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Oil palm pathways: an analysis of ACIAR's oil palm projects in Papua New Guinea

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Oil palm pathways: an analysis of ACIAR's oil palm projects in Papua New Guinea

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Cover: Oil palm harvesting in West New Britain, PNG. Oil palm is the most important crop in PNG in terms of export income. (Photo: Paul Jones)

Foreword

The oil palm industry in Papua New Guinea (PNG) is considered one of the nation's success stories. In 2010, palm oil made up 56% of the total value of PNG's agricultural exports. The oil palm industry includes both a plantation sector and a smallholder sector, with production per hectare in the smallholder sector being lower—while it accounts for around 40% of the area planted to oil palm it produces only around 32% of the fruit.

The Australian Centre for International Agricultural Research (ACIAR) has acknowledged the importance of the oil palm industry to PNG's economy in general and to poor smallholders in particular. It has therefore funded a range of projects designed to overcome some of the challenges to the smallholder sector.

The authors of this report first draw a comprehensive picture of ACIAR's activities in the PNG oil palm industry. They describe the projects that ACIAR has funded and the outputs that they have delivered, and list the notable outcomes associated with these projects.

They then move to fulfil the major intent of this study, which was to examine the pathways through which ACIAR's portfolio of oil palm projects have delivered benefits to the community. They do so through an analysis based on ACIAR's standard impact assessment framework. After broadly categorising ACIAR oil palm projects into three clusters—socioeconomic projects, biocontrol projects, and soil management and crop nutrition projects—they then focus their study on the impact pathways for the socioeconomic and biocontrol project clusters.

The authors observe that the reluctance to take up new technologies had tended to reduce the effectiveness of agricultural research and development in PNG. They note that the approach taken in the socioeconomic cluster of ACIAR projects was first to understand the key socioeconomic constraints on smallholder production. Such understanding enabled researchers to develop new schemes with a greater likelihood of being integrated into smallholder production systems. It also allowed extension service providers to develop strategies designed to maximise adoption.

Better understanding of the socioeconomic environment has led to development of new systems that directly tackle identified constraints. It is encouraging that the Mama Lus Frut and mobile-card payment schemes that have brought more people into oil palm production and increased output are being extended into new areas after successful trials. They are set to deliver benefits to many more of the smallholders most in need. They are also providing women with a degree of economic independence that benefits whole communities. The authors calculate that benefits of around A$34.5 million (in net present value terms, using a discount rate of 5%) can be attributed to ACIAR funding of the socioeconomic project cluster, equating to a benefit:cost ratio of over 20 and an internal rate of return of 76%.

A key characteristic of biocontrol projects is that adoption of their outputs does not need direct action by smallholders. The study has found instances where biocontrol research work will deliver excellent benefits to smallholders, especially over the long term.

Nick Austin
Chief Executive Officer, ACIAR

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Abbreviations

ACIAR	Australian Centre for International Agricultural Research
BREAD	Basic Research to Enable Agricultural Development
CABI	CAB International
CCEA	Cocoa and Coconut Extension Agency
CCRI	Cocoa and Coconut Research Institute
CLUA	Clan Land Use Agreement
CRPB	Customary Rights Purchase Blocks
FD	Finschhafen disorder
LSS	Land Settlement Schemes
MRPL	marginal revenue product of labour
NAQIA	National Agricultural Quarantine Inspection Authority (PNG)
NARI	National Agricultural Research Institute
OPIC	Oil Palm Industry Corporation
PNG	Papua New Guinea
PNGOPRA	PNG Oil Palm Research Association
R&D	research and development
RSPO	Roundtable on Sustainable Palm Oil
SADP	Smallholder Agricultural Development Project

Executive summary

The oil palm industry is an important part of the economy of Papua New Guinea (PNG). In 2010, palm oil accounted for 56% of the value of agricultural exports (Palm Oil Council 2011, p. 3). Although growing oil palm can provide good returns to smallholders, production in the smallholder sector has been constrained by a range of issues. The Australian Centre for International Agricultural Research (ACIAR) has funded a number of projects aimed at increasing smallholder oil palm production in PNG.

This study examines the pathways through which two of the three ACIAR-funded project clusters benefit oil palm smallholders:

- socioeconomic studies—ACIAR has funded three projects that have aimed to provide a better understanding of the socioeconomic constraints on smallholder production and provide solutions to overcome them
- biological control projects—ACIAR has funded four projects aimed at using biological agents to control various weed and insect pests affecting oil palm.

The pathways analysis is based on ACIAR's impact assessment framework (Davis et al. 2008). The study also quantifies some of the benefits delivered by the socioeconomic projects.

Outputs delivered by ACIAR

ACIAR-funded socioeconomic research has delivered a range of outputs, including the following:

- better understanding of the socioeconomic constraints on smallholder production
- new payment systems to encourage greater participation in oil palm production
- a new template for Clan Land Use Agreements (CLUAs) for Customary Rights Purchase Blocks that comply with Roundtable on Sustainable Palm Oil (RSPO) criteria
- improved extension strategies
- enhanced capacity of various PNG partner agencies in undertaking socioeconomic research.

The biological control (biocontrol) cluster has delivered a range of outputs, including:

- improved knowledge of various pests and diseases and their impacts
- information to inform the decisions of the PNG National Agricultural Quarantine Inspection Authority (NAQIA) on whether to allow the import and release of various biocontrol agents
- increased scientific knowledge on the impact of biocontrol agents on various pests under PNG conditions
- new scientific methods and techniques for rearing, releasing and monitoring various biocontrol agents, as well as techniques for monitoring insect pests
- enhanced capacity of partner agencies to conduct biocontrol research.

Pathways to adoption

The next users of the outputs delivered by the socioeconomic studies are the oil palm milling

companies and Oil Palm Industry Corporation (OPIC) extension officers.

- The 'mobile-card' payment system developed through the ACIAR-funded projects was adopted by the milling company in the Bialla project area, but not in Hoskins and Popondetta. Nevertheless, modified versions of the scheme are operating in those areas.
- The new CLUAs will be used, where relevant, in new plantings under the World Bank's Sustainable Agriculture Development Program.

The final users of these outputs are traditional landowners, block-holders and workers.

- Mobile-card schemes have achieved a moderate level of adoption. Around 20% of blocks are participating in the mobile-card scheme in Bialla, while around 52% of blocks are using modified versions of the scheme — the 'C-card' scheme in Hoskins.
- The ACIAR-funded projects also extended the Mama Lus Frut Scheme, which had already been operating in Hoskins, to Bialla and Popondetta. Around 95% of blocks in Popondetta and more than 60% of blocks in Bialla participate in the scheme.

A key advantage of controlling insect pests and weeds through biological agents is that smallholders generally do not need to change their practices. Encouraging smallholders to change their ways is a key challenge for agricultural research. For the biocontrol projects, NAQIA uses the information in the application to decide whether biocontrol agents can be imported and released in PNG. The agents must then be released, which is a task largely undertaken by project staff, except in more remote areas, where releases may be made by others.

Barriers to adoption

The main barriers to adoption of the outputs of the socioeconomic studies are the time and effort required to set up, administer and promote new payment schemes. There have also been various issues bearing on the effectiveness of the payment schemes, which could potentially threaten the longer term viability of these schemes.

Since the outputs of the biocontrol projects do not require the involvement of smallholders for adoption, there are relatively few barriers to their uptake. However, there is some risk that quarantine authorities will not permit the import and release of some biocontrol agents.

Outcomes

Key outcomes from the socioeconomic studies are:

- increased participation in oil palm production from women and mobile-card workers
- new oil palm development—without CLUAs that comply with RSPO criteria, it is unlikely that some of the planned new oil palm developments under the World Bank Sustainable Agriculture Program would have gone ahead
- more effective interactions with smallholders—increased recognition of the importance of socioeconomic factors in the production strategies employed by smallholders is likely to increase the effectiveness of the interactions between research and extension agencies and smallholders.

Key outcomes from ACIAR-funded biocontrol research include:

- permission to import and release a number of biocontrol agents in PNG
- a change in the production environment due to the release and establishment of those agents.

Impacts

Increased participation in oil palm production has increased the quantity of oil palm fruit (including loose fruit collected by women) harvested. We estimate that, in net present value terms, the benefits to PNG from various card payment schemes could be around $57.3 million (in 2011 Australian dollars), using a

discount rate of 5%. The cost of the research, including all cash and in-kind contributions, was around $2.7 million expressed in similar terms. The net present value of ACIAR-funded socioeconomic research could therefore be around $54.6 million. The benefit:cost ratio is estimated at around 20:1 and the internal rate of return at about 76%. In real terms, ACIAR contributed around 60% of the total research costs. On a cost-share basis, benefits of around $34.5 million (in net present value terms, using a discount rate of 5%) can be attributed to ACIAR.

Although the benefits were not quantified, it is also likely that the biocontrol projects delivered benefits to smallholders in the oil palm and various other industries through the need to expend less effort on weeding.

Conclusions

ACIAR-funded socioeconomic research has highlighted the importance of socioeconomic constraints on smallholder production. A more complete understanding has allowed researchers to develop new systems that directly address these constraints rather than working within them. This approach has had two advantages over more conventional solutions offered by the research and development (R&D) community:

- These new systems have been adopted on the least productive blocks, which are the ones that most need them. This is in contrast to most solutions developed through R&D, where the most progressive smallholders tend to be the adopters
- They have also delivered a range of social benefits that are not necessarily associated with technical solutions to increase smallholder production. These include an increase in the status of women and a reduction in the frequency of disputes between family members.

Understanding the socioeconomic factors affecting smallholder production will also help the R&D and extension communities to develop solutions and extension strategies that are more likely to be adopted.

The solutions developed through these ACIAR projects, however, rely on the nucleus-estate – smallholder model and the extension services provided by OPIC. Since those factors are absent in most other industries, it is not yet clear if this type of strategy has broader applicability in PNG.

A key characteristic of biocontrol projects is that smallholders do not need to be directly involved in the adoption of outputs. Since encouraging smallholders to adopt research outputs is often a key factor limiting the benefits of agricultural research, biocontrol research appears to be highly effective in delivering benefits to smallholders, especially over the longer term.

While biocontrol projects do not face the risk of non-adoption by smallholders, there are nevertheless risks related to adoption. The biosecurity agency could potentially refuse to issue a permit to import and release a new biocontrol agent, as has happened, for example, in Fiji. The logistics of releasing agents in all affected areas can also be problematic.

1 Background and 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).

Oil palm is an important export industry in PNG. In 2010, palm oil made up 56% of the total value of PNG's agricultural exports (Palm Oil Council 2011, p. 3). Given the importance of oil palm to PNG's economy and to smallholders in particular, ACIAR has funded a number of projects aimed at boosting productivity in the smallholder sector of the oil palm industry.

The oil palm industry in Papua New Guinea

The commercial oil palm industry in PNG was established in 1967. This followed a recommendation by the World Bank that an oil palm industry be established to diversify the agricultural economy and boost export income.

PNG's oil palm industry includes a plantation sector and a smallholder sector. The smallholder sector covers around 40% of the area planted to oil palm, but produces only around 32% of the fruit (Palm Oil Council 2011, p. 3). The main oil palm project areas are Hoskins and Bialla in West New Britain, and Popondetta in Northern province. There are also some smaller scale plantings at Milne Bay, New Ireland and, more recently, Ramu in Madang province.

There are three main land-tenure arrangements in the smallholder sector:

- Land Settlement Schemes (LSS)—these large blocks of government land were allocated to settlers to plant oil palm
- Village Oil Palm—this is where the traditional owners plant oil palm on their own land
- Customary Rights Purchase Blocks (CRPB)—this is where 'outsiders' lease customary land from traditional owners.

The area planted to oil palm has increased rapidly over recent decades. Smallholder oil palm plantings increased at an average annual rate of 5.5% over the 15 years to 2009 (Figure 1).

Smallholder oil palm plantings will also increase further in the medium term. A key component of the World Bank's Papua New Guinea Smallholder Agriculture Development Project (SADP) (see Box 1 for further details) is to increase smallholder plantings in the three main oil palm project areas (Hoskins, Bialla and Popondetta). Table 1 gives the current planting schedule.

Oil palm fruit production has increased even more rapidly than plantings over this period. Total smallholder oil palm fruit production has increased at an average annual rate of 7.5% over the same period (Figure 2).

This implies that production per hectare has improved at an average annual rate of around 2%.

Industry structure

The smallholder sector of the oil palm industry is described as a nucleus-estate – smallholder model. This involves smallholder oil palm blocks located around a central nucleus estate. The estate company owns and operates the processing mill, as well as its own plantation estates. The estate company may also be responsible for transporting smallholder fruit to its processing mills and providing seedlings, technical services and advice to smallholders (Koczberski et al. 2001, p. 11).

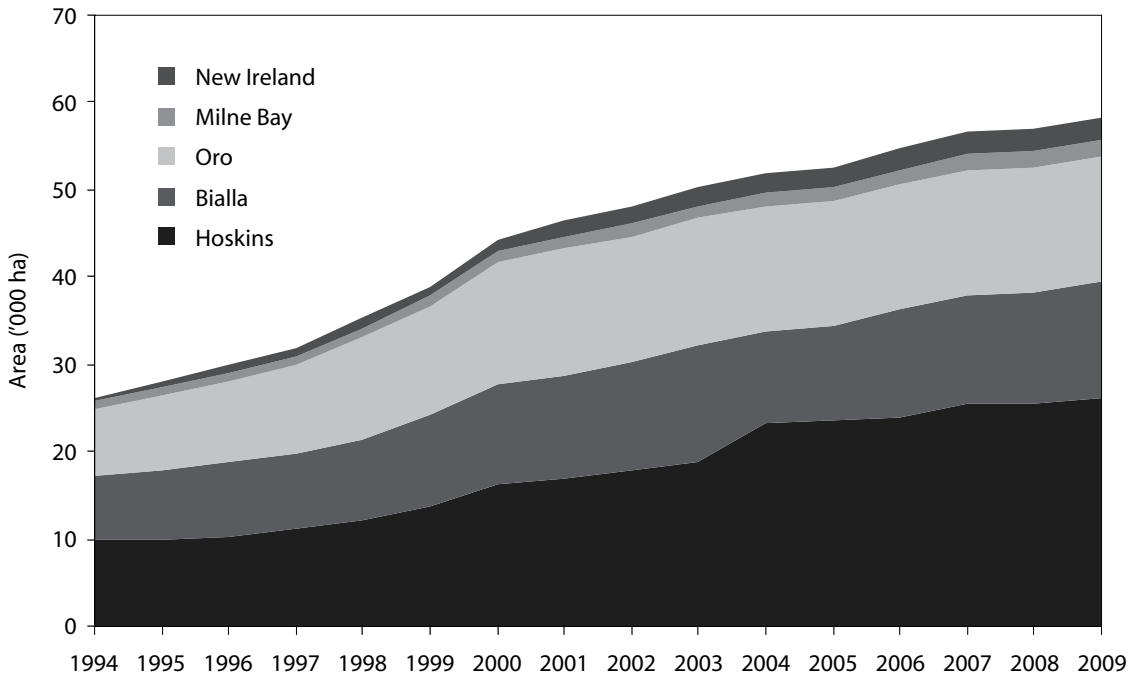

Figure 1. Smallholder oil palm plantings in Papua New Guinea. Data source: Oil Palm Industry Corporation website at <http://www.opicpng.org/opic/statistics.php>, accessed 11 October 2011.

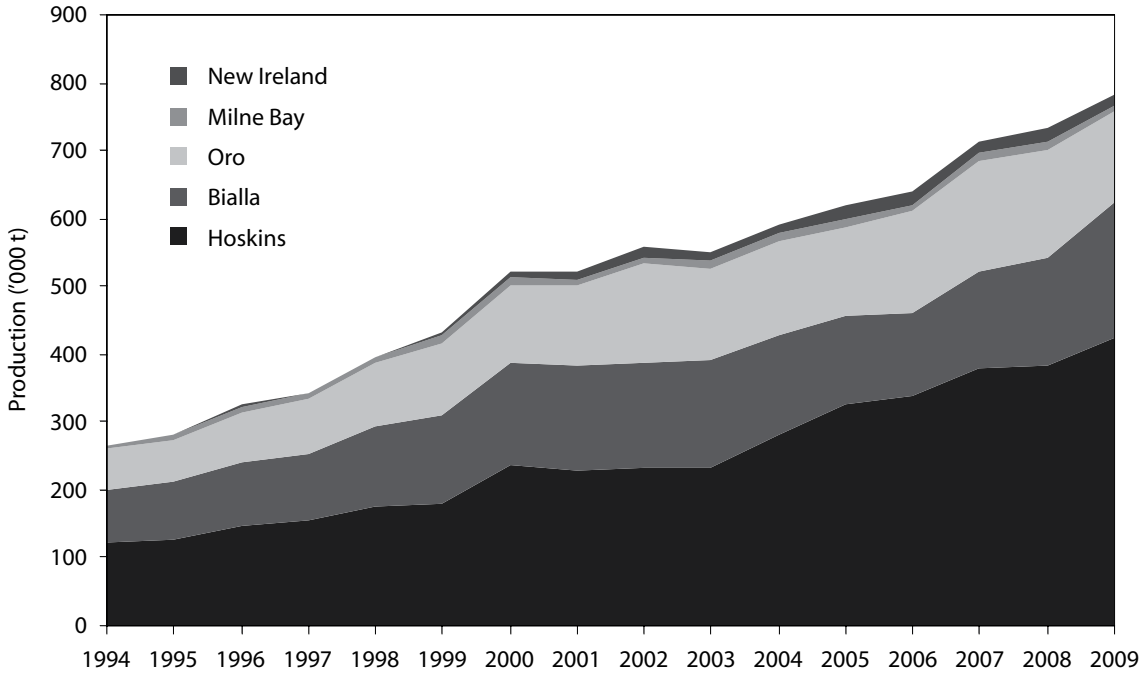

Figure 2. Smallholder oil palm fruit production in Papua New Guinea. Data source: Oil Palm Industry Corporation website at <http://www.opicpng.org/opic/statistics.php>, accessed 11 October 2011.

Table 1. Papua New Guinea Smallholder Agriculture Development Project planting schedule

	Hoskins	Bialla	Popondetta	Total
	ha	ha	ha	ha
2011	400	300	500	1,200
2012	600	600	800	2,000
2013	600	340	1,000	1,940
2014	600	–	1,000	1,600
Total	2,200	1,240	3,300	6,740

Source: Infill Planting Submanual at <http://www.opicpng.org/sadp/project-documents/7-pim-infill-sub-manual-2010.pdf>, accessed 27 April 2012.

Box 1. The Papua New Guinea Smallholder Agriculture Development Project

The World Bank's Papua New Guinea Smallholder Agriculture Development Project aims to increase, in a sustainable manner, the level of involvement of targeted communities in their local development through measures aimed at increasing oil palm revenue and local participation. The project has three components:

1. smallholder productivity enhancement—this component supports
   - planting of new village oil palm along existing access roads—referred to as infill planting—in the two project provinces (Northern province and West New Britain)
   - upgrading and maintenance of provincial access roads and the establishment of a sustainable financing mechanism for road maintenance
   - strengthening of extension services to enhance smallholder productivity
2. local governance and community participation—this component supports the improved provision of local services and infrastructure in the two project provinces through participatory processes
3. project management and institutional support—the component is strengthening
   - the capacity of OPIC to manage the project, with the assistance of a management agency for component 2 implementation
   - the smallholder sector, through supporting training, research and studies.

Source: World Bank website at <http://siteresources.worldbank.org/INTPAPUANEWGUINEA/Resources/PNGSADPProjectBrief090610.pdf>, accessed 27 April 2012.

Other key stakeholders in the oil palm industry are:

- the Oil Palm Industry Corporation (OPIC)—the main function of OPIC is to provide agriculture extension services to PNG oil palm smallholders that will raise growers' productivity. OPIC also assists to develop smallholder groups to represent the growers' interests, and collects and disseminates information about the smallholder oil palm subsector. As a PNG Commodity Board, OPIC liaises with the Government of Papua New Guinea on oil palm industry matters[1]

[1] OPIC website at <http://www.opicpng.org/opic/about-opic>, accessed 13 January 2012.

- the Papua New Guinea Oil Palm Research Association (PNGOPRA) is the research arm of the oil palm industry in PNG. It is an association of the two main milling companies and the smallholders on approximately 18,000 blocks who grow oil palm in the country. PNGOPRA's mission is to fulfil the research needs and solve the technical problems of the Association's members.[2]

Supply chain

Oil palm fruit bunches are generally harvested fortnightly. The harvested fruit bunches are then transported to the road in wheelbarrows. Loose fruit that becomes dislodged due to overripeness or during harvesting may also be collected by women. Loose fruit can account for up to 14% of the harvest. The fruit bunches and loose fruits are then stacked on the roadside edge for collection by the milling company for processing. The milling company weighs the fruit it collects and generally pays the smallholder either fortnightly or monthly through a card payment system. The price paid for the fruit is determined by the world price of palm oil and is based on an agreed formula developed by the government, the milling companies and the growers' associations.

Oil palm fruit must be processed within around 48 hours after harvest. There are essentially two primary products produced by the PNG estate mills: crude palm oil and palm kernels. Some mills in PNG also have the capacity for further processing to produce a range of secondary palm oil products such as palm kernel oil and other refined products. These products are largely exported and have a range of commercial and domestic uses, such as a cooking oil, food manufacturing, and soaps and cosmetics. The supply chain for palm oil is outlined in Figure 3.

Challenges

While the oil palm industry is generally considered one of PNG's success stories, several challenges have emerged in the smallholder sector. In particular, despite the improvements outlined above, production per hectare in the smallholder sector lags significantly behind the plantation sector (Figure 4).

Increasing population in some of the older LSS subdivisions is another social and economic issue emerging in the smallholder sector. Many blocks are now supporting several families and, in many cases, this is leading to conflict and social instability.

As with many agricultural industries in PNG, security of land tenure is also a major issue for smallholders, especially LSS smallholders and immigrants who have acquired land from customary landholders.

Outline of this report

Given the importance of the oil palm industry to PNG's economy in general and to poor smallholders in particular, ACIAR has funded a range of projects aimed at overcoming some of the challenges in the smallholder sector.

This study examines the pathways through which ACIAR's portfolio of oil palm projects has delivered benefits to the community. The pathway analysis is based on ACIAR's standard impact assessment framework (Davis et al. 2008).

The remainder of the report is set out as follows.

- Chapter 2 provides an overview of ACIAR's activities in the PNG oil palm industry.
- Chapter 3 outlines the outputs delivered by the selected ACIAR projects.
- Chapter 4 identifies the pathways to adoption.
- Chapter 5 outlines the outcomes associated with the ACIAR projects.
- Chapter 6 discusses the impacts of the ACIAR projects and outlines a framework for quantifying some of the tangible benefits of the socioeconomic projects.
- Chapter 7 sets out the benefits and costs of the socioeconomic projects in a cost–benefit analysis framework.
- Chapter 8 draws some conclusions from the analysis in the preceding chapters.

[2] PNGOPRA website at <http://www.pngopra.org.pg/index.html>, accessed 13 January 2011.

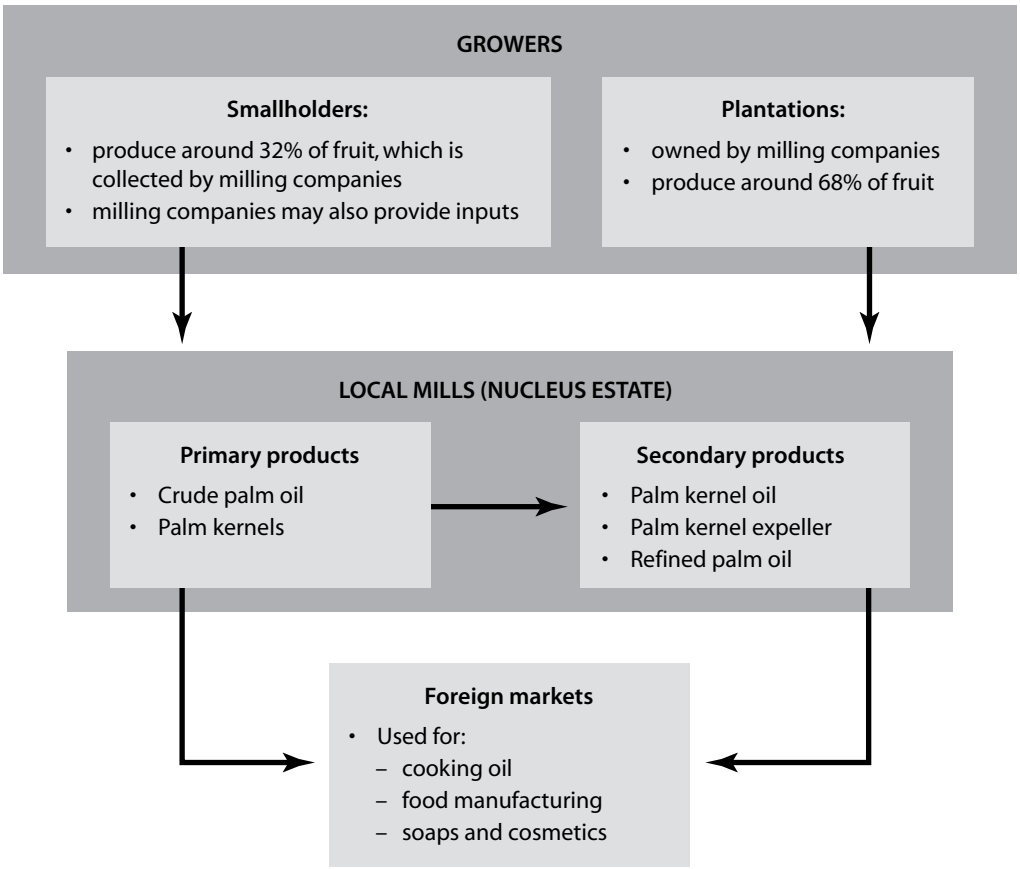

Figure 3. Palm oil supply chain in Papua New Guinea. Data sources: Palm Oil Council 2011; New Britain Palm Oil Limited Annual Report 2010.

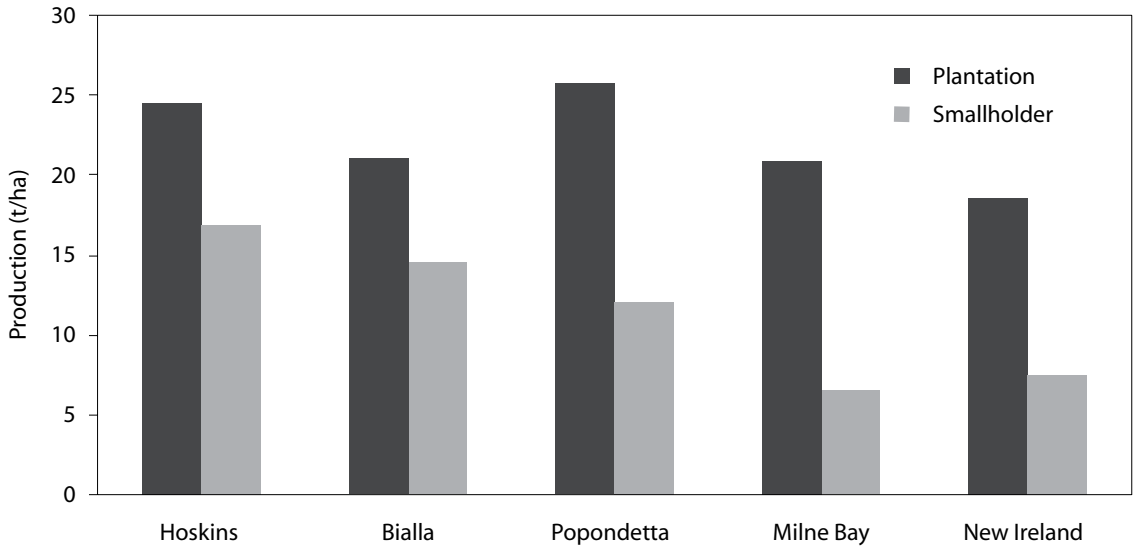

Figure 4. Oil palm production per hectare in the plantation and smallholder sectors in Papua New Guinea, 2010. Data source: Palm Oil Council (2011, p. 3).

2 Overview of ACIAR's oil palm activities in Papua New Guinea

ACIAR's oil palm activities in PNG broadly fall within three clusters (Table 2).

This study focuses on the first two clusters. The pathways to benefits are examined through:

- a full impact assessment of the socioeconomic cluster of projects, using ACIAR's standard impact assessment framework
- a qualitative assessment of the biocontrol cluster. This is also based on ACIAR's impact assessment framework.

The socioeconomic project cluster

Many research and development (R&D) projects aimed at the smallholder sector typically require the smallholders to adopt a new technology to deliver benefits. However, for a range of reasons, encouraging smallholders to change their practices has proved challenging in PNG.

Objectives

A key objective of the first ACIAR-funded socioeconomic study was to understand the socioeconomic factors that were constraining smallholder productivity and to develop strategies to overcome them. This followed a successful OPIC initiative to encourage more women to participate in the oil palm industry (Box 2).

The Mama Lus Frut scheme highlighted that socioeconomic factors were constraining productivity growth.

Following that initial OPIC project, ACIAR provided further funding through an extension and two subsequent projects that expanded the scope of the research in a number of ways, including:

- extending successful strategies to other oil palm project areas
- extending and adapting successful strategies to the cocoa industry.

The specific objectives of these projects are listed in Table 3.

Research agencies

The Australian National University was commissioned to undertake the initial socioeconomic study, in collaboration with Curtin University and PNGOPRA.

Curtin University was the commissioned organisation for the subsequent projects. PNGOPRA, the Cocoa and Coconut Research Institute (CCRI) and the Cocoa and Coconut Extension Agency (CCEA) were the PNG collaborating institutions. The University of Western Sydney also collaborated in the third project.

Funding

ACIAR has contributed around $1.7 million to the total research cost of about $2.8 million (including all cash and in-kind contributions) (Table 4). Australian partners the Australian National University, the University of Western Sydney and particularly Curtin University have also made substantial contributions to the projects, mainly through in-kind contributions. There have also been contributions from PNG partners PNGOPRA, CCRI and CCEA.

Table 2. Summary of ACIAR's oil palm–related projects in Papua New Guinea

Cluster	Projects
Socioeconomic cluster	• Improving productivity of the smallholder oil palm sector in PNG: a study of biophysical and socioeconomic interactions (ASEM/1999/084) • Improving productivity and the participation of youth and women in the PNG cocoa, coconut and oil palm industries (ASEM/2002/014) • Commercial sector/smallholder partnerships for improving incomes in the oil palm and cocoa industries in PNG (ASEM/2006/127)
Biocontrol cluster	• Biological control of *Chromolaena odorata* in PNG (CP/1996/091) • Integrated pest management for Finschhafen disorder of oil palm in PNG (PC/2006/063) • Biological control of *Mikania micrantha* in PNG and Fiji (PC/2004/064) • An investigation into mycoinsecticides as potential control agents of sexava in oil palms in New Britain (CP/2007/098)
Soil management and crop nutrition cluster	• Overcoming magnesium deficiency in oil palm crops on volcanic ash soils of PNG (SMCN/2000/046) • Towards a sustainable oil palm industry in PNG (SMCN/2008/028) • Sustainable management of soil and water resources for oil palm production systems in PNG (SMCN/2009/013)

Source: Australian Centre for International Agricultural Research.

Box 2. The Mama Lus Frut scheme

The high rate of loose fruit wastage had been a long-term concern of the oil palm industry. To reduce this wastage, OPIC introduced, at Hoskins in 1997, a direct payment system to encourage women to increase their collection of loose fruit.

Women were issued with their own harvesting net and a separate harvesting payment card. This enabled them to receive a direct payment for the loose fruit collected. Previously, payment for the loose fruit collected was paid to the men.

The Mama Lus Frut scheme has been highly successful in encouraging women to collect a greater proportion of loose fruit. In 2000, approximately 60,700 tonnes of loose fruit with a value of around 4.5 million kina were collected at Hoskins. Furthermore, payments to women through the scheme made up around 26% of total payments to smallholders.

The scheme also improved the quality of life of women receiving income.

Source: Koczberski et al. (2001, pp. 170–200).

Table 3. Socioeconomic cluster projects and their objectives

Project No.	Name	Objectives
ASEM/1999/084	Improving productivity of the smallholder oil palm sector in Papua New Guinea: a study of biophysical and socioeconomic interactions	• Gain better understanding of the biophysical and socioeconomic interactions in the smallholder sector of the PNG oil palm industry. • Evaluate the Mama Lus Frut scheme and its effect on oil palm production. • Develop additional strategies for increasing productivity in collaboration with key industry stakeholders. • Explore land tenure issues and potential risks associated with the introduction of mini-estates. **Extension project** • Monitor the socioeconomic impacts of the mobile card and extend the pilot. • Strengthen the gender identity of the Mama Lus Frut scheme. • Communicate the success of the Mama Lus Frut scheme to other areas, and explore the feasibility of extending a similar scheme to other tree crop industries in PNG. • Oversee the introduction of the Mama Lus Frut scheme in Popondetta. • Explore land-tenure issues associated with the introduction of mini-estates and potential risks of this intervention.
ASEM/2002/014	Improving productivity and the participation of youth and women in the PNG cocoa, coconut and oil palm industries	• Improve the capacity of research and extension services in the cocoa and coconut industries for meeting the needs of smallholders. • Promote the sharing of knowledge and expertise between the key smallholder agencies and research organisations in the three industries. • Evaluate OPIC's mobile-card trial at Hoskins for potential introduction to other smallholder oil palm areas. • Introduce and test in the smallholder cocoa sector, payment systems that have proven successful in the oil palm industry. • Expand payment systems to other groups experiencing labour constraints.
ASEM/2006/127	Commercial sector/smallholder partnerships for improving incomes in the oil palm and cocoa industries in Papua New Guinea	• Improve extension delivery through greater commercial sector engagement with smallholders. – The commercial sector provided smallholders with inputs such as seedlings, disease control advice and training in nutrient management. • Develop effective land-use agreements between the commercial sector and customary landowners.

Source: Australian Centre for International Agricultural Research project documents.

The biocontrol project cluster

The four biocontrol projects focused on improving knowledge about, and developing control methods for, two weeds affecting oil palm and other crops in PNG, and two insect pests. The two weeds were:

- *Chromolaena odorata* (chromolaena or Siam weed)—this is a fast-growing woody shrub that grows to about 3 m high and can invade farming lands, reducing farm productivity, smothering crops such as taro, cassava and papaw, and infest plantations where it can interfere with the harvesting of coconuts or establishment of oil palm and cocoa. In grazing areas, it can out-compete preferred pasture species reducing productivity (CP/1996/091, Project proposal)
- *Mikania micrantha*—this is a fast-growing vine found throughout much of Asia and the Pacific. It invades small subsistence farms, as well as plantations (Day et al. 2011).

Table 4. Research costs (including cash and in-kind contributions) of socioeconomic cluster projects

	ACIAR	ANU	CU	UWS	PNGOPRA	CCRI	CCEA	Total
	$		$	$	$	$		$
ASEM/1999/084								
2000–01	149,935	50,370	35,750	–	87,327	–	–	323,381
Extension								
2001–02	75,446	25,346	17,989	–	43,942	–	–	162,724
2002–03	74,403	24,996	17,741	–	43,335	–	–	160,474
Total	299,784	100,711	71,480	–	174,604	–	–	646,579
ASEM/2002/014								
2003–04	198,352	–	30,650	–	10,678	20,198	8,640	268,518
2004–05	129,500	–	30,650	–	5,945	16,570	6,060	188,725
2005–06	91,832	–	70,942	–	4,000	16,286	3,424	186,484
Extension 1								
2004–05	63,263	–	14,000	–	2,000	5,000	–	84,263
2006–07	16,231	–	7,000	–	1,000	2,500	–	26,731
Extension 2								
2005–06	77,510	–	10,000	–	10,000	5,000	–	102,510
2006–07	74,050	–	15,000	–	10,000	5,000	–	104,050
Total	650,738	–	178,242	–	43,623	70,554	18,124	961,281
ASEM/2006/127								
2007–08	66,156	–	47,164	3,885	11,750	5,225	–	134,180
2008–09	213,522	–	50,970	7,770	28,500	15,450	–	316,212
2009–10	173,715	–	50,970	7,770	28,500	15,450	–	276,405
2010–11	198,822	–	50,970	7,770	28,500	15,450	–	301,512
2011–12	92,280	–	25,485	3,885	14,250	7,725	–	143,625
Total	744,495	–	225,559	31,080	111,500	59,300	–	1,171,934
Grand total	1,695,016	100,711	475,281	31,080	329,727	129,854	18,124	2,779,794

Source: ACIAR project documents.

Notes:

Small discrepancies in totals are due to rounding of numbers.

ACIAR, Australian Centre for International Agricultural Research; ANU, Australian National University; CU, Curtin University; UWS, University of Western Sydney; PNGOPRA, Papua New Guinea (PNG) Oil Palm Research Association; CCRI, PNG Cocoa and Coconut Research Institute; CCEA, PNG Cocoa and Coconut Extension Agency.

ACIAR project documents did not provide any information on the in-kind contributions of research partners for the extension of project ASEM/1999/084. We assumed that the in-kind contributions were proportional to the ACIAR contribution in the initial proposal.

The two insect pests were:

- *Segestes decoratus* (known locally as sexava)—this is a key insect pest for both oil palm smallholders and plantations in West New Britain. It is also destructive on coconut in East and West New Britain, New Ireland, Manus, Madang and Morobe provinces in PNG. Heavy attack from sexava can cause almost total defoliation, which results in a significant reduction in fresh fruit production (PC/2007/098, Project final report, p. 5)
- Finschhafen disorder (FD)—this disorder was found to be caused by a leaf hopper, *Zophiuma butawengi*. FD affects coconut and oil palms.

The specific objectives of each project are listed in Table 5.

Research agencies

Table 6 lists the commissioned organisations and research partners for the projects.

Pathways to benefits

The main pathways to benefits for the socioeconomic and biocontrol clusters are summarised below. They are discussed in greater detail in subsequent chapters.

Table 5. Biocontrol cluster projects and their objectives

Project No.	Name	Objectives
CP/1996/091	Biological control of *Chromolaena odorata* in Papua New Guinea	• To mass produce and release existing biocontrol agents (*Pareuchaetes pseudo-insulata* and *Cecidochares connexa*) to establish populations in all areas of PNG. • To import, rear, field release and monitor the biocontrol agents *Lixus aemulus* and *Calycomyza eupatorivora*. • To monitor the establishment of the control agents and their effect on the weed. • To provide training to PNG provincial personnel in the identification of life stages of biocontrol agents, handling and release of biocontrol agents, and monitoring of release sites.
PC/2006/063	Integrated pest management for Finschhafen disorder of oil palm in Papua New Guinea	• Develop a comprehensive biological understanding of the causes of Finschhafen disorder. • Develop preliminary control methods for Finschhafen disorder
PC/2004/064	Biological control of 'mile-a-minute' (*Mikania micrantha*) in Papua New Guinea and Fiji	• To increase and support the capacity for weed biocontrol in PNG and Fiji. • To collect baseline data on the distribution and growth of *M. micrantha* under different conditions so as to quantify the effects and impacts of introduced agents. • To import, conduct host-specificity research and, if applicable, field release the butterflies *Actinote anteas* and *A. thyla pyrrha*. • To conduct host-specificity research on the rust fungus *Puccinia spegazzinii* and import and release it in Fiji and PNG if applicable. • To increase education, awareness, training and adoption of biocontrol of weeds and weed management to reduce herbicide usage among farmers.
CP/2007/098	An investigation into mycoinsecticides as potential control agents of sexava in oil palms in New Britain	• To identify suitable isolates, and to produce a formulation suitable to fulfil the second objective. • To undertake caged experiments in PNG to assess the virulence of the mycopesticides against sexava.

Source: Australian Centre for International Agricultural Research project documents.

Table 6. Biocontrol cluster projects: commissioned organisations and research partners

Project No.	Project	Commissioned organisation	Partner organisations
CP/1996/091	Biological control of *Chromolaena odorata* in Papua New Guinea	Queensland Department of Agriculture, Fisheries and Forestry (formerly the Queensland Department of Natural Resources and Water)	National Agriculture Research Institute Papua New Guinea (PNG) Oil Palm Research Association
PC/2006/063	Integrated pest management for Finschhafen disorder of oil palm in Papua New Guinea	Charles Sturt University	PNG Oil Palm Research Association
PC/2004/064	Biological control of 'mile-a-minute' (*Mikania micrantha*) in Papua New Guinea and Fiji	Queensland Department of Agriculture, Fisheries and Forestry (formerly Department of Employment, Economic Development and Innovation).	PNG National Agricultural Research Institute PNG Oil Palm Research Association PNG Coconut and Cocoa Research Institute
CP/2007/098	An investigation into mycoinsecticides as potential control agents of sexava in oil palms in New Britain	Imperial College London, International Pesticide Application Research Centre.	PNG Oil Palm Research Association

Source: Australian Centre for International Agricultural Research project documents.

Socioeconomic projects

The key to these projects was recognising the importance of socioeconomic factors in explaining the relatively low levels of production in the smallholder sector. The final outputs were generally aimed at overcoming these socioeconomic constraints. Adoption, however, required both the milling companies and OPIC to implement the new schemes developed, and then leaseholders and workers to participate in the schemes. The pathways to benefits are summarised in Figure 5.

Biocontrol projects

A key feature of the biocontrol projects is that they deliver benefits directly to smallholders, without requiring them to change existing practices.[3]

Encouraging smallholders to change farming practices is always a challenge. Adoption of new technologies by smallholders is therefore frequently the main factor that limits the benefits delivered by agricultural research, particularly in developing countries. By skipping this step, the biocontrol projects can potentially deliver significant benefits to the community. The pathway to benefits for the biocontrol cluster of projects is summarised in Figure 6.

[3] No change of practice has been required for oil palm farmers. However, other farmer who regularly try to control chromolaena through regular burning end up killing the agent and not controlling the weed. Therefore in some farming systems there has been a cultural change (M. Day, pers. comm., 9 March 2012).

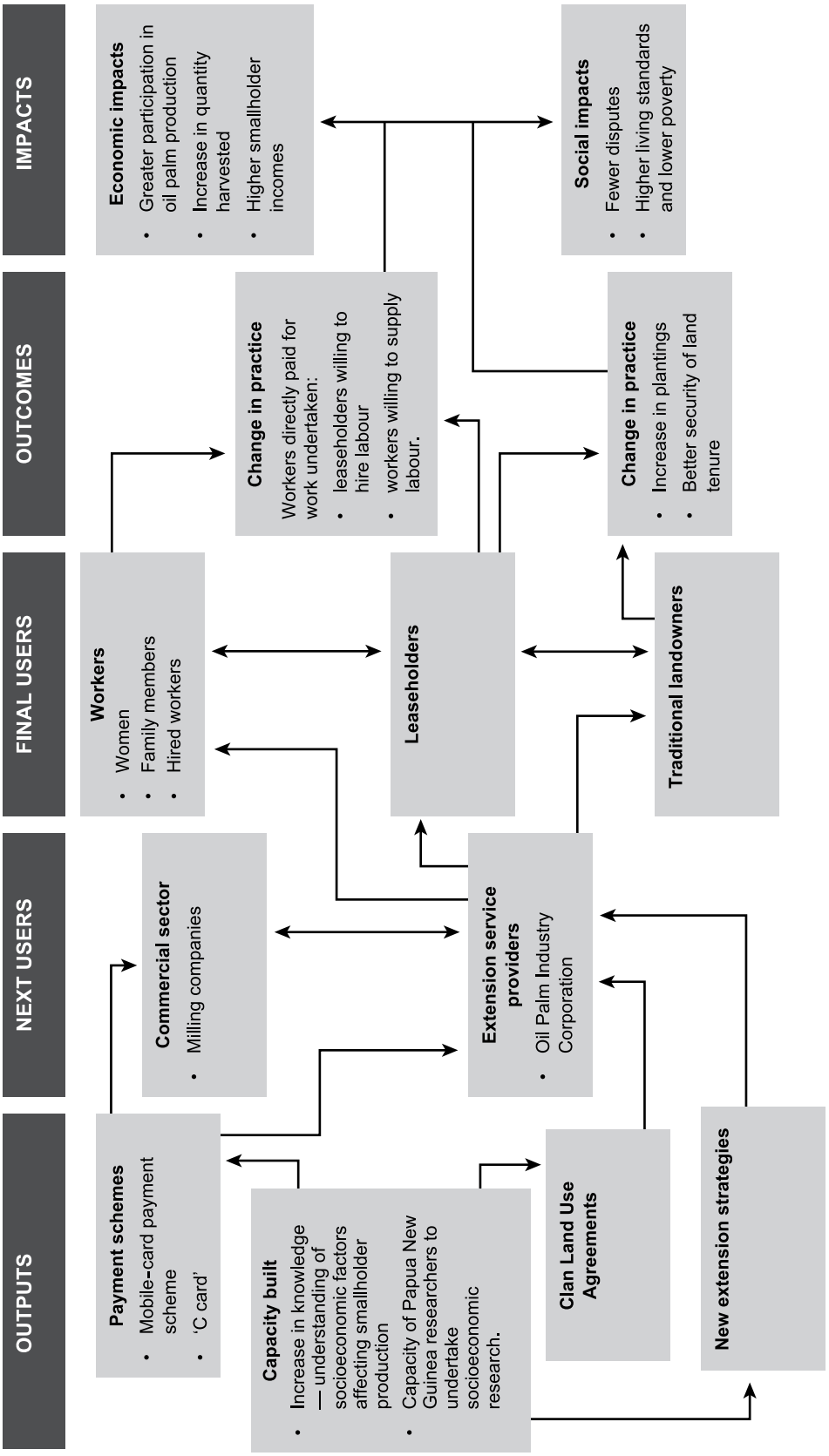

Figure 5. Socioeconomic project cluster—pathways to benefits

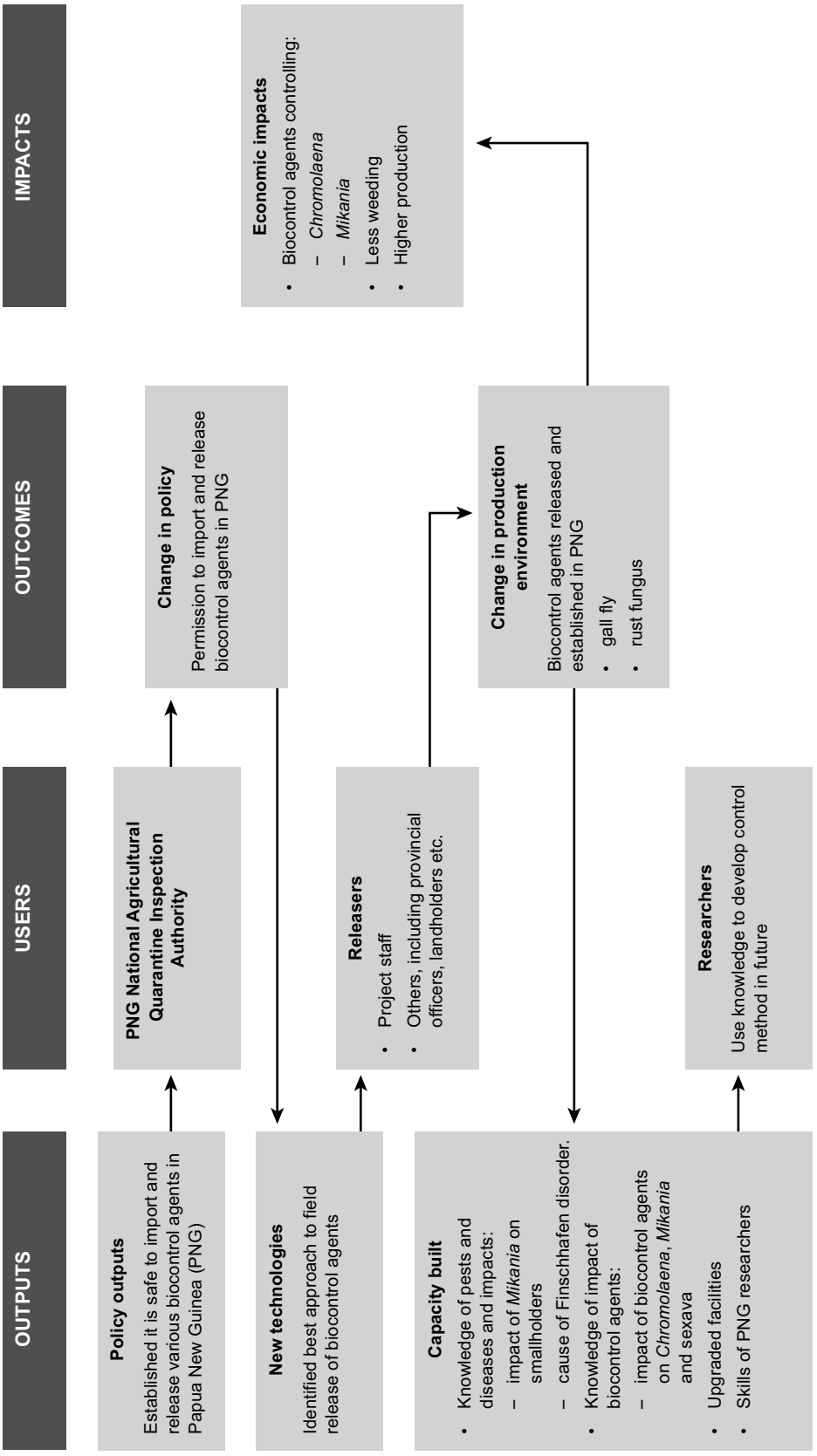

Figure 6. Biocontrol project cluster—pathways to benefits

3 Outputs

ACIAR's guidelines for assessing the impacts of research activities identify three broad categories of outputs of R&D projects (Davis et al. 2008 p. 17):

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

ACIAR socioeconomic and biocontrol research activities in the oil palm sector of PNG have delivered outputs in each of these categories.

Socioeconomic cluster projects

The socioeconomic cluster of projects has delivered a range of outputs, including:

- increased scientific understanding of the socioeconomic constraints on, and opportunities to improve, smallholder productivity
- a new payment system aimed at increasing participation in oil palm production
- a new template for Clan Land Usage Agreements
- new extension strategies in the cocoa industry
- enhanced capacity of PNG partner organisations to undertake socioeconomic research.

These outputs are described in greater detail below.

Improved understanding of socioeconomic factors affecting smallholder production

A key contribution of the socioeconomic cluster of projects was the improved understanding of socioeconomic factors affecting smallholder oil palm production. This included a better understanding of how monetary and social-based incentives influence smallholder productivity and the livelihood strategies smallholders adopt, and the importance of food gardens.

A key finding of the initial research (ASEM/1999/084) was that under-harvesting is a major contributor to low levels of production in the smallholder sector. The main factor contributing to under-harvesting is a shortage of labour. These labour shortages arise for a number of reasons, including the fact that many of the original LSS leaseholders are getting old and are unable to fully harvest their blocks.

Also, many highly populated blocks are moving away from a cooperative harvesting system in which adults from all households on the block contribute to the harvest (*wok bung*) to a labour rotation system (*makim mun*). Under a *wok bung* system, payment is determined by the holder of the 'Papa card' (the block-holder) and therefore may be based on factors such as gender, age and kinship status rather than being directly linked to effort. This has resulted in disputes and, in some cases, withdrawal of labour and harvesting disruptions (Koczberski et al. 2001, p. xxii). Under the *makim mun* system, harvesting is rotated among households. This could contribute to under-harvesting because fewer adults are contributing to each harvest.

The ACIAR-funded research also found that labour shortages are discouraging participation in extension programs aimed at encouraging better block maintenance. In addition, the *makim mun* system

provides no incentive to smallholders to invest in the block through replanting, fertiliser or general block maintenance because they cannot capture all of the benefits. Other factors contributing to relatively low levels of production by smallholders include lack of secure land tenure.

The socioeconomic cluster also built knowledge of the factors that contributed to the success of the Mama Lus Frut scheme in lifting the participation of women in oil palm production (ASEM/1999/084), as well as the feasibility of introducing this scheme to other tree crop industries. More generally, this improved the understanding of the capacity of innovative payment systems to deliver improved participation and productivity in the smallholder oil palm industry.

Mobile-card payment scheme

To overcome labour shortage issues identified, a mobile-card payment scheme was developed (ASEM/1999/084). Under the new system, mobile workers such as family members, hired labourers (living on another block) or caretakers each obtain a separate payment card and their own harvest nets. The mobile-card worker is paid an agreed share of the fruit weighed on the card, with the remainder paid to the block-holder (the Papa card).

Before a mobile card can be used on a block, the block-holder and the mobile-card worker must sign a work contract (from 2–12 months), which states:

- the agreed percentage split of fresh fruit bunches weighed on the mobile card
- the work to be done by the mobile-card worker (for example, harvesting, net stacking, pruning, fertiliser application etc.)
- where the work will be carried out (Phase 1, 2 or 3)
- who collects loose fruit from the phase where mobile-card holders will work.[4]

This payment system was designed to facilitate the across-block labour flexibility of underemployed young men from highly populated blocks. A key factor preventing underemployed labour from being mobilised was the perception that they would not be paid for their services. The mobile-card payment scheme means that block-holders do not have to pay cash to the worker.

The mobile-card payment system was trialled by OPIC officers at Hoskins (ASEM/2002/014) and Bialla (ASEM/2006/127) on a range of groups experiencing labour constraints. These groups included village oil palm growers and blocks managed by 'caretakers', elderly growers and young families.

The results of these trials were also used to design payment systems to mobilise labour in the cocoa industry (ASEM/2002/014 and ASEM/2006/127).

Clan Land Usage Agreements

To tackle land-tenure issues associated with CRPBs, a new template for a Clan Land Usage Agreement was developed in consultation with OPIC, customary landowners and migrant smallholders growing oil palm on customary land in Bialla, Hoskins and Popondetta (ASEM/2006/127).

The process for dealing with CRPBs is outlined in the guidelines developed as part of the ACIAR projects (see Box 3 for details). The new template CLUAs and the associated process are compliant with Roundtable on Sustainable Palm Oil requirements.

Extension strategies

New extension strategies to assist cocoa farmers' transition to high-input farming were also delivered by the socioeconomic cluster. The project worked in partnership with the exporting company NGIP–Agmark to provide new services for growers including: purchase of cocoa at the roadside edge of the cocoa block; a seedling support program including credit and training in cloning techniques and nursery establishment; general extension and advisory services including cocoa pod borer training and farmer group support; a savings scheme and modified repayment mechanisms for the supply of inputs such as replanting packages; and farm diversification support for growers affected by cocoa pod borer.

4 PNGOPRA, Mobile Card Payment Scheme for Oil Palm: Bialla Project, May 2011.

Box 3. Process for dealing with Customary Rights Purchase Blocks

The guidelines for dealing with Customary Rights Purchase Block (CRPB) transactions outline a seven-step process as follows.

1. It must be made clear to the customary landowners and the proposed lessee that the process towards formalising a Customary Land Usage Agreement (CLUA) will cease if various criteria are not met. At all stages the process must be transparent, public and all parties must be fully informed about all aspects of the proposed land transaction to be able to make Free, Prior and Informed Consent in accordance with Roundtable on Sustainable Palm Oil principles and the PNG national interpretation and guidance documents.
2. Confirm that there is agreement from the majority of the members of the landowning group for the proposed land transaction to go ahead. Confirmation to be obtained at a community meeting.
3. The Oil Palm Industry Corporation (OPIC) Lands Officer inspects the proposed CRPB and completes a Block Inspection Report including GPS coordinates of the boundary and a sketch plan of the land—with the local level government (LLG) Land Mediator, the proposed lessee and representatives from the landowning group and neighbouring land-owning groups.
4. The OPIC Lands Officer is then required to hold a community meeting for the public witnessing of the signing of the CLUA.
5. The OPIC Lands Officer must then assist landowners to open a bank account.
6. CLUA to be stamped by the Local District Lands Court and copies of the signed CLUA to be lodged with LLG Land Mediator, Lands Department and OPIC within 21 days.
7. An OPIC Planting Approval Form should then be completed.

Capacity of research organisations and individuals

Outputs related to building the research and extension service capacity of local research staff were also common to all projects within the socioeconomic cluster. Key capacity-building outputs included the following.

- The capacity of OPIC officers to identify the specific causes of problems with smallholder productivity and target interventions was built through developing an Extension Manual (ASEM/1999/084).
- The capacity of PNGOPRA research employees to undertake social surveying, in-depth interviewing and action research techniques was boosted. The PNGOPRA research program was also built through various training programs (ASEM/1999/084).
- The exchange of skills and information between separate industry organisations built combined research capacity. The socioeconomic cluster also contributed to improving the capacity of research and extension services in the cocoa sector (ASEM/2002/014).
- The capacity to develop land-use agreements between the commercial sector and customary landowners/smallholders for agricultural developments was built by producing a Manual of Best Practice. Improved research skills of local staff enhanced the research capacity of CCRI and PNGOPRA staff (ASEM/2006/127).

The capacity and skills of smallholder community groups were also built (ASEM/2006/127). Youth and community groups were trained to carry out block maintenance and other crop cultivation tasks.

Biocontrol cluster projects

Outputs of the biocontrol cluster of projects included:

- improved knowledge of pests and diseases and their impacts
- information to inform the decisions of the PNG National Agricultural Quarantine Inspection Authority (NAQIA) on whether to allow the import and release of various biocontrol agents
- increased scientific knowledge on the impact of biocontrol agents on various pests
- new methods and techniques for rearing and releasing biocontrol agents
- enhanced capacity of PNG partner organisations.

These outputs are discussed in greater detail below.

Knowledge of pests and diseases and their impacts

Projects within the biocontrol cluster contributed significantly to the stock of scientific knowledge on two weeds, an insect pest and a disease affecting oil palm and other crops in PNG and their impacts.

One project (PC/2004/064) improved knowledge of the distribution of mikania vine in PNG and the impacts of this weed on smallholders. More specifically, this project delivered the following outputs.

- A database on the distribution of mikania in PNG was established. The database contains good information on the distribution of the weed in the 15 provinces infested by it (M. Day, pers. comm., 9 March 2012).
- Field studies showed that mikania can grow up to 1 m/month in open areas, while in sheltered sites it can grow up to 1 m every 2 months.
- Completed questionnaires indicate that mikania has a significant economic cost to communities in PNG. In PNG, 74% of respondents clear mikania at least once a month from their land and 47% use hired help. Mikania was concluded to have severe negative impacts on plantation crops, food gardens, production and income.

This project also delivered increased awareness on mikania and its biocontrol agents through distribution of brochures, publication of papers, attendance at conferences and establishment of a website.

Another project (PC/2006/063) within the biocontrol cluster developed a comprehensive biological understanding of the causes of Finschhafen disorder.

- The research confirmed that FD is caused by a planthopper *Zophiuma butawengi (*zophiuma) and that this is the only species associated with FD.
  - A large, statistically designed insect cage experiment led to the conclusion that zophiuma induced FD symptoms in previously healthy coconut and oil palms. Further, a mesh sleeve experiment showed that FD was caused by a direct feeding effect by the planthopper and not by the transmission of a pathogen.
- The research also built the taxonomic knowledge of the group of insects to which the planthopper belongs. This knowledge led to a change in the specific name of the planthopper from *Z. lobulata* to *Z. butawengi.*
- Potential biocontrol agents were also identified, including one species new to science (C. Dewhurst, pers. comm., 9 March 2012).

Policy

Biosecurity procedures require that a permit be obtained before biocontrol agents can be imported into and released in PNG. An application containing relevant information on the weed or pest and the proposed biocontrol agent must therefore be submitted to NAQIA. The application must establish, based on scientific evidence, that the agent will not attack non-target plants, including important crops, or cause environmental damage. Since the information provided in an application aids the PNG National Agricultural Quarantine Inspection Authority's decision-making, it can be viewed as a policy output.

Potentially suitable biocontrol agents are typically identified through studies undertaken elsewhere in the world. The application process requires that robust testing has been undertaken on relevant plants. If some plants of economic or environmental significance in PNG have not already been assessed

elsewhere, testing is required before the permit will be granted. For the mikania project (PC/2004/064), an additional 37 plants required testing and this was undertaken by CAB International (CABI) as part of the ACIAR-funded project.

- As potential control agents for chromolaena, one of the ACIAR-funded projects (CP/1996/091) established that it was safe to import the following biocontrol agents into PNG:
  - the gall fly (*Cecidochares connexa*)
  - the leaf-mining fly (*Calycomyza eupatorivora*)
  - a moth (*Pareuchaetes pseudoinsulata*)

Lixus aemulus, a stem-boring weevil was also considered, but since it had not been approved for release in a chromolaena biocontrol program in South Africa, it was difficult to argue for its importation into PNG.

- As potential control agents for mikania, another ACIAR-funded project (PC/2004/064) established it was safe to import the following biocontrol agents into PNG:
  - a rust fungus (*Puccinia spegazzinii*)
  - a butterfly (*Actinote* sp.) whose larvae feed on mikania.

Scientific knowledge of the impact of biocontrol agents

Also among the outputs of the biocontrol cluster of projects were new scientific knowledge and extended understanding of existing and potential biocontrol agent populations.

Furthermore, project PC/2004/064 yielded greater scientific understanding of the biology and life cycle of the rust and its impact on mikania.

Finally, the biocontrol cluster delivered greater understanding of the effects of three fungus isolates on one species of sexava (*Segestes decoratus*). This was delivered through two experiments, both of which concluded that there was no noticeable difference in insect mortality between application of the fungi and control treatments (CP/2007/098).

New methods and technologies

The development of new techniques for DNA analysis was reported in project documents (PC/2006/063).

ACIAR-funded projects also identified the most efficient rearing, field release and monitoring methods for various biocontrol agents. These are typically based on advice from CABI, but often need to be adapted to local conditions. This is reflected in the development of a technique for successful development of the rust biocontrol agent on mikania in PNG. The technique is now applied in Fiji, Vanuatu and China, with other countries expressing interest.

The FD project also established that direct visual counting of *Z. lobulata* egg masses is an appropriate monitoring strategy for the disorder. Although the project was not able to deliver an appropriate control method, it was nevertheless established that nectar-rich groundcover plants positively affect the lifespan of the planthopper, and that honey enhances their activities. Also, it was found that colour makes no significant difference to the attractiveness/effectiveness of sticky-trap devices for monitoring its populations.

Capacity of research organisations and individuals built

ACIAR-funded projects built the capacity of PNG partner organisations to undertake future research. One way this occurred was through the upgrade of research infrastructure. Specifically:

- PNGOPRA's capacity to undertake research was enhanced through an upgrade to its premises, including IT facilities, an expanded research compound area and essential repositioning the perimeter security fence (PC/2006/063)
- successful upgrades to quarantine facilities in PNG were delivered by PC/2004/064, which then led to the approval to import the biocontrol agent *Puccinia spegazzinii*.

The capacity of PNGOPRA to respond to the threat of FD was also built through enhanced understanding of the disorder and the insect species that causes it. In particular, an electronic library of bibliographic information on FD and zophiuma, and on similar disorders and pests was compiled.

Various projects in the biocontrol cluster of palm oil sector projects also delivered outputs in terms of increased capacity of local research staff.

- The capacity of project officers and regional officers was built in most aspects of weed biocontrol, particularly in the rearing, release and monitoring of agents (CP/1996/091 and PC/2004/064).
- Greater understanding by local project staff of experimental design, and an increase in their capacity to collect, collate and present scientific data, were produced (CP/1996/091 and PC/2004/064). These outputs were delivered through formal and on-site training programs.
- Collaboration between various research institutions was also boosted (CP/1996/091).
- A John Allwright Scholarship–holder completed a research masters degree investigating the potential of entomopathogenic fungi as agents for biocontrol agents of *Z. butawengi.* Three fungi were isolated from *Z. butawengi* cadavers collected in field surveys, methods developed for laboratory growth and inoculum preparation, and preliminary tests made of their efficacy against the pest.

4 Adoption of outputs

For research projects to deliver benefits to the community, the outputs must be adopted in some way. This chapter outlines the pathways to adoption for the socioeconomic and biocontrol project clusters. It also identifies some of the key barriers to adoption.

Pathways to adoption

While the range of activities that can be described as 'agricultural research' is diverse, what could be considered a 'typical' output from an agricultural research project would be a new product, such as a new crop variety or livestock breed, or a new farming method or system. Adoption therefore typically involves a change in practice by farmers. Encouraging farmers to change established practices can be challenging, particularly in developing countries, where the agricultural sector is often characterised by many smallholders. Lack of adoption of research outputs by smallholders is the major factor limiting the benefits of agricultural research and has been a persistent challenge for ACIAR in PNG.

This section describes the pathways through which the socioeconomic and biocontrol projects have been adopted. The pathways to adoption for these project clusters are interesting variations from those for the 'typical' agricultural research project.

Socioeconomic cluster

The key final outputs of the socioeconomic cluster of projects must ultimately be adopted by smallholders. The pathway to adoption is guided by the structure of the oil palm industry.

Next users

The organisation of the oil palm industry—in particular, the nucleus-estate – smallholder model and the role of OPIC in providing extension services to smallholders—means that the next users of the key final outputs of the socioeconomic projects are the milling companies and OPIC officers. For the payment schemes to work, the milling company must set up accounts for participants and weigh separately the fruit collected under the different payment schemes operating. The administrative arrangements are handled by OPIC officers.

The milling company in the Bialla area has adopted the mobile-card payment scheme. In Hoskins and Popondetta, the milling companies have adopted modified versions of the scheme.

Similarly, the next users of the CLUAs are OPIC officers who facilitate agreement between traditional owners and the leaseholder. In cases where the smallholders are not the traditional landowners, the new agreements will be used for new plantings under the World Bank's PNG SADP.

The Mama Lus Frut scheme was already operating in the Hoskins area. It was extended to Bialla and Popondetta under ACIAR projects ASEM/1999/084 and ASEM/2002/014. The next users of the Mama Lus Frut scheme are also the milling companies and OPIC.

Final users

The final users of the payment schemes are smallholders. This includes both the cardholder—women and mobile workers—and the block-holder. It is critical that the scheme be accepted by the block-holder.

Regular training is essential to maintain the awareness of smallholders of how the payment systems operate.

OPIC/PNGOPRA strategies for encouraging adoption have included publicising the schemes through field days and talk-back radio shows.

The Mama Lus Frut scheme has achieved high levels of adoption in all project areas. Since the scheme was already operating in Hoskins before the ACIAR-funded research, any benefits there cannot be attributed to the ACIAR projects. However, the schemes were extended to Bialla and Popondetta under the ACIAR-funded projects. The high adoption rate achieved in Popondetta and, to a lesser extent, Bialla (Table 7), can therefore be attributed to the ACIAR projects. Widespread participation in the Mama Lus Fruit scheme started from around 2001–02 in Bialla, and from 2002–03 in Popondetta, with adoption rates reaching current levels relatively quickly (G. Curry, pers. comm., 30 May 2012).

While uptake of the mobile-card payment scheme in Bialla has been significantly lower than the Mama Lus Frut scheme, around 700 blocks are participating in the scheme (Table 8). This is around 20% of all blocks in the project.

A modified version of the mobile-card scheme—the 'C-card'—also operates in Hoskins. Only family members of LSS block-holders can register for the C-card scheme. Around 80% of eligible blocks participate in the scheme. Since LSS blocks make up around 65% of all blocks in Hoskins, this equates to a total adoption rate of around 52%.

The final users of the new CLUAs are the traditional landowners and the leaseholders. These CLUAs will be used, where relevant, for the new oil palm plantings under the SADP.

Biocontrol cluster

A key characteristic of biocontrol projects is that the outputs do not require the direct participation of smallholders for adoption. The pathway to adoption is therefore significantly different from that of a typical agricultural research project.

Table 7. Participants in the Mama Lus Frut scheme, October 2011

	Participants	Blocks	Adoption rate
	No.	No.	%
Hoskins[a]	5,864	7,126	82.3
Bialla	2,252	3,522	63.9
Popondetta	5,423	5,707	95.0

[a] The Mama Lus Frut Scheme in Hoskins pre-existed the ACIAR projects.

Source: J. Anjen, pers. comm., October 2011.

Table 8. Number of mobile-card holders—Bialla

	Participating blocks	Share of participating blocks	Share of all blocks
	No.	%	%
Deceased estate	530	74.9	15.0
Caretaker	30	4.2	0.9
Normal mobile card	138	19.5	3.9
New interest	10	1.4	0.3
Total	708	100.0	20.1

Source: J. Anjen, pers. comm., October 2011.

Next users

The next user of the information gathered as part the application process is NAQIA. This authority uses the information to decide whether or not to issue a permit to import a biocontrol agent into PNG and subsequently to release the agent in the field.

Final users

While adoption does not rely on smallholder participation, the biocontrol agents have to be released in the field. This is largely done by project staff. However, in some cases, releases have been made by provincial extension officers or landholders, particularly in remote areas that can be difficult and costly for project staff to reach.

Barriers to adoption

This section outlines some of the barriers to adoption for each cluster of projects.

Socioeconomic project cluster

The main barrier to adoption by next users is the time and effort required to implement, promote and administer the scheme. The mobile-card system was trialled in 1999–2000 in the Hoskins area. While the trial showed that there was a significant increase in production among participating blocks, the milling company in the Hoskins area, New Britain Palm Oil Limited, has not, as yet, implemented the scheme.

The scheme was successfully introduced in Bialla, with initially good levels of adoption supported by extension staff allocated to work on promoting the card scheme. However, adoption subsequently declined substantially as these personnel were relocated to other roles in OPIC. Some factors contributing to the decline in the use of mobile cards included:

- misunderstanding of mobile card implications—there were some concerns that mobile-card workers might try to claim ownership of the blocks
- the time needed to establish the logistics of hiring labour under the mobile scheme
- a perception by block-holders that mobile-card holders were paid substantial amounts of money, which the owners of blocks perceived as excessive (the percentage split between owner and mobile-card holder needed some adjustment).

There have also been various issues bearing on the effectiveness of both the Mama Lus Frut scheme and the mobile-card scheme. While these issues have not affected adoption per se, the schemes require the ongoing support of both OPIC and the milling companies. Any factors that reduce their effectiveness therefore pose some threat that they will lose the ongoing support of OPIC and the milling companies. In particular, there have been some instances of men shifting the harvest onto the Mama card, since loan repayments are deducted from the Papa card.

Biocontrol project cluster

A key advantage of biological agents to control weeds is that once they have been released and established, they spread naturally through a weed-infested area. However, due to PNG's geographic characteristics, the weed-infested areas are not always contiguous. This means that the biocontrol agents will not naturally spread to all weed-infested areas, such as some of the remote islands and isolated hinterlands.

Consequently, the biocontrol agents need to be released in each of these areas separately and regularly. However, many remote areas of PNG are difficult to reach, due to poor means of access, limiting the capacity of project staff to release the biocontrol agents in those areas (M. Day, pers. comm., 21 December 2011).

In some cases, the project team has used other parties, such as provincial extension officers and local landholders to release the biocontrol agents. At times, these people have asked for exorbitant fees to complete these tasks.

5 Outcomes

Outcomes are the changes in products, processes and policy that occur as a result of adopting outputs. This chapter outlines the outcomes that have occurred as a result of the ACIAR-funded socioeconomic and biocontrol projects.

Socioeconomic cluster projects

The socioeconomic projects funded by ACIAR have led to a number of important outcomes in both the oil palm and cocoa industries.

Increased participation in oil palm production

The extension of the Mama Lus Frut scheme under the ACIAR-funded research in Popondetta and Bialla has meant that women are participating in oil palm production to a much greater extent in those areas. This increased participation is not confined to additional loose fruit collection. It also includes block maintenance activities and harvesting of young oil palm. The Mama card has provided a non-cash mechanism for intra-family payments between men and women. This has been shown to deliver an increase in the quality of life for those families.

The mobile-card payment scheme has increased participation in oil palm production in Bialla and has therefore increased overall output. It has also provided a mechanism to ensure that workers are paid fairly for their efforts. It is unlikely that a mechanism would have developed without the intervention associated with the ACIAR project.

In a number of instances the mobile-card payment system developed through ACIAR-funded research has been adapted to suit local circumstances.

In Bialla, smallholders are referring to the mobile-card scheme as the 'Papa levy' because it enables the elderly leaseholder to hand over control of managing the blocks to the sons who are mobile-card holders. Under the 'Papa levy' version of the mobile card, the elderly leaseholder is guaranteed a fixed proportion of 20% of income from each block managed by a son, providing them with retirement income. The son gets 80% of the income from the mobile card.

In the Hoskins area, the mobile-card payment system developed under the ACIAR project was not adopted by New Britain Palm Oil Limited (see previous chapter). However, a modified version—the 'C-card'—has been implemented. Only family members are eligible for the C-card scheme. It therefore allows mobility of labour *within* a block, but not across blocks. As discussed previously, the growing population is a major issue in LSSs. Blocks within LSSs are now populated by multiple and intergenerational families. Under the card payment system, the payment for the oil palm fruit harvested was made to the holder of the Papa card. Payments to other family members are at the discretion of the Papa card holder, giving little incentive for other male residents, such as sons and grandsons, to contribute to the harvest because the compensation for their labour is uncertain. Alternatively, a *makim mun* system can be used, which has reduced the incentive for family members to cooperate and has led to under-harvesting. The C-card scheme has also increased participation in oil palm production, thereby increasing overall output, and has also provided a mechanism for fair payment for participants in the scheme.

A modified payment system to encourage the mobility of labour has also been developed by Agmark for the cocoa industry and is currently being trialled in parts of East New Britain. Under this system, farmers who require labour approach Agmark, specifying the work they require done and the price they are willing to pay. Agmark arranges for surplus workers to complete the work required and pays them directly. Those payments are then deducted from subsequent payments to the farmer. The mobilisation of labour as mentioned above has contributed significantly to responding to the devastation caused by cocoa pod borer in East New Britain province.

A similar scheme is also being trialled in Popondetta. This version of the scheme is similar to the cocoa version, where the labour is provided by the milling company and is then deducted from the block-holders' payments. This avoids the need for cash transactions.

New oil palm development

The new CLUAs will also be used, where relevant, in new estates being developed by the World Bank. The new CLUAs are expected to give lessees better security of tenure on the leased land. This is expected to increase production in several ways. First, there will be fewer disputes between lessees and traditional owners, and therefore fewer disruptions to production. Second, land tenure is critical to encourage investment in oil palm blocks, through replanting, applying fertiliser and general block maintenance. The CLUAs are expected to encourage greater investment in oil palm blocks.

It is important, however, that the outcomes of the research be assessed against an appropriate counterfactual. It is highly unlikely that any new oil palm developments would occur in PNG that do not comply with RSPO criteria (relevant RSPO criteria are outlined in Box 4). The pre-existing CLUAs do not comply with the standards set down by the RSPO and the World Bank. This effectively means that much of the area planned for oil palm development under the World Bank–supported SADP would not have been planted to oil palm without the new CLUAs (J. Anjen, pers. comm., 19 October 2011).

Policy outcomes

The contribution of the ACIAR projects to the knowledge base on the factors driving smallholders' decisions in the oil palm and cocoa industries has had an important impact on the key industry research agencies within PNG. There has been a major change in the thinking about how to deliver benefits to smallholders in these industries. This has been manifested in a number of ways. Importantly, CCRI and PNGOPRA now have socioeconomic sections (E. Omuru, pers. comm., 18 October 2011). It has also changed the way CCRI and OPIC carry out their extension activities. The new approach to extension work is more holistic and involves more dialogue with farmers. Farmer field schools have been established to engage better with farmers.

At the policy level, a PNG National Agricultural Research System (NARS) forum was held using Australian Agency for International Development funding. This forum recognised that technology alone cannot achieve the level of productivity increases sought. Rather, a new way of conducting research is needed, in which researchers take note of socioeconomic issues when developing research interventions. It is intended that the socioeconomic research undertaken by NARS agencies will be taken to this forum where it will be contested and debated and used to inform policy (E. Omuru, pers. comm., 18 October 2011).

While it is difficult to determine whether these changes have been solely brought about by the ACIAR-funded research, it is nevertheless clear it has been highly influential.

Biocontrol cluster projects

The biocontrol projects also led to significant outcomes. First, there were important policy outcomes. The project team, through the National Agricultural Research Institute (NARI), obtained permission to import four biocontrol agents:

- the gall fly *Cecidochares connexa* (CP/1996/091)
- the leaf-mining fly *Calycomyza eupatorivora* (CP/1996/091)

Box 4. Relevant Roundtable on Sustainable Palm Oil (RSPO) criteria

The relevant RSPO criteria include the following.

- Criterion 2.2: The right to use the land can be demonstrated, and is not legitimately contested by local communities with demonstrable rights.
- Criterion 2.3: Use of the land for oil palm does not diminish the legal rights, or customary rights, of other users, without their free, prior and informed consent.
- Criterion 6.4: Any negotiations concerning compensation for loss of legal or customary rights are dealt with through a documented system that enables Indigenous peoples, local communities and other stakeholders to express their views through their own representative institutions.
- Criterion 7.5: No new plantings are established on local people's land without their free, prior and informed consent, dealt with through a documented system that enables Indigenous peoples, local communities and other stakeholders to express their views through their own representative institutions.

- a moth *Pareuchaetes pseudoinsulata* (CP/1996/091)
- a rust fungus *Puccinia spegazzinii* (PC/2004/064).

Without the work undertaken as part of the ACIAR-funded projects—including background research, testing of additional plants and upgrading of NARI's quarantine facilities—it would have been impossible to gain this permission.

Second, there were technical/biological outcomes. All four of the biocontrol agents were subsequently imported into PNG, where they followed the usual pathway for such agents: holding in quarantine for one generation, then, following research to determine the best approach, release in areas affected by the weeds. Three of the agents became established at a number of sites, thereby changing the production environment for oil palm growers and other smallholders.

- The gall fly *Cecidochares connexa* has been released in all provinces affected by chromolaena and has been confirmed at about 400 sites, with another 60 unconfirmed records. It is expected that the gall fly will spread naturally to most of the remaining areas of the weed.
- The moth *Pareuchaetes pseudoinsulata* was released in nine provinces but established in only one province and is seasonally present at 20 sites.
- Field monitoring in PNG found that the rust had moved 7 km in 13 months.

The leaf-mining fly (*Calycomyza eupatorivora*), though imported into PNG seven times, failed to establish. Two other potential biocontrol agents, the butterflies (*Actinote* sp. and *A. thyla pyrrha*) were not imported, due to doubts about their host-specificity. Work on them was abandoned to focus on monitoring the spread of the rust fungus.

A third set of outcomes relates to use of the capacity built under the ACIAR-funded projects. Although the Finschhafen disorder (CP/2006/063) and sexava (PC/2007/098) projects did not succeed in developing a control method, they significantly increased the stock of knowledge on these problems and opened up further research opportunities that may eventually lead to identification of suitable control methods. PNGOPRA is collaborating with the Bill and Melinda Gates Foundation (Basic Research to Enable Agricultural Development—BREAD) to pursue these research opportunities for sexava control (C. Dewhurst, pers. comm., 19 October 2011). In particular, it is planned that parasitoids identified through the ACIAR-funded research will be reared for mass release.

The capacity built within NARI and CCRI to rear and mass-produce the rust is also being used in a number of ways. In particular, the capacity to mass-produce the

rust is being used to supply the rust to other countries, including other ACIAR partner countries. This is occurring in several ways. The NARI and CCRI project team is training counterparts in Fiji and Vanuatu to rear the rust, which was also exported from the NARI facility to China (M. Day, pers. comm., 9 March 2012). Furthermore, Thailand, Vanuatu and Guam are also considering importing the rust following the success in PNG (J. Fidelis, pers. comm., 18 October 2011).

The enhanced research capacity may also be useful if it is decided to introduce other biocontrol agents into PNG in the future.

6 Impacts

Impacts are the effects of the changes in policy, products or practices made as a result of the research. This chapter identifies the impacts of both the socioeconomic and biocontrol project clusters and develops a framework for quantifying them.

Socioeconomic cluster projects

Mobile-card payment scheme

A key finding of the initial research was that under-harvesting as a result of labour shortages is a key reason for low production in the smallholder sector. The quantity harvested by smallholders is determined by the market for harvesting labour (Figure 7).

The marginal revenue product of labour (MRPL) curve shows the additional revenue flowing to leaseholders (the Papa) from each additional unit of labour used for harvesting. Koczberski and Curry (2008) identified an 'edge effect' in their examination of harvesting patterns, in which harvesting tended to be greatest where oil palms are closest to the road (phase one) and lowest when the trees are farthest from the road (phase three). The labour required to harvest and transport the oil palm fruit to the collection point on the roadside is greater the farther away from the road. This implies that the MRPL curve is downward sloping; the return from each additional unit of labour declines as it becomes harder to harvest.

The labour supply curve shows the relationship between the amount of time workers are willing to spend harvesting oil palm fruit and their earnings per hour. As effective earnings per hour increase there are two effects on the quantity of labour workers are willing to supply:

- a substitution effect—as earnings per hour increase, working additional hours (and the associated consumption levels) becomes more attractive relative to leisure, so existing workers may be willing to work more hours or workers that were previously not willing to work may be now willing to do so
- an income effect—as earnings per hour increase, workers are required to work fewer hours for a given level of consumption and therefore may reduce the number of hours spent harvesting oil palm.

The impact of increased earnings per hour on the willingness to harvest oil palm is therefore ambiguous. However, consultation suggests that as the price received for oil palm fruit increases, the level of harvesting increases. This suggests that the substitution effect outweighs the income effect and the labour supply curve is upward sloping.

In the absence of the mobile-card payment system, all of the payment for the fruit harvested goes to the holder of the Papa card. Payment for the effort of other labourers therefore depends on the discretion of the cardholder. In cases where there are multiple families living on the same block, reward for effort is therefore uncertain and this often leads to sons refusing to supply their labour. Labourers from other blocks are also unwilling to supply their labour to other leaseholders because they perceive they may not be paid for it. This means that although there is excess labour within the community, they are unwilling to supply it to block-holders. In addition, block-holders are often unwilling to hire labourers from other blocks because this can lead to a land claim. These factors prevent the market from effectively intermediating the supply and demand for harvesting labour. As a result, many block-holders rely on their own

labour and, in some cases, limited labour from extended family members living on the block (LS_0 in Figure 7).

The mobile-card payment system guarantees payment for mobile-card holders and creates a direct link between effort and reward, without the need for a cash transaction between the block-holder and the worker. As a result, extended family and excess labour from other blocks are more willing to supply their labour to block-holders participating in the scheme. This can be represented as a shift in the labour supply curve (to LS_1).

Earnings for mobile-card holders are based on an agreed share of the value of the fruit they harvest. Mobile-card workers will be motivated to work by the additional revenue they receive, not by the total additional revenue generated by their efforts (i.e. they are unlikely to be motivated by the share of the revenue received by the Papa card holder). The mobile worker's MRPL curve is represented by $MRPL_{MC}$. Mobile-card holders will be willing to continue to supply their labour so long as the extra income they receive from continuing to work is higher than their opportunity cost of labour. That is, they will be willing to supply their labour up to the point where their MRPL ($MRPL_{MC}$) curve intersects with LS_1 (at L_1). The marginal revenue for both the block-holder and the mobile-card worker of that last unit of labour supplied is depicted by $MRPL_1$.

The benefit attributable to the scheme is essentially the increase in revenue flowing to both the mobile-card worker and the Papa card holder (the area below the MRPL curve between L_0 and L_1) less the opportunity cost of the additional labour inputs (the area below the LS_1 curve between L_0 and L_1). This is depicted by the shaded area in Figure 7.

Estimating the increase in revenue

The increase in revenue depends on the increase in the additional quantity of fruit harvested as a result of participation in the mobile-card payment scheme and the price obtained for the fruit. An estimate of the additional revenue for smallholders can be inferred from the trials undertaken in Bialla and estimates of the impact of the C-card.

The increase in production associated with the scheme depends on the relationship between the mobile-card worker and the owner. Based on the production increases implied by the trials and assuming a price of K300/tonne of fresh fruit bunches, we estimate that participation in the mobile-card payment scheme could increase revenue for smallholders by up to K250/fortnight (Table 9).

Estimating the change in labour inputs

Generating the additional revenue requires additional labour inputs. From Figure 7, the change in labour inputs is related to the change in total revenue as follows:

$$\Delta TR = \Delta L \times MRPL_1 + \frac{1}{2} \times \Delta L \times \Delta MRPL \qquad (1)$$

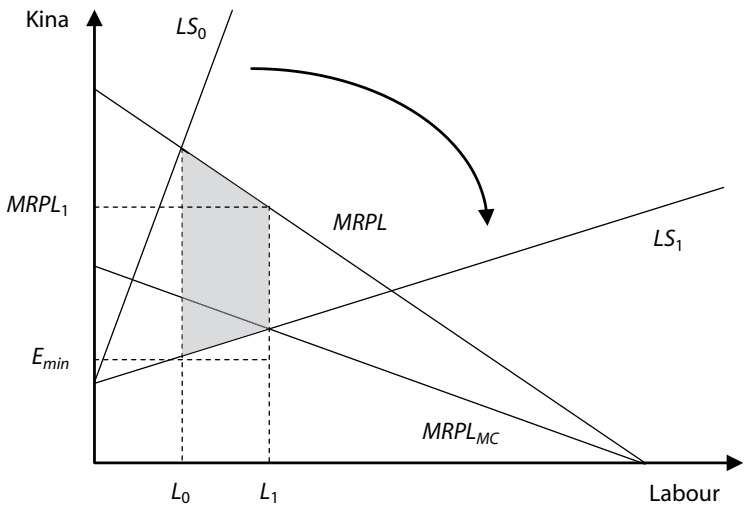

Figure 7. Market for harvesting labour. Data source: Centre for International Economics

Table 9. Estimated increase in revenue per harvest attributable to use of the mobile-card payment scheme

	Increase in production[c]	Increase in production per block[d]	Increase in revenue[e]
	%	tonnes/block/harvest	kina/block/harvest
Bialla trial[a]			
Caretaker–owner	40	0.74	222
Son–father	17	0.31	94
Hired labour–owner	45	0.83	250
Other	44	0.81	244
Hoskins[b]			
C-card	10	0.18	55

Sources: Koczberski and Curry (2008); D. Yanguem, pers. comm., February 2012; Centre for International Economics

a Estimates from Koczberski and Curry (2008) expressed as percentage point increase relative to the average.

b D. Yanguem, pers. comm., February 2012.

c Based on the average production per hectare from OPIC data.

d Assumes a typical block of 4 hectares planted to oil palm.

e Assumes a price of K300/tonne (fresh fruit bunches).

where ΔTR is the change in total revenue for smallholders, ΔL is the change in the labour used for harvesting, $MRPL_1$ is the marginal revenue product of the last unit of labour supplied and $\Delta MRPL$ is the change in the marginal revenue product of labour.

The change in the marginal revenue product of labour depends on the slope of the MRPL curve:

$$\Delta MRPL = -b \times \Delta L \tag{2}$$

where b is the slope of the MRPL curve (negative). Substituting (3) into (2) gives:

$$\Delta TR = \Delta L \times MRPL_0 - \frac{1}{2} \times b \times \Delta L^2 \tag{3}$$

Solving for ΔL, gives: [5]

$$\Delta L = \frac{MRPL_1 + \sqrt{-MRPL_1^2 - 4 \times \frac{1}{2} b \times \Delta TR}}{b} \tag{4}$$

An indicator of the slope of the MRPL is given as follows. Researchers estimate a 2 hectare (ha) block takes 2–3 person-days per fortnight to harvest (G. Curry, pers. comm., 13 January 2012). This estimate is broadly consistent with the smallholder guide to growing successful and profitable oil palm, which estimates a 2 ha block requires 3 person-days to harvest.

Based on the average annual production per hectare in Bialla, an average 2 ha block would produce around 1.12 tonnes of oil palm fruit per fortnight. At the current price of around K300/tonne, this implies average earnings of between K112 and K168/person-day of harvesting labour (Table 10).

Most blocks have around 4 ha planted to oil palm. Each block is normally harvested front (i.e. closest to the road) to back (i.e. farthest from the road). If we assume that the front half of the block takes 2 person-days and the back half of the block takes 3 person-days to harvest, this gives us two points on the average product of labour (APL) curve.[6] Assuming the APL curve is linear, the slope (c) is given by:

$$c = \frac{\Delta APL}{\Delta L} \tag{5}$$

5 Since this is a quadratic function, there are two solutions. However, increasing labour inputs past the turning point would imply total revenue decreases as labour inputs increase. As this is not economically meaningful, that solution is ignored.

6 The APL curve is not shown on the diagram.

Table 10. Average earnings per person-day

	Harvesting labour per 2 ha block	Production per 2 ha block	Revenue per 2 ha block	Average earnings per person-day
	person-days	tonnes	kina (K)	K
Minimum	2	1.12	336.30	168.15
Maximum	3	1.12	336.30	112.10
Total	5	2.24	672.60	134.52

Source: Centre for International Economics.

This implies that the slope of the average product of labour curve could be around –11.2. Assuming a linear MRPL curve, the slope of the MRPL curve is double the slope of the APL curve (see the appendix for details of the relationship between the MRPL curve and the APL curve). A reasonable estimate of the slope of the MRPL curve is therefore around –22.4.

The marginal revenue product of the last unit of labour added ($MRPL_1$) could vary by block. However, we assume that the blocks participating in the scheme are fully harvested. Based on the information shown in Table 10, a 4 ha block would take, on average, around 5 person-days to fully harvest. The MRPL of the fifth person-day is estimated at around K90. Based on these assumptions, the increase in labour inputs associated with the mobile-card payment scheme is shown in Table 11. The weighted average for Bialla is based on the current adoption rate shown in Table 8.

Estimating the opportunity cost of the additional labour

The opportunity cost of the mobile-card holder's labour depends on alternative uses of their time. This is likely to vary across mobile-card workers, implying an upward sloping labour supply curve. Many mobile-card holders will have few alternative employment options. The opportunity cost of their labour in those cases is leisure forgone.

The opportunity cost of labour of the mobile-card workers labour is the area below the labour supply curve between L_0 and L_1 (see Figure 7). This can be expressed as:

Table 11. Estimated increase in labour inputs per harvest

	Increase in revenue per block[c]	Increase in labour	Increase in labour
	kina/block/harvest	person-days/block/harvest	%
Bialla[a]			
Caretaker–owner	222	1.98	65.8
Son–father	94	0.94	23.2
Hired labour–owner	250	2.19	77.8
Other	244	2.15	75.3
Weighted average	131	1.23	32.7
Hoskins[b]			
C-card	55	0.58	13.0

Source: Centre for International Economics

[a,b] See Table 9.

[c] Assumes the marginal revenue product of labour of the last block is around K90.

Note: Assumes all blocks that participate in the scheme are fully harvested.

$$OC_L = \Delta L \times E_{\min} + \frac{1}{2} \times \Delta L \times \Delta E \quad (6)$$

where OC_L is the opportunity cost of the mobile-card holder's labour, ΔL is the labour supplied by mobile-card users and E_{min} is the minimum daily earnings any mobile-card worker is willing to work for.

How mobile workers value their time is difficult to determine from observations. Effective earnings through the mobile-card scheme may be significantly higher than many mobile workers' opportunity cost of labour. This would imply that some mobile-card workers would be willing to spend more time harvesting oil palm fruit, but are restricted by the availability of fruit to harvest on those blocks participating in the scheme.

Nevertheless, during the trial the minimum share any mobile-card worker accepted of the revenue generated by the fruit they harvested was 50%. If we assume the minimum any mobile worker is willing to work for is 50% of the MRPL of the final person-day required to fully harvest a 4 ha block, this implies the E_{min} may be around K45/person-day.

The change in effective earnings depends on the slope of the labour supply curve. As discussed above, the substitution effect and the income effect of higher earnings work in opposite directions. Consequently, the labour supply curve is likely to be relatively flat. We assume an elasticity of 0.3.

Mama Lus Frut scheme

The direct impact of the Mama Lus Frut scheme is on the market for labour to collect loose fruit (Figure 8). For cultural reasons, only women supply labour to this market. As with harvesting fresh fruit bunches, the MRPL curve is likely to be downward sloping. This is because collecting loose fruit that is further away from the collection point is more time-consuming. Consequently, earnings from each additional unit of labour decline.

In the absence of the scheme, women are not paid directly for the loose fruit they collect. They may, however, receive some indirect benefits from their husband or father. The MRPL curve faced by women ($MRPL_M$) and the amount of labour they are willing to supply depend on these uncertain, indirect benefits received from the income paid to the Papa card holder. Research found that men often spend oil palm income in ways that women disapprove, such as on beer and gambling (Koczberski 2007). In such circumstances, women often withdrew their labour completely, such that there would be no intersection between $MRPL_M$ curve and the labour supply curve (L_S).

Under the Mama Lus Frut scheme women are paid directly for the loose fruit they collect. While the scheme has also encouraged women to participate in oil palm production in other ways, this analysis focuses on loose fruit collection. The MRPL curve for women participating in the scheme is therefore the actual MRPL curve for loose fruit collection. Mama card holders therefore have the incentive to supply their labour up to the point where the MRPL curve intersects the labour supply curve, which is depicted as L^* in Figure 8. In practice, the amount of loose fruit women are able to collect is constrained by the quantity of loose fruit on the block. The amount of labour supplied by women may therefore be at a point such as L_1, where women would be willing to collect more loose fruit if it were available. The net benefit from the scheme is depicted by the shaded area in Figure 8.

As with the mobile-card payment scheme, one way to estimate the benefits of the Mama Lus Frut scheme is to estimate the additional revenue generated from the additional loose fruit collected (the area under the MRPL curve between the origin and L_1), less the opportunity cost of the women's labour (the area under the labour supply curve between the origin and L_1).

Increase in smallholder revenue

Data collected as part of the evaluation of the Mama Lus Frut scheme in Hoskins found that participation in the scheme increased oil palm income earned on each block by 10.8% (Warner and Bauer 2002, p. 11). It is reasonable to assume that increases in Bialla and Popondetta will be similar.

Opportunity cost of labour

Researchers estimate that women spend around 1 day per fortnight on oil palm production. The opportunity cost of the additional labour used for loose fruit collection depends on the possible alternative uses of that labour. This is likely to vary depending on what options each woman has available.

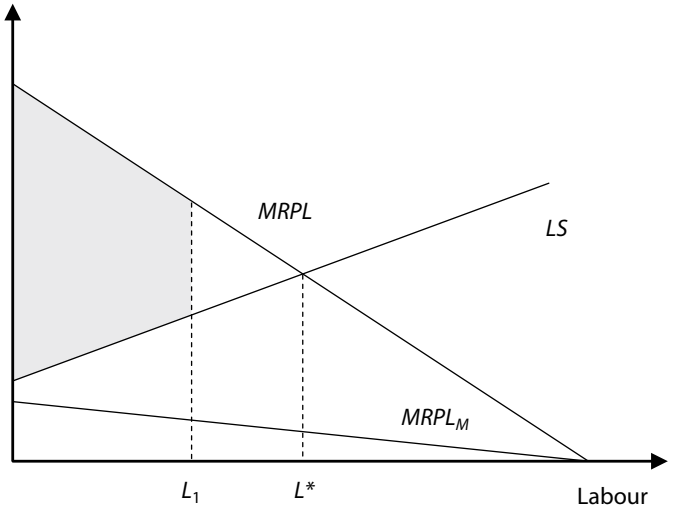

Figure 8. Labour market for loose fruit collection. Data source: Centre for International Economics.

One alternative use of women's labour is food gardens. Koczberski (2007) found that participation in the Mama Lus Frut Scheme did not affect income from food gardens. While this implies that women participating in the scheme shifted their labour from another activity (including leisure), the returns to food garden labour are nevertheless a reasonable indicator of the opportunity cost of women's labour.

Warner and Bauer (2002) estimated that the value of food gardens for smallholders in the Hoskins area was around K2,538 in (2001 kina terms), including K2,110 of food for own consumption and market income of K428. This estimate was based on earlier work by the World Bank. Inflating this estimate to 2011 kina terms using the food component of the PNG CPI gives an estimate of K5,285 (Table 12), or around K200/fortnight.

Koczberski (2007) also found that women spend around 28% of their time on food production. This equates to around 3.9 person-days/fortnight, and implies returns of around K53/person-day. This is compared with the estimated returns from loose fruit collection in Table 13. The return from loose fruit collection is estimated to be significantly higher than the returns from food gardens (based on a price of K300/tonne).

These estimates provide an indicator of the minimum amount for which women would be willing to collect loose fruit. As with the mobile-card payment schemes we assume an upward sloping supply curve with an elasticity of 0.3.

Clan Land Use Agreements

The new oil palm plantings under the World Bank's SADP are likely to deliver significant benefits to smallholders. Since the CLUAs are a necessary, though not sufficient, condition for that development to go ahead, some of the benefits from those new

Table 12. Estimated annual value of production from food gardens

	Value of production kina (2001)	Value of production kina (2011)
Food for own consumption	2,110	4,394
Market income	428	891
Total	2,538	5,285

Sources: Warner and Bauer (2002); Bank of PNG website.

Table 13. Estimated returns from labour

	Loose fruit collection	Estimated earnings per fortnight	Labour inputs	Earnings per person-day
	tonnes	kina (2011)	person-days	kina per person-day
Returns from food gardens	n.a.	203	3.9	52.8
Returns from oil palm labour				
Bialla	0.31	94	1.0	94.2
Popondetta	0.26	77	1.0	77.3

Source: Centre for International Economics

Note: n.a. = not applicable.

developments could therefore be attributed to the ACIAR projects.

New approaches to extension services

A trial including 200 farmers is currently being undertaken on the new approach to extension services in the cocoa industry that includes the private sector. Preliminary evidence suggests that these new approaches have increased cocoa yields from around 200–300 kg/ha to around 1 tonne/ha (G. Curry, pers. comm., 13 January 2012).

Biocontrol cluster projects

There is significant evidence that the biocontrol agents released under the ACIAR-funded projects are having some impact in controlling chromolaena and mikania. Field monitoring has found the following:

- The gall fly (*Cecidochares connexa*) has controlled chromolaena in Sandaun, New Ireland, Bougainville, and East and West New Britain. However, in drier and more open and exposed areas in Morobe and Madang provinces, it was slower to build up into effective populations. Chromolaena is not fully controlled in West New Britain where it is wetter, as adults need sunny days to mate and lay eggs.
- The moth (*Pareuchaetes pseudoinsulata*) has had limited effect and tends to have a seasonal impact on chromolaena. Its populations fall with the onset of summer rains and the plants can and do recover.
- The presence of the rust (*Puccinia spegazzinii*) significantly stunts the growth of mikania. Over time, its effectiveness is expected to increase further in suitable localities (C.F. Dewhurst, pers. comm., 19 October 2011).

Controlling weeds through biocontrol agents reduces the amount of manual labour required by smallholders to keep the weeds under control.

While the Finschhafen disorder (PC/2006/063) and sexava (CP/2007/098) projects have not yet resulted in any tangible impacts on smallholders, future research will build on the large and diverse knowledge base developed through the ACIAR-funded research and has identified potential biocontrol methods using naturally occurring parasitoids (C.F. Dewhurst, pers. comm., 9 March 2012). If control methods are identified that ultimately deliver benefits to smallholders, some of these benefits could be attributed to the ACIAR-funded projects. The skills gained from this project will also contribute towards increased understanding of a related coconut disorder, the Bogia syndrome. This disorder is localised to coconuts in Bogia and neighbouring areas in Madang province and poses a threat to oil palm.

7 Benefits and costs

This chapter sets out in a cost–benefit analysis framework the returns to the socioeconomic projects funded by ACIAR.

Benefits

The quantitative analysis focuses on benefits flowing to oil palm smallholders. Any benefits to the cocoa industry are therefore not included. The projects appear to have had a significant influence on the thinking of organisations such as PNGOPRA, OPIC, CCRI and the World Bank. This could potentially mean that future programs implemented by these agencies will be more effective. However, such benefits are difficult to quantify. Attribution of these future benefits to the ACIAR-funded research is also difficult to quantify. In quantifying the benefits of the socioeconomic research to oil palm smallholders, we therefore focus on the tangible benefits delivered by the mobile-card payment scheme (including the C-card scheme operating in Hoskins) and the extension of the Mama Lus Frut scheme to oil palm smallholders.

Mobile-card payment scheme

The annual benefits of the mobile-card payment scheme operating in Bialla are estimated in Table 14. These estimates assume that the current adoption rate of around 20% of blocks is maintained permanently. They also incorporate the scheduled increase in plantings under the World Bank's SADP.

While the scheme is estimated to deliver significant benefits to smallholders, there are also associated administrative costs, which are largely borne by OPIC. The administrative costs associated with the C-card scheme are estimated at around K55/day. If the administration of the mobile-card scheme has similar costs, annual administrative costs are estimated at around K20,000.

There are also likely to be some administrative costs borne by the milling companies, as well as additional collection costs. However, these are likely to be more than covered by the additional revenue from higher sales volumes. We have not included the benefits and costs to the milling companies in this analysis.

The benefits of the C-card scheme operating in the Hoskins area are estimated in Table 15. These estimates assume the current adoption rate of around 80% of all LSS blocks will be maintained permanently. As above, the administrative costs for the scheme are estimated at around K55/day, or K20,000/year.

In addition to the economic benefits of the mobile-card and C-card schemes, there are likely to be social benefits including:

- reduced conflict between family members
- a source of retirement income for ageing block-holders—the schemes will allow block-holders to hand over management of the block to their sons, while retaining a share of the oil palm income to sustain them in retirement
- improved security of land tenure—since the arrangements between block-holders and mobile-card workers are specified in a contract, there are less likely to be ownership claims made by family members, caretakers or other mobile-card workers.

Table 14. Benefits from the mobile-card payment scheme—Bialla

	Increase in revenue	Increase in labour	Opportunity cost of labour	Benefits to smallholders	Adminis-trative costs	Net benefit
	K '000	person-days	K '000	K '000	K '000	K '000
2000	–	–	–	–	–	–
2001	–	–	–	–	–	–
2002	–	–	–	–	–	–
2003	–	–	–	–	–	–
2004	–	–	–	–	–	–
2005	–	–	–	–	–	–
2006	–	–	–	–	–	–
2007	–	–	–	–	–	–
2008	–	–	–	–	–	–
2009	–	–	–	–	–	–
2010	2,404	22,692	1,067	1,337	20	1,317
2011	2,455	23,175	1,090	1,365	20	1,345
2012	2,558	24,141	1,136	1,422	20	1,402
2013	2,616	24,689	1,161	1,454	20	1,434
2014	2,616	24,689	1,161	1,454	20	1,434
2015–	2,616	24,689	1,161	1,454	20	1,434

Source: Centre for International Economics.

Mama Lus Frut scheme

The benefits of the extension of the Mama Lus Frut scheme to Bialla are estimated in Table 16. As above, these estimates assume that the current adoption rate of 63% of all blocks—including new blocks established under the SADP—will be maintained permanently. The cost of administering the Mama Lus Frut scheme is estimated at around K40/day, or K15,000/year (E. Germis, pers. comm., February 2012).

Similarly, the annual benefits of the extension of the Mama Lus Frut scheme to Popondetta are estimated in Table 17. These estimates also assume that the current adoption rate of 95% of blocks is maintained permanently.

In addition to the economic benefits, there are various social benefits associated with the Mama Lus Frut scheme. An increase in the income going to women raises expenditure on items such as food and clothing for the family. The scheme also improves the status of women and contributes to reduced poverty and improved livelihood in oil palm project areas. It also decreases family disputes caused by unequal distribution of revenue generated from oil palm. Through the Mama Lus Frut scheme, women have been empowered, showing that smallholders can respond to financial incentives. Furthermore, collecting loose fruits complements existing gender roles so there has not been a major shift in labour patterns.

Summary of benefits

The estimated benefits to PNG from the payment schemes are summarised in Table 18. The estimates are given in kina and Australian dollars, the latter calculated using the average daily exchange rate published by the Bank of Papua New Guinea. For future periods, the exchange rate is held constant at the average daily rate

Table 15. Benefits from the C-card scheme—Hoskins

	Increase in revenue	Increase in labour	Opportunity cost of labour	Benefits to smallholders	Administrative costs	Net benefit
	K'000	person-days	K'000	K'000	K'000	K'000
2000	–	–	–	–	–	–
2001	–	–	–	–	–	–
2002	–	–	–	–	–	–
2003	–	–	–	–	–	–
2004	–	–	–	–	–	–
2005	–	–	–	–	–	–
2006	–	–	–	–	–	–
2007	–	–	–	–	–	–
2008	–	–	–	–	–	–
2009	–	–	–	–	–	–
2010	5,335	55,487	2,537	2,798	20	2,778
2011	5,410	56,266	2,572	2,837	20	2,817
2012	5,522	57,434	2,626	2,896	20	2,876
2013	5,634	58,602	2,679	2,955	20	2,935
2014	5,747	59,770	2,732	3,014	20	2,994
2015–	5,747	59,770	2,732	3,014	20	2,994

Source: Centre for International Economics.

in December 2011. The benefits from these projects are expected to be permanent. Following ACIAR's guidelines, all future benefits are converted to an annuity once they reach a steady state. The annuity shown in Table 18 assumes a discount rate of 5%.

Distribution of benefits

The direct beneficiaries of the Mama Lus Frut scheme are the women who participate in it. However, these benefits are likely to flow onto to their families as a greater share of the household income is spent on food and other essential items. Women who participate in the scheme also enjoy a higher status within the community.

The distribution of the benefits of the mobile-card payment schemes (including the C-card) depends on the agreed split between the block-holder and the mobile-card worker. The block-holder receives the agreed share of the additional revenue, but does not incur any additional costs. The mobile-card worker receives their agreed share, but also incurs the cost associated with supplying their labour. This cost could be an alternative source of income, but more likely is a loss of leisure time.

Attribution of benefits

While the benefits of the mobile-card scheme in Bialla can clearly be attributed to the ACIAR-funded research, attribution for the extension of the Mama Lus Frut scheme and the C-card scheme is less clear.

The Mama Lus Frut scheme was already operating in Hoskins, and was not an output developed by ACIAR-funded research. However, the scheme was extended to Bialla and Popondetta under the ACIAR projects. In that sense it was similar to a technology transfer project where a pre-existing technology is transferred—and, where necessary, adapted—to an

Table 16. Benefits from the Mama Lus Frut scheme—Bialla

	Increase in revenue	Increase in labour	Opportunity cost of labour	Benefits to smallholders	Admin costs	Net benefit
	K'000	person-days	K'000	K'000	K'000	K'000
2000	–	–	–	–	–	–
2001	–	–	–	–	–	–
2002	3,015	32,017	1,437	1,578	15	1,563
2003	3,092	32,835	1,473	1,618	15	1,604
2004	2,812	29,864	1,340	1,472	15	1,457
2005	2,535	26,920	1,208	1,327	15	1,312
2006	2,288	24,298	1,090	1,198	15	1,183
2007	2,728	28,974	1,300	1,428	15	1,413
2008	3,140	33,341	1,496	1,643	15	1,629
2009	3,872	41,125	1,845	2,027	15	2,012
2010	3,716	39,466	1,771	1,945	15	1,931
2011	3,801	40,362	1,811	1,989	15	1,975
2012	3,969	42,153	1,892	2,078	15	2,063
2013	4,065	43,168	1,937	2,128	15	2,113
2014	4,065	43,168	1,937	2,128	15	2,113
2015–	4,065	43,168	1,937	2,128	15	2,113

Source: Centre for International Economics.

area where it was not previously in use. We therefore consider it appropriate to treat the development of the scheme in Hoskins as a sunk cost and attribute the benefits of the scheme in Bialla and Popondetta to the ACIAR-funded projects.

The C-card was not implemented under the ACIAR projects. It does, however, operate in a similar way to the mobile-card payment scheme developed by ACIAR-funded research, the main difference being that it applies within, rather than across, blocks. The mobile-card payment scheme introduced under the ACIAR project therefore influenced the development of the C-card scheme. Since the mobile-card scheme was developed and trialled under the ACIAR project, and the C-card scheme is extremely similar, it is reasonable to attribute the benefits of the C-card scheme to the ACIAR-funded research.

Costs

Table 19 gives the nominal costs of the ACIAR-funded socioeconomic projects—including all cash and in-kind contributions—converted to real 2011 dollars using the Australian GDP deflator published by the Australian Bureau of Statistics. In real 2011 dollars, the total cost of the research was around $3.4 million.

Summary measures

In net present value terms, we estimate the mobile-card payment scheme and the extension of the Mama Lus Frut scheme to Bialla and Popondetta could deliver

Table 17. Benefits from the Mama Lus Frut scheme—Popondetta

	Increase in revenue	Increase in labour	Opportunity cost of labour	Benefits to smallholders	Admin costs	Net benefit
	K'000	person-days	K'000	K'000	K'000	K'000
2000	–	–	–	–	–	–
2001	–	–	–	–	–	–
2002	–	–	–	–	–	–
2003	3,696	47,816	2,146	1,550	15	1,536
2004	3,928	50,820	2,281	1,648	15	1,633
2005	3,672	47,510	2,132	1,540	15	1,526
2006	4,198	54,308	2,437	1,761	15	1,746
2007	4,531	58,622	2,631	1,900	15	1,886
2008	4,365	56,479	2,535	1,831	15	1,816
2009	3,691	47,757	2,143	1,548	15	1,534
2010	3,977	51,459	2,309	1,668	15	1,654
2011	4,144	53,611	2,406	1,738	15	1,723
2012	4,410	57,053	2,560	1,850	15	1,835
2013	4,742	61,357	2,753	1,989	15	1,974
2014	5,075	65,660	2,947	2,129	15	2,114
2015–	5,075	65,660	2,947	2,129	15	2,114

Source: Centre for International Economics

net benefits to PNG of around A$57.3 million in 2011 dollars, using a discount rate of 5%. When the total research cost of A$2.7 million (expressed in similar terms) is subtracted from these benefits, the net benefits are estimated at around $54.6 million (Table 20). This represents a benefit of around $21 for every dollar invested. The internal rate of return is estimated at around 76%. While these results are sensitive to the discount rate used, the projects are nevertheless expected to deliver benefits to PNG that significantly exceed the research costs, even when a discount rate of 10% is used.

These estimates are likely to underestimate the true value of these research projects, since we have focused on quantifying only the tangible benefits of these payment schemes on oil palm smallholders. Any benefits from these projects to cocoa smallholders have not been included. There are also likely to be other benefits associated with the changes within PNGOPRA and CCRI.

In real terms, ACIAR contributed around 60% of the total research costs. On a cost-share basis, benefits of around $34.5 million (in net present value terms, using a discount rate of 5%) can be attributed to ACIAR.

Sensitivity analysis

The estimates presented above are based on a number of assumptions about key variables, such as prices and adoption rates. As most of the benefits occur in the future, there is necessarily some uncertainty around the future value of these key variables.

Table 18. Net annual benefits of payment schemes to Papua New Guinea

	Mobile card — Bialla	C-card — Hoskins	MLFS[a] — Bialla	MLFS — Popondetta	Total	Exchange rate	Total
	K '000	K '000	K '000	K '000	K '000	A$/kina	A$'000
2000	–	–	–	–	–	0.62	–
2001	–	–	–	–	–	0.57	–
2002	1,563	–	–	–	1,563	0.47	741
2003	1,604	1,536	–	–	3,139	0.43	1,357
2004	1,457	1,633	–	–	3,090	0.42	1,304
2005	1,312	1,526	–	–	2,838	0.42	1,200
2006	1,183	1,746	–	–	2,929	0.43	1,273
2007	1,413	1,886	–	–	3,299	0.40	1,330
2008	1,629	1,816	–	–	3,445	0.45	1,547
2009	2,012	1,534	–	–	3,546	0.46	1,634
2010	1,931	1,654	1,317	2,778	7,719	0.40	3,092
2011	1,975	1,723	1,345	2,817	7,860	0.42	3,274
2012	2,063	1,835	1,402	2,876	8,176	0.46	3,744
2013	2,113	1,974	1,434	2,935	8,457	0.46	3,873
2014	2,113	2,114	1,434	2,994	8,655	0.46	3,964
2015–[b]	42,262	42,280	28,683	59,881	173,106	0.46	79,270

Sources: Tables 14–17; Bank of Papua New Guinea; Centre for International Economics.

[a] Mama Lus Frut scheme

[b] All future benefits from 2015 onwards are reported as a perpetuity in line with ACIAR impact assessment guidelines.

We therefore test the sensitivity of the results to variation in these assumptions. This will provide some insight into whether the conclusions drawn from the estimates are robust. The following variables are included in the sensitivity analysis.

- The price of oil palm fruit—the estimated returns are based on a price received by smallholders of K300/tonne, which was the prevailing price in October 2011. The price paid to smallholders is driven by changes in the world price of palm oil. The price paid to farmers will therefore fluctuate significantly over time. We therefore test the sensitivity of the results to a lower bound assumption of K200/tonne and an upper bound assumption of K400/tonne.
- Adoption rates—adoption rates are a key driver of the benefits flowing from agricultural R&D. The estimates presented above assume that current adoption rates are maintained in the future.
  - We can be relatively confident that this will be the case for the Mama Lus Frut scheme, which has been operating successfully for a number of years and is popular among participants, as evidenced by the high adoption rates. Nevertheless, we test the sensitivity of the results to varying the adoption rate by 20 percentage points each way (except for Popondetta where the upper bound for adoption is 100%).
  - The mobile-card schemes, on the other hand, are newer and have lower adoption rates. It is possible that, unless the level of adoption reaches what could be considered a critical

mass, these schemes could fold. As a lower bound, we test the scenario that in 2 years, adoption falls to zero. As an upper bound, we use the adoption rate achieved by the Mama Lus Frut scheme in each particular project area.

- The impact of participating in the schemes—the assumptions used for the production increase associated with participation in the schemes are based on published research, including the trials undertaken as part of the project. The trials showed that the impact of participating in the schemes varied depending on a range of factors, including the relationship between the block-holder and the mobile-card worker. The estimates presented above are based on a weighted average of current

Table 19. Annual research costs

	Nominal costs	Australian GDP deflator	Real costs
	A$ (nominal)	Index (2011 = 100)	A$ (real 2011)
2001	323,381	68.2	473,927
2002	162,724	70.1	232,022
2003	160,474	72.1	222,514
2004	268,518	74.3	361,273
2005	272,988	77.2	353,740
2006	288,994	80.9	357,208
2007	130,781	84.9	154,127
2008	134,180	88.8	151,117
2009	316,212	93.3	339,058
2010	276,405	94.2	293,555
2011	301,512	100.0	301,512
2012	143,625	103.0	139,442
Total	2,779,794		3,379,493

Sources: Table 4; ABS Catalogue No. 5206.0; Centre for International Economics.

Table 20. Summary measures

	1%	5%	10%
Present value of benefits (A$m)	367.9	57.3	22.1
– Mama Lus Frut (Bialla)	92.6	16.2	7.2
– Mama Lus Frut (Popondetta)	92.0	15.7	6.7
– Mobile card (Bialla)	59.4	8.2	2.7
– C-card (Hoskins)	123.9	17.2	5.6
Present value of costs (A$m)	3.2	2.7	2.2
Net present value (A$m)	364.7	54.6	19.9
Benefit:cost ratio	114.3	21.3	10.0
Internal rate of return (%)	76.1	76.1	76.1

Source: Centre for International Economics.

participants in the scheme. As lower and upper bound alternative assumptions, we test the impact on the results of using the lower and upper bound found in the trial.

- The opportunity cost of labour—the way participants in the scheme value their labour is difficult to estimate. We took the approach of estimating a minimum amount workers are likely to be willing to work for and assumed an elasticity of supply of labour.
  - For the Mama Lus Frut scheme, the minimum amount any worker is willing to work for was estimated at around K55/person-day, based on estimated returns to food garden labour. As upper and lower bound estimates we vary this assumption by K10/person-day either way.
  - For participants in the mobile-card schemes, the minimum amount any worker would be willing to work for was estimated at around K45/person-day. As above, we test the impact on the results of varying this estimate by K10/person-day either way.
- The elasticity of supply of labour—there was no information available on the elasticity of supply of labour. The estimates are based on an assumption of 0.3. As upper and lower bounds, we test the impact of an elasticity of supply of labour of zero (perfectly inelastic labour supply) and 0.6.

The central case assumption and the lower and upper bound alternative assumptions are given in Table 21.

The benefit:cost ratios (using a discount rate of 5%) for the projects under each of the alternative assumptions (holding all other variables constant) are shown in Table 22. A key finding is that the benefit:cost ratio under all of the alternative scenarios is greater than one. The conclusion that these projects are likely to deliver a net benefit to PNG above the cost of the research can therefore be considered robust.

The benefit:cost ratio is most sensitive to the assumption about the price smallholders receive for oil palm, but is relatively insensitive to most of the other assumptions. This is partly because the benefits are spread across four different schemes. Varying an assumption that applies to

Table 21. Alternative assumptions used in sensitivity analysis

	Central case	Lower bound alternative	Upper bound alternative
Price of oil palm fruit (K/tonne)	300	200	400
Adoption rates (%):			
– Mama Lus Frut scheme (MLFS) (Bialla)	64	44	84
– MLFS (Popondetta)	95	75	100
– C-card (Hoskins)	52	0	82
– Mobile card (Bialla)	20	0	64
Impact on production (%):			
– MLFS (Bialla and Popondetta)	10	n.a.	25
– C-card (Hoskins)	10	5	15
– Mobile card (Bialla)	33	17	45
Opportunity cost of labour (K/person-day)			
– MLFS	53	43	63
– Mobile-card schemes	45	35	55
Elasticity of supply of labour	0.3	0.0	0.6

Source: Centre for International Economics.

Note: n.a. = not applicable.

only one of those schemes therefore leaves the estimated benefits of the other schemes unchanged.

Table 22. Project benefit:cost ratio under alternative assumptions

	Central case	Lower bound alternative	Upper bound alternative
Price of oil palm fruit (K/tonne)			
Adoption rates (%):	21.3	9.6	33.0
– Mama Lus Frut scheme (MLFS) (Bialla)	21.3	19.5	23.1
– MLFS (Popondetta)	21.3	20.2	21.6
– C-card (Hoskins)	21.3	16.2	26.6
– Mobile card (Bialla)	21.3	18.7	28.2
Impact on production (%):			
– MLFS (Bialla and Popondetta)	21.3	n.a.	34.5
– C-card (Hoskins)	21.3	18.0	24.7
– Mobile card (Bialla)	21.3	19.7	26.4
Opportunity cost of labour (K/person-day)			
– MLFS	21.3	23.8	18.6
– Mobile-card schemes	21.3	23.1	19.4
Elasticity of supply of labour	21.3	19.1	23.5

Source: Centre for International Economics.

Note: Using a discount rate of 5%.

8 Conclusions

Given the importance of the oil palm industry to PNG's economy, ACIAR has funded a range of projects in this industry. These projects can be grouped into three broad clusters:

- socioeconomic projects
- biocontrol projects
- soil management and crop nutrition projects.

This study has examined the impact pathways for the socioeconomic and biocontrol clusters.

It is well known that encouraging smallholders to adopt new technologies is highly challenging, particularly in PNG. These challenges have tended to reduce the effectiveness of agricultural R&D in PNG.

The way a R&D project meets the challenges associated with adoption is often the main factor determining the success of the project. The impact pathways for the biocontrol and socioeconomic clusters differ from what could be described as a 'typical' agricultural research project in which the research develops a technical solution to a specific problem, which must then be adopted by farmers.

Socioeconomic project cluster

The approach taken by the socioeconomic cluster was first to understand the key socioeconomic constraints on smallholder production. A major contribution of these projects has been to highlight the importance of socioeconomic factors on smallholder production decisions.

One way a more complete understanding of the socioeconomic constraints on smallholder production can deliver benefits is through changing the way research and extension activities are conducted. Understanding the socioeconomic environment can allow researchers to develop new systems that are more likely to be integrated into smallholder production systems. It also allows extension service providers to develop strategies that are more likely to maximise adoption.

Perhaps more importantly, a more complete understanding of the socioeconomic environment has allowed the development of new systems, such as the payment systems of these projects, that directly address, rather than attempt to work within, these constraints. We estimate that the extension of the Mama Lus Frut to Bialla and Popondetta and the mobile-card payment scheme (including the C-card) will deliver net benefits to the community of around A$54.6 million (using a discount rate of 5%).

Systems that tackle socioeconomic constraints directly have also had other significant advantages.

- First, these systems are most beneficial for, and are most likely to be adopted on, the least productive blocks. This is in contrast to most new technologies, which are most likely to be adopted by the more progressive smallholders; in closed markets where an increase in supply by adopters can put downward pressure on prices, this can leave the less progressive farmers worse off. Where the payment systems are adopted by the least productive blocks, this means that the benefits flow to the smallholders that need them most.
- Second, directly addressing the socioeconomic constraints on smallholder production has delivered a range of social benefits that are not necessarily seen in other types of R&D projects. In particular,

the payment schemes have raised the status of women, led to increased expenditure on food and other essential items, and reduced family and community conflicts (Koczberski 2007). These social benefits would not necessarily be seen in a project that increased production by a similar amount, but for which all the benefits flow to the block-holder.

While the strategies developed to overcome socioeconomic barriers to greater smallholder production have been successful in the oil palm industry, it is currently not clear if they can be successfully adapted to other industries in PNG. These systems rely on the nucleus-estate – smallholder model and the extension services provided by OPIC. These factors are absent in most other industries in PNG. Nevertheless, ACIAR-funded research has looked at the possibility of adapting to other industries the strategies that have been successfully implemented in oil palm. In particular, the research projects covered as part of this study looked at adapting the strategies to the cocoa industry, with preliminary results looking promising. Subsequent projects are also looking at the coffee industry. However, it is too early to tell if these endeavours will be successful. At the time of writing this report the Government of PNG is exploring the agro-nucleus estate model, as used in the oil palm industry, for other commodities, particularly coffee.

Biocontrol projects

A key characteristic of biocontrol projects is that adoption of the outputs does not need direct involvement of smallholders. Since encouraging smallholders to adopt research outputs can be challenging in developing countries—particularly in PNG—and often limits the benefits of agricultural research, biocontrol research can be highly effective in delivering benefits to smallholders, especially over the long term. Although we did not undertake a full impact assessment of ACIAR's biocontrol projects relevant to the oil palm industry in PNG, they nevertheless appear to have been successful in reducing the impact of chromolaena and mikania weeds. While the projects relating to Finschhafen disorder and sexava do not appear to have delivered any tangible benefits to smallholders to date, they have increased the knowledge on these pests and potential biocontrol agents. If subsequent research that builds on this knowledge develops control methods, some of the benefits could be attributable to ACIAR-funded research. The use of biocontrol agents reduces the need to use pesticides and herbicides and is therefore environmentally much more acceptable.

While biocontrol projects do not face the risk of non-adoption by smallholders, there are nevertheless risks related to adoption. The biosecurity agency could potentially refuse to issue a permit to import and release a new biocontrol agent, as has happened in Fiji. Releasing agents in all affected areas can also be problematic.

Appendix The relationship between an average and marginal product of labour curves

The marginal revenue product of labour (MRPL) curve is assumed to be linear and is of the form:

$$MRPL = a - bL \tag{1}$$

where a is the intercept and b is the slope.

The total revenue (TR) curve is therefore given by:

$$TR = \sum_{i=1}^{L} MRPL_i \tag{2}$$

Substituting (1) into (2) gives the total revenue curve:

$$TR = aL - \frac{L(L+1)}{2}b \tag{3}$$

The average product of labour (APL) curve is given by:

$$APL = \frac{TR}{L} \tag{4}$$

Substituting (3) into (4) gives:

$$APL = a - \frac{1}{2}b - \frac{1}{2}bL \tag{5}$$

If we let the intercept and slope of the APL curve be c and d respectively. Therefore:

$$d = \frac{1}{2}b \quad \text{or} \quad b = 2d \tag{6}$$

and

$$c = a - \frac{1}{2}b \quad \text{or} \quad a = c - \frac{1}{2}b \tag{7}$$

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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
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28	Harris D. 2004.	Water and nitrogen management in wheat–maize production on the North China Plain	LWR1/1996/164
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