are selected, 'bulked up' using tissue culture, and used to establish a shoot-propagation area. In the case of inter-specific hybrids, cuttings are taken from the shoot-propagation area for the commercial production of young trees. Alternatively, in the case of intra-specific hybrids, the cuttings are used to establish a clone seed orchard from which seed is generated for commercial production. It takes approximately 8 years to develop hybrid clones suitable for commercial use. China's breeding program began yielding hybrid clones in around 1998. Again, ACIAR's support was instrumental in RITF's development of these hybrids.

In the early 1990s, most of the breeding effort was concentrated on tropical and subtropical species of eucalypts. It was not until 1999 that cold-tolerant species received specific attention. ACIAR project FST/1996/125 funded work specifically on the breeding and development of eucalypts for cooler regions of south-central China. Between 1999 and 2003, this project established 10 species/provenance and provenance/family trials in Yunnan, Guangxi, Hunan and Fujian. Breeding plans were formulated for *E. globulus*, *E. maideni* and *E. smithii* in Yunnan and for *E. dunnii* in Guangxi. As discussed in Chapter 2, high-yielding trees selected from this program are already being used in commercial plantations in Yunnan.

Figure 4. Selection and breeding process



Source: RITF workshop 23–25 May 2004

The rights to use clones are typically made freely available for commercial use. In only a few instances has a private plantation company paid for the rights to use 'advance release' clones; a once-off payment of about 20,000 Yuan (A$3570). Certified seed is sold 'at cost' to plantation companies, households and SOFEs. Seed and clone material (tissue-cultured plants) are available from RITF or one of the other 5 or 6 state forest research centres, including Dongmen Forest Farm and Leizhou Forest Bureau. Most large companies have their own nursery with tissue-culture facilities for establishing shoot-propagation areas and propagating cuttings. Households and village collectives tend to obtain their plant stock from nurseries that specialise in propagation.

Concurrent to the genetic-improvement research, numerous trials have been undertaken to develop best-practice silvicultural techniques. Improved methods for site preparation, weed control and nutrient application have been formulated and are now widely applied by plantation companies.

3.3 Ectomycorrhiza research

During the 1990s, ACIAR funded three projects on ectomycorrhizas, which were carried out by CSIRO's Division of Forestry and Forest Products and Murdoch University in collaboration with the Chinese Academy of Forestry through RITF.

The objective of these projects was to identify strains of ectomycorrhizas that are effective in enhancing the growth of eucalypts in different soil types, particularly those low in nutrients. Ectomycorrhizal fungi grow in soil as fine strands of hyphae, gathering water and nutrients which are transferred to the tree. Many native fungi in China evolved with northern hemisphere trees such as pines and oaks and therefore do not form beneficial associations with eucalypts. The goal of the ACIAR-funded work was to introduce beneficial Australian fungi that have evolved with eucalypts. Part of the research involved the development of isolation techniques, storage methods and bulk production of fungi for nursery use.

There was also a focus on formulating appropriate fertiliser recommendations based on effective blends of macronutrients and micronutrients. The nutrient status of soils and the success of mycorrhizal treatments are closely linked and these two areas of research were thus undertaken jointly. The main outputs of the research were as follows:

- development of cost-effective fungi inoculation procedures

- identification of site factors determining mycorrhizal responses and nutrient interactions
- establishment of field trials at three sites in China
- development of molecular techniques developed for confirming the presence of some introduced fungi on tree roots in the field
- development of recommendations for macro and micro-nutrient fertilisers for eucalypts.

The research demonstrated that, on some sites, ectomycorrhizas have the capacity to increase seedling survival ratios and improve growth rates by up to 20%. However, the effect of the inoculation is most noticeable in the first two years of the tree's life. By the third year, the impact on yield becomes less discernible. Nevertheless, some private plantation companies are routinely inoculating their seedlings. It is estimated that about 25% of total plantings are now being inoculated and it is known that 10 technicians with specialist skills in mycorrhizal technology are working for these companies (Dell 2004).

The biggest tangible benefit from this research has been the more judicious use of fertiliser, especially micronutrients. On some sites this alone has increased mean annual increment (MAI) by 10 m^3/ha/year (Dell 2004). Most new commercial plantations are using fertiliser formulations based on the research recommendations. At least three companies are producing their own nitrogen–phosphorus–potassium (NPK) blend containing boron. Several companies are routinely using foliar analysis to determine limiting nutrients for tree growth.

3.4 Eucalypt sustainability research

With the rapid expansion of eucalypt plantation area in China, concerns have been expressed about the long-term sustainability of high-yield, monoculture tree cropping. The main issues revolve around nutrient depletion, excessive water use, soil erosion due to inappropriate site preparation and the build-up of pests and diseases. In 1996, ACIAR funded a 6-year project (FST/1997/077) which examined two of these concerns: water use and nutrient depletion. China was concerned that recently established eucalypt plantations may deplete groundwater resources used by farmers for irrigating crops during the dry season. A reported productivity decline in the latter part of the first rotation and subsequent rotations was suspected of being due to exhaustion of soil water and possibly nutrient depletion associated with litter harvesting for fuel wood.

The overarching objective of the ACIAR project was to model the water use and growth of eucalypts under different management practices, thus enabling insights into whether or not eucalypts are in fact responsible for depleting groundwater. Existing Australian models of stand growth (3PG) and local hydrological processes (TOPOG) were parameterised and validated using data from Leizhou Peninsula in Guangdong Province. This research found that eucalypt plantations do not use excessive amounts of water compared with crops. The project also determined that eucalypts in China are more efficient at using water than in other countries, due to their smaller leaf area index, high levels of humidity and the fact that most rainfall is received during the warm months, when growth rates are fastest.

The findings have allayed concerns that plantations are excessive users of water, competing with adjacent crops for irrigation water. Furthermore, the modelling skills imparted by the project could prove useful for future land-use planning in China.

Another component of the project examined the practices used by households to manage their plantations, and the reasons underpinning declining productivity. It was found that smaller plantations established by households often suffered from nutrient depletion and soil degradation due to excessive litter collection (for household fuel) and insufficient fertiliser. The problem of under-fertilising was found to be related to the relatively low profitability of eucalypts, principally due to high taxes and the perceived lack of security over forest land. Since this project finished, taxes have been substantially reduced.

4 Research outcomes

China's eucalypt research program has produced a variety of beneficial outcomes. Some of the outcomes link directly to the outputs of ACIAR-funded projects. But in many instances, multiple agencies have contributed to the achievements.

4.1 Increased adoption of eucalypts

The area of eucalypt plantations in southern China has grown from 325,000 ha to 1.1 million ha in just 20 years, a more than threefold increase, and further plantations are planned. The R&D pursued by China has made eucalypt plantations a commercially attractive proposition for growers. Without the high yields being achieved by eucalypts, particularly from the late 1990s onwards, the industry would almost certainly have been smaller, and prospects for future expansion would be limited without considerable subsidies to growers. Furthermore, the breeding of suitable cold-tolerant species has extended the geographical range over which eucalypts can be profitably grown.

4.2 Wood yields

China's tree-improvement program, combined with silvicultural research, has unambiguously increased the yield and growth rate of eucalypts grown in southern China. While there is considerable variability in yields and rotation lengths from one region to another, on average the MAI of well-managed commercial plantations has increased from 7 to 20 m^3/ha/year since 1985 (Table 6). The faster growth rates mean that it is now possible to harvest earlier. On average, rotation length has declined from 10 years to 7 years.

These productivity gains have been made in two steps, with the first major improvement being achieved in the 10-year period 1991 to 2001 when the initial introductions became available and widely adopted. Average yields during this period were 11 m^3/ha/year. As China's breeding program progressed, a second round of new clones was released. While new clones were available from 1998 onwards, average yields of 20 m^3 in commercial plantations were reached only in about 2001.

Again it is stressed that these yields and rotations are averages for well-managed commercial plantations. Many of the plantations established by village collectives and households do not achieve these yields because a lower-input regime is used, rotation length is shorter (3 years in some cases) and planting density is higher. For the benefit–cost analysis, it is assumed that 45% of post-2001 plantings achieve the higher yields; that is, an average MAI of 20 m^3/ha.

Table 6. Eucalypt yield gains in China: average for commercial plantations

		Pre 1991	1991–2001	Post 2001
Dominant species		*E. exserta* *E. robusta* *E. citriodora* *E. camaldulensis*	*E. urophylla* *E. grandis* *E. tereticornis*	Interspecific hybrids and *E. urophylla* clones
Mean annual increment	m^3/ha/year	7	11	20
Rotation length	years	10	7	7
Yield at harvest	m^3/ha	70	77	140

Source: RITF workshop, 23–25 May 2004

4.3 Pulp yields and quality

Initial selections of eucalypt species were made primarily on the basis of wood yield rather than maximising wood density. Wood density is an important trait with respect to the value of eucalypt wood for pulp production, because it is highly correlated to pulp yield. *Eucalyptus urophylla* and selected hybrids of this species, which are now widely grown in southern China, generally produce good-quality pulpwood under favourable growing conditions (Jianzhong 2003). Pulp yield ratios (raw material to pulp) are typically 1:5 and this has not changed significantly under the breeding program. Wood density is a highly heritable trait relative to growth rate, so as China's breeding program progresses there could be prospects for future improvements in wood density through genetic selection.

For paper mills, pulpwood from 6-year-old trees is significantly more profitable than younger material because wood density (and thus pulp yield) increases with age (Jianzhong 2003).

4.4 Production costs and returns

The higher yields and shorter rotation lengths that are now being achieved generate significantly higher returns to the plantation grower. Table 7 summarises the typical production costs and returns for a eucalypt plantation based on traditional species (10-year rotation) and one that uses high-yielding species (7-year rotation). While coppicing is possible—that is, leaving the stumps to regenerate for a second harvest—this is not widely practised by plantation companies because it tends to be more profitable to replant using newly developed clones with higher yields.

Table 7 Typical production costs and returns of eucalypt plantations in China[a]

	Traditional eucalypts — 10-year rotation — MAI 7 m^3/ha		High-yielding eucalypts — 7-year rotation — MAI 20 m^3/ha	
	Yuan	A$	Yuan	A$
Per hectare growing costs				
Land rental (400 Yuan/year)	4000	714	2800	500
Seedlings	300	54	450	80
Site preparation	500	89	750	134
Planting	750	134	750	134
Fertiliser	1400	250	2400	429
Weed control	0	0	600	107
Maintenance	800	143	1800	321
Total nominal cost	7750	1384	9950	1705
Per cubic metre production cost[b]	150	27	84	15
Per hectare returns[c]				
Nominal gross revenue	11 900	2125	23 800	4250
Net present value	896	160	8956	1599
Annuity	116	21	1548	276

[a] Assumes an exchange rate of 5.6 Yuan to the A$.
[b] Production costs compounded at 5% rate of interest.
[c] Based on a stumpage price of 170 Yuan (A$ 30)/m^3 and a 5% discount rate.
Source: RITF workshop 23–25 May 2004

In nominal terms, average production costs are in the order of 7750 Yuan (A$1384) per hectare for the traditional species and 9950 Yuan (A$1705) per hectare for the new species. Production costs are higher for the new species because increased inputs are required to support the higher yields. Apart from land rental, fertiliser is the biggest cost item. For the new species, production costs *per cubic metre of wood* are substantially lower owing to the higher yields (140 m^3/ha at harvest compared with 70 m^3/ha).

Standing eucalypts are currently selling for about 170 Yuan (A$30)/$m^3$. This is a stumpage price, net of harvesting and transport costs. Mill door prices range from 230 to 280 Yuan/m^3. Based on the stumpage price of 170 Yuan, the new species return a NPV of 8956 Yuan (A$1599)/ha, which is equivalent to an annuity of 1548 Yuan (A$276)/ha. This return is approximately 10 times the net returns generated from the traditional species. Income taxes and input subsidies are excluded from the budget because the benefit–cost analysis requires estimates of the net economic worth of eucalypt plantations, free of tax and subsidy distortions.

4.5 Environmental outcomes

Forest plantations provide a range of environmental benefits. Some of the benefits are 'spill-overs' associated with commercial plantations, while in other cases eucalypts have been planted specifically for forest conservation. Environmental benefits cannot be totally attributed to China's eucalypt research because some afforestation would have occurred regardless of the research outcomes. However, the availability of fast-growing, commercially attractive eucalypts has no doubt accelerated the rate of afforestation in southern China and possibly extended the range of soil types and environments over which forest plantations can be successfully established.

Environmental benefits include the following.

- There is reduced pressure on natural forests, as plantations provide a source of industrial raw material and fuel wood. Put another way, plantations have reduced the economic impact of natural forest logging restrictions imposed by government in 1998.
- Eucalypt plantations provide a biological corridor between discrete areas of natural forests.
- Water-borne soil erosion is reduced on degraded land that has previously been prone to erosion.
- Water quality is improved due to lower turbidity, reduced sedimentation of waterways and lower nutrient run-off.
- Plantations can protect agricultural crops from strong winds, sandstorms and soil erosion; eucalypts are commonly used by farmers as windbreaks. For example, in Zhanjiang (in Guangdong Province), there was very little vegetative cover in the 1950s and the region suffered from severe typhoon damage and high evaporation. Plantations now cover about 27% of land area. As a result, evaporation has fallen and damage from strong winds is less severe (Yaojian 2003).
- Carbon sequestration by eucalypts reduces greenhouse gas emissions. Forestry plantations, managed on a sustained rotational basis, sequester more carbon per hectare than agricultural crops.

Balanced against these benefits is the potential for poorly managed plantations to result in harm to the environment. For example, fast-growing eucalypt plantations harvested on short rotations may remove more soil nutrients and water than some agricultural crops. Thus, appropriate fertilisers must be applied and a proportion of wood residues and leaf litter must be retained. Soil erosion can be a problem on some soil types where the site has not been correctly prepared. Again, this is a problem that can be overcome through appropriate management. Eucalypt plantations are a monoculture, which gives rise to the potential for disease and pest build-up. Ways to minimise this risk are being investigated, for example through the development of multiple clones with different genetic origins and mixed species plantings. The number of eucalypt clones available for mass distribution is still very limited in China, partly because the local breeding institutions are struggling to keep up with the demand from plantation growers for new clones.

This impact assessment focuses on the economic contribution of eucalypt plantations and does not quantify the environmental outcomes.

4.6 Social outcomes

The development of high-yielding eucalypts and subsequent increase in plantation area in southern China is expected to have had an overall positive influence on rural incomes and living standards. Eucalypts are providing farmers with an alternative source of income. Rural households are adopting short-rotation eucalypts as an integral part of their farm enterprise; in particular, the short rotation length ameliorates the cash-flow problems associated with traditional forestry plantations where the grower must wait up to 12 years before receiving a return on investment.

The extent to which plantations are contributing to higher rural incomes depends partly on the ability of households to own plantations and thus derive a direct income from tree growing. In turn, this depends on a number of factors, including:

- access to forest land and the security of land tenure
- access to capital and timber markets
- the quality of roads and other infrastructure required for transporting and processing wood
- the management skills of farmers and their ability to achieve high yields

- access to technical advice and good-quality planting stock from certified nurseries.

Where these conditions are not met, households may not be able to benefit directly from plantations through ownership. On the other hand, plantation companies, SOFEs and wood-processing mills provide off-farm employment opportunities for farm workers.

In Chapter 6 a closer examination is made of the impacts that eucalypt plantations are having on the welfare of rural households and the main factors that are influencing these effects.

5 Benefit–cost analysis

5.1 Methodology

The economic impact of eucalypt research in China is estimated by calculating the net returns to plantations developed over the period 1985 to 2015, with and without the research. The difference between these two scenarios, less the cost of research, represents the total net benefit.

In undertaking this assessment it is important to carefully define the 'with' and 'without' scenarios in terms of:

- productivity improvements per hectare of plantation
- the scale of industry, defined by the rate and level of new plantation development.

The scenarios must also be specified to reflect the contributions made by ACIAR-funded projects. Recall from Chapter 3 that these projects played a critical role in introducing new eucalypt species into China and developing a breeding program. The ACIAR-funded projects in 1985 to 1992 served as a catalyst because they put in place a foundation of genetic material and knowledge which, in turn, promoted further R&D investment in eucalypts by the Chinese and other agencies. Therefore, the approach taken is to assume that ACIAR's assistance brought forward the development of high yielding species by 8 years. Hence, the 'without' scenario assumes a baseline of improving yields through time and the 'with' scenario is specified to reflect *additional* yield improvements facilitated by the ACIAR-funded projects, together with inputs from other projects.

In both scenarios, the area of eucalypt plantations is assumed to expand in response to increasing demand for raw material. But in the 'without' scenario, the rate of expansion beyond 1999 is slower than that experienced in the 'with' scenario, reflecting the lower commercial attractiveness of eucalypts. In the 'with' scenario, the area of new plantation establishment follows the observed pattern of development up to 2004, with ongoing increases in area until 2013, at which time a steady-state plantation area is reached.

5.1.1 *Plantation development model*

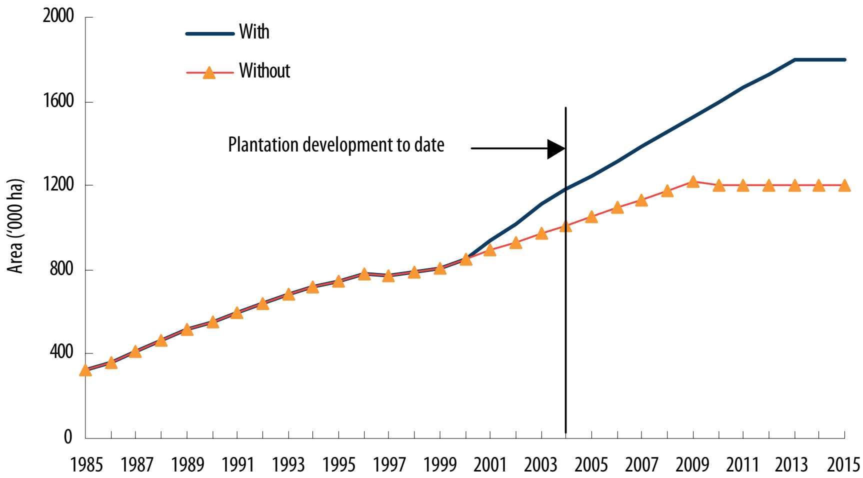
A plantation development model is used to simulate the total annual area of trees planted in the 'with' and 'without' scenarios. Annual plantings include additions plus replacements following harvest. It is assumed that, on average, 10% of the plantation estate is harvested each year. While a faster turnover rate will be possible in the future (i.e. 14% per annum, representing a 7-year rotation), the current estate includes a significant proportion of older, longer rotation trees. Other key parameters of the model are summarised in Table 8. The cumulative area of eucalypts under each scenario is shown in Figure 5, and the annual plantings are shown in Figure 6.

Table 8. Key parameters in the eucalypt plantation development model used for the benefit–cost analysis

		With research	Without research
Plantation growth model			
Maximum area of eucalypt plantations	'000 ha	1800	1200
Year in which maximum is reached	year	2013	2007
Proportion of plantation estate harvested each year	%	10	10
Plantation returns[a]			
Initial returns from old species			
Years		1985–90	1985–98
Net present value (NPV)	A$/ha	160	160
1st yield improvement			
Year commencing		1991	1999
NPV	A$/ha	172	172
2nd yield improvement			
Year commencing		2001	2009
NPV	A$/ha	1599	1599
Proportion of new plantings achieving high yields	%	45	45

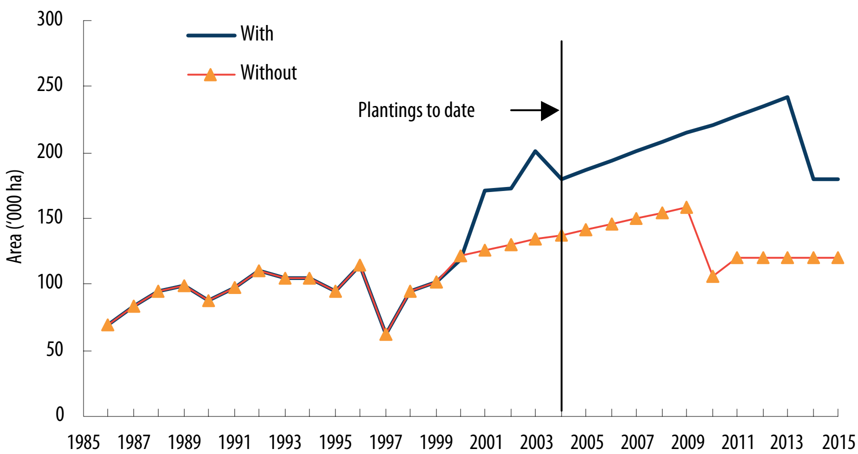
[a] Lump sum NPV of a single rotation. NPV estimates sourced from Table 7.
Source: Based on discussions with RITF scientists.

Figure 5. Eucalypt plantation development in China with and without research



Source: RITF survey data (unpublished). Future projections for the 'with' and 'without' scenarios are based on consultations with RITF staff.

Figure 6. Area of eucalypts planted in China each year, with and without research[a]



[a] Includes replacements for harvested plantations.
Source: RITF survey data (unpublished) and CIE model estimates.

Up to 1999, plantation development is assumed to be the same for the 'with' and 'without' scenario, reflecting China's strong demand for pulpwood during the 1990s and the government's willingness to subsidise plantations with the assistance of the World Bank. Beyond 1999, investment in plantation establishment has come mainly from the private sector, principally foreign investment. In the absence of R&D, eucalypt yields would be lower and therefore less attractive to investors. Thus, in the 'without' scenario, the cumulative area of eucalypts is assumed to grow more slowly than that for the 'with' scenario. Without the high-yielding trees, it is assumed that a maximum steady-state area of 1.2 million ha is reached by 2007.

The 'with' scenario uses observed plantation rates up to 2004. It is projected that plantation area will continue to expand. The State Forest Administration plans to establish an additional 2.6 million ha of high-yielding pulpwood plantations in southern China over the next decade, some of which will comprise eucalypts (Xu Daping 2003). This represents a 1.5 million ha increase on the current area. However, this may be an optimistic target because plantation companies are reporting difficulties in securing additional land. Future investment may instead be focused on regenerating existing, degraded forest land with high-yielding eucalypts, rather than afforesting new areas. Therefore, a conservative view is taken and it is assumed that the plantation estate will grow to 1.8 million ha by 2013 and be maintained at this level. This represents a net increase of 700,000 ha on the current area.

The pulpwood market is expected to absorb this extra production and prices should not be affected significantly. As discussed in Chapter 2, domestic production of raw material falls well short of China's growing demand for paper and fibreboard. This demand should maintain prices, provided China continues to improve its competitiveness with processed wood imports. One down-side risk to wood prices is the possibility of reduced import tariffs on paper and fibreboard, which could result in higher imports of these products and subsequently lower domestic demand for raw material. The implication of this risk on the benefit–cost results is examined using sensitivity analysis.

5.1.2 *Annual benefit calculation*

The gross annual benefit from eucalypt research (before research costs) is equal to the difference between the economic returns generated from trees planted in the 'with' scenario (TP^1) and those from trees planted in the 'without' scenario (TP^0). Thus, the annual benefit is given by:

$$(TP^1{}_t \times NPV^1) - (TP^0{}_t \times NPV^0)$$

where TP is the total area of new plantings (additions plus replacements) in year t, NPV is the lump sum returns ($/ha) for a single rotation of trees expressed as a net present value. The superscripts 1 and 0 denote the with and without scenarios, respectively. The NPV values used in the analysis are summarised in Table 8.

Returns are recorded in the year that trees are *planted* rather than the year of harvest. This allows plantation costs and harvest revenue to be consolidated to a single figure, which simplifies the accounting of plantation returns. It also means that returns from trees planted in the last year of the assessment period (2015) are included in the analysis.

5.2 Research costs

Table 9 provides a breakdown of the total costs of the seven ACIAR-funded projects. The costs include ACIAR's investment plus funds contributed by commissioned research organisations and collaborating institutions in Australia and abroad. In nominal terms, A$11.8 million was invested in the projects, which is equivalent to a present value of A$18.2 million.

Since 1992, China has undertaken research independently of ACIAR, which is estimated to have cost A$3.6 million in nominal terms (A$5.0 million present value). The funding sources for these projects are listed in Table 10. The research was undertaken by RITF, the China Eucalypt Research Centre and several provincial forest research bureaus.

5.3 Results

Returns from eucalypt research in China are estimated to be strongly positive with a NPV of A$1.3 billion over 30 years, a benefit–cost ratio (BCR) of 57 to 1 and an internal rate of return (IRR) of 40% (Table 11). Some of the R&D benefits have already been realised through the development of plantations with high-yielding trees. The NPV returns to date are estimated to be A$485 million. This value includes the expected revenue from trees that have been planted but not yet harvested. The returns are strong because:

- considerable yield gains have been achieved in a relatively short time frame—an increase in MAI from 7 to 20 m^3/ha in just 16 years
- the area of eucalypt plantations has expanded rapidly—from 325,000 ha in 1985 to 1.1 million ha in 2003, with an expectation of reaching 1.8 million ha by 2015 (the expansion being partly driven by research outcomes)
- private plantation companies have entered the forest sector and these companies are quickly adopting the new high-yielding trees and implementing best management practice—the analysis assumes that 45% of new plantings are achieving the high yields
- China's domestic demand for industrial wood is strong, which should maintain wood prices into the future.

Table 9. Costs of ACIAR-funded eucalypt projects—nominal values[a]

	1984/057 Species selection & cultivation trials	1988/048 Species selection & cultivation trials	1987/036 Mycorrhiza research	1990/044 Mycorrhiza research	1994/025 Mycorrhiza research	1996/125 Selection trials for cold-tolerant eucalypts	1997/077 Sustainability of eucalypt plantations	Total
	$	$	$	$	$	$	$	$ million
1985	83 550							0.1
1986	212 900							0.2
1987	148 500							0.1
1988	212 018		277 000					0.5
1989		428 554	299 778					0.7
1990		472 670	275 125	128 950				0.9
1991		534 524		380 548				0.9
1992		339 959		363 791				0.7
1993				317 024				0.3
1994								0.0
1995					246 387			0.2
1996					516 373			0.5
1997					477 473			0.5
1998					240 386	879 086		1.1
1999						1 040 129	432 023	1.5
2000						965 535	413 036	1.4
2001						943 772	373 260	1.3
2002						453 954	384 510	0.8
2003								0.0
2004								0.0
Total ($ mill)	0.7	1.8	0.9	1.2	1.5	4.3	1.6	11.8

[a] Includes investment by collaborating agencies.
Source: ACIAR project database. Cost data for 1984/057 and 1988/048 sourced from McKenney et al. (1998).

Table 10. Cost of China's eucalypt breeding program since 1992

Funding sources	Chinese currency Yuan million	Australian currency[a] A$ million
Chinese central government	5	0.9
Provincial governments	5	0.9
World Bank Afforestation Research Program	2	0.4
International Tropical Timber Organisation (ITTO)	3	0.5
Forestry enterprise contributions	5	0.9
Total	20	3.6

[a] Exchange rate of 5.61 Yuan to the A$.
Source: Xu Daping, RITF, pers. comm., 23 July 2004.

The results presented in Table 11 are for *all* eucalypt research activities undertaken in China, not just the ACIAR-funded projects. While the ACIAR-funded projects in the 1980s were critical to the subsequent success of developing high-yielding eucalypts, other organisations helped by funding complementary projects. Therefore, a proportion of the A$1.3 billion NPV is attributable to this other research. One approach to benefit attribution is to assign benefits according to the proportion of funding contributed by each funding body. On this basis, the returns to ACIAR-funded projects would be A$1.0 billion, reflecting the 78% share of overall research costs contributed by ACIAR and associated organisations.

An earlier benefit–cost assessment of eucalypt breeding and selection research in China by McKenney et al. (1998) produced much lower estimates of net returns. A NPV of A$122.3 million in 1996 dollars was reported (equivalent to A$181 million in today's dollars). The study estimated a BCR of 53 and an IRR of 35%. Since that study was published, China has achieved a much greater afforestation rate than that assumed earlier. The 1998 study assumed that annual plantings would reach 70,000 ha by 2003, whereas actual plantings are currently in the order of 192,000 ha/year when allowing for second rotation 'replacement' plantings. Further to this, the 1998 study assumed a lower yield gain relative to the base yield of traditional species. The base yield used by McKenney et al. (1998) was 10.8 m^3/ha, while the present study assumes 7 m^3/ha, which is more realistic. The new species yield of 20 m^3 is consistent for both studies but because the 1998 study uses a lower base yield, it underestimates the size of the productivity gains—13 m^3 as opposed to 9.2 m^3. In turn, the gains in terms of *reduced production costs* per cubic metre of wood are much lower in the 1998 study—a reduction of 10.7 Yuan/m^3 compared with 66 Yuan/m^3 in the present study.

Table 11. Returns from eucalypt research in China—base case results

	Unit	1985–2004	1985–2015
Present value gross benefit to R&D	A$ million	508	1340
Present value R&D cost			
ACIAR funded projects	A$ million	18	18
Other projects	A$ million	5	5
Total	A$ million	23	23
Net returns to R&D			
Net present value	A$ million	485	1317
Benefit–cost ratio	ratio	21	57
Internal rate of return	%	37	40

Source: CIE estimates

5.4 Sensitivity analysis

The results are conditional on an array of assumptions, including expectations about future wood prices, industry expansion rates, potential yields and the proportion of new plantings expected to achieve the higher yields. A sensitivity analysis was conducted to take account of the uncertainty associated with these parameters.

5.4.1 *Scale of industry*

The benefits to R&D are a combination of both higher productivity per hectare and an increase in the number of hectares planted. In the base case analysis it is assumed that the area of eucalypt plantations has been influenced by the R&D; that is, without the development of high-yielding eucalypts, the industry would have been smaller. However, if the view is taken that plantation area would have expanded regardless of the research, benefits reduce by A$418 million. This indicates that most of the research benefits (68%) are due to productivity gains rather than the assumed increase in plantation area.

5.4.2 *Other parameters*

The sensitivity of the base-case results to different input values for several other parameters is examined using the software program @Risk. The three parameters examined are wood yield, stumpage price and the proportion of new plantings that are achieving the potential yields of the new species. The @Risk program calculates a probability distribution of NPV, BCR and IRR outcomes based on multiple iterations using different values for each of the input parameters. The range of possible values for the variables is specified by assuming a particular probability distribution for each variable. In this analysis, a triangular distribution is assumed with the minimum, mean and maximum values of each parameter given in Table 12. The mean values are equivalent to the 'best-bet' values used to calculate the base-case set of results. The upper and lower values of the distribution reflect the degree of uncertainty associated with each parameter.

Table 13 summarises the sensitivity results. The NPV returns to research range from A$669 to A$2148 million over a 30-year period, with a 95% chance that the returns fall within a range of A$809 to A$1868 million. Similarly, the confidence interval for the BCR ranges from a lower bound value of 35 to an upper bound value of 80. These results indicate that the returns are robust and remain positive over the range of values assumed for the input parameters.

Table 12. Range of values used for key input parameters in the sensitivity analysis of the level of returns to eucalypt research in China

	Unit	Minimum	Mean	Maximum
New species yield (mean annual increment)	m^3/ha/year	18	20	22
Stumpage price	Yuan/m^3	140	170	200
Proportion of new plantings achieving the high yields	%	30	45	60

Source: CIE estimates

Table 13. Results of the sensitivity analysis of the level of returns to eucalypt research in China[a]

	Net present value	Benefit–cost ratio	Internal rate of return
	A$ million	ratio	%
Minimum	669	29	25
Maximum	2148	92	58
Mean	1319	57	40
95% confidence interval	809–1868	35–80	28–54

[a] Results are for the whole period 1985–2015.
Source: CIE estimates

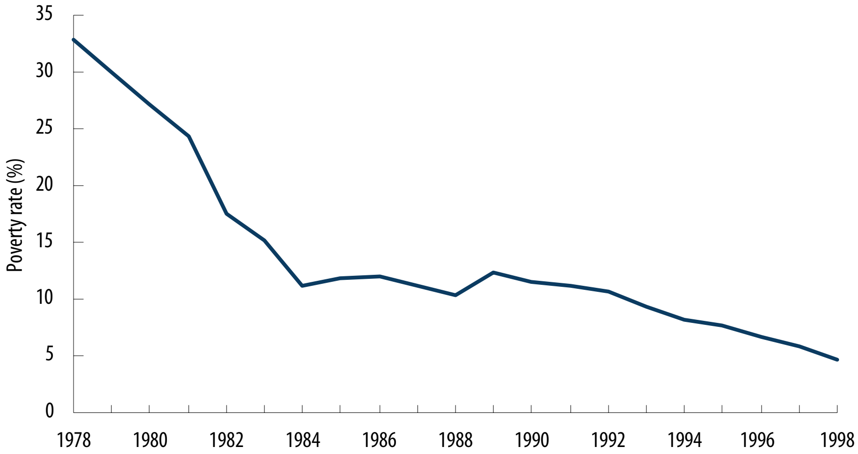
6 Contribution to reducing poverty

China has undergone a period of sustained economic growth since it began reforming its rural sector in 1978. Reforms have included the allocation of land-use rights to agricultural households and the relaxation of central controls on product pricing, subsequently allowing markets to determine prices. As a consequence, per capita growth in gross domestic production (GDP) has grown at an annual rate of 3 to 14% since 1978. Over the period 1995 to 2002, GDP growth averaged 7.4%. Furthermore, there has been a significant reduction in poverty, particularly in the early 1980s (Figure 7). In 1980, almost 30% of China's rural population lived below the poverty line. The most recent statistics estimate a poverty rate of about 5% (World Bank 2000). Government expenditure on education, agricultural R&D and rural infrastructure has also contributed to better living standards among rural households.

However, pockets of extreme poverty still exist. Rural poverty is concentrated in mountainous areas, primarily in several ranges and high plateaus that define the western boundary of traditional Han agriculture. Another pocket of poverty is in China's northern plain. Figure 8 shows the poverty rates in four of the provinces where eucalypts are grown. Poverty is worst in Yunnan and Guangxi, where 6 and 23% of rural households, respectively, are living in poverty. Good agricultural land in these provinces is limited and thus income from cropping is low. By comparison, Guangdong and Fujian provinces are better endowed with agricultural land, skilled labour and infrastructure such as roads and irrigation. These provinces correspondingly have lower rural poverty rates. Thus, the provinces with the most to gain from eucalypt plantation forestry—in terms of reducing extreme poverty—are Yunnan and Guangxi. Some of the reductions that have been observed to date (see Figure 8) may have been due to the development of high-yielding eucalypts, although it is difficult to draw definitive conclusions without a thorough empirical study.

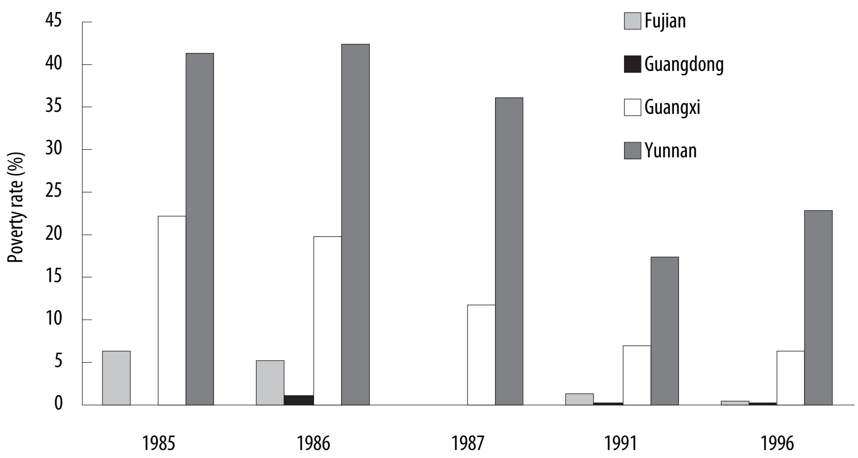
Rural households benefit from plantation forestry either directly, through growing trees on their forest land, or indirectly through increased employment opportunities generated by plantation companies and processing mills. Plantations also have the potential to provide rural villages with improved public infrastructure, financed through taxes raised on plantation sales, and access to a stable supply of firewood.

Figure 7. The declining poverty rate in rural China[a]



[a] Percentage of rural population living below the poverty line.
Source: World Bank (2000).

Figure 8. Rural poverty rates in provinces of China where eucalypts are grown[a]



[a] Percentage of rural provincial population living below the poverty line.
Source: Fan et al. (2002).

6.1 Direct benefits through plantation ownership

Unlike in many developing countries, the allocation of land-use rights to households for the purposes of forestry has been egalitarian in China. Forest land was first divided into plots according to tree species, age, density, site quality and distance to the village etc. The plots were then allocated such that households of similar family size received similar mixes of high and low-quality land and accessible/inaccessible plots. The average household in southern China obtained 4 to 5 plots totalling just 1 to 2 ha (Xu and Hyde 2002). Equitable distribution of land was achieved, but at the cost of many fragmented and scattered plots, which increased the demands on the managerial resources of each household. Nevertheless, the land-allocation process has provided the majority of households with a share of land for growing trees, so there are few landless labourers in China.

The current structure of plantation ownership in each of the provinces where eucalypts are extensively grown is summarised in Table 14. In most provinces, the proportion of plantations under private ownership (village collectives, individual households and companies) has increased over the past 20 years. For example, before 1996 most of the plantations in Yunnan Province were state-owned (80%). The residual was owned mainly by village collectives (18%), with only 2% owned by individual households. Over the past 6 years or so, foreign companies have invested heavily in plantation development. Approximately 55% of plantation area is now owned by private companies. The proportion under the ownership of collectives and households has increased to 25%.

A similar trend has occurred in Guangxi. In 1985, the state was responsible for 27% of plantation area, while collectives owned 73%. Since the various market-orientated reforms in the forestry sector, however, foreign companies now own 36% of eucalypt plantations, households 5%, collectives 42%, and state-owned plantations have shrunk to 17%.

Table 14. Eucalypt plantation ownership in China in 2004

Province	State-owned forest enterprises %	Village collectives and private households %	Private companies %
Hainan	30	10	60
Guangdong	10	5	85
Guangxi	17	47	36
Yunnan	20	25	55
Fujian	60	25	15

Source: RITF workshop 23–25 May 2004

Thus, in the provinces of Guangxi and Yunnan, new plantation development in recent years has been driven mainly by foreign companies. This will no doubt generate employment opportunities in plantation establishment, management, harvesting and transport. But also important is the scope for higher incomes arising from the productivity improvements of trees grown by households and collectives. Village collectives still retain a significant share of plantation area and therefore there should be potential for increased incomes by direct participation in tree growing. For instance, in some parts of Yunnan it is not uncommon for up to 80% of rural households to be growing eucalypt plantations. Box 1 summarises the situation in Jiangpo Village. Over the past 3 years farmers have benefited from a modest increase (4%) in incomes mainly due to the sale of pulpwood and oil. In this village, eucalypts are proving to be a competitive cash crop on mountainous land where it is difficult to grow agricultural crops. Increased demand for pulpwood and oil, together with the higher-yielding species, has improved the relative profitability of growing eucalypts as a short-rotation crop.

Box 1. Case study—eucalypts and Jiangpo Village, Mouding County, Yunnan

- Village population is 2533 persons and 596 households.
- The village comprises 162 ha of land, which is used for both agriculture and forest plantations. Common agricultural crops are rice, maize, tobacco, tea and Chinese medicine.
- About 80% of households are growing eucalypts, either as a member of the village collective or individually. The area of plantation per household ranges from 3 to 5 mu to 100 to 300 mu (15 mu to the ha).
- Three main products are derived from eucalypts. Pulpwood constitutes 50–55% of wood sales, while 30 to 35% comes from oil. Firewood accounts for the remaining 10 to 15%. On average, a household consumes 3 tonnes of firewood per year.
- Six households in the village specialise in distilling oil from the leaves and they purchase fresh eucalypt foliage from growers at about 0.2 to 0.5 Yuan/kg.
- Pulpwood is transported at a cost of 100 Yuan/tonne to the Jingge pulp mill, which is 115 km from the village.
- Annual household income ranges between 5500 and 6300 Yuan. Poorer households generally do not grow eucalypts for commercial production but may maintain trees for shelter around the farm.
- The average wage for a farm worker is about 1360 Yuan/year. Wages have increased by about 4% since 2000.
- Asia Pulp and Paper plans to expand its plantation estate by 200,000 ha but is finding it difficult to obtain land. Farmers are reporting that the rents being offered to them for land are too low. After 14 years, Asia Pulp and Paper is proposing to pay farmers 20% of plantation profits as rental payment for land.

However, the poorest of the poor are not expected to receive a large share of the benefits generated by eucalypt plantations. While empirical data are not available on the distribution of benefits across different income groups, a detailed study on the poverty implications of bamboo plantation development in China is a useful guide to what might occur (Ruiz Perez et al. 2003). During the 1990s, bamboo production increased significantly due to a lowering of harvest taxes, high bamboo prices and the introduction of a ban on the harvesting of natural forests. It was found that households in all income groups gained from the rapid improvement in bamboo productivity. However, middle and higher-income groups gained relatively more. Opportunities from growing bamboo were important, but off-farm employment was even more important for increasing household income. The middle to high-income groups benefited the most from these off-farm opportunities. Bamboo production was found to be a good starting point for early industrialisation, particularly for provinces with good access to markets. The lowest income groups tend to gain the least because of:

- limited access to capital
- limited access to markets
- difficulties in achieving economies of scale in plantation activities relative to larger households with more land
- poor households have inadequate management skills and low education.

6.2 Off-farm employment

The rapid increase in plantations being established by companies, and the construction of new paper mills, should lead to higher incomes in rural areas. For example, a review of the employment situation in Fujian Province shows the following:

- Plantation establishment employs 20–30% of village people for 2 months of the year. Harvesting provides employment to 20% of village people for 1 month each year.
- Most plantation tasks require unskilled labour. There is little mechanisation. Some labour is being sourced from other, poorer provinces, such as Guizhou, Sichuan and Hunan, where labour is cheap.

- Unlike other provinces where eucalypts are grown, ownership of forest land in Fujian resides mainly with village collectives and the state. Farmers are employed by state-owned forest farms or village collectives to plant and maintain the trees. The wage for establishment and harvesting work is typically 1000 Yuan/month. The average annual income of farmers in the south of the province is 7000–8000 Yuan. In the north-west, annual wages are just 4000 Yuan.

- Relatively few people are employed in propagation nurseries. They provide temporary work for about 500–600 people.

- Most wood is used for veneer and MDF. Processing is carried out in factories located in the larger towns. There are two large MDF factories in Fujian Province, one in Fuzhou, the other in Yougan. Together, these factories employ about 2000 people. There are about 70 veneer factories in the province. Each employs about 50 to 200 workers.

6.3 Provision of public infrastructure

In some provinces, the taxes collected from eucalypt sales have been instrumental in financing the upgrade of public infrastructure. Village Administration Committees have the authority to raise revenue from taxing the revenues from plantations owned by village collectives. A survey of several villages located on Leizhou Peninsula, Guangdong Province, found that public infrastructure in these villages has been improved since the development of eucalypt plantations (Zhou Zaizhi et al. 2002). New schools, irrigation and reticulated water systems, roads and power facilities have been built. The extent of improvement has varied across the villages, depending on the area and tenure of eucalypt plantations. Villages with relatively more eucalypt plantations owned and managed by collectives generally have more tax revenue at their disposal for funding public infrastructure. Table 15 summarises the plantation tax revenue spent on infrastructure over 1994 to 1998 for three villages. Spending ranged between 100,000 and 840,000 Yuan (A$17,860–150,000) over the 3-year period. Note that Quanshui village, which has spent the least, has a large plantation area but the majority of this is owned by individual households. Thus, the revenue base is not as large as that of the other villages.

Table 15. Contribution of eucalypt plantation taxes to fund public infrastructure in three villages on Leizhou Peninsula, Guandong Province, China

	Yanggan	Kengwei	Quanshui
Number of households	680	485	1509
Area of eucalypts (ha)			
Village collective	133	47	40
Contracted to specialists	0	67	33
Household owned	0	20	193
Total	133	133	267
Eucalyptus contribution to infrastructure 1994–98 ('000 Yuan)			
Irrigation systems	240	50	20
Roads, bridges	150	450	20
Electricity and tap water	250	150	30
School construction	200	100	30
Total	840	750	100

Source: Zhou Zaizhi et al. (2002)

6.4 Firewood supply

Eucalypt plantations are an important source of fuel wood for farmers, especially for poorer households that cannot afford to purchase liquefied petroleum gas. Communities living around state or collective forestry plantations are generally allowed unrestricted access to forest litter (twigs, leaves and fallen branches) for firewood. Some managers of private plantations also allow this practice. In the Leizhou Peninsula survey referred to above, it was reported that, of the 70% of households on the Peninsula classified as being 'poor', all totally depend on litter for fuel (Zhou Zaizhi et al. 2002). The development of plantations in the region has been of great benefit to these households, who would otherwise be struggling to meet their fuel requirements.

Some farmers sell litter to brick and lime mills and to other households. However, this practice is not widespread and most firewood collected is for subsistence. On the other hand, harvest contractors make a living from selling wood residues (branches, bark, stumps and roots) for firewood. The labour rates paid to harvesters by plantation managers make allowance for this added revenue source.

7 Conclusions

While no hard data are available, the development of high-yielding eucalypts is almost certainly making a considerable contribution to improving the living standards of rural people in southern China. Many households are benefiting directly through growing eucalypts on their own farm or sharing in the increased profits from collective ownership. For others, eucalypts are providing new employment opportunities. There is no evidence to suggest that households are being displaced from their land or marginalised by plantation companies. Indeed, in some provinces companies are leasing land from households, thus providing an alternative source of income for those households. Furthermore, a proportion of plantation revenue is being redistributed through the tax system to help fund public infrastructure development.

The contributions of eucalypts must be viewed against the backdrop of a general decline in poverty rates over the past 20 years, achieved principally through agricultural reforms. While agricultural productivity improvements and market liberalisation have reduced poverty significantly, the gains from productivity improvements in plantation forestry may not be as large. This is because the poorest of households find forestry an enterprise that is relatively difficult to participate in. The very poor lack management skills, access to capital and land. However, it is expected that this cohort of people will nevertheless gain indirectly through plantation development.

References

APEC (Asia Pacific Economic Commission) 2001. APEC Tariff Database. <www.apectariff.org>.

Dell, B. 2004. Impact statement for project FST/1994/025. Prepared for ACIAR.

Fan, Zhang, L. and Zhang, X. 2002. Growth, inequality and poverty in rural China: the role of public investments. Washington DC, International Food Policy Research Institute, Research Report 125.

FAO (Food and Agriculture Organization of the United Nations) 2004. FAOSTAT forestry statistics database, <www.fao.org/forestry>. Accessed 26 August 2004.

Hyde, W.F., Belcher, B. and Xu, J., ed. 2003. China's forests: global lessons from market reforms. Washington DC, Resources for the Future.

Jianzhong, L. 2003. Variation in growth and wood density of *Eucalyptus urophylla*. In: Turnbull, J.W., ed., Eucalypts in Asia. Proceedings of an international conference held in Zhanjiang, Guangdong, People's Republic of China, 7–11 April 2003. Canberra, ACIAR Proceedings No. 111, 94–100.

McKenney, D.W., 1998. Australian tree species selection in China. Canberra, ACIAR, Impact Assessment Series 8.

McKenney, D.W., Davis, J.S., Turnbull, J.W. and Searle, S.D. 1991. The impact of Australian tree species research in China. Canberra, ACIAR Economic Assessment Series 12.

Minsheng, Y. 2003. Present situation and prospects for eucalypt plantations in China. In: Turnbull, J.W., ed., Eucalypts in Asia. Proceedings of an international conference held in Zhanjiang, Guangdong, People's Republic of China, 7–11 April 2003. Canberra, ACIAR Proceedings No. 111, 9–15.

Ruiz Perez, M., Belcher, B., Fu, M. and Yang, X. 2003. Forestry, poverty and rural development: perspectives from the bamboo subsector. In: Hyde, W., Belcher, B. and Xu, J., ed., China's forests: global lessons from market reforms. Washington DC, Resources for the Future, 151–176.

Wang, S. and Wilson, B. 2001. Assessing forestry investment in China: an economic and policy perspective. Paper presented at an international symposium on lessons from the Chinese forestry policy experience, 20–23 June 2001, Dujiangyan, Sichuan Province, China.

World Bank 2000. China: overcoming rural poverty. Washington DC, World Bank.

Xiufang, S., Katsigris, E. and White, A. 2004. Meeting China's demand for forest products. In: China and forest trade in the Asia–Pacific region: implications for forests and livelihoods. Washington, DC, Forest Trends, 31p.

Xu Daping 2003. Scenarios for a commercial eucalypt plantation industry in southern China. In: Turnbull, J.W., ed., Eucalypts in Asia. Proceedings of an international conference held in Zhanjiang, Guangdong, People's Republic of China, 7–11 April 2003. Canberra, ACIAR Proceedings No. 111, 39–45.

Xu, J. and Hyde, W.F. 2002. Changing ownership and management of state forest plantations: China. Prepared for the International Institute for Environment and Development (IIED) following an international conference of the same title, Cape Town, South Africa, 6–8 November 2002.

Yainshet 2002. Wood and paper product markets in China. In: ABARE Current Issues 02.4, March 2002. Canberra, Australian Bureau of Agricultural and Resource Economics.

Yaojian, X. 2003. Developing a strategy for sustainable management of *Eucalyptus* plantations in China. In: Turnbull, J.W., ed., Eucalypts in Asia. Proceedings of an international conference held in Zhanjiang, Guangdong, People's Republic of China, 7–11 April 2003. Canberra, ACIAR Proceedings No. 111, 32–38.

Zhou Zaizhi et al. 2002. Socio-economic assessment of *Eucalyptus p*lantations in Suixi Country, Southern China. Journal of Forest Planning, 8, 57–65.

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