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Forestry in Papua New Guinea: a review of ACIAR's program

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Forestry in Papua New Guinea: a review of ACIAR's program

Hayden Fisher
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Cover: Gorethy Dipsen inspects *Eucalyptus pellita* seedlings in the ACIAR-funded nursery in the Ramu Valley. Photo: Tony Bartlett

Foreword

The forestry industry in Papua New Guinea (PNG)—comprising a large log-export industry (largely operated by foreign companies), a small plantation sector and widespread agroforestry systems—has made a substantial contribution to the country's economic and social development. But the industry faces significant constraints on growth with the rapid depletion of the accessible primary forest resource. Within the next 15 years, timber will be increasingly harvested from logged-over secondary forests where the yield is uncertain. Another concern is the lack of access to customary-owned land for expansion of the plantation forestry industry. Furthermore, there is limited information on germplasm and growth characteristics for potentially high-value plantation species, and a lack of processing capacity.

As part of the move to overcome such constraints the Australian Centre for International Agricultural Research (ACIAR) has made a significant investment in forestry research in PNG. This report is a thematic study of those activities. It provides an overall assessment of the program, based on a combination of desk reviews of project documentation, discussions with project participants and visits to a selection of sites to assess both completed and current projects. Using ACIAR's standard impact assessment framework, it also has taken a more in-depth look at a cluster of projects relating to nuts produced by the *Canarium indicum* tree, known locally as galip nuts.

The report gives an overview of ACIAR's forestry activities in PNG and lists the outputs from a selection of both completed and current ACIAR projects. The discussion about the likely adoption of these outputs highlights the pathways to adoption and notes any barriers that to date have prevented or reduced adoption. Identified outcomes of the selected projects are detailed.

In determining the impacts (or likely impacts) of ACIAR's forestry program in PNG, the reviewer points to a number of lessons drawn from the study that may guide future projects in forestry and other ACIAR program areas.

In developing a framework to identify and quantify the impacts of the galip nut projects, the reviewer concludes that increased planting of galip is likely to provide good returns to smallholder farmers. In the context of a cost–benefit analysis, it is estimated that the galip nut research program could potentially deliver benefits to PNG of around A$163 million in 2010 dollars, a benefit of around A$22.60 for every dollar invested.

Nick Austin
Chief Executive Officer, ACIAR

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Summary

Introduction

Papua New Guinea (PNG) is one of the most important partner countries of the Australian Centre for International Agricultural Research (ACIAR). In recent years, projects in PNG have accounted for around 11% of ACIAR's total budget for bilateral projects.

PNG has a number of natural advantages as a location for forestry, including extensive areas of accessible native forest, climate and soils conducive to tree growing and extensive areas of land that would be suitable for tree planting. In addition, there is a range of high-value species (teak, for example) that are known to grow well in PNG, or are likely to, and there is a long history of successful incorporation of trees into agricultural systems.

The forestry industry has therefore been a major contributor to the economic and social development of the nation. The forestry industry in PNG currently includes a large log-export industry (largely operated by foreign companies), a small plantation sector and widespread agroforestry systems.

There is currently little downstream processing of timber in PNG. The PNG Government is aiming to increase it.

However, despite its natural advantages, the forestry industry faces significant constraints on growth. The accessible primary forest resource is being rapidly depleted, and harvesting from natural forests will, within the next 15 years, necessarily be based on an uncertain yield from logged-over secondary forests. Gaining access to customary-owned land is a major constraint on the expansion of the plantation forestry industry. There is limited information on germplasm and growth characteristics for potentially high-value plantation species and, as mentioned above, there is a lack of processing capacity.

ACIAR's forestry program in PNG

Forestry projects have formed an important component of ACIAR's PNG program. Around 12% of ACIAR funding of completed projects that have included PNG as a partner country went to the forestry program.

The PNG projects funded through the forestry program have broadly fallen into four main categories:

- Scoping and feasibility studies—these have aimed either to identify a possible future research agenda or to test whether new industries are likely to be commercially viable.
- Sustainable forest management—ACIAR projects have targeted PNG policymakers and local communities managing forests.
- Agroforestry—several ACIAR projects have aimed to encourage smallholders to more effectively incorporate trees into their agricultural systems.
- Downstream processing—ACIAR has funded projects aimed at increasing the level of downstream processing that occurs in PNG.

Three projects that, collectively, have aimed to establish a commercial galip nut[1] industry in East New Britain have been funded through ACIAR's forestry program. This

[1] Galip nut is the local name for nuts produced by *Canarium indicum* trees.

cluster of projects has been selected for more detailed analysis using ACIAR's impact assessment framework.

Outputs

ACIAR-funded projects have delivered, or have made significant progress towards delivering, a range of outputs. The feasibility studies have increased knowledge about the contextual environment and the feasibility of uptake of future research results.

The sustainable forest management projects have increased the scientific knowledge critical for effective forest management; developed forest management plans for local communities and a range of tools to assist the decision-making of PNG forest agencies and local communities; and built capacity within PNG forest agencies, non-government organisations (NGOs) and local communities.

The agroforestry projects have improved the scientific understanding of trees in the context of agroforestry systems and knowledge on community attitudes and current production systems. In addition, these projects have developed new technologies and systems relevant for use in agroforestry systems and tools to assist decision-making, and have built capacity within PNG collaborators and local communities.

While the downstream processing project has not yet been completed, it has nevertheless delivered a number of outputs. Capacity building has been a key focus. The project has also improved understanding of domestic timber processing in PNG and industry capabilities, delivered drying schedules for nine commercial native species and designed low-cost sustainable houses for both rural communities and urban settlements.

The galip nut cluster of projects has improved understanding on the contextual environment and the feasibility of a commercial galip nut industry, and the scientific understanding of phenotypic variation between different galip tree populations. Vegetative propagation protocols have also been developed and a clonal garden has been established. The postharvest research undertaken resulted in enhanced scientific understanding of handling and processing methods, developed commercial processing methods, identified appropriate processing equipment, improved the understanding of barriers to adoption in different production environments and built capacity at the National Agricultural Research Institute (NARI) and within local communities.

Adoption

Adoption of project outputs has been mixed.

- The feasibility and scoping studies have led to subsequent projects.
- Adoption of project outputs appears to have been greatest in the projects aimed at local communities. There is evidence of the following in a number of communities:
  - small-scale planting of teak and other species by individuals and schools (up to around 0.5 hectares)
  - small-scale plantings of fast-growing fuelwood species for both local and commercial use
  - integration of trees into agricultural systems, such as gardens (to avoid weeding or to reduce erosion).
- Despite increasing the capacity of policymakers to manage PNG's forest resources more sustainably, it is unlikely that there was any significant change in forest management policy as a direct result of the ACIAR-funded policy-related projects. However, the tools developed through the ACIAR project aimed at better and more sustainable community management of cut-over forests have been used in the development of forest management plans that may ultimately lead to Forest Stewardship Council certification.
- It is too early to obtain a clear view on the likelihood of adoption of any outputs produced by the downstream processing projects.

More than 100,000 galip seedlings have been distributed to small-scale farmers under complementary European Union-funded projects. This is expected to eventually increase to around 1 million. Galip trees start to produce nuts in around their 5th year and reach the maximum yield after about 15 years. Once the maximum yield is

reached, the superior trees distributed under the project are likely to produce almost 60,000 tonnes (t) of nut in shell, or around 12,000 t of processed kernel.

The project team is currently setting up a pilot facility to process nuts and demonstrate the technology to a commercial investor. A major agribusiness company (Agmark) has shown considerable interest in establishing a commercial-scale processing facility.

Pathways to adoption

The pathway to adoption has been, in most cases, through extension services provided by one or more of the project partners. Generally, this was an NGO or private company that ran complementary programs and often had established links to relevant communities.

There was some evidence of government involvement in extension activities. In particular, the NARI team running the galip nut program has provided extension services to local farmers. However, the project team largely operates at arm's length to NARI's management structures and mostly relies on donor funding. In other projects, there was some government involvement in the project's extension activities but, in most cases, extension was driven primarily by non-government partners.

It is too early to tell whether any outputs produced by the main downstream processing project will be adopted. However, with any project that develops a new product, there is a significant risk that no market for the product will be found. It is therefore essential for existing timber processors (such as PNG Forest Products) that will ultimately be responsible for marketing the product to be fully engaged in product development research.

Barriers to adoption

A range of barriers to adoption was evident in the projects reviewed as part of this study. They included:

- weak governance
- lack of government extension services
- limited supply of germplasm
- aversion to changing established practices
- long time frame to receive benefits
- lack of infrastructure.

However, there was also evidence of strategies to avoid or overcome a number of these barriers. These included:

- collaborating with NGOs with established links to relevant communities
- improving germplasm distribution mechanisms
- prioritising projects for which the final user groups are local communities.

Outcomes

Changes in behaviour directly attributable to the ACIAR projects included the following:

- Better forest management was evident through communities incorporating the recommendations of ACIAR-funded research into the development of forest management plans.
- There was greater and more effective incorporation of trees into agricultural systems, including high-value timber species and fast-growing fuelwood species, and soil erosion on sloped garden beds was reduced through the use of biological terrace gardens.
- Planting of galip trees increased and is likely to provide good returns for smallholder farmers.
- There is evidence of use of some of the capacity built through the ACIAR projects.

Impacts

The potential economic impacts of ACIAR's forestry program in PNG include:

- higher and more sustainable incomes from cut-over forests managed by local communities
- future income from planting high-value timber species such as teak
- future income from fuelwood species for commercial use

- an increase in the availability of fuelwood and construction material for local use
- increase in the usable land in sloped areas such as in the Highlands due to decreased erosion attributable to strategic tree planting.

There may also be environmental benefits from greater incorporation of trees into agricultural systems. These might include:

- reduced erosion on sloped areas and riparian zones
- less reliance on natural forests for fuelwood and construction material.

Since most of the benefits from many of ACIAR's projects are likely to flow to poor local communities, increased incomes due to tree planting could contribute to the alleviation of poverty in some areas. Also, tree growing can provide an important means of saving for the future.

The ultimate impact of the galip nut projects could be the establishment of a commercial galip nut industry in East New Britain. Since there are likely to be economies of scale in processing, a likely industry structure in PNG is for a commercial-scale processing facility to process the nuts produced by a cluster of surrounding smallholders.

A commercial processing facility could provide much-needed formal employment opportunities in the region, particularly for women.

Benefits and costs

In present value terms, we estimate that the galip nut research program could potentially deliver benefits to PNG of around $163.0 million in 2010 Australian dollars, using a discount rate of 5%. Assuming farmers receive a price of around 1 PNG kina (K)/kilogram (kg) (nut in shell) and processors earn a margin of around K2.50/kg of processed kernel, around 60% of these benefits are estimated to flow to processors, with the remaining 40% flowing to farmers. The real research costs are estimated at around A$7.2 million (expressed in similar terms). This includes funding committed to date from all sources and an estimated K2 million/year for the next 10 years. The research program could deliver net benefits of around A$155.8 million. This is a benefit of around A$22.60 for every dollar invested. The internal rate of return on the research is estimated at around 20%.

Since all of the separate projects that make up the overall research program are considered necessary to deliver benefits, the benefits can be attributed to individual projects on a cost-share basis. The three ACIAR projects have made up around 68% of the total funding committed to date. However, when expected future funding requirements are taken into account, this becomes around 31% of the total estimated research costs. Therefore, around A$51 million of the estimated benefits can be attributed to the three ACIAR projects. Based on ACIAR's contribution to these projects, around A$34.4 million can be attributed to ACIAR.

Conclusions

Forestry has been an important component of ACIAR's PNG program. While PNG has significant natural advantages in forestry, it is a difficult environment to deliver successful research and development (R&D) projects. Despite this, ACIAR's approach in the area of forestry over recent years has had some success in overcoming many of the barriers to adoption.

A range of different types of projects has been funded through ACIAR's forestry program. Of the projects reviewed as part of this study, the achievements have been mixed. There are nevertheless a number of lessons that can be drawn from this study that may be useful in guiding future projects in both forestry and other ACIAR program areas.

There appears to be a number of advantages to funding feasibility and scoping studies. These studies tend to require less funding than a full-scale R&D project and minimise the risk of funding a large project in an area that ultimately turns out to have little commercial potential. These studies can also provide a road map for new industries, particularly where coordination is required.

The projects for which ACIAR has been most successful in having research outputs adopted are those aimed at local communities. Nevertheless, adoption to date appears to have been on a relatively small scale. It may be worth revisiting these projects to determine whether adoption was high enough for the benefits to the community to outweigh the cost of the research. Strategies that have supported adoption include:

- building extension activities into the project design by partnering with NGOs or other private providers of extension activities
- focusing on new products or methods that require little change from current practice and can readily be integrated into existing low-input farming systems
- specifically tackling barriers to adoption, such as the supply of germplasm.

ACIAR appears to have been less successful in having outputs adopted in the challenging environment of PNG policymaking. While ACIAR-funded projects can increase capacity within PNG forest authorities, its delivery model is not well suited to overcoming underlying governance problems. ACIAR research is likely to improve forest management only if lack of capacity is the key constraint.

Where ACIAR research develops new products, significant marketing effort is likely to be needed to find markets for those products. This may require a long-term funding commitment.

1 Introduction

Papua New Guinea (PNG) is, in terms of funding, the second most important partner country of the Australian Centre for International Agricultural Research (ACIAR). In recent years, around 11% of ACIAR's budget for bilateral projects has gone to PNG (ACIAR 2009). Despite this significant investment, ACIAR has, in general, been less successful in delivering benefits in PNG than it has in some other partner countries. Forestry is an important industry in PNG and one that faces significant challenges. Forestry research has therefore been an important component of ACIAR's PNG program.

Forestry in Papua New Guinea

PNG has a number of natural advantages as a location for forestry (Haines 2009). In particular, there are extensive areas of accessible native forest that, properly managed, could provide an ongoing source of valuable timbers, as well as large areas of land that would be suitable for tree planting. In addition, climate and soils are conducive to good tree growth, there is a range of high-value species (teak, for example) that could grow successfully and a long history of incorporation of trees into agricultural systems.

Forestry has therefore been an important contributor to the overall economic and social development of the country. The following are major elements of the forestry industry in PNG:

- There is a large log-export industry, based on harvesting of natural primary forests. Logging of primary forests is largely undertaken by foreign logging companies, with very little value-adding processing in PNG. As almost all of PNG's remaining primary forest resources are on customary land, the PNG Forest Authority must acquire the rights from customary owners before the resources are allocated to logging companies through a tender process (R. Turia, pers. comm., 17 May 2010). Royalties are currently around K30/m^3 plus a range of other smaller levies, with most of the proceeds returned to the landowners.
- There is a small, conventional plantation sector. The PNG Forest Authority currently manages around 35,000 hectares (ha) of plantation forest and there are three commercial plantations covering around 33,000 ha in total (F. Vilamur, pers. comm., 17 May 2010).
- Agroforestry systems are widespread and are a major element of subsistence agriculture (Haines 2009). Incorporating trees into agricultural systems can have significant economic advantages for smallholders.
  - High-value timber species, such as teak, can be an important source of income for landowners. Tree-growing is relatively low risk and, since it is a longer term investment than annual crops, it can act as a store of value or a 'bank' for landowners, allowing them to save for future large expenses.
  - Trees can provide an important source of construction material for new houses or school buildings etc.
  - Trees integrated into agricultural systems are an important source of fuelwood.
  - Some trees can be used to shade other crops, such as cocoa.
  - Some trees can act as a cash crop (as in the case of *Canarium indicum*, which produces galip nuts).
  - When incorporated into gardens, trees can reduce erosion in mountainous areas and can therefore extend the area of land that can be used for gardens.

Currently, only a small amount of timber processing is undertaken within PNG. However, the PNG Government established a new policy in 2010 prohibiting the export of logs from new timber concessions. This will require logging companies to commit to downstream processing in PNG. Since this policy has been in place no new allocations have been granted. However, this may present an opportunity for enhanced outcomes from the ACIAR project on value-added processing of wood products, provided there is significant engagement with private-sector partners.

Under its 2011–15 Medium Term Development Plan, the PNG Government aims to:

- increase processed-timber exports from 20% currently to 80% of all forestry exports by 2030
- produce all logs from plantations and managed forests by 2030
- increase plantation forests from 62,000 ha to well over 150,000 ha by 2030.

Constraints on the forestry industry in PNG

Despite PNG's natural advantages as a location for forestry, the industry faces some major constraints on its growth:

- The accessible primary forest resource is being rapidly depleted, and harvesting from natural forests will, within the next 15 years, be based on logged-over secondary forests.
- Gaining access to customary-owned land is a major constraint on the expansion of the plantation forestry industry.
- There is limited information on germplasm and growth characteristics for potential high value plantation species.
- There is a lack of capacity for value-adding processing.

Outline of this report

This report is a thematic study of ACIAR's forestry activities in PNG. It aims to provide an overall assessment of the program, based on a combination of desk reviews of project documentation, discussions with project participants and site visits to a selection of both completed and current projects funded through the forestry program. It also takes a more in-depth look at a cluster of projects relating to galip nuts, using ACIAR's standard impact assessment framework. Conclusions are then drawn from these assessments that may help to guide future investment decisions.

The remainder of the report is structured as follows:

- Chapter 2 provides an overview of ACIAR's forestry activities in PNG.
- Chapter 3 outlines the outputs produced by a selection of both completed and current ACIAR projects.
- Chapter 4 discusses the likely adoption of these outputs. Pathways to adoption and any barriers that have prevented or reduced adoption are highlighted.
- Chapter 5 identifies the outcomes achieved by the selected projects.
- Chapter 6 discusses the impacts or likely impacts of ACIAR's forestry program in PNG. It also sets out a framework for identifying and quantifying the impacts of the galip nut projects.
- Chapter 7 quantifies the impacts of the galip nut projects and sets them out in a cost–benefit analysis framework.
- Chapter 8 draws conclusions from the analysis outlined above.

2 ACIAR's forestry activities in Papua New Guinea

ACIAR's research in Papua New Guinea

ACIAR's program in PNG focuses on securing improvements in food supply and rural incomes for smallholder farmers through increased productivity and enhanced access to markets and services. This is in line with the PNG Government's Medium Term Development Strategy to promote economic growth in the rural sector (comprising agriculture, forestry and fisheries).[2]

The program has five main themes:

1. Addressing social, cultural and policy constraints to the adoption of agricultural technologies
2. Enhancing smallholder incomes from horticulture and root crops
3. Improving smallholder returns from export tree crop production and marketing
4. Promoting new livelihoods from smallholder fisheries, aquaculture and forestry
5. Sustainable management of forestry and fisheries resources, and agricultural biosecurity.

ACIAR's forestry projects relate mainly to the second, fourth and fifth themes.

[2] ACIAR website, http://aciar.gov.au/node/8982, accessed 14 April 2010.

ACIAR's forestry program in Papua New Guinea

Despite the significant constraints on the PNG forestry industry, it is ACIAR's view that forestry can continue to play a major role in the PNG economy, based on its natural advantages. ACIAR suggests (FST/2002/010 Final report) that the PNG forestry industry in 15–20 years could include:

- harvesting from secondary forests managed on sustainable cutting cycles, providing logs of high-quality timber species, probably in smaller log sizes than currently harvested
- a significant plantation sector based on high-value timber and multipurpose species, grown in particular in:
  - agroforestry systems
  - community plantings
  - larger rehabilitation plantings
- a significant domestic processing industry producing, for example, sawn timber and sliced and peeled veneer
- an enhanced local trade in non-timber forest products
- potential returns from carbon capture.

Forestry and agroforestry projects have therefore formed an important component of ACIAR's PNG program. Around 12% of the funding for ACIAR's completed projects in PNG—including all bilateral and multilateral projects that have included PNG—have related to forestry or agroforestry (Figure 1). When only bilateral projects are considered, around 16% of the funding for the PNG program has gone to forestry and agroforestry projects.

Overview of ACIAR's forestry activities in PNG

The projects ACIAR has funded through the forestry program fall into several broad categories, although several individual projects overlap them:

- scoping and feasibility studies
- sustainable forest management projects
- agroforestry projects
- downstream processing projects.

A selection of the projects that ACIAR has funded within each of these categories is analysed as part of this study. The selected projects under each category are outlined below.

Scoping and feasibility studies

ACIAR has funded a number of scoping and feasibility studies to identify future research opportunities on a particular theme, or to look into the feasibility of establishing new industries. Projects in this category include:

- Domestication and commercialisation of multipurpose indigenous trees and shrubs for food and other products in Papua New Guinea, the Solomon Islands and Queensland: a feasibility study with special reference to Canarium nut (FST/2002/010)

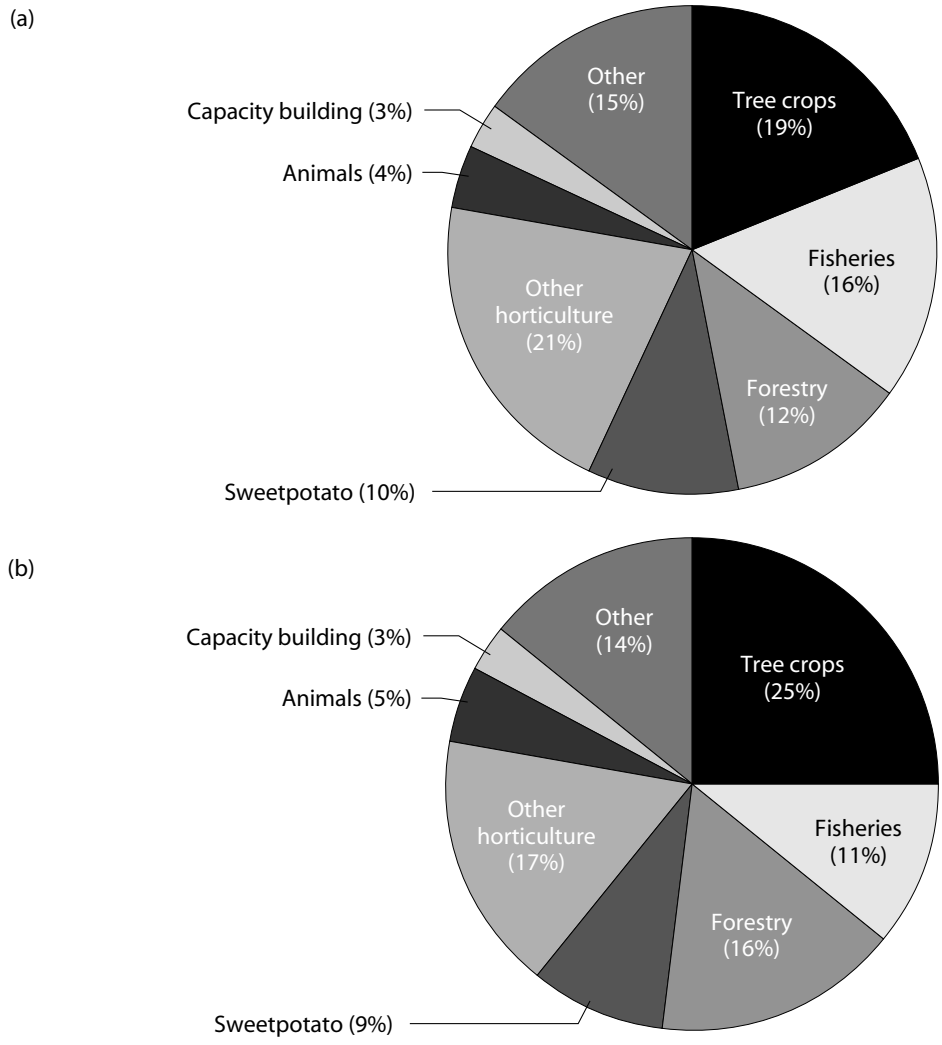

Figure 1. Distribution of ACIAR project expenditure in Papua New Guinea: (a) all projects; (b) bilateral projects. Data sources: ACIAR project database and Centre for International Economics' calculations

- Identification of researchable issues underpinning a vibrant balsawood industry in Papua New Guinea (FST/2009/012).

Sustainable forest management

In line with the sustainable resource management theme underpinning the PNG program, ACIAR has funded a number of projects focused on sustainable forest management. Projects in this category include:

- Testing the utility of the north Queensland rainforest growth and timber yield model in Papua New Guinea (FST/1995/123)
- Planning methods for sustainable management of timber stocks in Papua New Guinea's forests (FST/1998/118)
- Assessment, management and marketing of goods and services from cut-over native forests in Papua New Guinea (FST/2004/061).

The first two of these projects were aimed at policymakers, and focused on improving the planning and management systems to enhance sustainability. The more recent project was aimed at improving the management of cut-over native forests managed by both PNG government agencies and local communities.

Agroforestry systems

ACIAR has funded a number of projects aimed at integrating trees in village-based agricultural systems. These projects link in with ACIAR's theme of new livelihoods for smallholders. Projects in this category include:

- New leucaenas for South-East Asian, Pacific and Australian agriculture (FST/1994/033)
- Value-adding to Papua New Guinea agroforestry systems (FST/2004/050)
- Domestication and commercialisation of *Canarium indicum* in Papua New Guinea (FST/2004/055)
- Promoting diverse fuelwood production systems in Papua New Guinea (FST/2006/088)
- Germplasm development and delivery to underpin a Papua New Guinea timber industry based on planted forests (FST/2007/078).

Downstream processing

There is currently little downstream processing of timber or non-timber forest products in PNG. The PNG Forest Authority is keen to see greater timber processing occurring within PNG. ACIAR has therefore funded postharvest processing projects relating to both timber and other products. Projects in this category include:

- Processing of *Canarium indicum* nuts: adapting and refining techniques to benefit farmers in the South Pacific (FST/2006/048)
- Increasing downstream value adding in Papua New Guinea's forest and wood products industry (FST/2006/120).

Figure 2 is a schematic of the PNG forestry industry and the industry segments targeted by the abovementioned projects.

Funding

The funding ACIAR has committed to the selected projects amounts to around A$8.1 million in nominal terms (Table 1).

Collaborators

A wide range of organisations has collaborated on ACIAR-funded projects (Table 2). Although the collaborators vary from project to project, a typical arrangement appears to be for one or more Australian organisations to collaborate with a PNG government organisation and various other PNG partners, including non-government organisations (NGOs), private businesses and universities.

Summary of pathway to impacts for selected projects

The framework ACIAR uses for impact assessments for its research and development (R&D) projects involves mapping the pathway to impacts, as summarised in Figure 3.

Table 3 maps the pathways to impact for the selected projects. It summarises the key outputs, outcomes and impacts already delivered by ACIAR projects, as well as potential outputs, outcomes and impacts where substantial progress has been made but the projects are incomplete. The outputs, outcomes and impacts highlighted in Table 3 are discussed in further detail in subsequent chapters.

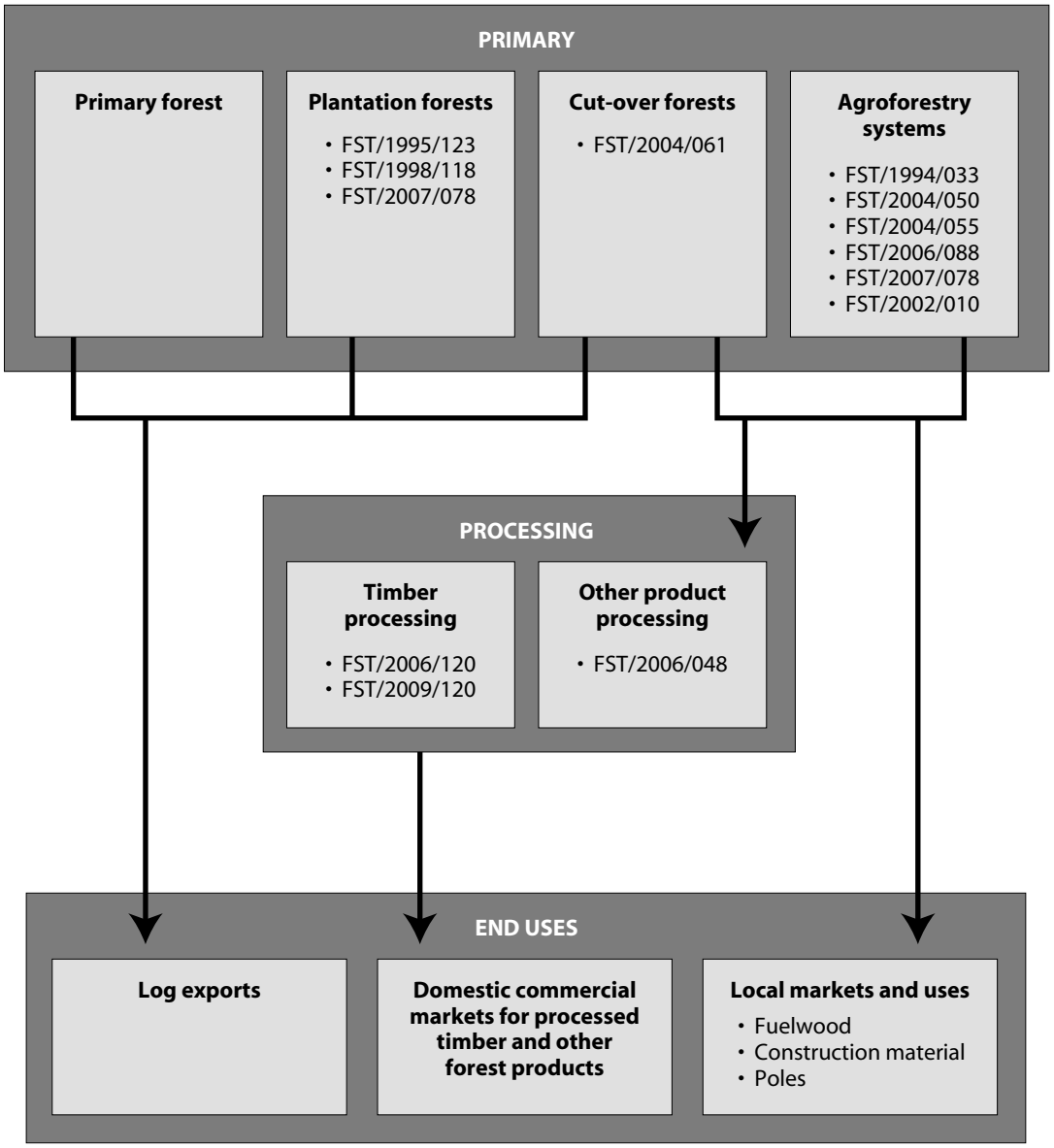

Figure 2. Industry segments targeted by ACIAR forestry projects in Papua New Guinea. Data source: Centre for International Economics. Note: See Table 1 for a full description of the ACIAR projects.

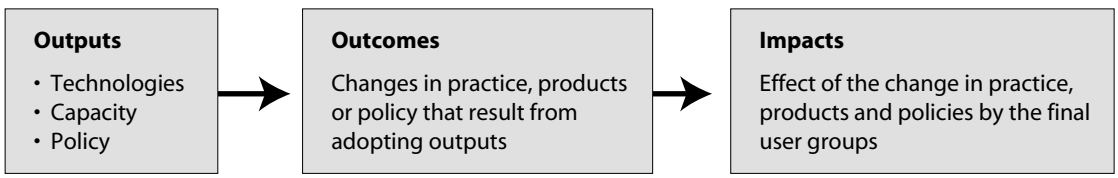

Figure 3. Pathway to project benefits. Source: Davis et al. (2008)

Table 1. ACIAR funding to forestry projects in Papua New Guinea (PNG)

Project number	Project name	ACIAR funding A$
Scoping and feasibility studies		
FST/2009/012	Identification of researchable issues underpinning a vibrant balsawood industry in PNG	59,910
FST/2002/010	Domestication and commercialisation of multipurpose indigenous trees and shrubs for food and other products in PNG, Solomon Islands and Queensland: a feasibility study with special reference to canarium nut	203,606
Sustainable forest management		
FST/1995/123	Testing the utility of the north Queensland rainforest growth and timber yield model in PNG	161,983
FST/1998/118	Planning methods for sustainable management of timber stocks in PNG's forests	842,009
FST/2004/061	Assessment, management and marketing of goods and services from cut-over native forest in PNG	783,318
Agroforestry		
FST/1994/033	New leucaenas for South-East Asian, Pacific and Australian agriculture	1,279,049
FST/2004/050	Value-adding to PNG agroforestry systems	912,087
FST/2004/055	Domestication and commercialisation of *Canarium indicum* in PNG	634,571
FST/2007/078	Development of a PNG timber industry based on community-based planted forests: design and implementation of a national germplasm delivery system	1,009,760
FST/2006/088	Promoting diverse fuelwood production systems in PNG	923,079
Downstream processing		
FST/2006/120	Increasing downstream value-adding in PNG's forest and wood products industry	682,816
FST/2006/048	Processing of *Canarium indicum* nuts: adapting and refining techniques to benefit farmers in the South Pacific	651,776
	Total	**8,143,964**

Source: ACIAR website at < http://aciar.gov.au/home>, accessed 9 August 2010.

The galip nut cluster of projects

Three of the projects listed in Tables 2 and 3 (FST/2002/010, FST/2004/055 and FST/2006/048) have formed an important component of a broader R&D program that ultimately aims to establish *Canarium indicum* nuts as a key export industry for PNG and other parts of Melanesia.

Canarium indicum—known in PNG as galip—is a tree species native to parts of Melanesia, including East New Britain and the nearby islands of PNG, as well as Vanuatu and Solomon Islands. The nuts produced by these trees are eaten locally. The nut has significant commercial potential elsewhere in the region and as an export item, and could potentially be an important source of income for smallholder farmers.

Previous attempts at establishing a commercial galip nut industry have failed for a range of reasons. In particular, they have relied on sourcing the nut from wild resources, which has resulted in unreliable supply and variable quality.

ACIAR and other donors have funded a series of projects aimed at overcoming the various constraints, so that galip nut production can reach its commercial potential. This cluster of projects has been selected for a full impact assessment.

Table 2. Collaborators in ACIAR forestry projects in Papua New Guinea (PNG)[a]

Project number	Project name	Australian collaborators	PNG government partner	Other PNG partners
Scoping and feasibility studies				
FST/2009/012	Identification of researchable issues underpinning a vibrant balsawood industry in PNG	• Salwood Asia Pacific Pty Ltd[b] • Four Scenes Pty Ltd • Mr Alan Brown		• University of Vudal • Mr Tommy Kosi
FST/2002/010	Domestication and commercialisation of multipurpose indigenous trees: a feasibility study with special reference to canarium nut	• James Cook University[b] • Queensland Department of Primary Industries and Fisheries • Macro Agribusiness Consultants Pty Ltd • Michael Davis Consultants	• National Agricultural Research Institute	
Sustainable forest management				
FST/1995/123	Testing the utility of the north Queensland rainforest growth and timber yield model in PNG	• Queensland Forest Research Institute[b] • Center for International Forestry Research	• Forest Research Institute	
FST/1998/118	Planning methods for sustainable management of timber stocks in PNG's forests	• Bureau of Rural Sciences[b] • Southern Cross University • Queensland Forest Research Institute • Australian National University	• Forest Research Institute	
FST/2004/061	Assessment, management and marketing of goods and services from cut-over native forest in PNG	• University of Melbourne[b] • Australian National University	• Forest Research Institute	• Village Development Trust

Table 2. (continued)

Project number	Project name	Australian collaborators	PNG government partner	Other PNG partners
Agroforestry				
FST/1994/033	New leucaenas for South-East Asian, Pacific and Australian agriculture	• University of Queensland[b] • Agriculture Western Australia • Queensland Department of Primary Industries • CSIRO Tropical Agriculture		• University of Technology • Rural Development Bank
FST/2004/050	Value-adding to PNG agroforestry systems	• Australian National University[a]	• Forest Authority	• Papua New Guinea University of Technology • OK Tedi Development Foundation • Village Development Trust • Papua New Guinea Ecoforestry Forum • Ramu Agri-industries
FST/2004/055	Domestication and commercialisation of *Canarium indicum* in PNG	• James Cook University[a]	• National Agricultural Research Institute	• Cocoa and Coconut Institute
FST/2007/078	Germplasm development and delivery to underpin a PNG timber industry based on planted forests	• James Cook University[b] • CSIRO Plant Industry	• Forest Authority • Forest Research Institute	• Ok Tedi Development Foundation • Foundation for People and Community Development Inc. • Organisation of Industrial, Spiritual and Cultural Advancement • University of Vudal • Pacific Islands Projects
FST/2006/088	Promoting diverse fuelwood production systems in PNG	• University of Adelaide[b] • Ensis	• Forest Research Institute	• Foundation for People and Community Development • WR Carpenter & Co. Estates Ltd • People's Action for Rural Development • HOPE worldwide

Table 2. (continued)

Project number	Project name	Australian collaborators	PNG government partner	Other PNG partners
Downstream processing				
FST/2006/120	Increasing downstream value-adding in PNG's forest and wood products industry	• University of Melbourne[b] • Engineered Wood Products Association of Australasia	• Forest Research Institute	• University of Technology • Timber and Forestry Training College • PNG Forest Products Ltd • Village Development Trust • PNG Forest Industries Association
FST/2006/048	Processing of *Canarium indicum* nuts: adapting and refining techniques to benefit farmers in the South Pacific	• University of the Sunshine Coast[b] • Hidden Valley Plantations • Macro Agribusiness Consultants Pty Ltd	• National Agricultural Research Institute	

Source: ACIAR website at <http://aciar.gov.au/home>, accessed 9 August 2010

[a] Includes Australian commissioned organisation and Australian and PNG collaborating institutions

[b] Commissioned organisation

Table 3. Summary of the outputs, outcomes and impacts of selected ACIAR forestry projects in Papua New Guinea (PNG)

Project number	Project name	Key outputs	Outcomes	Impact
Scoping and feasibility studies				
FST/2002/010	Domestication and commercialisation of multipurpose indigenous trees: a feasibility study with special reference to canarium nut (completed)	Greater understanding of the contextual environment and the feasibility of uptake of future research.	Led to subsequent ACIAR projects (FST/2004/055 and FST/2006/048).	Any benefits delivered by the subsequent projects can be partly attributed to the feasibility study.
FST/2009/012	Identification of researchable issues underpinning a vibrant balsawood industry in PNG (completed)	Greater understanding of the contextual environment and identification of future research needs.	A new ACIAR project (FST/2009/016) is being developed.	Any benefits delivered by the subsequent projects can partly be attributed to the scoping study.
Sustainable forest management				
FST/1995/123	Testing the utility of the north Queensland rainforest growth and timber yield model in PNG (completed)	Greater understanding that the structure of the forest management system developed for north Queensland is sufficiently generic to incorporate new data for PNG species, but that a number of modifications are required before it can be used reliably in PNG.	Led to a subsequent ACIAR project (FST/1998/118).	
FST/1998/118	Planning methods for sustainable management of timber stocks in PNG's forests (completed)	Increased knowledge of sustainable forest management in PNG, including how the forest responds to harvesting, optimal cutting cycles and diameter limits. In particular, the project identified that the current 35-year cutting cycle is probably too short to allow for commercially viable future harvest if all trees greater than 50 cm DBH (diameter at breast height) are cut.	No changes identified in terms of forest resource management.	No impacts identified in terms of forest resource management.

Table 3. (continued)

Project number	Project name	Key outputs	Outcomes	Impact
FST/1998/118 (continued)	Planning methods for sustainable management of timber stocks in PNG's forests (completed)	A revised strategic forest inventory method and an improved database PERSYST to integrate existing forest area, inventory and growth information. A model (PINFORM) for use in forest estate planning that included new volume equations was also developed. Capacity built within the PNG Forest Authority, the PNG Forest Research Institute and the Department of Environment and Conservation on how to develop and apply planning systems.	No changes identified in terms of forest resource management.	No impacts identified in terms of forest resource management.
FST/2004/061	Assessment, management and marketing of goods and services from cut-over native forests in PNG (completed)	Increased scientific knowledge relating to timber and carbon stocks and dynamics following timber harvesting, as evidenced by three publications in international journals. Re-measurement of permanent sample plots and creation of database incorporating previous inventory data. Development of forest growth models for PNG's cut-over forests, based on permanent sample plot data. Development of modern and efficient approach to forest inventory in PNG. A rapid and cost-effective assessment method for cut-over forests in PNG.	Non-government organisations (NGOs) working with forest communities have used the community forest assessment tools produced by the project, allowing them to provide better advice to communities in the development of forest management plans. Change in forest management practices in line with forest management plans. This may eventually allow some communities to achieve Forest Stewardship Council certification. One community is producing sustainable timber for local construction and local sales.	This project could eventually lead to more sustainable benefits from forest resources and potentially higher incomes for communities with access to capital to purchase equipment. Certification could allow communities to receive a better price for timber products from local timber mills. More sustainable flow of environmental services from forest resources.

Table 3. (continued)

Project number	Project name	Key outputs	Outcomes	Impact
FST/2004/061 (continued)	Assessment, management and marketing of goods and services from cut-over native forests in PNG (completed)	Financial models for community small-scale sawmills. Forest management plans prepared for four community forests. Greater understanding of international markets for tropical hardwoods. Capacity built within PNG forest agencies, NGOs and communities.	Evidence that the capacity built through the project within the PNG Government is being used: • Forest Research Institute using plot data to estimate forest carbon stocks in different forest types and treatments for use in Reducing Emissions from Deforestation and Degradation (REDD) carbon payment schemes. • Forest Research Institute staff used new skills to develop an inventory system to measure soil carbon in different forest types. • Forest Authority using assessment and modelling tools to create project-level merchantable volume and forest carbon estimates. As a result of the capacity built, PNG is taking a leadership approach in United Nations Framework Convention on Climate Change negotiations on payments for forest carbon associated with REDD.	This project could eventually lead to more sustainable benefits from forest resources and potentially higher incomes for communities with access to capital to purchase equipment. Certification could allow communities to receive a better price for timber products from local timber mills. More sustainable flow of environmental services from forest resources.

Table 3. (continued)

Project number	Project name	Key outputs	Outcomes	Impact
Agroforestry				
FST/1994/033	New leucaenas for South-East Asian, Pacific and Australian agriculture (completed)	The project was primarily undertaken in Australia, Vietnam, the Philippines and PNG. The outputs relevant to PNG included the following: • Improved scientific understanding of lesser known species of *Leucaena* and hybrids, including: – cold and frost tolerance, acid-soil tolerance and psyllid resistance – the extent to which environmental factors constrain growth – their animal production potential. • Development of a vegetative propagation technique. • Identification of high-yielding hybrids suitable for ruminant feed.	No direct outcomes identified in PNG. The hybrid requires vegetative propagation, so adoption was considered unlikely without a government extension service. Since a commitment to government extension services was not forthcoming, no further work was undertaken in PNG. Nevertheless, subsequent private-sector research built on the knowledge developed through the ACIAR project, which led to large areas of leucaena being planted in the Markham Valley.	No direct impact identified in PNG. Some of the benefits of the subsequent research can be attributed to the ACIAR project.
FST/2004/050	Value-adding to PNG agroforestry systems (active)	Identification of appropriate species for the pilot study regions. Greater understanding of landowners' attitudes to commercial tree growing. Development of village-level nursery systems. Establishment of nursery facilities. Production of superior quality seedlings.	High-value timber species and fuelwood grown in small plantations or incorporated into village agricultural systems.	Provides a source of savings to meet large and irregular expenditure requirements (e.g. school fees). Provides better access to building material for communities. Better access to fuelwood.

Table 3. (continued)

Project number	Project name	Key outputs	Outcomes	Impact
FST/2004/050 (continued)	Value-adding to PNG agroforestry systems (active)	Preliminary business models for commercial tree growing by landowners. Capacity built within communities, including understanding of the benefits of tree growing and associated techniques.		
FST/2004/055	Domestication and commercialisation of *Canarium indicum* in PNG (active)	Greater understanding of phenotypic variation between 15 *Canarium indicum* (galip nut) populations in five provinces. Greater understanding of the domestic market for galip nuts. Development of vegetative propagation protocols and capacity at the National Agricultural Research Institute. Establishment of a clonal garden with over 80 clones. Villagers trained in propagation and selection techniques in 15 communities.	Increased planting of galip nut in communities.	Together with European Union (EU) development projects, will eventually lead to increased production of galip nuts, providing an alternative income source for farmers affected by cocoa pod borer.
FST/2007/078	Development of a PNG timber industry based on community-based planted forests: design and implementation of a national germplasm delivery system (active)	Better understanding of community preferences for local priority species. Developed methodology for participatory selection of local priority species. Upgrading of seedling production capability. Capacity built within NGOs and communities.	No outcomes yet.	No impacts yet, although important groundwork has been carried out.

Table 3. (continued)

Project number	Project name	Key outputs	Outcomes	Impact
FST/2006/088	Promoting diverse fuelwood systems in PNG (active)	Greater understanding of fuelwood production systems, including the performance of different species at different spacings. Identification of best-performing species at various locations. Greater understanding of the PNG fuelwood economy. Development of new fuelwood production systems: • short-rotation coppicing systems • biological terrace gardens to prevent erosion. Establishment of nurseries. Production of superior seedlings. Capacity built through training of project participants.	Establishment of woodlots in local communities. Establishment of alley-cropping systems on sloped gardens.	Will eventually lead to better access to fuelwood for domestic use. This could also reduce reliance on natural forests for fuelwood needs. Potentially higher incomes for landowners from commercial fuelwood sales. Potential for income from selling seedlings. Less erosion and therefore reduced loss of fertility on sloped garden beds.
Downstream processing				
FST/2006/120	Increasing downstream value-adding in PNG's forest and wood products industry (active)	This project remains in its early stages. The following are some initial outputs: • Improved understanding of domestic processing in PNG and industry capabilities. • Drying schedules for nine commercial native species developed. • Design of low-cost kit homes. • Capacity built through providing equipment and delivering training courses.	Rural communities involved in processing and packaging building materials for low-cost kit homes. Low-cost sustainable houses built in rural communities and urban settlements.	Income for rural communities. Lower cost and better quality housing in rural communities and urban settlements.

Table 3. (continued)

Project number	Project name	Key outputs	Outcomes	Impact
FST/2006/048	Processing of *Canarium indicum* nuts: adapting and refining techniques to benefit farmers in the South Pacific (active)	Greater understanding of optimal galip nut processing methods. Development of commercial processing methods for galip nuts. Identification of appropriate equipment. Understanding of the barriers to uptake in different production environments. Local staff trained in processing galip nuts.	A commercial processing facility is likely to be established using the methods developed through the project.	Potential establishment of a commercial market for processed galip nuts.

Sources: ACIAR project documents; B. Ozarska, pers. comm., 1 May 2011; M. Shelton, pers. comm., 8 April 2011.

a While the seedlings planted in communities have been distributed under an EU development project, both the ACIAR and EU projects are considered necessary for the galip nut industry to develop.

Although galip nuts could equally be considered a horticulture industry, galip is also a well-known timber species and the projects have been funded through the forestry program.

Project context

It is important to understand the contextual setting for the galip nut R&D program. Cocoa is a major source of income for smallholder farmers in East New Britain province. It is grown as a relatively low input system.

Cocoa requires shade to thrive. Currently, gliricidia (*Gliricidia sepium*) is the main shade tree used for cocoa in East New Britain. Gliricidia grows quickly and can provide adequate shade after around 3 years. However, it subsequently requires managing, which can add significantly to costs. It also has no additional economic use, other than fuelwood.

In addition, the cocoa industry in East New Britain has been hit hard in recent years by the emergence of cocoa pod borer. This pest can reduce cocoa yields by up to 90% (J. Moxon, pers. comm., 13 May 2010). Cocoa pod borer requires intensive management of cocoa crops, but a shift from the low-input systems used by smallholder farmers in the region to a more intensive management system would require a lifestyle change by these farmers (J. Moxon, 13 May 2010). Consequently, there is a need for alternative sources of income in the region.

A commercial galip nut industry is a potential solution for both of these problems: galip provides suitable shade tree for cocoa, with no management costs, and could also provide an alternative cash crop when intercropped with cocoa.

Objectives

The overarching objective of the galip nut research program is to provide local farmers with an alternative source of income through the establishment of a commercial galip nut industry. The specific objectives of each of the individual ACIAR-funded projects are shown in Table 4.

Collaborators

The overall research program has been run by the National Agricultural Research Institute (NARI) at Keravat in East New Britain province. While NARI has contributed the salaries of the researchers and the use of its facilities, the project team has relied on donor funding and operates, to a large extent, at arm's-length from NARI.

James Cook University was commissioned to undertake the scoping study and the domestication project, while the University of the Sunshine Coast was commissioned for the processing project. The project has also drawn on significant private-sector expertise in agribusiness and the Australian macadamia nut industry.

Project inputs

The three ACIAR project have been a major component of the overall research program. ACIAR has contributed almost A$1.5 million (in nominal terms) to the three projects, making up around 64% of the total budget of around A$2.3 million (Table 5). This includes money spent in Solomon Islands and Vanuatu as well as PNG. The next largest contributors (mainly in-kind contributions) were the University of the Sunshine Coast, NARI and James Cook University. There were also smaller contributions from the PNG Cocoa and Coconut Research Institute, Hidden Valley Plantations and the Department of Forestry in Vanuatu.

Other relevant research

The three ACIAR projects have formed part of a broader R&D endeavour that has included other significant donor funding, in particular from the European Union (EU). The EU has also provided donor funding worth a total of around K2.5 million (approx. A$1.1 million) in nominal terms to the NARI project team to undertake related research (Table 6).

While significant progress has been made, it is also important to note that the ACIAR domestication and processing projects have yet to be completed. Beyond the life of the current ACIAR projects, it will take significant further R&D effort to achieve the ultimate goal of a commercially viable galip nut industry. The NARI project team estimates that it may need a further K2 million/year over the next 10 years, before the industry is self-sustaining, and further research and marketing could be funded through levies and an industry association (J. Moxon, pers. comm., 13 May 2010).

Table 4. Objectives of the galip nut projects in Papua New Guinea (PNG)

ACIAR project	Objectives
Scoping study (FST/2002/010)	The overall goal is to determine the feasibility of developing a strategy and methodology for the parallel improvement of the food/nutritional security, and income-generating opportunities of smallholder farmers through the domestication and commercialisation of galip nuts in PNG and Solomon Islands. Specific research objectives include the following: • Determine the attitudes and perceptions of communities towards indigenous fruits and nuts in the household food intake and in land use in PNG – identify the role of indigenous nut and fruits in the household diet of rural PNG – establish the willingness and ability of landholders to cultivate indigenous nuts and fruits if needs and/or markets exist – document the indigenous knowledge of the use and cultivation of galip in PNG – evaluate consumer acceptability and potential of galip in PNG. • Identify the potential opportunities and constraints for domestication and commercialisation of indigenous fruits and nuts in PNG, Solomon Islands and Queensland: – evaluate the consumer acceptability and potential of galip nut in Australia – determine the opportunities and constraints to local production and local export marketing. • Identify the research and development issues for domestication and commercialisation of indigenous nuts and fruits. • Enhance the abilities of project staff in methodologies of community survey and interpretation. • Inform stakeholders/participants of outputs and conclusions of the project.
Domestication (FST/2004/055)	• Prospect, characterise, select and multiply individual trees in PNG that have superior commercial traits for cultivar development and field tests. • Improve market prospects for these products. • Deliver selected cultivars and training to the participating communities. • Disseminate information to stimulate adoption.
Processing (FST/2006/048)	• Adaptively develop and evaluate with relevant stakeholders the appropriateness of different galip nut processing techniques. • Identify the most appropriate methods and equipment for pulping, drying, cracking, testa removal, roasting, packaging and storing of galip nuts. • Provide training and capacity exchange in optimal galip nut processing.

Source: Notes from project inception workshop

A new ACIAR project focusing on product development and marketing for galip nuts in PNG, Solomon Islands and Vanuatu that could provide A$1.1 million over 4 years is currently being developed. The PNG component of this project would focus on developing processing technologies designed for export markets.

Table 5. Funding inputs (A$) to three ACIAR galip nut projects in Papua New Guinea (PNG)

	Funding source[a]							Total
	ACIAR	JCU	USC	NARI	PNG CCRI	HVP	DOF*b*	
Feasibility								
2004	132,713[c]	10,139	–	14,996	–	–	–	157,848
2005	70,893[d]	10,139	–	14,996	–	–	–	96,028
Subtotal	203,606	20,278	–	29,992	–	–	–	253,876
Domestication								
2006	265,909[e]	22,157	–	60,460	3,896	–	–	352,422
2007	133,614[f]	22,157	–	60,460	3,896	–	–	220,127
2008	113,716[f]	22,157	–	60,460	3,896	–	–	200,229
2009	121,324	22,157	–	60,460	3,896	–	–	207,837
Subtotal	634,563	88,628	–	241,840	15,584	–	–	980,615
Processing								
2008	174,249	–	111,050	12,500	–	17,410	–	315,209
2009	253,315[g]	–	111,050	12,500	–	17,410	6,120	400,395
2010	224,211[h]	–	111,050	12,500	–	17,410	6,120	371,291
2011	–	–	–	–	–	9,672	–	9,672
2012	–	–	–	–	–	9,672	–	9,672
Subtotal	651,775	–	333,150	37,500	–	71,574	12,240	1,106,239
Total	1,489,944	108,906	333,150	309,332	15,584	71,574	12,240	2,340,730

Source: ACIAR project budgets

[a] JCU = James Cook University; USC = University of the Sunshine Coast; NARI = National Agricultural Research Institute (PNG); CCRI = Cocoa and Coconut Research Institute; HVP = Hidden Valley Plantations; DOF = Department of Forestry (Vanuatu).

[b] All DOF contributions were spent in Vanuatu.

[c] Includes A$11,319 spent in Solomon Islands.

[d] Includes A$7,707 spent in Solomon Islands.

[e] Includes A$47,608 spent in Solomon Islands.

[f] Includes A$6,521 spent in Solomon Islands.

[g] Includes A$56,200 spent in Vanuatu.

[h] Includes A$33,745 spent in Vanuatu.

Table 6. European Union funding of forestry-related research in Papua New Guinea

Project	Year	Funding Kina	Funding[a] A$
Alternative cash crop research	2003	344,000	141,894
East New Britain Province Development Project	2006	1,258,000	559,635
Papua New Guinea Development Project	2010	876,000	367,308
Total		2,478,000	1,068,837

Sources: J. Moxon, pers. comm., May 2010; Ozforex website at <http://www.ozforex.com.au/>, accessed 30 July 2010; Centre for International Economics

[a] Converted to Australian dollars using the annual average exchange rate.

3 Outputs of ACIAR's forestry research in Papua New Guinea

The outputs of R&D projects fall into one of three broad categories (Davis et al. 2008, p. 22):

- technologies—new and better products, processes and approaches
- capacity—scientific knowledge, understanding and skills at the organisational and individual level
- policy—knowledge, models and frameworks to aid policy and decision-making.

ACIAR projects have delivered outputs in each of these categories. This chapter outlines them.

Scoping and feasibility studies

The purpose of the scoping and feasibility studies is generally to examine if future research on a particular theme is likely to benefit the industry and local communities, or to determine if a new industry is likely to be feasible. The purpose is not therefore to produce outputs that are adopted by local communities. Rather, the output is knowledge of the contextual environment and the feasibility of uptake of future research results. During site visits, a number of project participants commented that good-quality scoping studies can play a vital role in coordinating research efforts in new industries (G. Cameron, pers. comm., 14 May 2010; J. Moxon, pers. comm., 13 May 2010), particularly where there are multiple donors working within an industry.

Sustainable forest management projects

The three sustainable forest management projects delivered a range of outputs, including improved knowledge, tools to assist forest decision-makers that were subsequently used to develop forest management plans, and capacity building of individuals within forest agencies, NGOs and local communities.

These projects expanded the stock of scientific knowledge critical for effective forest management. This was evidenced by the publication of a number of scientific papers in academic journals. The following were specific outputs of the projects:

- Improved knowledge of how the forest responds to harvesting, optimal cutting cycles and diameter limits (FST/1998/118)—a key finding was that the current 35-year cutting cycle is probably too short to allow for commercially viable future harvest if all trees greater than 50 cm diameter at breast height (DBH) are cut. Longer cutting cycles, higher diameter limits for species that can reach large sizes, leaving a proportion of current commercial trees for future harvest and reducing harvest impact, would provide for more economically and ecologically sustainable timber harvesting (FST/1998/118, Final report).
- Improved understanding of the processes governing tree growth, carbon stocks and dynamics following timber harvesting in PNG's complex and diverse forests (FST/2004/061).

- In addition to greater scientific knowledge, the projects have also led to a greater understanding of international markets for tropical hardwoods (FST/2004/061).

The projects also developed a range of tools to assist the decision-making of PNG forest agencies and local communities on the sustainable management of forests. ACIAR-funded research initially established that the structure of the forest management system developed for north Queensland is sufficiently generic to incorporate new data for PNG species as they become available, but that a number of modifications are required before they can be used reliably in PNG (FST/1995/123). Forest management tools subsequently developed under ACIAR projects included:

- a revised strategic forest inventory method and an improved database (PERSYST) that would result in cheaper and more accurate inventories in future project areas (FST/1998/118)—a more modern and efficient approach to forest inventory was subsequently developed (FST/2004/061)
- a system (PINFORM) that integrates existing forest area, inventory and growth information and produces more reliable estimates of future timber yield under different harvesting scenarios (FST/1998/118)
- growth models for PNG's cut-over forests that facilitate accurate growth and yield estimates (FST/2004/061)
- a database incorporating previous inventory data, including the re-measurement of permanent sample plots (FST/2004/061)
- a rapid and effective assessment method for cut-over forests in PNG (FST/2004/061)
- financial models that predict returns from different types of community-based, small-scale timber-processing operations (FST/2004/061).

Some of these tools have also been used to develop forest management plans for two community-owned primary forests and draft plans for two community-owned secondary forests.

The ACIAR projects have also built capacity at the individual level. In particular, the projects have trained government research officers on how to develop and apply planning systems and how to predict outcomes under different management scenarios (FST/1998/118 and FST/2004/061). One project (FST/2004/061) also developed the capacity of NGOs to provide scientifically based advice to communities and the capacity of some local communities to effectively manage their forest resources.

Agroforestry projects

Over recent years, ACIAR has funded a number of interrelated projects aimed at encouraging local communities to more effectively incorporate trees into their agricultural systems. While work on many of these projects is ongoing, this cluster of projects has already delivered—or made progress towards—a number of outputs, as described below.

The agroforestry projects have improved the scientific understanding of various trees in the context of agro-forestry systems. In particular, the projects have led to:

- improved scientific understanding of lesser known species of *Leucaena* and hybrids (FST/1994/033), including
  - cold and frost tolerance, acid-soil tolerance and psyllid resistance
  - the extent to which environmental factors constrain growth
  - their animal production potential
- a better understanding of the growth of various tree species in different locations in PNG (FST/2006/088).

In addition to greater scientific knowledge, the agroforestry projects have contributed to a better understanding of community attitudes and current production systems, including:

- community attitudes towards commercial tree growing (FST/2004/050) and preferences on high-value trees for agroforestry systems (FST/2007/078)
- the sourcing and use of fuelwood in areas of fuelwood stress (FST/2006/088).

The projects have also delivered, or have made significant progress towards delivering, a number of new technologies, including:

- identification of the best performing timber and fuelwood species in various locations (FST/2004/050 and FST/2006/088), leading to the production of superior quality seedlings for planting in local communities (FST/2004/050, FST/2006/088)
- identification of high-yielding *Leucaena* hybrids suitable for ruminant feed (FST/1994/033).

Several new systems or techniques have been (or are being) developed as part of the agroforestry cluster of projects, including new tools to assist decision-makers, and new production systems. The new tools include:

- a methodology for participatory selection for local priority species (FST/2007/078)
- preliminary business models for commercial tree-growing by landowners (FST/2004/050).

New production systems or techniques include:

- short-rotation coppicing systems for fuelwood and charcoal production (FST/2006/088)
- biological terrace gardens, in which rows of trees are planted horizontally across sloped areas to prevent soil erosion (FST/2006/088)
- village-level or hub nursery systems (FST/2004/050, FST/2004/009, FST/2006/088 and FST/2007/078)
- a vegetative propagation technique for high-yielding *Leucaena* hybrids (FST/1994/033).

By establishing or upgrading seed production and nursery facilities (FST/2004/050, FST/2007/078, FST/2006/088), ACIAR-funded research has also improved the capacity of PNG collaborators to supply germplasm.

The capacity of individuals within local communities has also been built by developing an understanding of the benefits of tree-growing (FST/2004/050, FST/2006/088 and FST/2007/078) and by training NGOs to conduct participatory rural appraisals with communities to determine local species preferences (FST/2007/078).

Downstream processing projects

The project relating to the downstream processing of galip nuts (FST/2006/048) is discussed in the next section.

ACIAR has also invested in a project (FST/2006/120) focused on downstream timber processing to improve PNG's capacity in this area. While the project remains active, a number of significant outputs have already been delivered (B. Ozarska, pers. comm., 1 May 2011).

Capacity building has been a key focus of the project. Capacity has been built within PNG partner institutions through providing equipment and laboratory instruments, as well as a comprehensive training program. In particular, a 'train the trainers' program has been developed and diploma and advanced diploma training courses in wood processing and products have been designed.

Other significant outputs delivered so far, include:

- improved understanding of domestic timber processing in PNG and industry capabilities
- drying schedules for nine commercial native species
- design of low-cost sustainable houses for both rural communities and urban settlements.

Outputs of the galip nut projects

The principal output of the feasibility study (FST/2002/010) was a greater understanding of the potential feasibility of a commercial galip industry in PNG, as well as Vanuatu and Solomon Islands, and the contextual environment. This information was presented in a detailed, three-part, final report. A summary of the contents of each part follows.

1. *Canarium indicum* in Papua New Guinea and Solomon Islands

   This part included:

   – a literature review of the domestication potential and marketing of galip nuts in the Pacific
   – a review of the market commercialisation activities within the past 10 years

- a survey of farmer households in East New Britain
- characterisation of the variation in morphological and chemical content of galip nuts
- a consumer acceptance study on selected nuts, including galip
- a niche market survey.

2. Bush tucker in Far North Queensland

   This part included:
   - a review of commercial aspects of the native food industry in north Queensland
   - a review of traditional indigenous knowledge and intellectual property rights issues associated with a potential bush food industry.

3. Conclusions on the feasibility of domesticating and commercialising canarium (galip) nuts

   This part delivered the following eight-point plan designed to ensure the successful development of a canarium nut industry in PNG.
   - Develop market confidence (both regional and export) to ensure the supply of nuts, focusing initially on satisfying local demand.
   - Domesticate the species through germplasm prospecting, vegetative propagation, phenotypic selection, and cultivar dissemination to ensure product quality, consistency and reliability of supply.
   - Promote canarium kernels as a high-value, unique product, building on the recent model of the high-quality, high-value, modest-volume, highly integrated macadamia nut industry.
   - Identify commercial champions in Melanesia and potential export markets. Ensure that supply chains are carefully assessed and managed.
   - Ensure that processing systems and product handling are cost effective and viable at the village level. Maintenance of the 24-hour deadline from cracking to processing is critical for quality end products.
   - Resolve current constraints such as lack of training, processing equipment and transport limitations.
   - Seek significant job creation and rural income streams with proper industry development.
   - Use 'nucleus estates' to properly link infrastructure, population centres, market access and capacity, communities with political clout and communication networks, so creating a 'commercial hub'.

The domestication project (FST/2004/055) has made significant progress towards developing a vegetative propagation stock of high-quality galip trees that will contribute to a high-yielding, commercial galip nut industry in East New Britain.

The project improved the scientific understanding of the phenotypic variation between 15 galip tree populations in five provinces. It also led to a greater understanding of the domestic market for galip nuts.

The project developed vegetative propagation protocols. The techniques developed through the project are critical to creating the high-quality resource base necessary for a commercial industry to become established.

The project improved the capacity of NARI to conduct further research and distribute high-quality genetic material to farmers through the establishment of a clonal garden with over 80 clones of high-yielding galip trees. The project also built capacity in propagation and selection techniques in villages through training activities.

The processing project (FST/2006/048) has made significant progress towards a commercially viable method of processing galip nuts (FST/2006/048, Annual report 2009–10). Importantly, the projects have increased the scientific knowledge on postharvest handling and processing methods (drying, storage, transport, roasting). This knowledge has been used to develop commercial processing methods, which will eventually lead to written protocols for pulping, drying, roasting, storing and packaging for optimal quality and food safety. Better processing methods already identified include:

- in drying—drying the kernels before processing means that the nuts do not need to be processed within 24 hours of cracking

- in testa removal—a 90-second hot water dip has been confirmed as the best method for testa removal
- in roasting—trials have highlighted the importance of moisture content for roasting.

Through the greater scientific understanding and the development of processing methods, appropriate equipment for processing galip nuts has been identified, including:

- depulping equipment adapted from the macadamia nut industry
- two crackers, one suited to village-level cracking, the other to commercial-scale processing.

Another focus of the project has been on understanding the barriers to uptake of these techniques in different production environments.

The project has built capacity within local staff and villages through:

- instructing local staff in participatory training techniques and in postharvest handling and processing of galip nuts
- disseminating information packages about the project, including the galip nut industry
- a training package that guides users of the new techniques.

4 Adoption of project outputs

For R&D projects to ultimately deliver benefits to partner countries, it is necessary for the research outputs to be adopted by final users. Lack of adoption due to a range of barriers has reduced the effectiveness of many of ACIAR's projects in PNG.

This chapter examines the level of adoption of the selected forestry projects. It also examines the pathways to adoption and the barriers that have either prevented adoption or restricted its scale. Where applicable, evidence of strategies to minimise these barriers and therefore reduce the risk of non-adoption is presented, highlighting the fact that a number of more recent projects have been successful in achieving a significant level of adoption.

Adoption

This section presents evidence from the desk review of project documents and site visits on the extent to which the project outputs have been adopted by final users.

Scoping and feasibility studies

While the findings of scoping and feasibility studies are not designed to be adopted by PNG forestry industry stakeholders, a number have been adopted in the sense that they have led to further R&D projects. Where these subsequent projects deliver benefits to the community, some of them can be attributed to the scoping or feasibility study.

Sustainable forest management projects

The two final-user groups for the outputs delivered by the sustainable forest management projects are the PNG forest policymakers and local communities.

Two of these projects (FST/1995/123 and FST/1998/118) were aimed exclusively at PNG forest policymakers. Although the projects may have increased the capacity of the PNG Forest Authority to manage PNG's primary forest resources more sustainably through training staff and developing various management tools, it is not clear that this improved capacity has yet directly led to improved forest management. A key finding of the research was that the 35-year cutting cycle used in PNG is probably too short to allow for commercially viable future harvests. Nevertheless, 35-year cutting cycles continue to be used (FST/2004/061, Final report, p. 27).

The more recent sustainable forest management project (FST/2004/061) was aimed at both policymakers and community forest managers. Although this project has only recently been completed, there appears to have been greater success in having the research outputs adopted.

There is evidence from project reports, site visits and discussions with PNG partners and local communities that some of the intermediate outputs—the community forest assessment tools—have been used in the development of forest management plans. Forest management plans have been developed for two community-owned primary forests, and draft plans for two community-owned secondary forests. These forest management plans are an essential step towards achieving forest certification. One community is already producing sustainable timber for local construction and sales.

There is also recent evidence that some of the capacity built through the project is being used. PNG forest research staff have used the skills and technologies gained from the project to undertake new work to assist the PNG Government to develop scientifically based estimates of the emissions reductions associated

with changed forest management practices. This would enable payments for these environmental services to be made under the Reduced Emissions from Deforestation and Forest Degradation (REDD) component of the United Nations Framework on Climate Change Convention (UNFCCC).

Agroforestry projects

The final users of the agroforestry cluster of projects are landowners in local communities. There was considerable enthusiasm for tree planting within a number of the local communities visited, and clear evidence of small-scale adoption of the outputs of various ACIAR projects. In particular, there was evidence of the following in a number of villages:

- small-scale planting (up to around 0.5 ha) of teak and other species by individuals in a number of local villages
- small-scale planting of teak and other species by schools
- small-scale plantations of fast-growing fuelwood species for both local and commercial use
- integration of high-value trees into agricultural systems.

Indicators of scale of adoption to date include the following:

- Ramu Agri-industries (RAI) has provided around 15,000 seedlings to 88 farmers in the Ramu and Markham valleys, with another 50–60 farmers to be provided with seedlings from the remaining 30,000 seedlings in the Ramu nursery.
- Some 18,000 seedlings were raised in the RAI nursery in 2009–10. A further 2,000 seedlings were raised and distributed by Unitech (FST/2004/050, Annual report 2009–10).
- Around 18,000 trees have been planted through the ACIAR fuelwood project (FST/2006/088, Annual report 2009–10).

There were also other organisations involved in disseminating project outputs.

Downstream processing

Since the main downstream processing project (FST/2006/120) has not been completed, it is too early to tell if any outputs produced will be adopted. The final users for these projects are downstream processors.

Although downstream processing of forest products in PNG has increased in recent years, the sector remains small. Adoption of outputs is therefore a key risk for this project to have an impact. That markets will not be found is an inherent risk in projects that develop new products. It is therefore essential that the organisations that will ultimately be marketing the products—the existing timber processors—are fully engaged in the development of these new products. One timber processor, PNG Forest Products, has been actively involved in the project's training on improved timber-processing methods. On the other hand, this project contains multiple subprojects, and the PNG Government has set a target of achieving 80% of harvested logs processed domestically by 2030, both of which factors reduce the risk of non-adoption.

Galip nut projects

The three final user groups for the galip nut projects are the smallholder farmers who plant superior galip tree seedlings, larger scale agribusiness companies that hold rights over large land areas and, potentially, an agribusiness company to establish a commercial-scale processing facility.

Adoption of the research outputs among these final user groups is interlinked. To make a commercial processing facility viable, access to a consistent resource base will be essential.

To date, more than 100,000 galip tree seedlings have been distributed, mainly to small-scale farmers. They have been planted in cocoa plantations. While the seedlings have been distributed under the EU project, the ACIAR project played a critical role in collecting and characterising the superior genetic material. There are firm orders for 1 million seedlings. However, it may take a number of years to fill these orders. The EU project team's projections indicate that it will be able to supply around 70,000 seedlings/year (J. Moxon, pers. comm., 13 May 2010). Figure 4 shows prospective plantings based on this information.

Galip trees begin to produce nuts by around the 5th year after planting. The yield is estimated to increase linearly to reach a maximum at around 15 years (J. Moxon, pers. comm., 13 May 2010). Conservatively assuming maximum nut production of 5,000 nuts/tree at a nut-in-shell weight of 12 grams/nut, this implies a maximum yield of around 60 kg/tree. Based on these assumptions, the estimated nut production profile is shown in Figure 5. The quantity of processed nuts assumes a kernel weight of 2.5 grams.

The EU project team is currently establishing a pilot commercial processing facility based on the methods developed in the ACIAR project. The pilot facility was expected to have the capacity to process some galip nuts from late 2010 (J. Moxon, pers. comm., 13 May 2010). More importantly, it will demonstrate the processes developed through the ACIAR project to commercial processors who may have the capacity to develop a large-scale processing and distribution facility.

A large PNG agribusiness company (Agmark) has shown interest in developing a commercial processing facility once the technologies developed have been demonstrated at pilot scale. It is expected that there will eventually be sufficient commercial processing capacity in East New Britain to process the nuts produced by the superior seedlings distributed under the projects.

Adoption by farmers has occurred through extension activities associated with the complementary EU project. Seedlings have been directly provided to farmers under the EU project. While the cost of producing the seedlings is estimated at around K2.20/seedling, to encourage adoption, farmers have initially been charged only K0.50/seedling.

There have been other important factors that have stimulated adoption:

- The emergence of cocoa pod borer—this development has provided a significant impetus for local farmers to find alternative sources of income (C. Bunt, pers. comm., 3 August 2010), due to losses in cocoa production. These losses were up to 90% in some areas (J. Moxon, pers. comm., 13 May 2010).
- Familiarity with galip nut—smallholder farmers are typically highly risk averse and therefore reluctant to adopt new technologies and products. However, galip nuts have been produced and eaten in the region for many years; most farmers in the region are therefore familiar with the tree and its products.
- Low costs—the upfront investment required is relatively low and it is a low management input crop that will not require a major change in current farming practices or labour availability.

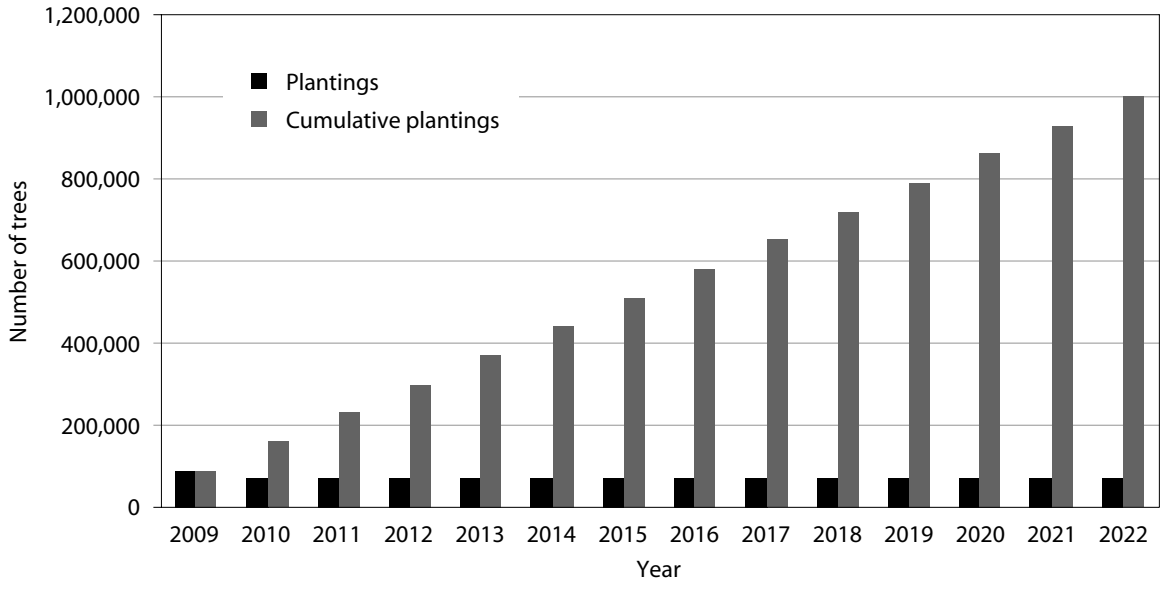

Figure 4. Estimated galip tree plantings in East New Britain, Papua New Guinea, 2009–22. Sources: J. Moxon, pers. comm., 14 May 2010; Centre for International Economics

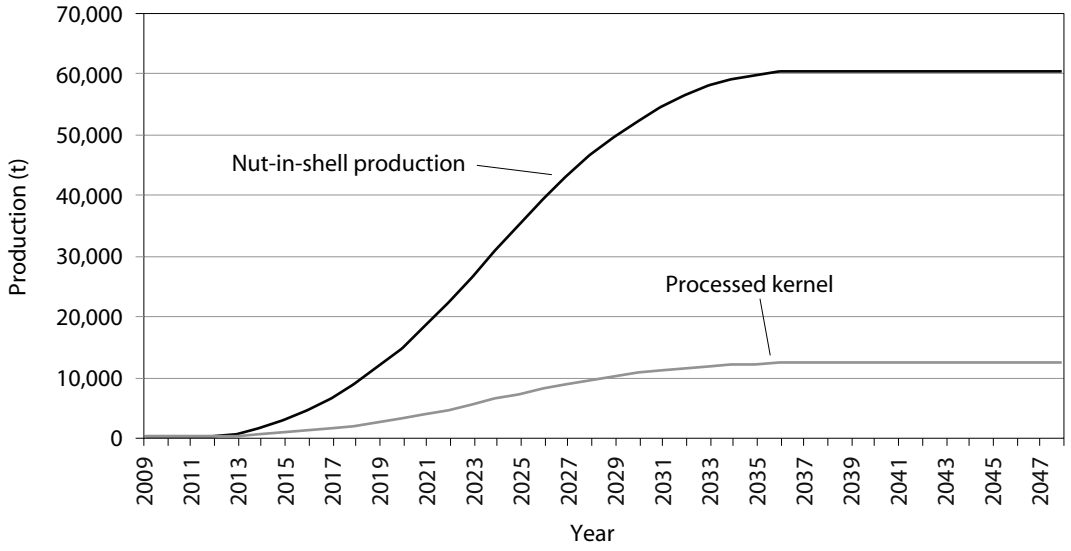

Figure 5. Estimated galip nut production in Papua New Guinea, 2009–47. Data source: J. Moxon, pers. comm., 13 May 2010; Centre for International Economics.

- Low risk—the galip tree is also a well-known and valuable timber species. This reduces the risk to farmers since, if the commercial market for galip nuts does not emerge, they would be able to harvest their galip trees as timber and earn some return on their investment; Agmark has reportedly told its shareholders that there is little risk in planting galip trees (J. Moxon, pers. comm., 13 May 2010).

Pathways to adoption

ACIAR forestry projects in PNG appear to have achieved the highest levels of adoption when the final user groups were local communities. In these cases, the pathway to adoption has invariably been through extension services provided through one of the PNG project partners working closely with local communities.

In a number of cases, the project partner was an NGO that was included in the project specifically to encourage adoption (e.g. FST/2004/050, FST/2004/061, FST/2006/088 and FST/2007/078). These NGO partners were already operating complementary programs and, in many cases, the ACIAR project was able to leverage off established relationships with local communities.

In other cases, the PNG research partners worked closely with local communities to ensure that research outputs were adopted. For example, Ramu Agri-industries and Unitech have been working with communities in the Markham and Ramu valleys to encourage them to incorporate trees into their agricultural systems (FST/2004/050).

There was some evidence of PNG Government involvement with extension activities, but this was a less common pathway to adoption. In the case of the galip nut projects, the NARI project team is providing the extension services to encourage greater galip tree plantings. The project team is largely funded through donor funding and essentially operates at arm's-length from NARI. The distribution of galip seedlings has occurred under the complementary EU-funded project, rather than the ACIAR project directly. There were other instances of government involvement with extension activities, although these were mostly driven by non-government project partners.

Barriers to adoption

In PNG there are a number of barriers that can inhibit the uptake of the results of ACIAR research. While many of these barriers were evident to some extent in the forestry projects, there was also evidence of strategies to reduce these barriers and minimise the risk of non-adoption.

Weak governance

Forest management in PNG has a long history of governance problems. A wide-ranging commission of inquiry into the PNG forest sector was undertaken in the late 1980s (the Barnett Inquiry). The Barnett Inquiry identified a number of impediments, including the division of authority between the different tiers of government (central, provincial and local authorities) (ODI 2007, p. 16). Inadequate governance of accountability frameworks was also earmarked for attention.

The Barnett Inquiry led to a comprehensive reform of the regulatory and institutional framework, including the establishment of the PNG Forest Authority.

Subsequent reviews during the early 2000s found a continuing level of governance deficiencies in the forest sector (ODI 2007, p. 19). Moreover, at about the same time, the World Bank withdrew from a major forestry and conservation project in PNG. According to the bank, implementation of the forest-related laws and associated codes of conduct developed over the past 20 years has often been difficult because of political ambivalence and governance problems resulting from relationships between industry players, politicians and officials (World Bank 2006).

While ACIAR projects can contribute to building the capacity within the relevant institutions to manage forest resources more effectively, its delivery model is not suited to handling underlying governance issues. In recent years, ACIAR has therefore accorded higher priority to projects that are likely to directly benefit smallholders than to new policy-related forestry research in PNG.

There were also other instances where progress on projects was limited by a lack of engagement on the part of some PNG government partners (FST/2006/088, Annual report 2009–10).

Lack of extension services

The lack of government extension services has been identified as a key factor limiting the adoption of agricultural R&D in PNG. There was evidence of this occurring within ACIAR's forestry program. PNG was dropped from one multilateral project (FST/1994/033) that also included Vietnam and the Philippines because it was recognised that adoption was unlikely without a government extension service.

ACIAR has, to some extent, been able to overcome the lack of government extension services in more recent projects by partnering with NGOs and private-sector organisations.

While partnering with NGOs has been a successful strategy in encouraging adoption in many cases, it can also be a risk in PNG where governance standards can be weak. A recent audit of the Village Development Trust (VDT)—a partner on two ACIAR projects—found that the trust's management was unable to account for a significant proportion of the funding it controlled. This led to the donors withdrawing the funding and the replacement of VDT's board and management. Under the new management regime and until it was disbanded, VDT continued work on one of the ACIAR-funded projects for a short period. The collapse of VDT means that there is no capacity for ongoing work with the communities in these project areas, reducing the potential for future adoption of research outputs.

ACIAR's strategy of involving multiple PNG partners in many projects appears to have gone some way to reducing the risk of project failure due to the organisational failings of a single project partner. While VDT's collapse is likely to have reduced adoption, those projects have nevertheless achieved some uptake of project outputs through other project partners.

Supply of germplasm

A key barrier to greater adoption of the agroforestry projects was the supply of seedlings. Site visits showed that some communities have enthusiastically incorporated trees into their agricultural systems. These systems included incorporating *Eucalyptus pellita*, galip tree and teak into cocoa crops or subsistence gardens. In areas where land is more abundant, such as the Ramu and Markham valleys, some farmers had also established small plantations on previously unused

land. However, the demand for germplasm (particularly teak) from communities has outstripped the capacity of the project partners (Ramu Agri-industries, Unitech and the PNG Forest Authority) to supply it, due to shortages of seed. This obviously reduces the extent of adoption of the research outputs. A separate ACIAR project (FST/2007/078) is designed to overcome these constraints.

A related issue that has been experienced in FST/2004/050 is the lack of transport for seedlings, which affects both how often seedlings can be delivered to farmers and how far from project nurseries smallholders can gain access to seedlings.

Resistance to change

A resistance to change established practices was identified by one NGO as a key factor reducing the uptake of tree planting (Y. Bun, pers. comm., 17 May 2010). Communities are often reluctant to accept advice unless there is an established relationship and it can take a long time to build trust.

Projects aimed at smallholders have been designed so that they do not require major changes in practice. For example, several projects have encouraged communities to more effectively incorporate trees into their existing agricultural systems. PNG communities have a long history of agroforestry, so incorporating high-value timber species or species landholders are already familiar with (such as *E. pellita*) into their agricultural systems does not require a major change of practice. Furthermore, teak has been grown in PNG for many years (Haines, pers. comm., 13 May 2010) and is a low-input crop.

Long time frames to receive benefits

One reason why small-scale farmers can be reluctant to plant trees is the long time frame before the benefits are realised. For example, teak trees take around 15–20 years before they are big enough to harvest. For that reason, the ACIAR projects have emphasised integrating tree crops into agricultural systems and planting a range of species to provide intermediary benefits.

Lack of infrastructure

It is well documented that the lack of transport infrastructure in PNG discourages local communities from adopting the outputs of agricultural research. However, only one of the local communities visited raised lack of transport infrastructure as a significant disincentive to adoption of the outputs produced by the ACIAR-funded research covered in this assessment. Waterlogging had prevented it from operating its portable sawmill and the community was unable to use it in alternative locations because of a lack of road infrastructure to transport the rough sawn logs to a central marketing unit. The lack of road infrastructure was therefore a disincentive for them to adopt the forest management advice provided under the ACIAR project.

Most other communities were confident that they would be able to find a market for their goods, particularly high-value timber such as teak.

5 Outcomes of ACIAR's forestry research in Papua New Guinea

This chapter discusses the outcomes of adopting the research outputs. Outcomes must be compared against a counterfactual of what would have happened without the ACIAR funding.

Scoping and feasibility studies

Both of the scoping and feasibility studies examined as part of this review have led to subsequent ACIAR projects. If these subsequent projects ultimately delivered benefits to PNG, some of these benefits can be attributed to the initial studies.

Sustainable forest management projects

As discussed in the previous chapter, it is not clear that the capacity built through the policy-related projects (FST/1995/123 and FST/1998/118) has yet led to a change in forest management practices. In particular, the cutting cycle has remained at 35 years, despite the findings of the research (FST/1998/118) suggesting that this may be too short to allow for commercially viable future harvest if all trees greater than 50 cm DBH are cut.

On the other hand, there was evidence from project documentation, site visits and discussions with PNG partners that, as a result of the ACIAR project aimed at improving community management of cut-over forests (FST/2004/061), NGOs have been using some of the assessment tools developed through the project and are able to provide local communities with better advice based on scientific evidence.

This advice has been incorporated into the development of forest management plans. One community is already producing sustainable timber for local construction and sales. The forest management plans are also expected to lead to more effective management of primary and secondary forest resources in the other communities that participated in the project, ultimately providing a sustainable source of income for landowners. This may eventually allow some communities to achieve Forest Stewardship Council certification.

There is also evidence that some of the capacity built within PNG government agencies is being used in the context of REDD carbon payment schemes. For example, for use in such schemes, the Forest Research Institute is using plot data to estimate forest carbon stocks in different forest types and treatments. Institute staff also used new skills to develop an inventory system to measure soil carbon in different forest types. In addition, the PNG Forest Authority is using assessment and modelling tools to estimate merchantable volume and forest carbon at the project level.

Use of the capacity built within the PNG Government in research related to the REDD carbon payment schemes, has allowed PNG to take a leadership approach in UNFCCC negotiations. If this process—and specifically PNG's leadership role within this process—ultimately leads to some future benefits for PNG, some of those benefits can be attributed to the capacity built under the ACIAR-funded project.

Agroforestry projects

Although not all outputs were adopted, there was significant evidence from site visits that ACIAR projects had resulted in changed behaviour in local communities. In some cases, communities were incorporating trees into agricultural systems or establishing small-scale plantations when they otherwise would not have. In other cases, communities were using superior germplasm or better performing species than they would have used in the absence of the ACIAR projects. Examples include greater planting of high-value timber species (mainly teak) and multipurpose trees (mainly *E. pellita*). Woodlots in villages have also been established using fast-growing fuelwood species, and trees in alley cropping systems have been planted on sloped garden beds to prevent erosion.

While a number of the agroforestry projects have achieved significant uptake, in other cases (e.g. FST/1994/033), due to a lack of adoption no direct outcomes were identified. However, subsequent private-sector research built on the knowledge developed through the ACIAR project. This subsequent research led to large areas of leucaena being planted in the Markham Valley as feed for cattle production (M. Shelton, pers. comm., 8 April 2011).

Downstream processing projects

The main downstream timber-processing project is not far enough advanced to make a reasonable judgment on the likelihood of adoption of many of the outputs, and the outcomes from these projects are therefore uncertain.

Nevertheless, there have already been some outcomes from the project. In particular, rural communities were involved in processing and packaging the building materials required to build the low-cost kit homes designed through the project. Houses were built both in rural communities and urban settlements in December 2010 (B. Ozarska, pers. comm., 1 May 2011).

Galip nut projects

The galip nut projects are expected to ultimately lead to the establishment of a commercial galip nut industry in East New Britain. A viable galip nut industry is likely to be based around a commercial-scale processing facility that will process the nuts produced by nearby farmers. While a small local market for galip nuts already exists, a commercial-scale processing facility would link local farmers to wider domestic and export markets that they would not otherwise have access to.

It is unlikely that this industry would have become established in PNG in the absence of the research program and the associated EU-funded Facilitating Agriculture Commodity Trade project. There is potentially a 'chicken and egg' problem if the efforts of the various industry players are not coordinated through the research program. Farmers may have been reluctant to plant additional galip trees unless they had a market to sell the nuts into. This requires a commercial processing facility. However, for a commercial processing facility to be viable, it requires access to a reliable source of high-quality nuts. Previous attempts at establishing a commercial galip industry have failed because they have relied on harvesting wild galip nuts. Private investors are likely to be reluctant to establish a commercial processing facility unless they can be assured of a regular and reliable source of high-quality nuts. In the absence of a coordinated approach, the risks for both parties are likely to have been too great unless the other moves first.

It is also unlikely that an agribusiness company operating a processing facility would be able to obtain access to sufficient land to grow its own supply of nuts in PNG due to the customary land ownership system.

Outcomes for farmers

A key outcome from the galip nut research program will be increased planting of galip trees, mainly by smallholders. These farmers have a fixed supply of land, but can vary the quantity of galip nut production by changing the density of plantings. We consider two galip nut production systems:

- Low-density production (around 40 trees/ha), intercropped with cocoa—at low density, galip nuts can be successfully intercropped with cocoa. After around 3 years, galip is an effective shade tree for cocoa. It would therefore effectively replace gliricidia (the main existing shade tree for cocoa), which has no alternative economic uses (other than firewood).
- High-density galip nut production (around 139 trees/ha)—when galip trees are planted at high density, cocoa can no longer be grown after around the 5th year.

There is a range of costs associated with producing galip nuts (Table 7). They include the following:

- Set-up costs—one-off costs associated with establishing a galip plantation.
  - Many of these costs are quasi-fixed; that is, the farmer must incur them to produce galip nuts, but they do not vary with the density of plantings and therefore the level of production. The quasi-fixed set-up costs are estimated at around K561/ha.
  - The variable set-up costs (that is, costs that vary depending on the density of plantings). The main one is the cost of seedlings, which is estimated at around K2.20/seedling.
- The following costs are incurred annually.
  - The cost of weeding—estimated at around K120/ha—which is quasi-fixed (does not vary with planting density).
  - The opportunity cost of cocoa revenue forgone—while there has been little formal research to date, anecdotal evidence suggests that, at low density, there is no cost to cocoa yields from using galip trees as an alternative to gliricidia (J. Moxon, pers. comm., 13 May 2010). However, when galip is planted at high density, cocoa can no longer be grown from around the 5th year. The farmer would therefore forgo the revenue from cocoa. The average cocoa yield in East New Britain is around 0.4 tonnes (t)/ha and farmers receive around K400/65 kg sack (K6,154/t). Assuming harvesting costs of around K500/t, this implies a loss of cocoa income (net of harvesting costs) of around K1,962/ha/year.
  - The change in cocoa management costs—galip has advantages as a shade tree for cocoa, compared with gliricidia. Maintaining gliricidia can amount to around 10% of annual cocoa management costs (J. Moxon, pers. comm., 13 May 2010). Replacing gliricidia with galip planted at low density could therefore reduce annual cocoa management costs by around K10/ha. However, if galip is planted at high density, cocoa can no longer be grown after 5 years, so cocoa management costs could decrease by K100/ha.
- Other variable costs—these include harvesting, packing and transport costs, and are estimated to be around K567/t (nut in shell).

Outcomes for processors

While there have been no outcomes to date, it is expected that a commercial galip nut processing facility will ultimately be established in East New Britain. As the processing research is ongoing, it is not yet possible to estimate the cost of establishing such a facility.

Table 7. Galip nut production costs (kina)

	Low density	High density
Set-up costs (per ha)		
Quasi-fixed		
Clearing[a]	200	200
Lining[b]	30	30
Holing[c]	50	50
Tools	50	50
Weeding[f]	140	140
Pruning[g]	20	20
Census/infill[h]	13	13
Transport	58	58
Total quasi-fixed set-up costs	561	561
Variable		
Seedlings	88[d]	306[e]
Total variable set-up costs	88	306
Annual costs (per ha)		
Quasi-fixed		
Weeding	120	120
Total annual quasi-fixed costs	120	120
Variable		
Change in cocoa management costs[i]	−10	−100
Cocoa revenue forgone[j]	–	1,962
Total annual variable costs	−10	1,862
Other variable costs (per tonne of nut in shell)		
Harvest	110	110
Depulping	192	192
Sun drying	74	74
Packaging	147	147
Transport to market	44	44
Total variable costs	567	567

Sources: J. Moxon, pers. comm., 13 May 2010; Centre for International Economics

[a] Based on an estimated 20 person days at an opportunity cost of K10/day. [b] Based on an estimated 3 person days. [c] Based on and estimated 5 person days. [d] Based on 40 seedlings at K2.20/seedling. [e] Based on 139 seedlings at K2.20/seedling. [f] Based on an estimated 14 person days. [g] Based on an estimated 2 person days. [h] Based on an estimated 1.25 person days. [i] Cocoa annual management costs are estimated at around K100/ha. Around 10% of this relates to managing the shade provided by gliricidia. Therefore, using galip trees as an alternative to gliricidia saves around K10/ha. [j] At low density, galip can be intercropped with cocoa with no loss of yield. However, at high density, cocoa can no longer be grown from around the 5th year. From then on, the farmer would forgo the income from cocoa. This estimate assumes a cocoa yield of around 0.4 t/ha at a price of K400/65 kg sack (around K6,154/t) and assumes harvesting costs of around K500/t.

Note: Galip provides adequate shade to cocoa from around 3 years. At this point gliricidia can be removed. We have not included the cost of removing gliricidia or the benefits of its use or sale as firewood. To a large extent, these costs are likely to cancel out.

6 Impacts of ACIAR's forestry research in Papua New Guinea

In this chapter we provide a brief outline of the economic, environmental and social impacts (or likely impacts) of the selection of projects funded through ACIAR's forestry program. We also analyse the impacts of the galip nut projects in more detail.

Sustainable forest management projects

Since the outputs of the policy-related sustainable forest management projects (FST/1995/123 and FST/1998/118) do not appear to have been adopted yet, there are no impacts identified from those projects.

However, there is some evidence of adoption for the sustainable forest management project aimed at local communities (FST/2004/061). The impact of changes in forest management practices by local communities could include more-sustainable economic benefits from forest resources. However, the project final report notes that the extent to which the communities involved in the project will be able to realise financial benefits will depend on their access to capital to purchase equipment. The project outputs will put communities in a better position to prepare a business case for commercial finance or development assistance. However, without further training in business development and management these communities may not be able to develop sustainable business enterprises based on the models developed in the project (FST/2004/061 Final report, p. 39).

More effective and sustainable management of these forest resources could also eventually allow some communities to obtain Forest Stewardship Council certification. This would have several benefits for communities. First, certification gives communities access to a wider range of markets, some economies such as Australia and the EU having restrictions on non-certified timber. Second, some buyers are willing to pay a higher price for certified timber. For example, certified timber can sell for around K900/m^3 (depending on quality), compared with around K400/m^3 for non-certified timber (F. Inude, pers. comm., 10 May 2010).

More sustainable management of forest resources also has positive environmental impacts. As well as providing a more sustainable flow of income for local communities, a better-managed forest would also provided a more sustainable flow of environmental services.

Agroforestry projects

There is a range of impacts from the various projects aimed at encouraging communities to incorporate trees into their agricultural systems. The economic impacts are likely to include the following:

- Future income from planting high-value tree species such as teak—these trees provide an important source of savings for local landowners. These savings can be used for large future payments such as education expenses for their children.
- Improved access to fuelwood for own use or sale in local and commercial markets.
- Improved access to construction material needed to build new dwellings or school buildings.

- For some communities, increased income from selling seed.
- Decreased erosion, which increases the area of usable land in steep areas such as the Highlands.

In addition, subsequent private-sector research on leucaena built on the knowledge developed through the ACIAR-funded research (FST/1994/033). This later research led to the planting of large areas of leucaena in the Markham Valley, to support cattle production (M. Shelton, pers. comm., 8 April 2011). Some of the benefits of the improved productivity of cattle raising can be attributed to the ACIAR-funded research.

There may also be some beneficial environmental impacts from greater incorporation of trees into agricultural systems. These may include:

- reduced erosion on sloping land and in riparian zones
- less reliance on natural forests for fuelwood and construction material.

The main beneficiaries from these projects are low-income smallholders. The greater incomes and source of savings may therefore lead to higher living standards and improvements on various social indicators.

Downstream processing projects

A key impact delivered to date by the downstream processing project (FST/2006/120) is the lower cost (and better quality) of housing for rural communities and urban settlements. There is also the potential for rural communities to earn income from producing structural building components from their community forests (B. Ozarska, pers. comm., 1 May 2011).

It is too early to tell whether there will be any other significant impacts from this project. However, the economic impacts could ultimately include a larger domestic downstream timber-processing industry within PNG, providing much-needed formal employment and higher export earnings from value-added forest products.

Galip projects

The ultimate impact of the research program is likely to be the establishment of a commercial galip nut industry in East New Britain. Since there are likely to be economies of scale in processing, a likely industry structure in PNG is for a commercial-scale facility to process the nuts produced by a cluster of surrounding smallholders (C. Bunt, pers. comm., 3 August 2010). A possible industry supply chain is shown in Figure 6.

The processing project has identified a number of processing stages the nuts will undergo. The first stage of processing essentially produces a dried nut in shell. This involves the following steps:

- nut-in-pulp de-husking
- nut-in-shell float test and sampling
- nut-in-shell drying.

The dried nuts in shell can be stored for 2–3 months in airtight drums.

The second stage of production involves removing the shell and testa, and drying the kernel to produce the dried kernel. The steps involved are:

- nut-in-shell grading
- nut-in-shell cracking—after cracking, the nuts will pass through a critical control point to kill germs
- kernel-in-testa scalding
- removal of testa
- kernel drying.

The final product of this stage is dried galip kernel.

The next stage is subsequent value-adding. The level of value-adding is likely to depend on marketing efforts. Final products made from whole kernels may include:

- dried or salted galip nuts
- roasted or sugar- or honey-coated galip nuts
- chocolate-coated galip nuts
- galip nuts for use in baking.

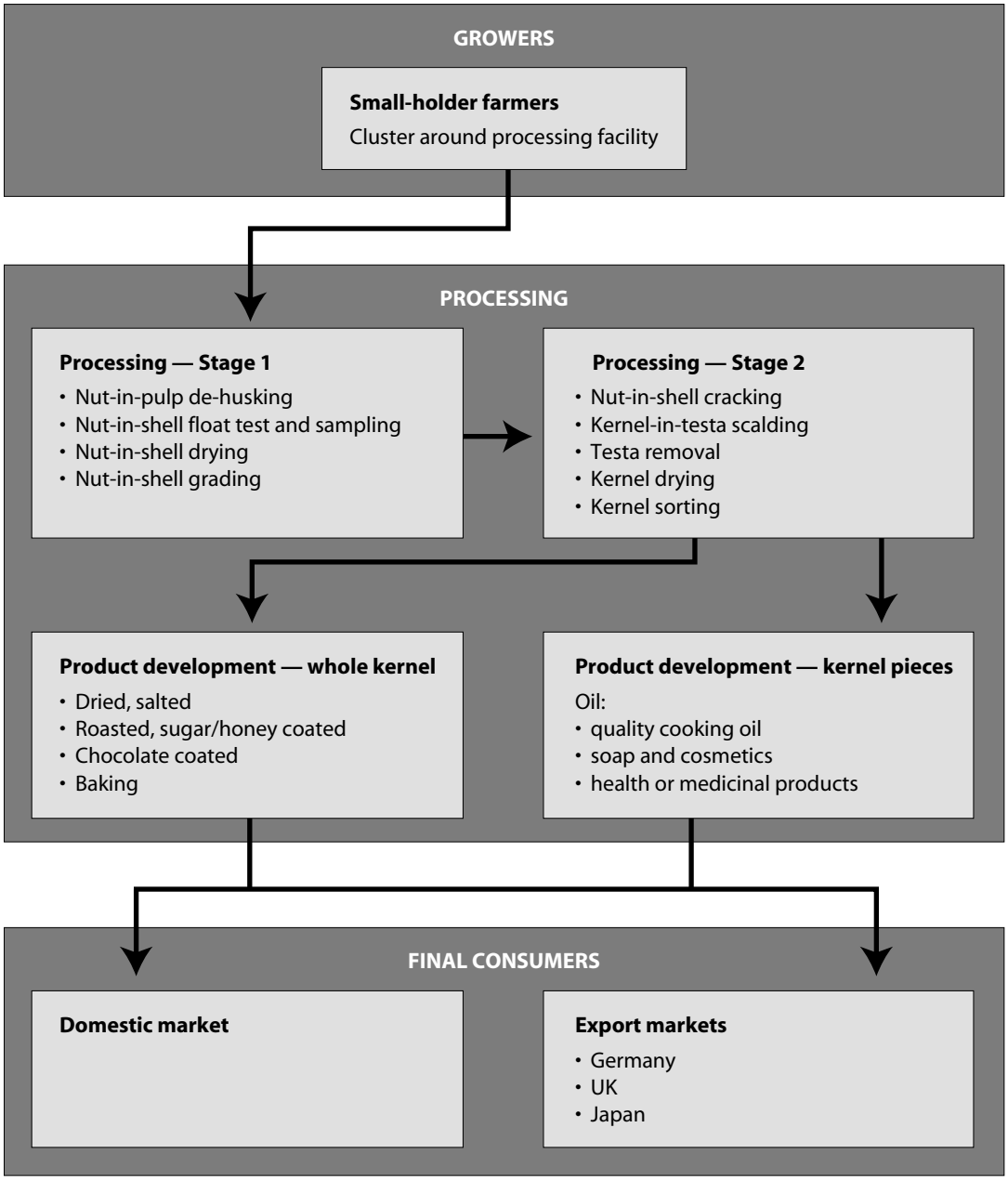

Figure 6. Possible supply chain for galip products. Source: Centre for International Economics

Kernel pieces can be pressed to make oil, which has several uses, including:

- in value-added products such as muesli and confectionary
- as ground meal for baking
- to make high-quality cooking oil, or oil for use in soap, cosmetics, or health or medicinal products.

These final products may be sold in domestic and export markets. The PNG domestic market is highly price driven; consumers are far more concerned about price than value. Galip nuts are therefore likely to have to compete with cheap peanuts imported from China, a low-quality product that sells for around K3 for a 180 gram tin. To be competitive, galip nuts will therefore have to sell for around K3. It is estimated that the domestic market could absorb around 20% of the maximum yield (C. Bunt, pers. comm., 3 August 2010).

In export markets, galip nuts will be marketed as a premium product. Processing galip is unlikely to be commercially viable if marketed as a low-value commodity such as almonds (C. Bunt, pers. comm., 3 August 2010). The most likely export markets are high-value markets, such as Germany, the UK and Japan, where consumers are willing to pay a premium price for a high-quality product.

Since the level of value-adding that will take place is not yet clear, we concentrate here on:

- the market for unprocessed nuts
- processing up to the dried kernel stage, which has been the focus of the ACIAR processing project.

Final product development and future value-adding is not yet clear and is likely to depend on marketing efforts.

The market for unprocessed galip nuts

The market for unprocessed galip nuts is likely to consist mainly of a cluster of smallholder farmers selling to a central commercial processing facility. These smallholders have a fixed supply of land, but can vary their production of galip nuts by changing the planting density. The smallholder farmers are likely to be price takers; that is, each farmer's production decisions are unlikely to affect the market price. They will therefore face a horizontal demand curve at the market price.

The marginal benefits and cost profile associated with replacing gliricidia with galip planted at low density (40 trees/ha) in existing cocoa plantations are shown in Table 8.

The marginal revenue estimates are based on the following assumptions:

- A price of K1/kg (nut in shell)—this is based on a conservative estimate from the project team (J. Moxon, pers. comm., 13 May 2010).
- A maximum annual yield of 5,000 nuts/tree, with each tree commencing production in year 5 and increasing linearly to reach the maximum yield by year 15. Galip trees can produce nuts for up to 200–300 years (J. Moxon, pers. comm., 13 May 2010).
- Average nut weight of 12 grams (J. Moxon, pers. comm., 14 May 2010), implying a maximum annual yield of 60 kilograms/tree.

The marginal cost profile is based on the cost estimates provided in Table 7.

The marginal costs and benefits of moving from a low-density galip nut production system (intercropped with cocoa) to high-density (139 trees/ha) galip nut production are shown in Table 9. The marginal net benefit of moving to high-density production is significantly lower, largely due to the opportunity cost of cocoa income forgone. By definition, farmers incur no further quasi-fixed costs from increasing the tree density.

Table 10 shows the marginal benefit and marginal cost estimates in present-value terms using various discount rates. Since the benefits of establishing a commercial galip nut industry are expected to be permanent, we follow ACIAR's Impact Assessment Guidelines (Davis et al. 2008, p. 47) and convert all future benefits and costs to an annuity once they have reached a steady state (maximum yield is reached after 15 years).

Using ACIAR's standard discount rate of 5% (see Davis et al. 2008, p. 32), the marginal net benefit to farmers from replacing gliricidia with galip planted at low density (40 trees/ha) in existing cocoa plantations is estimated at around K10,931/ha in present-value terms. The net marginal benefit from moving from low- to high-density galip production (139 trees/ha) is estimated at around K3,650/ha.

Since the marginal benefit of moving to high-density galip production exceeds the marginal cost (using a 5% discount rate), this implies that farmers are better off abandoning cocoa and moving to a high-density galip nut production system. However, there are two reasons why smallholders may choose to produce galip nuts in a low-density production system intercropped with cocoa.

- First, smallholder farmers are likely to base their production decisions on a higher discount rate. While 5% may be a reasonable reflection of the social discount rate and is therefore appropriate for discounting future costs and benefits, the time preference of smallholder farmers (private discount rate) is likely to be significantly higher. When a discount rate of 10% is used—a rate that is likely to be closer to smallholder farmers' time preference—the marginal benefit of moving to a low-density galip nut production system intercropped with cocoa remains higher than the marginal cost. However, the marginal benefit of moving to high-density galip nut

Table 8. Marginal costs and benefits (kina/ha) of moving from no galip nut production to a low-density production system[a]

	Marginal revenue[b]	Marginal quasi-fixed costs[c]		Marginal variable costs				Total marginal cost	Net benefit
		Set-up	Manage-ment	Set-up	Manage-ment[d]	Cocoa income	Other[e]		
Year 1	–	561	–	88	–	–	–	649	–649
Year 2	–	–	120	–	–	–	–	120	–120
Year 3	–	–	120	–	–	–	–	120	–120
Year 4	–	–	120	–	–10	–	–	110	–110
Year 5	218	–	120	–	–10	–	124	234	–15
Year 6	436	–	120	–	–10	–	247	357	79
Year 7	655	–	120	–	–10	–	371	481	174
Year 8	873	–	120	–	–10	–	495	605	268
Year 9	1,091	–	120	–	–10	–	618	728	363
Year 10	1,309	–	120	–	–10	–	742	852	457
Year 11	1,527	–	120	–	–10	–	866	976	552
Year 12	1,745	–	120	–	–10	–	989	1,099	646
Year 13	1,964	–	120	–	–10	–	1,113	1,223	741
Year 14	2,182	–	120	–	–10	–	1,236	1,346	835
Year 15	2,400	–	120	–	–10	–	1,360	1,470	930
Year 15+	2,400	–	120	–	–10	–	1,360	1,470	930

Sources: J. Moxon, pers. comm., 13 May 2010; Centre for International Economics (see Table 7)

[a] Assumes 40 trees/ha.

[b] Marginal revenue estimates assume: trees commence production in the 5th year, with yields increasing linearly to reach maximum production of 60 kg (nut in shell) in year 15 and a nut-in-shell price of K1/kg.

[c] Quasi-fixed costs are included in the marginal cost estimates because they are incurred by farmers when they choose to go from no galip nut production to a low-density production system (see Table 7 for cost details).

[d] The benefits of reduced shade management costs for cocoa occur after the 3rd year.

[e] Other variable costs are estimated at K567/t (nut in shell) of galip nuts produced (see Table 7 for cost details).

production falls below the estimated marginal cost (see Table 10), suggesting that farmers are better off producing galip nuts with low-density plantings.

- Second, smallholder farmers are likely to make decisions based on a much shorter time horizon. When a 20-year time horizon is used, the marginal net benefit of low-density galip nut production remains positive, whereas moving to high-density galip nut production would impose a significant net cost, even when a 5% discount rate is used. Intercropping cocoa with galip nuts may also help to diversify away some of the risks associated with investing in the galip nut industry before it becomes fully established.

Although farmers in areas severely affected by cocoa pod borer may be better off moving to high-density galip nut production, the project team indicated that farmers are unlikely to move away from cocoa production altogether. For these reasons it is reasonable to assume that galip nuts will be produced mostly in low-density systems intercropped with cocoa, in line with the project team's recommendations.

Table 9. Marginal costs and benefits (kina/ha) of moving from a low-density to a high-density galip nut production system[a]

	Marginal revenue[b]	Marginal quasi-fixed costs[c]		Marginal variable costs				Total marginal cost[f]	Net benefit
		Set-up	Management	Set-up	Management[d]	Cocoa income[e]	Other		
Year 1	–	–	–	218	–	–	–	218	–218
Year 2	–	–	–	–	–	–	–	–	–
Year 3	–	–	–	–	–	–	–	–	–
Year 4	–	–	–	–	–90	–	–	–90	90
Year 5	540	–	–	–	–90	1,962	288	2,159	–1,619
Year 6	1,080	–	–	–	–90	1,962	575	2,447	–1,367
Year 7	1,620	–	–	–	–90	1,962	863	2,735	–1,115
Year 8	2,160	–	–	–	–90	1,962	1,151	3,022	–862
Year 9	2,700	–	–	–	–90	1,962	1,439	3,310	–610
Year 10	3,240	–	–	–	–90	1,962	1,726	3,598	–358
Year 11	3,780	–	–	–	–90	1,962	2,014	3,886	–106
Year 12	4,320	–	–	–	–90	1,962	2,302	4,173	147
Year 13	4,860	–	–	–	–90	1,962	2,589	4,461	399
Year 14	5,400	–	–	–	–90	1,962	2,877	4,749	651
Year 15	5,940	–	–	–	–90	1,962	3,309	5,180	760
Year 15+	5,940	–	–	–	–90	1,962	3,309	5,180	760

Sources: J. Moxon, pers. comm., 13 May 2010; Centre for International Economics (see Table 7)

a Assumes moving from 40 trees/ha to 139 trees/ha.

b Marginal revenue estimates assume: trees commence production in the 5th year, with yields increasing linearly to reach maximum production of 60 kg (nut in shell) in year 15 and a nut-in-shell price of K1/kg.

c Quasi-fixed costs do not vary with tree density. Therefore no additional costs are incurred in moving up to high-density galip nut production (see Table 7 for cost details).

d The benefits of reduced shade management costs for cocoa occur after the 3rd year (see Table 7 for cost details).

e The opportunity cost of cocoa income forgone is incurred from the 5th year onwards. (see Table 7 for cost details).

f Other variable costs are estimated at K567/t (nut in shell) of galip nuts produced (see Table 7 for cost details).

Based on the above information, the marginal cost curve for each farmer can be depicted as a step function (Figure 7). The marginal cost of moving to high-density production increases, because galip can no longer be intercropped with cocoa. In reality, the marginal cost curve may increase more gradually than shown in Figure 7. For example, in medium-density plantings it may be possible to continue to grow cocoa if the galip trees are pruned regularly. However, the step function shown in the diagram is likely to be a reasonable approximation.

In the period where nut production is ramping up (Figure 7, left panel), the marginal net benefit to farmers growing galip nuts at low density—depicted by the shaded area—is relatively low because production is low (Q_L). During this period there is a significant marginal net cost to farmers in moving to high-density planting (depicted by the striped area) because the farmer is forgoing cocoa revenue, while galip nut production is still relatively low (Q_H).

Table 10. Marginal costs and benefits (kina/ha, present value) of galip production systems[a]

	1% discount rate		5% discount rate		10% discount rate	
	Low density[b]	High density[c]	Low density[b]	High density[c]	Low density[b]	High density[c]
Marginal benefit						
Marginal revenue[d]	219,678	543,704	31,722	78,512	11,737	27,564
Marginal cost						
Quasi-fixed costs[e]						
Set-up costs	561	–	561	–	561	–
Management costs	11,897	–	2,342	–	1,171	–
Variable costs						
Set-up costs	88	218	88	218	88	218
Management costs[f]	–972	–8,745	–177	–1,589	–80	–722
Cocoa income forgone[g]	–	188,695	–	32,945	–	14,268
Other variable costs[h]	124,493	302,202	17,977	43,288	6,311	15,068
Total marginal cost	136,067	482,370	20,791	74,862	8,051	28,832
Net benefit						
Net revenue	83,612	61,334	10,931	3,650	3,086	–1,268

Sources: J. Moxon, pers. comm., 13 May 2010; Centre for International Economics

[a] Marginal benefits and costs are expressed in present value terms over an infinite time horizon.

[b] Based on 40 trees/ha.

[c] Based on 139 trees/ha.

As production increases, the marginal cost curve shifts down and out (Figure 7, right panel). At full production the marginal net benefit to farmers growing at low density is therefore significantly larger. There is also a smaller net marginal benefit from moving to high density once the galip trees reach full production. However, as discussed above, the net losses in the previous periods outweigh these benefits (at least when a 10% discount rate is used). The net benefit to farmers is therefore the sum of the shaded area over time (including the losses in the periods before the galip trees commence producing nuts).

Assuming all farmers use the same technology, the market supply curve would be the horizontal sum of the per-hectare marginal cost curve for each hectare planted to galip. Based on the expectation that one million seedlings will be distributed through the EU and ACIAR projects, this corresponds to 250,000 ha planted at a density of 40 trees/ha. This is about half of the total area currently planted to cocoa in East New Britain, which seems a reasonable maximum adoption rate.

The market for processed galip nuts

There have been previous attempts at establishing a commercial galip market in parts of Melanesia, which have not been successful. Previous efforts have relied on the wild harvest, and a major impediment has been sourcing sufficient volume and quality to ensure consistent supply (C. Bunt, pers. comm., 3 August 2010). The resource base established through the combined ACIAR and EU projects will overcome this major impediment.

The benefits to processors from establishing a commercial processing facility will depend on the price received and the cost of processing. Neither can be known at this stage because there is currently no international wholesale

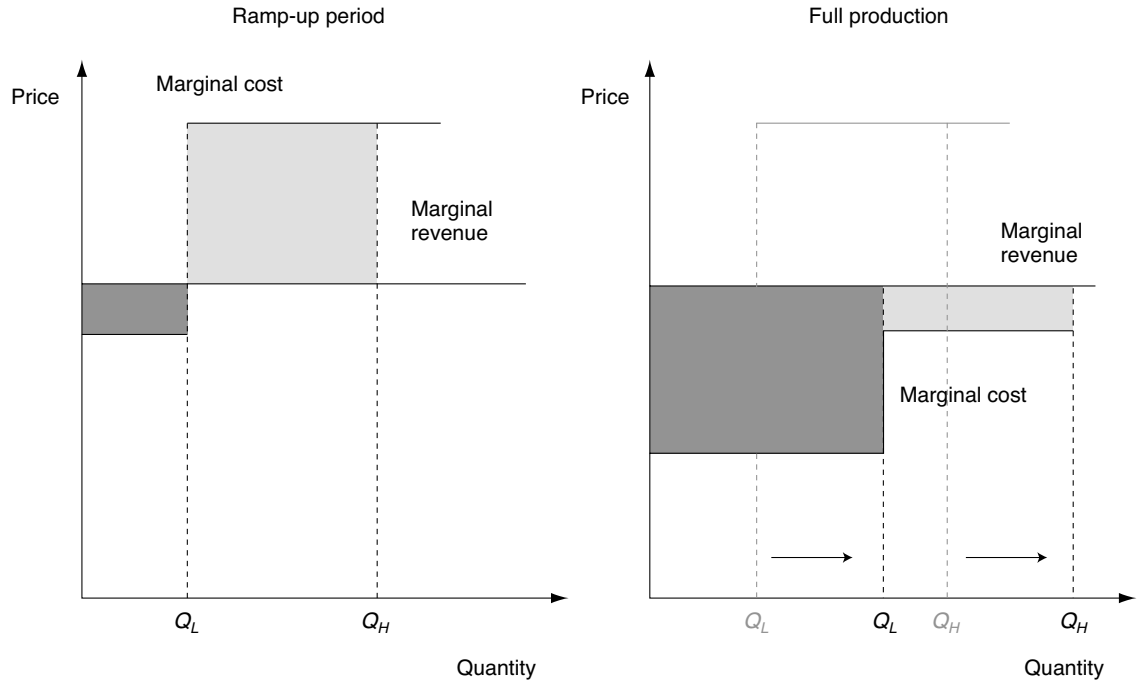

Figure 7. Representation of the market for unprocessed galip nuts. Source: Centre for International Economics

market for processed galip nuts and the processing project is not sufficiently far advanced to estimate costs (H. Wallace, pers. comm., 5 August 2010).

Although PNG processors would be the world's main supplier of galip nuts, they are unlikely to have significant market power in the competitive global nut market. Since there a many close substitutes for galip nuts, demand is likely to be highly elastic. The world price will be determined by the perceived quality of galip nuts in comparison to other nuts, although this may also be affected by marketing effort.

The current intention is to market galip nuts as a premium niche product. Conservatively, the project team suggests that processed galip nuts could fetch a price of around K15/kg (J. Moxon, pers. comm., 13 May 2010). This is above the current price of almonds at around K10/kg, but significantly below the price received for macadamia nuts at around K30/kg (J. Moxon, pers. comm., 13 May 2010).

Although it is too early to make an informed estimate on production costs, researchers are confident that they will be able to develop a commercially viable production method (H. Wallace, pers. comm., 5 August 2010).

However, commercial viability will also depend on future marketing effort, as the galip nut industry is unlikely to be viable if marketed as a commodity, in a style similar to almonds (C. Bunt, pers. comm., 4 August 2010).

If galip nut processing is likely to be commercially viable at a price of K15/kg, but not so at K10/kg, this implies that production costs may be somewhere between K10 and K15/kg. Using the midpoint of this range, production costs could be around K12.50/kg, including the cost of the unprocessed nuts. Our assumptions of a nut-in-shell weight of 12 grams/nut and a kernel weight of 2.5 grams imply that around 3.8 kg of unprocessed nuts are required to produce 1 kg of processed kernel. This implies that the processing costs are around K8.70/kg (assuming farmers are paid a price of K1/kg for nut in shell).

The difference between the sale price (K15/kg) and the estimated cost of production (K12.50/kg) may be a reasonable indicator of the potential benefits to processors (over and above the normal risk-adjusted rate of return on capital). Since the market structure is likely to involve a single processor in a particular region, it may be difficult for new processors to enter the market and compete away this excess profit. It is therefore plausible that this K2.50/kg benefit to processors will persist in the long run.

7 Benefits and costs of the galip nut projects

This chapter sets out the costs and potential benefits of the galip nut cluster of projects in a cost–benefit analysis framework.

Benefits

The estimated benefits from the galip nut R&D program are shown in Table 11. To estimate the total benefits the R&D program could deliver to PNG farmers, we combine the estimated per hectare net benefits estimated in Table 10 (using a discount rate of 5%) with an estimate of the area planted to galip trees over time. The estimated area planted to galip is based on the planting profile shown in Figure 4 and assumes the seedlings are planted at a density of 40 trees/ha. The estimated benefits shown in each period are therefore the permanent future net benefits of the galip trees planted in that period.

As an indicator of the potential benefits to processors, we multiply the estimated quantity of processed kernel produced over time (Figure 5) by the estimated margin of K2.50/kg. The benefits of a commercial galip nut industry are expected to be permanent. Following the ACIAR guidelines, we therefore convert all future benefits to an annuity once they have reached a steady state (by 2036).

The estimated benefits to farmers and processors are then converted to Australian dollars. Average monthly exchange rates are averaged over the year to produce an annual exchange rate. Actual monthly exchange rates are used to July 2010 and are then held constant for all subsequent periods.

Distribution of benefits

Based on the above assumptions, around 60% of the benefits are predicted to flow to processors (using a discount rate of 5%). The remaining 40% of the benefits flow to farmers.

Project costs

The ACIAR-funded projects have formed part of a broader R&D program. Each individual project making up the program has been a necessary step towards the overall aim of establishing commercial galip nut markets (J. Moxon, pers. comm., 13 May 2010). While all projects are considered necessary, no individual project has been sufficient in isolation to achieving the ultimate aim. It is therefore necessary to include all the research costs as a project input.

In Table 12, the nominal research costs shown in Tables 5 and 6 are converted to real 2010 dollars using the Australian GDP implicit price deflator published by the Australian Bureau of Statistics. Only funding relevant to PNG is included (i.e. all funding for Vanuatu and Solomon Islands has been omitted). It is also assumed that R&D funding of around K2 million/year will be required over the next 10 years to support additional research and marketing efforts. ACIAR has committed around A$485,000 over the next 4 years, which has been included in the table. Subsequently, the industry would be self-sustaining and any further research would presumably be funded through industry levies.

Table 11. Estimated potential benefits of the galip nut R&D program in Papua New Guinea

	Benefits to farmers[a]	Benefits to processors[b]	Exchange rate[c]	Benefits to farmers	Benefits to processors
	Kina (K) '000		K/A$	A$ '000	
2003	–	–	0.4125	–	–
2004	–	–	0.4032	–	–
2005	–	–	0.4581	–	–
2006	–	–	0.4449	–	–
2007	–	–	0.4128	–	–
2008	–	–	0.4542	–	–
2009	24,594	–	0.4783	11,763	–
2010	19,129	–	0.4193	8,021	–
2011	19,129	–	0.4202	8,039	–
2012	19,129	–	0.4202	8,039	–
2013	19,129	256	0.4202	8,039	107
2014	19,129	710	0.4202	8,039	298
2015	19,129	1,364	0.4202	8,039	573
2016	19,129	2,216	0.4202	8,039	931
2017	19,129	3,267	0.4202	8,039	1,373
2018	19,129	4,517	0.4202	8,039	1,898
2019	19,129	5,966	0.4202	8,039	2,507
2020	19,129	7,614	0.4202	8,039	3,200
2021	19,129	9,460	0.4202	8,039	3,976
2022	19,129	11,506	0.4202	8,039	4,835
2023	–	13,750	0.4202	–	5,778
2024	–	15,938	0.4202	–	6,698
2025	–	18,125	0.4202	–	7,617
2026	–	20,313	0.4202	–	8,536
2027	–	22,301	0.4202	–	9,372
2028	–	24,091	0.4202	–	10,124
2029	–	25,682	0.4202	–	10,792
2030	–	27,074	0.4202	–	11,377
2031	–	28,267	0.4202	–	11,879
2032	–	29,261	0.4202	–	12,297
2033	–	30,057	0.4202	–	12,631
2034	–	30,653	0.4202	–	12,882
2035	–	31,051	0.4202	–	13,049
2036	–	31,250	0.4202	–	13,132

Table 11. (continued)

	Benefits to farmers[a]	Benefits to processors[b]	Exchange rate[c]	Benefits to farmers	Benefits to processors
	Kina (K) '000		K/A$	A$ '000	
2037[d]	–	625,000	0.4202	–	262,649

Sources: Centre for International Economics; oxforex website at <http://www.ozforex.com.au/>, accessed July 2010

[a] The benefit to farmers is estimated by multiplying the marginal net benefit of producing galip nuts in a low-density system (K10,912/ha in present value terms over an infinite time horizon, using a discount rate of 5% (see Table 10 for details) by the estimated planting profile.

[b] The benefit to processors is estimated by multiplying a profit margin of K2.5/kg by the estimated annual production of processed nuts (see Figure 5).

[c] The average monthly exchange rates sourced from http://www.ozforex.com.au/ are averaged over the year to produce an annual exchange rate. Actual monthly exchange rates are used to July 2010 and are held constant thereafter.

[d] The benefits are estimated to reach a steady state by 2036. We therefore converted all future benefits to an annuity by dividing by the discount rate. This assumes a discount rate of 5%.

Table 12. Real project costs (including estimated future funding requirements) of the galip nut R&D program in Papua New Guinea

	ACIAR projects			Other projects[b]	Future funding requirements[c]	Total
	ACIAR[a]	Other sources[a]	Total[a]			
	A$ (2010)	A$ (2010)	A$ (2010)	A$ (2010)	A$ (2010)	A$ (2010)
2003	–	–	–	184,485	–	184,485
2004	151,564	31,382	182,946	–	–	182,946
2005	75,737	30,128	105,865	–	–	105,865
2006	249,987	99,070	349,057	640,865	–	989,922
2007	139,956	95,269	235,226	–	–	235,226
2008	291,281	235,424	526,705	–	–	526,705
2009	327,992	234,297	562,289	–	–	562,289
2010	190,466	140,960	331,426	367,308	–	698,734
2011	117,718	9,390	127,109	–	688,887	815,996
2012	114,290	9,117	123,407	–	668,823	792,229
2013	110,961	–	110,961	–	658,194	769,155
2014	107,729	–	107,729	–	639,023	746,752
2015	–	–	–	–	725,002	725,002
2016	–	–	–	–	703,885	703,885
2017	–	–	–	–	683,384	683,384
2018	–	–	–	–	663,480	663,480
2019	–	–	–	–	644,155	644,155
2020	–	–	–	–	625,393	625,393

Sources: J. Moxon, pers. comm., 14 May 2010; ACIAR Project budgets; ABS Cat. No. 5204.0, Australian System of National Accounts.

[a] From ACIAR project budgets (see Table 5 for details). Includes additional funding of A$485,000 over the next 4 years that ACIAR has already committed.

[b] EU funding (see Table 6 for details).

[c] Assumes funding of around K2 million/year in nominal terms for the next 10 years will be required.

Summary measures

In present-value terms, we estimate that the galip nut research program could deliver benefits to PNG of around A$163.0 million in 2010 dollars, using a discount rate of 5% (Table 13). This exceeds the estimated cost of the research of around A$7.2 million (expressed in similar terms) by around A$155.8 million, representing a benefit of around A$22.60 for every dollar spent. The internal rate of return on the research program is estimated at around 20.4%.

These results depend on the discount rate used. When a discount rate of 1% is used, the benefit:cost ratio is estimated to be around 176.5, but falls to about 6.6 at a 10% discount rate. Nevertheless, the broad conclusion that the project is likely to deliver significant net benefits to PNG is robust to varying the discount rate within a normal range.

Attribution of benefits

Since all of the projects that made up the overall research program are considered necessary to achieve the ultimate objective it is appropriate to attribute benefits on the basis of cost shares.

The three ACIAR projects plus the future project to which ACIAR has committed funds contributed around 68% of the total funding allocated to the program to date. However, when expected future funding requirements are taken into account, this is around 31% of the total estimated research costs. Around A$50.9 million of the estimate total benefits can therefore be attributed to the ACIAR projects. Based on ACIAR's direct contribution to these projects, around A$34.3 million can be attributed to it (Table 14).

Aside from the future funding committed by ACIAR, the source of the remaining future funding requirements is not yet known.

Table 13. Summary measures of the benefits of the galip nut R&D program in Papua New Guinea

	1% discount rate	5% discount rate	10% discount rate
Present value of benefits to farmers (A$m)	787.5	65.1	11.0
Present value of benefits to processors (A$m)	1,064.4	97.9	20.7
Present value of total benefits (A$m)	1,851.9	163.0	31.7
Present value of costs (A$m)	10.5	7.2	4.8
Net present value (A$m)	1,841.3	155.8	29.9
Benefit:cost ratio	176.5	22.6	6.6
Internal rate of return (%)	20.4	20.4	20.4

Source: Centre for International Economics

Table 14. Attribution of benefits of the galip nut R&D program in Papua New Guinea

Source of funding	Share of costs	Benefits attributed
	%	A$ million
ACIAR projects	31.3	51.0
• ACIAR	21.1	34.4
• Other sources	10.2	16.6
European Union projects	14.7	23.9
Future projects	54.1	88.1
Total	100.0	163.0

Source: Centre for International Economics

Risk and sensitivity analysis

While the prospects look promising, the establishment of a commercial market for galip nuts is by no means certain. This is the key risk to the project delivering net benefits of the magnitude estimated above.

Finding markets for galip nuts at a price that would make investment in large-scale processing commercially viable is likely to depend to a large extent on product development and marketing effort. A key risk is therefore a lack of investment in this area.

A new ACIAR project will provide an additional A$485,000 over the next 4 years for product development and marketing. However, the project team estimates that significantly more funding from donors or the PNG Government will be required before a commercial galip nut industry is self-sustaining.

If a commercial galip nut industry is not established, the farmers that have already planted galip may be able to sell some galip nuts locally and recoup most of their investment from harvesting the galip trees as timber. However, the benefits for farmers would be much lower than estimated above.

Even if a market does become established, there is more than the usual uncertainty surrounding our estimates. Some of the key uncertainties relate to the following factors:

- Prices—as there are currently no commercial galip nut markets, it is not possible to estimate accurately what price galip nuts consumers would be willing to pay and, as a consequence, what price a commercial processor would be willing to pay farmers for unprocessed nuts.
- Processing costs—the costs associated with processing galip nuts on a commercial scale are currently not known.
- Yield variables—since the characteristics of the galip seedlings distributed to date have not been fully tested, there is some uncertainty surrounding variables such as the number of nuts per tree (at maximum yield), the nut-in-shell weight and the kernel weight.

Break-even analysis

Given that there is some risk that a commercial market will not become established, it is useful to undertake a break-even analysis. Table 15 compares the assumptions used to estimate the benefits with the break-even point; that is, the point at which the farmer or processor breaks even (assuming no change in all other variables). The table also shows the point at which it becomes attractive for farmers to move to high-density production

Table 15. Break-even analysis on returns from galip nut production and processing

	Current assumption	Break even	Threshold for the viability of high-density plantings
Farmers			
Price of unprocessed nuts (kina/kg)	1.00	0.77	1.12
Annual nuts per tree after 15 years (number)	5,000	2,350	5,604
Nut-in-shell weight (grams)	12.00	5.64	13.44
Processors			
Price of unprocessed nuts (kina/kg)	1.00	1.52	n.a.
Price of processed nuts (kina/kg)	15.00	12.50	n.a.
Implied production costs (kina/kg)	7.70	10.20	n.a.
Kernel weight (grams)	2.50	1.64	n.a.

Source: Centre for International Economics

assuming that they base their production decisions on a 20-year time horizon and a discount rate of 10%.

Since the break-even point is mostly significantly below (or above where relevant) the already conservative assumptions used, this suggests that a commercial galip nut market should be viable, subject to sufficient future R&D funding.

Sensitivity analysis

While the estimates used in the above analysis seem reasonable in the context of the current price of substitutes and observed technical parameters, it is nevertheless important to test the robustness of our conclusions to variations in these assumptions. The low and high alternative assumptions we use in this sensitivity analysis are shown in Table 16.

The range used for the price of unprocessed nuts was influenced by the break-even analysis. If the nut-in-shell price is below K0.77/kg, farmers are unlikely to plant galip. However, if the price is above 1.52 kg, establishing a processing facility is unlikely to be commercially viable (unless the price of processed nuts also increases).

The lower range for the price of processed nuts is also based on the break-even point for processors. Based on the assumptions used in our estimates, the industry is unlikely to be viable if the price falls below K12.50. The upper price is based on the wholesale price of macadamia nuts.

Since we have used a very conservative estimate of the number of nuts produced per tree, we do not test the impact of using a lower assumption. The upper limit of 8,000 nuts per tree is based on research observations (J. Moxon, pers. comm., 13 May 2010).

The range used for the kernel weight is also based on observed variations. The kernel weights of nuts from unselected trees are around 1.5 grams, but can be up to 5 grams in elite trees (J. Moxon, pers. comm., 13 May 2010).

The nut-in-shell weight is based on variation in the kernel as a percentage of the nut-in-shell weight being between 15 and 25%.

The net present value and the benefit:cost ratio have been re-estimated using the alternative assumptions, leaving all other assumptions unchanged (Table 17). Since the high alternative assumptions for the price of unprocessed nuts, nut yield per tree and nut-in-shell weight are all above the threshold that makes high-density production viable (see Table 15), we have assumed that farmers will change their behaviour and plant galip trees at high density. We therefore retain the assumption that the maximum adoption rate is 25,000 ha. However, the expansion of plantings is likely to remain constrained by the supply of germplasm. We therefore retain the assumption that plantings increase by only 70,000 seedlings/year. This implies it would take until around 2058 to reach the maximum adoption rate.

Reducing the price to around the break-even point for farmers has little impact on the overall benefits. Lower benefits for farmers are offset by higher benefits to processors. Assuming that the price of processed nuts remains unchanged, varying the price of unprocessed nuts between the thresholds where it will change

Table 16. Alternative assumptions for sensitivity analysis

	Low	Central	High
Prices			
Price of unprocessed nuts (kina/kg)	0.77	1.00	1.52
Price of processed nuts (kina/kg)	12.50	15.00	30.00
Yield			
Annual nuts per tree after 15 years (number)	–	5,000	8,000
Nut-in-shell weight (grams)	10.0	12.0	16.7
Kernel weight (grams)	1.64	2.5	5.0

Source: Centre for International Economics

Table 17. Summary measures using alternative assumptions

	Low	Central	High
Net present value (A$m)			
Price of unprocessed nuts (kina/kg)	155.8	155.8	215.5
Price of processed nuts (kina/kg)	57.9	155.8	742.9
Annual nuts per tree after 15 years (number)	n.a.	155.8	690.1
Kernel weight	57.5	155.8	441.5
Nut-in-shell weight	173.4	155.8	224.1
Benefit:cost ratio			
Price of unprocessed nuts (kina/kg)	22.6	22.6	30.9
Price of processed nuts (kina/kg)	9.0	22.6	104.2
Annual nuts per tree after 15 years (number)	n.a.	22.6	96.9
Kernel weight	9.0	22.6	62.3
Nut-in-shell weight	25.1	22.6	32.1

Source: Centre for International Economics

farmers' or processors' behaviour will change only the distribution of benefits between farmers and processors. However, increasing the price to around K1.52/kg increases the overall benefits because it becomes viable for farmers to produce at high density.

The net benefits flowing to PNG are highly sensitive to the price of processed nuts. This highlights the importance of marketing to achieve a premium price.

The net benefits are also relatively sensitive to the nut yield per tree. If the nut yield is higher than around 5,600/tree (which is quite possible), high-density plantings may be viable. The net benefits are also relatively sensitive to the kernel weight. This demonstrates the importance of selecting seedlings with desirable commercial characteristics.

Somewhat counterintuitively, the net benefits appear to increase if the nut-in-shell weight assumption is either increased or decreased. This arises because all of the other assumptions (including kernel size) are held constant. Decreasing the nut-in-shell weight while holding the kernel size constant implies a reduction in the kernel:nut ratio. Since prices are also held constant, the loss to farmers is more than offset by benefits to processors. On the other hand, when the nut-in-shell weight is increased beyond 13.4 grams, it becomes viable for farmers to move to high-density plantings. The benefits therefore outweigh the decrease in the kernel:nut ratio.

8 Conclusions

Forestry has been an important component of ACIAR's PNG program. While PNG has significant natural advantages in forestry, it is a difficult environment to deliver successful R&D projects.

A range of different types of projects has been funded through ACIAR's forestry program. Of the projects reviewed as part of this study, the achievements have been mixed. There are also several lessons that have emerged from the review.

Feasibility studies

In recent years, ACIAR has funded a number of feasibility and scoping studies, particularly into new and emerging industries. These studies can highlight major constraints on an industry and where future research could deliver benefits to the community. Industry stakeholders have reported that these studies have been well regarded and have provided a road map for progress, particularly in industries where coordination between various players is required for the industry to develop.

Both of the feasibility and scoping studies reviewed as part of this study have led to further ACIAR-funded research. In the case of the galip nut projects, the subsequent research appears likely to deliver significant benefits to PNG. From ACIAR's point of view, these scoping and feasibility studies reduce the risk of funding projects in areas that ultimately have limited commercial viability.

Projects aimed at local communities

The ACIAR forestry projects that have been most successful in having research outputs adopted are those where the final users are local communities. This includes a project that aimed at improving community management of cut-over forests and a range of projects that have encouraged local farmers to incorporate trees into their agricultural systems.

Achieving adoption of R&D outputs is a significant challenge in PNG. Indeed, there have been instances of projects aimed at local communities failing to achieve any adoption due to a lack of extension services (FST/1994/033). However, many of these projects have to some extent overcome these challenges through a number of strategies. For example, more recent projects have sought to overcome the lack of government extension services through partnering with NGOs or other private-sector providers of extension services. While partnering with NGOs can in itself pose a risk to a project's success, partnering with multiple providers of extension services can help to minimise the risk. Projects have also focused on new products or methods that require little change from current practices. In addition, ACIAR has funded projects aimed specifically at providing communities with access to germplasm.

While many of these projects will undoubtedly deliver benefits to communities, adoption has, so far, been on a relatively small scale. Achieving large-scale adoption is likely to require an ongoing funding commitment. It therefore remains an open question as to whether adoption will ultimately be high enough for the project to deliver benefits to communities in excess of the cost of the research. It may be worthwhile revisiting this

issue through a full impact assessment once more of these projects have been completed.

Projects aimed at policymakers

ACIAR has also funded projects aimed at the sustainable management of forest resources, where the final users were PNG forest policymakers. As has been the case with policy-related projects in other areas, it is not clear that the capacity and systems developed through these projects ultimately led to improved forest management. In recent years, ACIAR has given higher priority to projects that have directly benefited local communities than to policy-related research.

Forestry in PNG has a long history of weak governance. While ACIAR projects can help to build capacity within PNG forest agencies, ACIAR's delivery model is not well suited to addressing underlying governance issues. ACIAR projects are likely to improve forest management only if lack of capacity is the key barrier to better forestry practice.

Projects aimed at downstream processors

Although it has grown over recent years, downstream timber-processing capacity within PNG remains limited. Nevertheless, both ACIAR and the PNG Forest Authority see establishing greater timber-processing capacity as a key priority for the PNG forestry industry, even although it is not clear that PNG has a comparative advantage in this area. Recent policy changes have provided an opportunity for further growth in this sector, although any new timber-processing capacity would presumably be established by foreign logging companies bringing relevant technology with them.

Where research focuses on developing new products, there is an inherent risk that a market will not be found for them. Overcoming this risk is likely to require significant marketing effort. The galip projects show that a long-term funding commitment may be necessary.

Funding research in the commercial timber-processing sector in PNG is relatively new to ACIAR. It will therefore be important to rigorously assess the impacts of the current project once it has been completed. Given that the current timber-processing project has multiple subcomponents, useful lessons for future funding are likely to emerge.

The galip nut cluster of projects

One activity through which ACIAR could deliver significant net benefits to the community is the galip nut cluster of projects. We estimate that the galip nut R&D program—of which ACIAR has been a major funder—could deliver benefits to the East New Britain province of around A$163 million (in real 2010 dollars using a discount rate of 5%). These estimated benefits exceed the estimated cost of the whole research program (including future funding requirements) by around A$156 million, expressed in similar terms. The benefit:cost ratio is around 22.6.

However, given that the projects have yet to be completed, there is some risk that the project will not deliver the expected benefits. The main risk to the establishment of a successful commercial galip nut market is failure to find exports markets over the next few years, before nut production accelerates. This will require significant marketing effort.

The galip nut projects reinforce some of the key lessons outlined above:

- Establishing a new industry takes a long-term R&D commitment. A high-quality feasibility study is therefore crucial to set out the road map for future R&D activities and to minimise the risk of investing in an industry that turns out to be unviable.
- Adoption is more likely when the research focuses on new products or systems that require little change to current practices.

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IMPACT ASSESSMENT SERIES

No.	Author(s) and year of publication	Title	ACIAR project numbers
1	Centre for International Economics 1998.	Control of Newcastle disease in village chickens	AS1/1983/034, AS1/1987/017 and AS1/1993/222
2	George P.S. 1998.	Increased efficiency of straw utilisation by cattle and buffalo	AS1/1982/003, AS2/1986/001 and AS2/1988/017
3	Centre for International Economics 1998.	Establishment of a protected area in Vanuatu	ANRE/1990/020
4	Watson A.S. 1998.	Raw wool production and marketing in China	ADP/1988/011
5	Collins D.J. and Collins B.A. 1998.	Fruit fly in Malaysia and Thailand 1985–1993	CS2/1983/043 and CS2/1989/019
6	Ryan J.G. 1998.	Pigeonpea improvement	CS1/1982/001 and CS1/1985/067
7	Centre for International Economics 1998.	Reducing fish losses due to epizootic ulcerative syndrome—an ex ante evaluation	FIS/1991/030
8	McKenney D.W. 1998.	Australian tree species selection in China	FST/1984/057 and FST/1988/048
9	ACIL Consulting 1998.	Sulfur test KCL–40 and growth of the Australian canola industry	PN/1983/028 and PN/1988/004
10	AACM International 1998.	Conservation tillage and controlled traffic	LWR2/1992/009
11	Chudleigh P. 1998.	Postharvest R&D concerning tropical fruits	PHT/1983/056 and PHT/1988/044
12	Waterhouse D., Dillon B. and Vincent D. 1999.	Biological control of the banana skipper in Papua New Guinea	CS2/1988/002-C
13	Chudleigh P. 1999.	Breeding and quality analysis of rapeseed	CS1/1984/069 and CS1/1988/039
14	McLeod R., Isvilanonda S. and Wattanutchariya S. 1999.	Improved drying of high moisture grains	PHT/1983/008, PHT/1986/008 and PHT/1990/008
15	Chudleigh P. 1999.	Use and management of grain protectants in China and Australia	PHT/1990/035
16	McLeod R. 2001.	Control of footrot in small ruminants of Nepal	AS2/1991/017 and AS2/1996/021
17	Tisdell C. and Wilson C. 2001.	Breeding and feeding pigs in Australia and Vietnam	AS2/1994/023
18	Vincent D. and Quirke D. 2002.	Controlling *Phalaris minor* in the Indian rice–wheat belt	CS1/1996/013
19	Pearce D. 2002.	Measuring the poverty impact of ACIAR projects—a broad framework	
20	Warner R. and Bauer M. 2002.	*Mama Lus Frut* scheme: an assessment of poverty reduction	ASEM/1999/084
21	McLeod R. 2003.	Improved methods in diagnosis, epidemiology, and information management of foot-and-mouth disease in Southeast Asia	AS1/1983/067, AS1/1988/035, AS1/1992/004 and AS1/1994/038
22	Bauer M., Pearce D. and Vincent D. 2003.	Saving a staple crop: impact of biological control of the banana skipper on poverty reduction in Papua New Guinea	CS2/1988/002-C
23	McLeod R. 2003.	Improved methods for the diagnosis and control of bluetongue in small ruminants in Asia and the epidemiology and control of bovine ephemeral fever in China	AS1/1984/055, AS2/1990/011 and AS2/1993/001
24	Palis F.G., Sumalde Z.M. and Hossain M. 2004.	Assessment of the rodent control projects in Vietnam funded by ACIAR and AUSAID: adoption and impact	AS1/1998/036

IMPACT ASSESSMENT SERIES <CONTINUED>

No.	Author(s) and year of publication	Title	ACIAR project numbers
25	Brennan J.P. and Quade K.J. 2004.	Genetics of and breeding for rust resistance in wheat in India and Pakistan	CS1/1983/037 and CS1/1988/014
26	Mullen J.D. 2004.	Impact assessment of ACIAR-funded projects on grain-market reform in China	ANRE1/1992/028 and ADP/1997/021
27	van Bueren M. 2004.	Acacia hybrids in Vietnam	FST/1986/030
28	Harris D. 2004.	Water and nitrogen management in wheat–maize production on the North China Plain	LWR1/1996/164
29	Lindner R. 2004.	Impact assessment of research on the biology and management of coconut crabs on Vanuatu	FIS/1983/081
30	van Bueren M. 2004.	Eucalypt tree improvement in China	FST/1990/044, FST/1994/025, FST/1984/057, FST/1987/036, FST/1988/048, FST/1996/125 and FST/1997/077
31	Pearce D. 2005.	Review of ACIAR's research on agricultural policy	
32	Tingsong Jiang and Pearce D. 2005.	Shelf-life extension of leafy vegetables—evaluating the impacts	PHT/1994/016
33	Vere D. 2005.	Research into conservation tillage for dryland cropping in Australia and China	LWR2/1992/009 and LWR2/1996/143
34	Pearce D. 2005.	Identifying the sex pheromone of the sugarcane borer moth	CS2/1991/680
35	Raitzer D.A. and Lindner R. 2005.	Review of the returns to ACIAR's bilateral R&D investments	
36	Lindner R. 2005.	Impacts of mud crab hatchery technology in Vietnam	FIS/1992/017 and FIS/1999/076
37	McLeod R. 2005.	Management of fruit flies in the Pacific	CS2/1989/020, CS2/1994/003, CS2/1994/115 and CS2/1996/225
38	ACIAR 2006.	Future directions for ACIAR's animal health research	
39	Pearce D., Monck M., Chadwick K. and Corbishley J. 2006.	Benefits to Australia from ACIAR-funded research	AS2/1990/028, AS2/1994/017, AS2/1994/018, AS2/1999/060, CS1/1990/012, CS1/1994/968, FST/1993/016 and PHT/1990/051
40	Corbishley J. and Pearce D. 2006.	Zero tillage for weed control in India: the contribution to poverty alleviation	CS1/1996/013
41	ACIAR 2006.	ACIAR and public funding of R&D. Submission to Productivity Commission study on public support for science and innovation	
42	Pearce D. and Monck M. 2006.	Benefits to Australia of selected CABI products	
43	Harris D.N. 2006.	Water management in public irrigation schemes in Vietnam	LWR2/1994/004 and LWR1/1998/034
44	Gordon J. and Chadwick K. 2007.	Impact assessment of capacity building and training: assessment framework and two case studies	CS1/1982/001, CS1/1985/067, LWR2/1994/004 and LWR2/1998/034
45	Turnbull J.W. 2007.	Development of sustainable forestry plantations in China: a review	
46	Monck M. and Pearce D. 2007.	Mite pests of honey bees in the Asia–Pacific region	AS2/1990/028, AS2/1994/017, AS2/1994/018 and AS2/1999/060

No.	Author(s) and year of publication	Title	ACIAR project numbers
47	Fisher H. and Gordon J. 2007.	Improved Australian tree species for Vietnam	FST/1993/118 and FST/1998/096
48	Longmore C., Gordon J. and Bantilan M.C. 2007.	Assessment of capacity building: overcoming production constraints to sorghum in rainfed environments in India and Australia	CS1/1994/968
49	Fisher H. and Gordon J. 2007.	Minimising impacts of fungal disease of eucalypts in South-East Asia	FST/1994/041
50	Monck M. and Pearce D. 2007.	Improved trade in mangoes from the Philippines, Thailand and Australia	CS1/1990/012 and PHT/1990/051
51	Corbishley J. and Pearce D. 2007.	Growing trees on salt-affected land	FST/1993/016
52	Fisher H. and Gordon J. 2008.	Breeding and feeding pigs in Vietnam: assessment of capacity building and an update on impacts	AS2/1994/023
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54	Monck M. and Pearce D. 2008.	Impact of improved management of white grubs in peanut-cropping systems	CS2/1994/050
55	Martin G. 2008.	ACIAR fisheries projects in Indonesia: review and impact assessment	FIS/1997/022, FIS/1997/125, FIS/2000/061, FIS/2001/079, FIS/2002/074, FIS/2002/076, FIS/2005/169 and FIS/2006/144
56	Lindner B. and McLeod P. 2008.	A review and impact assessment of ACIAR's fruit-fly research partnerships—1984 to 2007	CS2/1983/043, CS2/1989/019, CS2/1989/020, CS2/1994/003, CS2/1994/115, CS2/1996/225, CS2/1997/101, CS2/1998/005, CS2/2003/036, CP/1997/079, CP/2001/027, CP/2002/086, CP/2007/002, CP/2007/187, PHT/1990/051, PHT/1994/133, and PHT/1993/87
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59	Chupungco A., Dumayas E. and Mullen J. 2008.	Two-stage grain drying in the Philippines	PHT/1983/008, PHT/1986/008 and PHT/1990/008
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