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Sustaining cocoa production: impact evaluation of cocoa projects in Indonesia and Papua New Guinea

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Sustaining cocoa production: impact evaluation of cocoa projects in Indonesia and Papua New Guinea

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The Centre for International Economics

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Cover photo: ACIAR cocoa project in Papua New Guinea (by Richard Markham)

Foreword

Between 2009 and 2015, the Australian Centre for International Agricultural Research (ACIAR) funded a series of projects designed to improve the livelihoods of smallholder cocoa producers in Indonesia and Papua New Guinea (PNG). Before then, production in Indonesia had been maintained only through increasing the area planted with cocoa. For future production, it was important to examine how to increase yields rather than to continually expand the planting area. Thus, the projects in Indonesia addressed declining yields, tree ageing, and pest problems that had arisen in recent decades. The ACIAR research was one part of a large and ongoing effort in the country, and frequently involved a partnership or close association with private sector organisations.

In contrast, the work in PNG focused on controlling cocoa pod borer (CPB) moth—known throughout Asia as a major pest of cocoa trees. CPB was discovered on East New Britain in 2006. Initial attempts to eradicate the moth, through large-scale destruction of trees, were not successful, and CPB became established throughout PNG. This created great uncertainty and distress among cocoa farmers, leading many to abandon their cocoa plots.

Fortunately, the integrated pest and disease management techniques developed through the ACIAR projects have been successful in controlling CPB, and dissemination of the techniques to farmers has led to dramatically increased confidence in growing cocoa. Moreover, development of the techniques has created an opportunity to introduce improved practices that lead to healthier plants and higher yields.

The suite of on-farm techniques to improve yields includes techniques that require different levels of effort, and farmers can choose those that are most appropriate for them. In addition, the research teams have tested new methods for farm extension. Our model farmers are achieving substantial increases in yield, and adoption has now extended beyond original project areas.

The impact assessment reported here has attempted to attribute benefits to the ACIAR-funded projects. As always, there are some limitations to this attribution. Author David Pearce informs us that the overall benefits of the projects depend crucially on the adoption profile and actual achievement of yield gains in both countries. While most of this adoption will take place in the future—and thus the impact analysis outcomes are associated with some uncertainty—it is gratifying to learn that the real project expenditure in the two countries of just under $12 million may produce total benefits of $58.4 million—a benefit:cost ratio of 5 to 1.

Although the full adoption story for outputs from the projects funded by ACIAR and other organisations is not yet complete, this is a strong affirmation that the major push to lift cocoa productivity will have long-term benefits for the smallholder cocoa producers in both Indonesia and PNG.

Nick Austin
Chief Executive Officer, ACIAR

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Abbreviations

ACIAR	Australian Centre for International Agricultural Research
BCR	benefit:cost ratio
CPB	cocoa pod borer
GERNAS	Gerakan Peningkatan Produksian Mutu Kakao Nasional [National Movement to Increase the Production and Quality of Cacao]
IPDM	integrated pest and disease management
PNG	Papua New Guinea
PPAP	Productive Partnerships in Agriculture Project

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- the team from NGIP Agmark—John Nightingale, Graeme McNally and Otto Kuaimba.

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Summary

- A series of Australian Centre for International Agricultural Research (ACIAR)–funded research projects in Indonesia and Papua New Guinea (PNG) was designed to improve the livelihoods of smallholder cocoa producers.

- In both Indonesia and PNG, ageing trees, diseases and pests have proved challenging and have led to rapid declines in yield in recent years.

- In addition, farming practices have not always led to the best management of cocoa trees.

- The ACIAR-funded projects delivered a suite of on-farm techniques to improve yields—techniques requiring different levels of effort, with farmers able to choose those most appropriate to them.

- The ACIAR-funded projects have also examined new methods for farm extension, including participatory methods and careful examination of cultural constraints at the farm level.

- The ACIAR-funded research has taken place in the context of a number of other, sometimes large, research and extension projects in Indonesia and PNG. The impact assessment reported here has attempted to attribute benefits to the ACIAR-funded projects. As always, there are some limitations to this attribution.

- The overall benefits of the ACIAR-funded projects depend crucially on the adoption profile and actual achievement of yield gains in both countries. Most of this adoption takes place in the future, so impact analysis outcomes are associated with some uncertainty.

- Looking at the midpoint of a range of outcomes, our estimates suggest that the real project expenditure in the two countries of just under $12 million will lead to:
  - total benefits (measured as an increase in economic surplus, in real, present-value terms) of $58.4 million
  - net benefits of $46.7 million
  - a benefit:cost ratio of 5 to 1
  - an internal rate of return of 18.9%
  - an external rate of return of 4.6%.

1 Introduction

This report presents an impact evaluation of Australian Centre for International Agricultural Research (ACIAR)–funded projects in the cocoa sector in Indonesia and Papua New Guinea (PNG). These projects were completed between 2009 and 2015, so most of this evaluation is an analysis of potential outcomes.

Cocoa is a well-studied sector. Because it is an important (and sustainable) source of smallholder income, a large research and dissemination effort has been applied around the world—including in Indonesia and, to a lesser extent, PNG. Cocoa is unique in that most of this work involves a substantial level of public and private interaction. Importantly, private food-processing companies (including Mars, a partner in the ACIAR projects) working in cocoa focus on the supply end of the production chain—they are particularly interested in helping smallholders achieve sustainable productivity and incomes.

While this extensive activity and interaction will probably ultimately benefit smallholders, it makes the evaluation of ACIAR-funded research particularly challenging because of the very large number of intersecting research and extension projects in place. This is particularly the case in Indonesia, where (in dollar terms at least) ACIAR is a relatively small player. In PNG, ACIAR's role is more dominant but still a small share of total expenditure.

The various projects (ACIAR and others) are, in effect, all seeking the same outcomes: a sustainable and profitable increase in cocoa yields. Although evidence indicates that significant yield increases have been achieved by farmers associated with the projects, and there is a strong expectation of future increases, a number of different research and extension avenues have been explored to get there. The ACIAR-funded projects have made important contributions to this overall effort, but, given the number of different activities involved, it is not possible to put a definitive ring around ACIAR-related activities and outcomes so that they can be neatly compared with ACIAR costs.

As is the case for all projects, adoption rates are particularly important in determining the ultimate economic benefits of research and extension projects. Adoption is particularly important in the case of cocoa for two reasons:

- Cocoa is a cash crop and, in many cases, one of a number of alternatives for smallholder producers.
- The outputs of the projects are, in part, a suite of farming practice options that generally require more effort on the part of the farmer. In some regions, this is a major constraint to adoption.

Because the full adoption story for the outputs from ACIAR and other projects is not yet complete, it is difficult to attribute benefits to the ACIAR-funded projects and to provide definitive estimates of future adoption.

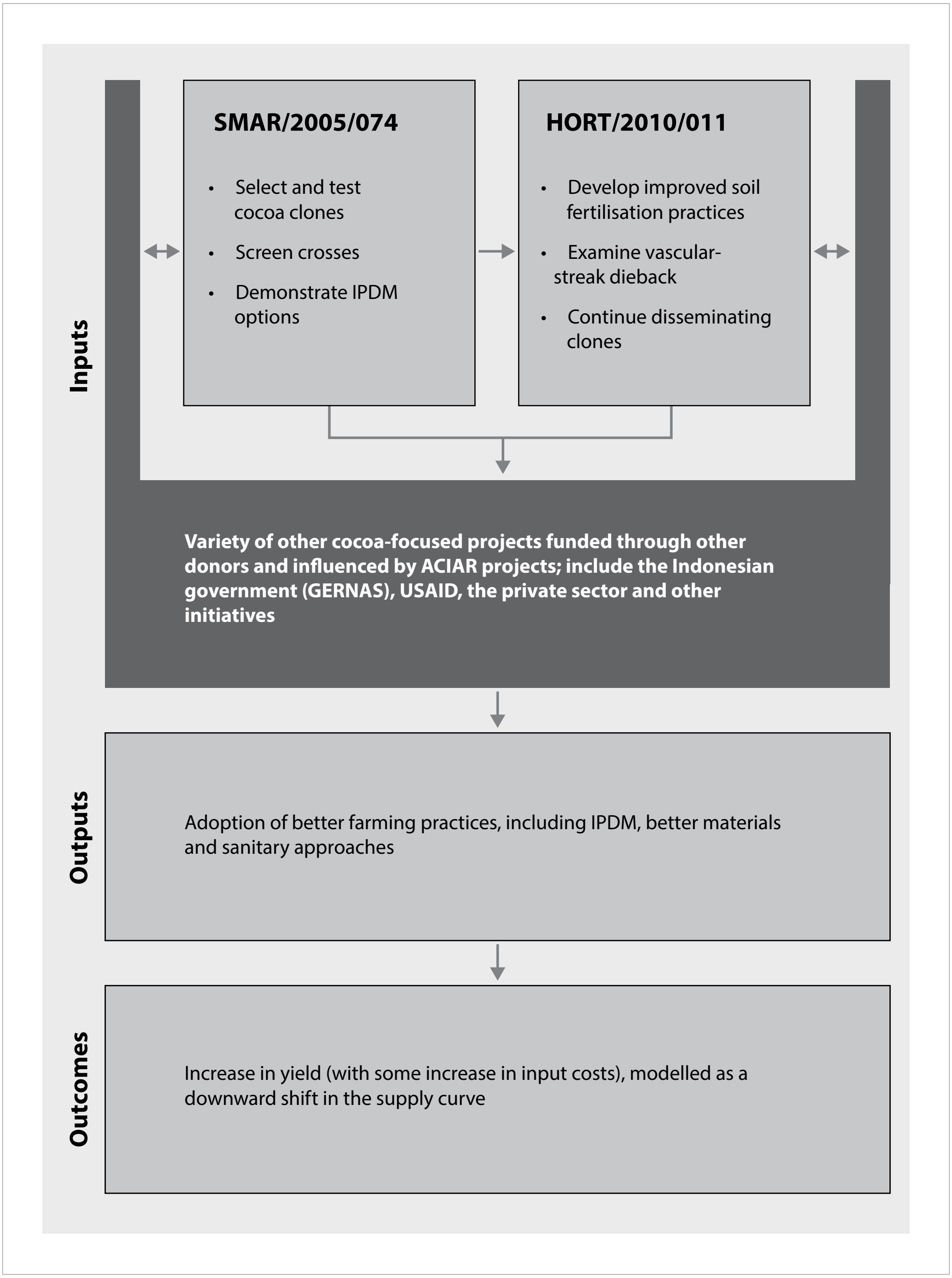
2 The projects

The Indonesian projects covered in this report are summarised in Figure 2.1 and Table 2.1, and the PNG projects are summarised in Figure 2.2 and Table 2.2.

The projects are essentially concerned with smallholder cocoa production declining as a result of a range of factors, but, in PNG, particularly from the cocoa pod borer (CPB) moth. They all provide farmers with a suite of options for cost-effectively improving yields while at the same time seeking to understand the factors that drive adoption and develop innovative methods of extension.

None of the projects deliver radical new technologies. Rather, they provide a carefully formulated menu of options for farmers to adopt, according to their own means and abilities. A key feature of these projects is that adoption of this menu requires changed farming practices—they all involve additional inputs. This is likely to be particularly challenging in the case of PNG, given the traditional 'foraging' nature of much of the cocoa farming there (see Curry et al. 2007).

The two Indonesian projects took place when considerable effort was being devoted to the Indonesian cocoa sector. The wide-ranging projects, funded by a range of agencies (set out in more detail in Section 3), have both influenced and been influenced by the ACIAR-funded projects. A common link in many of the projects is the involvement of a variety of private sector organisations, including Mars, which was one of the ACIAR project partners.



IPDM = integrated pest and disease management; USAID = United States Agency for International Development
Data source: Project documents, field visits

Figure 2.1 Indonesian projects—inputs, outputs and outcomes

Table 2.1 Summary of Indonesian projects

SMAR/2005/074: Improving cocoa production through farmer involvement in demonstration trials of potentially superior and pest/disease-resistant genotypes and integrated management practices	
Timeline	January 2007 to June 2012
Budget (nominal)	$1,537,546
Objectives	Select and test local cocoa clones in different locations, screen progeny of crosses between productive and resistant genotypes, demonstrate IPDM options with reduced material inputs and assess technology uptake by farmers
Key outputs	Engagement with the GERNAS program (which started in 2009) Successful testing of clones that could lead to increased yield Demonstration that cultural methods (including recycling of farm waste into compost) could substitute for high cost inputs
Key outcomes	Some clones taken up by farmers for top or side grafting Evidence of substantial yield improvement associated with some clones
Nature of impacts	Increased net economic surplus by adopting improved clones and cultural techniques
HORT/2010/011: Improving sustainability of cocoa production in eastern Indonesia through integrated pest, disease and soil management in an effective extension and policy environment	
Timeline	April 2011 to March 2015
Budget (nominal)	$2,519,721
Objectives	Develop improved smallholder soil fertilisation practices, investigate changes in vascular-streak dieback symptoms, continue on-farm testing and dissemination of improved cocoa clones, and implement and test improved extension methods, including IPDM trials involving farmer participation and farmer-to-farmer extension
Key outputs	Establishment of fertiliser and IPDM trials
Key outcomes	Direct and indirect participants gained access to improved techniques
Nature of impacts	Increased net economic surplus by adopting improved clones and cultural techniques

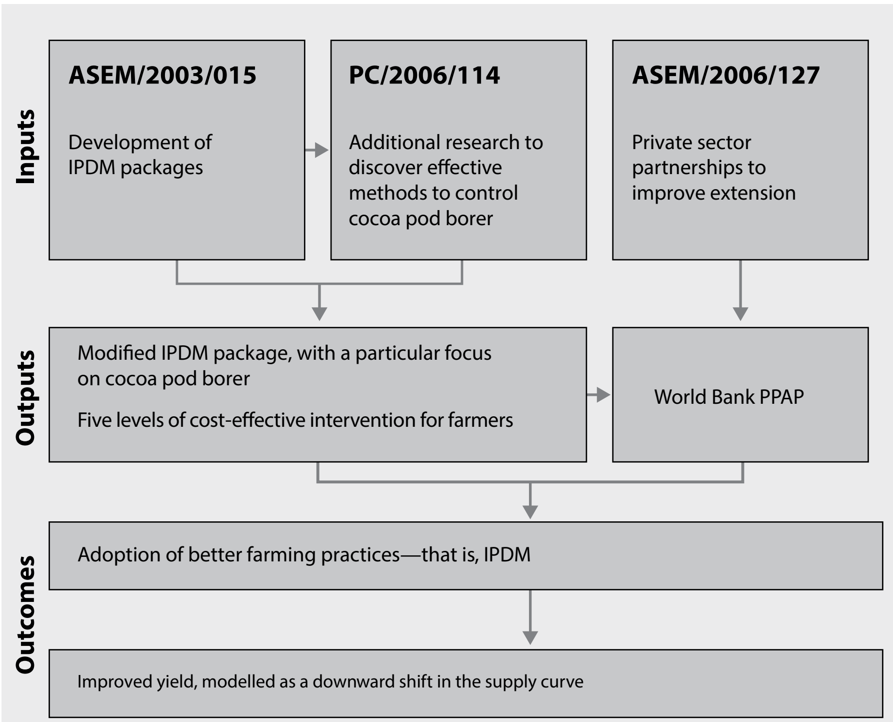
IPDM = integrated pest and disease management
Source: Project documents, field visits

The three projects in PNG combined in a unique way with each other and with the World Bank Productive Partnerships in Agriculture Project (PPAP) (funded through a loan facility to the PNG Government) to provide a comprehensive set of farming options, and a well-defined extension and adoption approach. The ACIAR projects contributed to the development of the PPAP and substantially to the understanding of integrated pest and disease management (IPDM) practices in PNG, with a particular focus on CPB. The interaction with the private sector purchasers of cocoa (in this case, NGIP Agmark) provides a unique approach to disseminating research outcomes.

Project budgets in real and present-value terms

In present-value terms, the project-related spending was $5.3 million in Indonesia (Table 2.3) and $6.4 million in PNG (Table 2.4).

While in nominal terms the total of the PNG project budgets was smaller than that of the Indonesian projects, because the PNG projects started and finished earlier, the effect of converting to present-value, real 2015 terms tends to inflate the PNG project costs relatively more.



IPDM = integrated pest and disease management; PPAP = Productive Partnerships in Agriculture Project
Data source: Project documents, field visits

Figure 2.2 **Papua New Guinea projects—inputs, outputs and outcomes**

Table 2.2 Summary of PNG projects

ASEM/2003/015: Enhancing PNG smallholder cocoa production through greater adoption of disease control practices	
Timeline	January 2005 to May 2009
Budget (nominal)	$1,510,381
Objectives	Use participatory on-farm research techniques and farmer training to disseminate information and technologies to farmers, with a view to increase adoption of IPDM systems and to increase cocoa management input
Key outputs	Documentation of disease losses, and smallholder skills and attitudes Fostering evaluation and adoption of a range of IPDM strategies, including development of a menu of IPDM management options that are culturally and economically appropriate Development of farmer trials to encourage farmer evaluation and adoption Enhanced expertise at the Papua New Guinea Chamber of Commerce and Industry Production of an IPDM training manual
Key outcomes	Increased adoption of IPDM (more than 1,000 farmers and extension staff trained) Evidence of substantially increased yields; yields before the project were around 500 kg/ha (or less); some IPDM options indicate yields of up to 2 t/ha IPDM package subsequently modified for PC/2006/114 (see below) IPDM manual translated and fed into Indonesian project SMAR/2005/074
Nature of impacts	Increased economic surplus as a result of yield increases in excess of the extra costs required to achieve the yield increase. Impacts were achieved through project activities and follow-up projects funded by the World Bank
ASEM/2006/127: Commercial sector/smallholder partnerships for improving incomes in the oil palm and cocoa industries in Papua New Guinea	
Timeline	January 2008 to September 2012
Budget (nominal)	$1,171,934
Objectives	Improve extension delivery through greater commercial sector engagement, and develop effective land-use agreements between the commercial sector and customary landowners New extension approaches are particularly important in the context of the control of CPB, which requires greater inputs than are typically used in PNG
Key outputs	Improved understanding of sociocultural factors affecting smallholder productivity and levels of farm inputs Development of NGIP Agmark 'Training by association' trial

Key outcomes	Notable improvement in block maintenance and sanitation for the 1,000 farmers who participated in training Evidence of yield improvement from 300–400 kg/ha to up to 1 t/ha Successful transition to high-input farming for some families Version of the extension model formed the basis of the World Bank–funded Productive Partnerships in Agriculture Project
Nature of impacts	Increased economic surplus as a result of yield increases in excess of the extra costs required to achieve the yield increase. Impacts were achieved through project activities and follow-up projects funded by the World Bank
PC/2006/114: Managing CPB in PNG through improved risk incursion management capabilities, IPM strategies and stakeholder participatory training	
Timelines	2008 to 2011
Budget (nominal)	$1,156,464
Objectives	Provide improved CPB monitoring and surveillance, along with effective and appropriate IPDM strategies. This project builds on ASEM/2003/015
Key outputs	Development of modified, cost-effective IPDM CPB recommendations in a variety of media and their incorporation into the IPDM training manual Materials for, and implementation of, farmer field schools
Key outcomes	IPDM has become the standard approach to cocoa farming in PNG, including through extension efforts of private sector agencies Considerable potential for improved yields as observed in ASEM/2003/015
Nature of impacts	Increased economic surplus as a result of yield increases in excess of the extra costs required to achieve the yield increase. Impacts were achieved through project activities and follow-up projects funded by the World Bank

CPB = cocoa pod borer; ha = hectare; IPDM = integrated pest and disease management; IPM = integrated pest management; kg = kilogram; PNG = Papua New Guinea; t = tonne

Source: Project documents, field visits

Table 2.3 Indonesian project budgets

Year	Nominal budget (A$)			Budget in real 2015A$	
	SMAR/2005/074	HORT/2010/011	Total	Current value	Present value
2007	297,742		297,742	361,659	534,335
2008	287,162		287,162	334,266	470,346
2009	363,330		363,330	415,568	556,901
2010	279,349		279,349	310,453	396,225
2011	203,652	465,841	669,493	720,241	875,457
2012	106,310	680,382	786,692	831,663	962,753
2013		693,452	693,452	715,562	788,907
2014		680,046	680,046	684,694	718,929
Total	**1,537,545**	**2,519,721**	**4,057,266**	**4,374,106**	**5,303,853**

Note: Current value refers to the value in that particular year. Present value refers to the value in 2015 dollars after taking into account the discount rate.

Source: ACIAR project documents, Centre for International Economics estimates

Table 2.4 PNG project budgets

Year	Nominal budget (A$)				Budget in real 2015A$	
	ASEM/2003/015	ASEM/2006/127	PC/2006/114	Total	Current value	Present value
2005	554,269			554,269	713,419	1,162,084
2006	486,491			486,491	604,681	938,058
2007	469,621			469,621	570,436	842,793
2008		300,688	325,398	626,086	728,785	1,025,473
2009		292,958	341,416	634,374	725,581	972,348
2010		294,469	307,578	602,047	669,081	853,936
2011		283,819	182,071	465,890	501,204	609,217
Total	**1,510,381**	**1,171,934**	**1,156,463**	**3,838,778**	**4,513,187**	**6,403,909**

Note: Current value refers to the value in that particular year. Present value refers to the value in 2015 dollars after taking into account the discount rate.

Source: ACIAR project documents, Centre for International Economics estimates

Background context

Cocoa prices

Throughout the late 1970s to the mid 1990s, cocoa prices fell almost continuously, after which they increased fairly steadily until the past couple of years, when prices again declined (Figure 2.3). The World Bank (2015) forecasts that prices will continue to decline in real and nominal terms to 2025.

The price path is important when considering potential adoption of project outcomes: adoption is more likely when prices are increasing. Field visits indicate that some cocoa farmers and extension officers still expect prices to increase.

Historical production and yield

Indonesia

The historical area planted with cocoa, and cocoa yield and production information for Indonesia are summarised in Figure 2.4.

Indonesia's yield cycle—rapid increase, levelling off and then decline—follows a typical cocoa cycle, where initial forest conversion to cocoa plantings leads to a rapid increase in yield (the boom), followed by steadily dwindling yield as trees age, and pest and disease pressures increase (see, for example, Ruf and Siswoputranto 1995, and Clough et al. 2009).

For the 20 years between 1973 and 1993, yields grew at around 6% per year. Since then, they have declined to around 3% per year. The aggregate data show no evidence that this rate of decline is slowing.

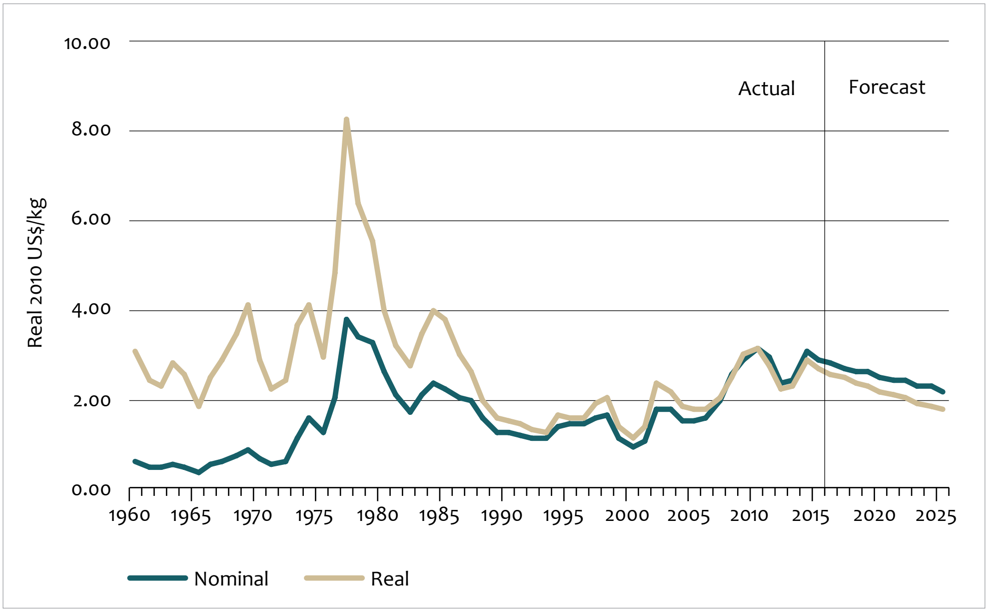
Production in Indonesia has been maintained only through increased area; the future of production can reasonably be expected to depend on future yields rather than on continual expansion in area.

Papua New Guinea

The historical area planted with cocoa, and yield and production information for PNG are summarised in Figure 2.5.

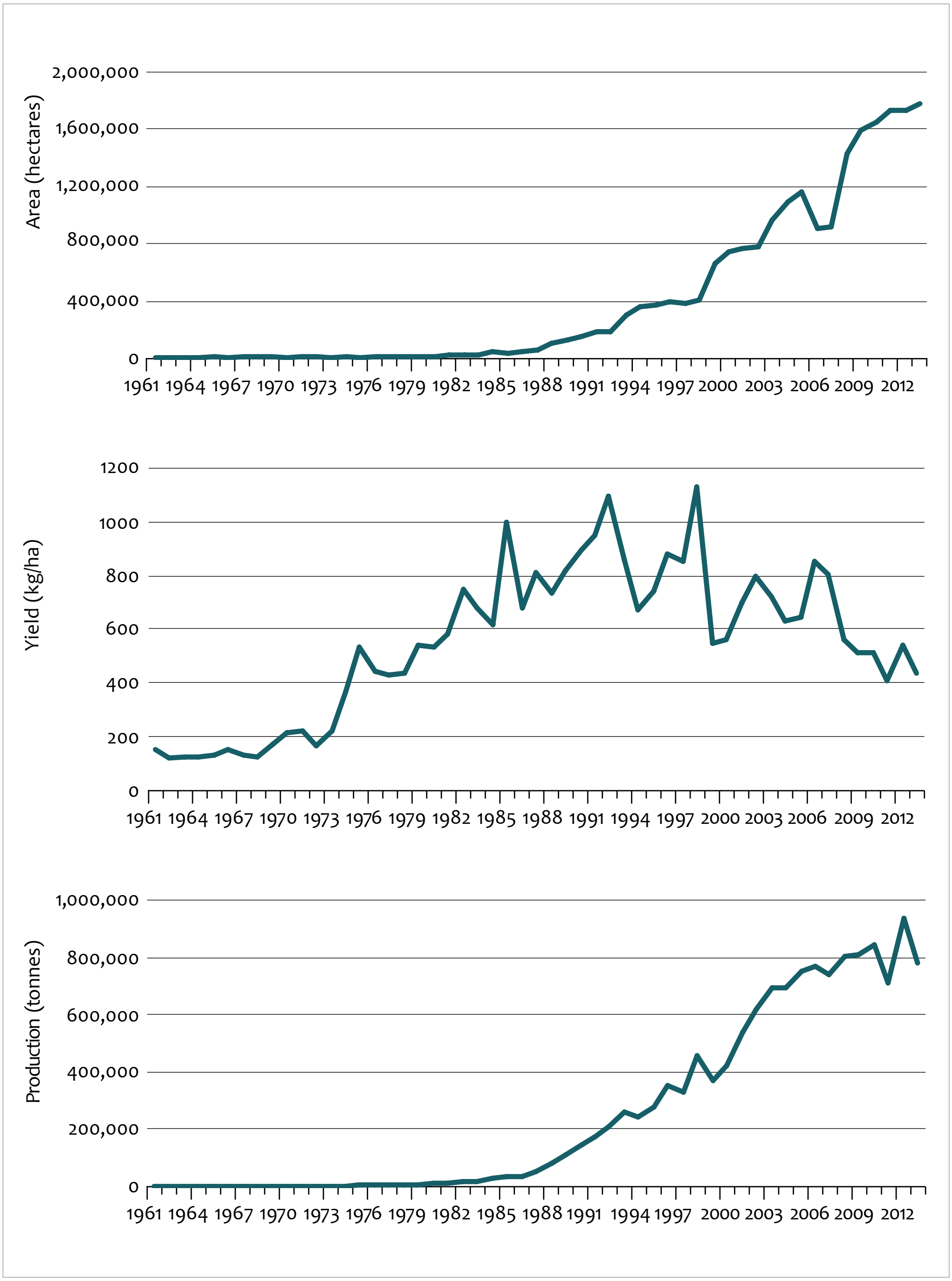
The area planted and growth in production have been more steady in PNG than in Indonesia, and the pattern of yield is very different. Since 1961, yield has fallen by an average of 0.4% per year, although with considerable variation from year to year.
It has fallen by 1% per year since 1995 and by around 6% per year since 2006. Thus, the decline seems to be accelerating, and is most likely a consequence of the emergence of CPB throughout PNG.

The most recent yield declines have contributed to significant production declines, offsetting the effect of recent increases in area planted, and have put production back almost to levels seen 20 years ago.



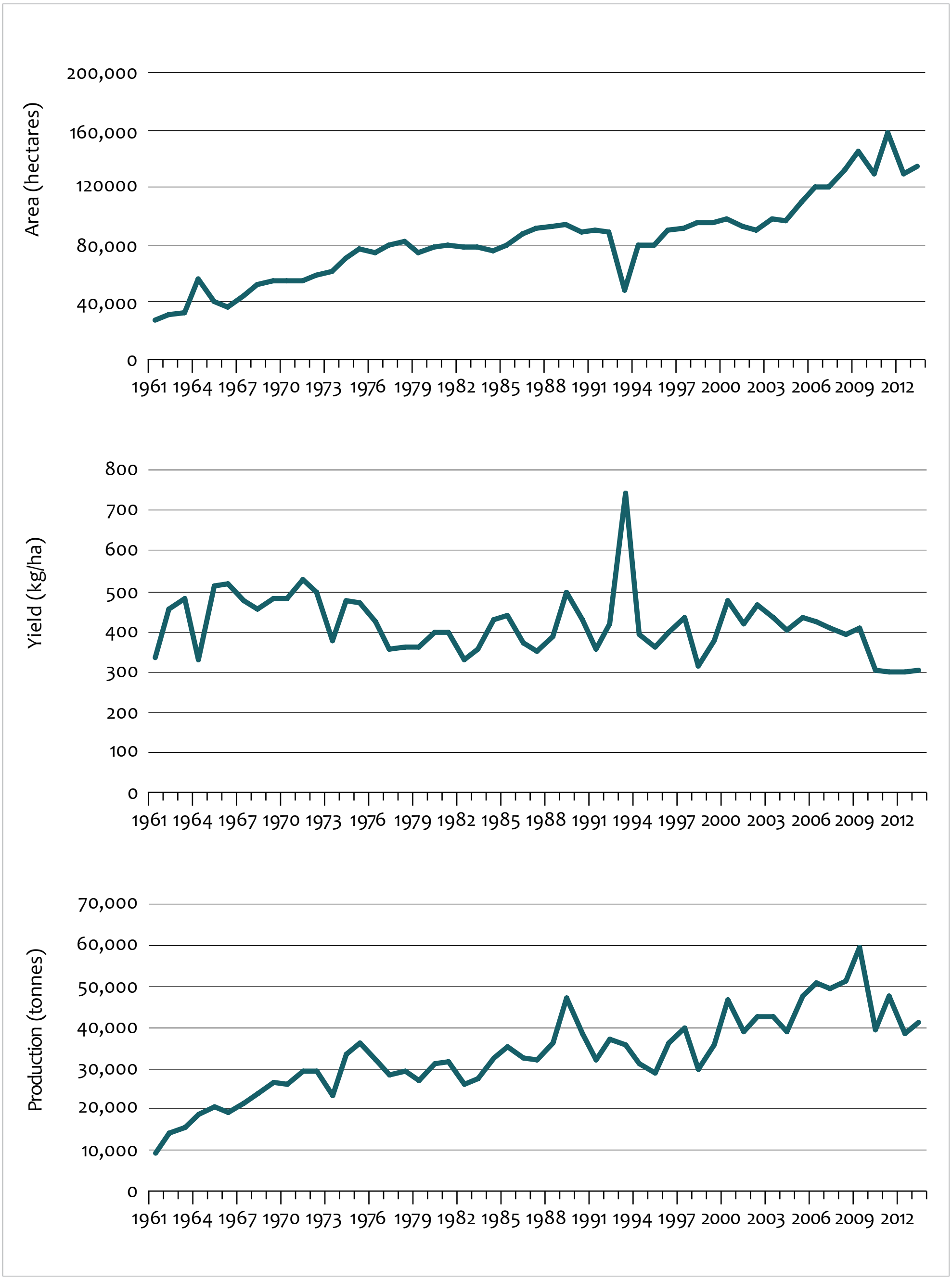
Data source: World Bank (2015)

Figure 2.3 Historical and forecast cocoa prices



Data source: Food and Agriculture Organization of the United Nations database at <http://faostat3.fao.org/home/E>

Figure 2.4 Cocoa area, yield and production in Indonesia



Data source: Food and Agriculture Organization of the United Nations database at <http://faostat3.fao.org/home/E>

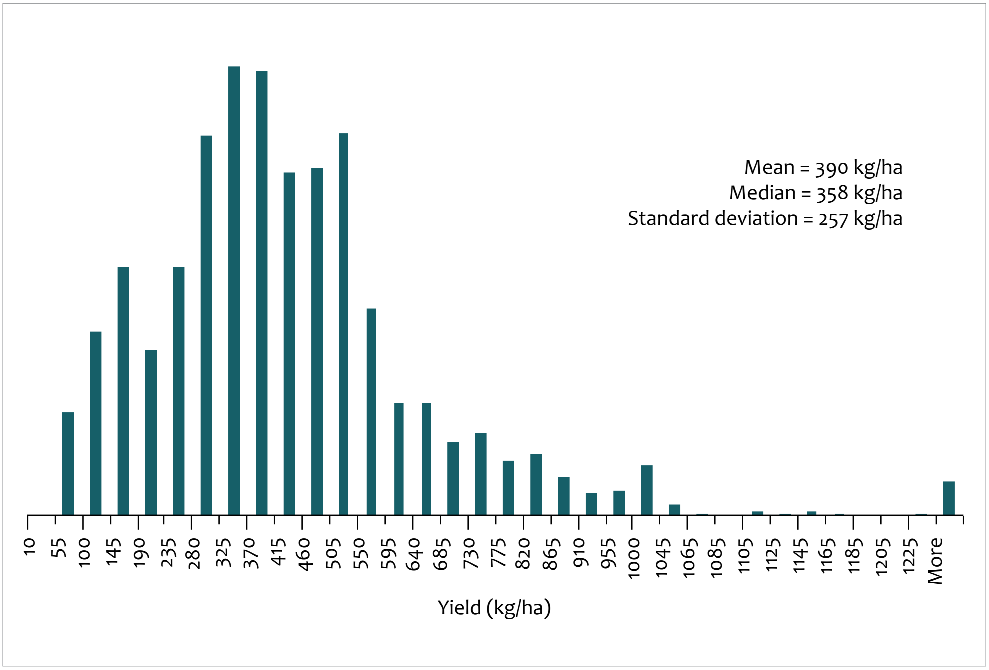
Figure 2.5 Cocoa area, yield and production in Papua New Guinea

The global yield context

Figure 2.6 shows the frequency distribution of cocoa yields for all cocoa-producing nations for the years for which data are available. This figure thus summarises much of the dynamics in cocoa production. As well as differences between countries, it also implicitly captures cocoa cycles (rapid growth and the fall in yield) for a number of countries. The frequency distribution is for aggregate observed yields across all production and so does not reflect the very high yields that can be achieved in individual circumstances.

These data help put yields from Indonesia and PNG in context, and provide some basis for assessing whether increases in yields as a consequence of research and extension activities are reasonable. For example:

- Indonesia's peak yields of just over 1000 kg/ha (in 1992 and 1998) were in the 98th percentile for global yields (i.e. in the top 2% of aggregate yields ever observed).
- Indonesia's current yield (around 440 kg/ha) puts it in the 66th percentile (the top 34% of observed aggregate yields).
- PNG's peak yield of around 500 kg/ha (in 1998, ignoring the peak in the graph that appears to be a data issue) was in the 78th percentile (top 22%).
- PNG's current yield (around 300 kg/ha) puts it in the 37th percentile.



Data source: Centre for International Economics calculation, based on Food and Agriculture Organization of the United Nations data

Figure 2.6 Frequency distribution of observed global cocoa yields

Modelling the impacts

In this report, the benefits of the research are modelled as an increase in economic surplus, arising from a vertical shift in the cocoa supply curve. Since the key project outcomes all involve an increase in yield, calculating the shift in the supply curve and measuring the associated economic surplus are consistent with ACIAR's guidelines for impact assessment.

While it is common practice to continue benefits indefinitely into the future, this approach has not been adopted here. Rather, benefits are assumed to accrue only to 2040.

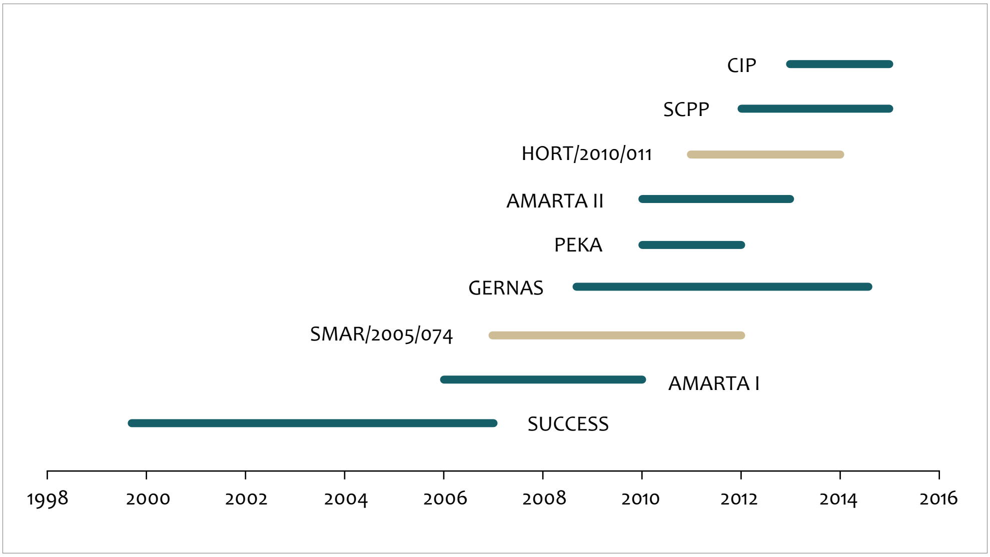
Because of the nature of pests and diseases, particularly the development of resistance and the emergence of new pests (as was seen dramatically in PNG) and diseases, it is unlikely that the technologies developed now will remain relevant in the future. Further, unless there is additional future research, we expect that the benefits of the current technologies will decline over time, so modelling benefits as continuing indefinitely is not appropriate.

3 Indonesia

ACIAR projects in context

ACIAR's projects in Indonesia represent one part of a very large and ongoing effort in Indonesia to improve cocoa yields. These projects have all been designed to deal with declining yields, tree ageing and pest problems that have arisen in recent decades.

In many cases, ACIAR projects have been undertaken in partnership with private sector organisations or associations of private sector organisations. Other projects have occurred before, during and after the ACIAR projects (Figure 3.1), and, in many cases, the content of the projects was very similar (see Table 3.1). In some cases, the various projects had similar partners (including the key private sector partner, Mars).



Data source: Various

Figure 3.1 **Broad timing of selected Indonesian cocoa projects**

Table 3.1 Overview of selected cocoa projects in Indonesia

Project and key players	Objective	Key outcomes
SUCCESS (including SUCCESS ALLIANCE): Sustainable Cocoa Enterprise Solutions for Smallholder Projects. Funded by the USDA and implemented by ACDI/VOCA. Included collaboration with private sector partners, including Mars	Initial focus was on CPB infestation Train Indonesian farmers in CPB control methods, particularly frequent harvesting, pruning, sanitary control of pod husks and litter	More than 100,000 farmers were trained Substantial reported adoption (up to 50%) of key control methods Reported benefits of US$435 per hectare per year
AMARTA I: USDA-funded Agribusiness Market and Support Activity. Included links with a wide variety of private sector agencies	Designed to strengthen value chains through improved links between smallholders and other stakeholders Included training in good agricultural practices (including IPDM) Project drew on material from ACIAR	Cocoa yields increased from 600 kg/ha to 995 kg/ha Just under 50,000 farmers were trained
GERNAS Kakao: Indonesian Government program covering Sumatra, Sulawesi and Java	Replant 70,000 ha of old and unproductive cocoa trees, and rehabilitate 235,000 ha of trees by side grafting Intensify production of 145,000 ha of trees Train 450,000 farmers in pest control ACIAR projects provided some input to program	Mixed views about the outcomes after the significant spending of US$100 million A common view is that it met with very mixed success
PEKA: Peningkatan Ekonomi Cacao Aceh, undertaken by Swisscontact and funded through a multidonor trust fund. Included interaction with private sector, including Mars	Rehabilitate aged cocoa gardens Intensify cultivation Train farmers	12,540 farmers were trained Mixed evidence on adoption
AMARTA II: continuation of AMARTA project funded by the USDA	See above	Limited evidence on outcomes

Table 3.1 ***continued***

Project and key players	Objective	Key outcomes
SCPP: Sustainable Cocoa Production Program, operated by Swisscontact with funding from the governments of Switzerland and the Netherlands, and private sector partners, including Cargill, Mars and Nestle	Train local government extension officers to serve as Farmer Field School facilitators Develop training manuals in cultivation practice, post-harvest operations and household nutrition Train 60,000 farmers Increase cocoa income by 75%	By end 2014, 46,000 farmers were trained Observed yield increased from 422 kg/ha to 688 kg/ha
CIP: Cocoa Innovations Project, undertaken by ACDI/VOCA in conjunction with the World Cocoa Foundation and specific World Cocoa Foundation members, including Mars	Essentially a continuation of activities under AMARTA I and II, including microfinance facilities for farmers	Limited information; benefit:cost ratio of around 7:1 was claimed in some documentation

CPD = cocoa pod borer; ha = hectare; IPDM = integrated pest and disease management; kg = kilogram; US = United States; USDA = United States Department of Agriculture

Source: Wolf, ACDI/VOCA, Swisscontact

Full information on the cost of these projects is not available; however, over the course of these projects, nominal expenditure has been estimated to be about US$150 million (including, for example, US$109 million for GERNAS, US$5.5 million for SUCCESS, US$5.8 million for AMARTA I, and probably around $5 to $10 million for the other main projects). Depending on the exact timing of this expenditure, in present-value, real terms, this is equivalent to $261 million. This compares with the ACIAR projects that have a real, present value of spending of $5.3 million. Thus, of the total resources devoted to very similar goals as the ACIAR projects, ACIAR spending is around 2%.

Potential for yield improvements as a consequence of research and extension

Evidence for the magnitude of yield improvements that could arise from a combination of better planting material, IPDM and general sanitary practice on-farm comes from several sources, including the following:

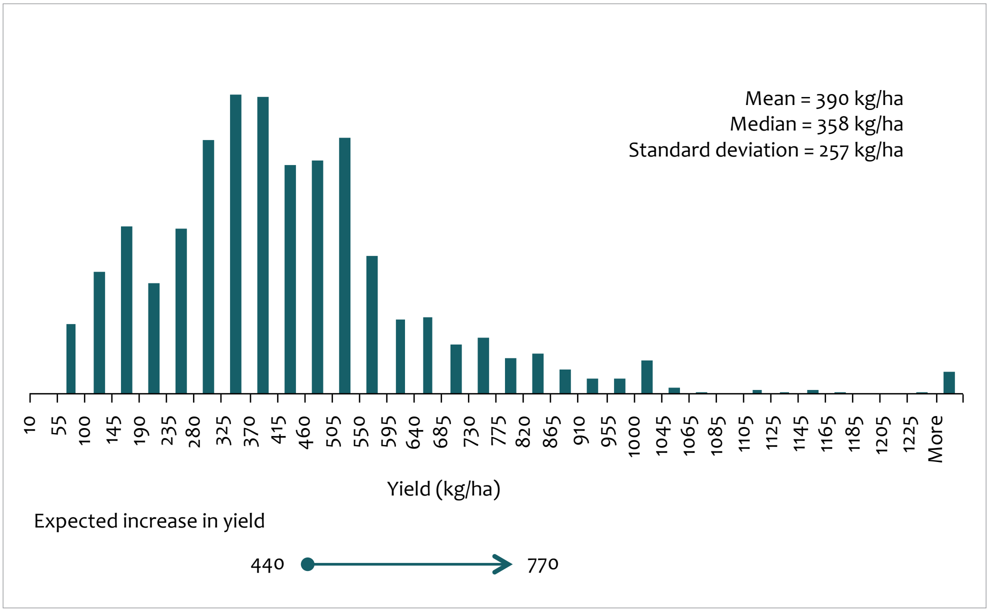
- Findings from the ACIAR research projects indicate the potential for a doubling of yield as a result of improved clones and farming practices.
- Field visits confirmed that farmers directly involved in extension activities associated with the ACIAR projects had doubled their yield (from around 500 kg/ha to 1,000 kg/ha, although this varies considerably between farmers).

- Valenzuela et al. (2014) report yield losses from CPB ranging from 10% to 40%. This implies a potential yield increase (assuming pest control) of between 11% and 67%.
- Juhrbandt et al. (2010) report yield loss from CPB and black pod disease of 44.8%. This implies a potential yield increase (assuming pest control) of 81%.
- Swisscontact (2015) report an observed yield increase from 422 kg/ha to 688 kg/ha, an increase of 63%.
- The United States Agency for International Development (USAID)–funded AMARTA project (2006–10) reported increases in yield from 600 kg/ha to 995 kg/ha, an increase of 66% (de Wolf 2013).

For the evaluation scenarios discussed below, we used a simple average of these results and assumed that a 75% increase in yield (relative to the 'without research' case) can be sustainably achieved by adopting the research outcomes from both the ACIAR projects and the related projects. As discussed further in 'Production costs', this increase in yield will also require the use of additional production inputs, and so 75% is not the net economic gain to farmers.

Putting the yield increase in context

If fully adopted, this projected yield increase would take Indonesian average yield from the current 66th percentile to the 94th percentile (Figure 3.2). This would move Indonesia back towards outcomes seen before the recent declines. The implications of particular adoption rates for aggregate yields are discussed in 'Implications of this adoption profile'.



ha = hectare; kg = kilogram

Data source: Food and Agriculture Organization of the United Nations, Centre for International Economics estimates

Figure 3.2 Indonesian increase in cocoa yield as a proportion of global yield

Production costs

Table 3.2 summarises representative data for smallholder production costs, derived from published studies and field visits. Two variants are shown, reflecting a range of observed yields and cost structures. The costs are the pre-research costs, which are adjusted to estimate the magnitude of the vertical shift in the supply curve that is attributed to the research outcomes.

The two variants presented reflect a substantial difference in the use of purchased inputs for production, with the 'high yield, high input' variant producing almost double the yield but at higher purchased input costs (and a smaller profit margin). These variants are designed to reflect a range of outcomes that are currently (or recently) observed in Indonesia.

It is difficult to completely disentangle the effects of previous extension programs on these measured cost structures, but, given current aggregate yields observed in Indonesia, it is reasonable to interpret the 'low yield, low input' variant as representing the pre-research outcome. This is certainly consistent with the reported experience of farmers interviewed during field visits.

The high-yield, high-input variant is included as a form of sensitivity analysis, but also to capture that some producers may not use inputs as efficiently as possible, or not combine them with the best IPDM practice. Thus, even relatively high-yielding farmers have the opportunity to further improve economic outcomes.

Table 3.2 Indonesian smallholder cost structures, per hectare, pre-research

Variable	Low yield, low input	High yield, high input
Cost as a share of revenue (%)		
Family labour	15	15
Hired labour	2	4
Purchased inputs	6	12
Total	23	31
Dry bean yield (kg/ha)	440	800
Exchange rate (Rp to US$)	0.000077	0.000077
Dry bean price (US$/kg)	2	2
Dry bean price (Rp/kg)	25,974	25,974
Total revenue (Rp)	11,428,571	20,779,221
Total cost (Rp)	2,628,571	6,441,558
Profit/revenue	0.77	0.69

ha = hectare; kg = kilogram; Rp = rupiah; US = United States

Source: Centre for International Economics estimates, based on field visits; Ruf and Siswoputranto (1995), Perdew and Shively (2009), Fahmid (2013)

Supply shift following research

Table 3.3 shows the calculations of the vertical shift in the supply curve associated with the potential research and extension–induced increase in yield summarised above. This supply shift accounts for both the increase in yield and the required increase in input costs needed to achieve the increased yield.

The increase in yield alone lowers costs (per kilogram) by around 43%. This is assumed to be the same for both cost variants, although it leads to a very high yield in the case of the high-yield, high-input variant.

The nature of the techniques and practices generated by the research also requires that input costs increase to allow the yield increase. This is either an increase in labour costs or an increase in other input costs, such as fertiliser. An estimate of the required increase in input costs is taken from a recent survey of 600 smallholders in Sulawesi (Perdew and Shively 2009), and is consistent with interviews undertaken for the Indonesain and PNG projects during field visits.[1]

Accounting for this increase in costs, the net cost saving (in kilograms) as a consequence of adopting the research outcomes ranges from 0.23 to 0.28 of the output price (in kilograms). This is a measure of the extent of the vertical shift in the supply curve induced by the research.

Table 3.3 Net cost savings after research (vertical shift in supply curve), Indonesia

Variable	Low yield, low input	High yield, high input
Yield increase induced by adoption of research outcomes (%)	75	75
New yield (kg/ha)	770	1400
Cost before research (Rp/kg)	25,974	25,974
Cost before research (Rp/ha)	11,428,571	20,779,221
Cost after research (due to yield increase, Rp/kg)	14,842	14,842
Cost reduction due to yield increase alone (Rp/kg)	11,132	11,132
Required increase in inputs to achieve yield increase (%)	110	110
Incremental cost (Rp/ha)	2,891,429	7,085,714
Incremental cost (Rp/kg)	3,755	5,061
Net cost saving after research (Rp/kg)	7,377	6,071
Net cost saving as a proportion of price	0.28	0.23

ha = hectare; kg = kilogram; Rp = rupiah

Note: Increase in inputs is calculated from elasticities reported in Table 7 of Perdew and Shively (2009). These elasticities indicate that a 0.679% increase in inputs leads to a 1% increase in yield. Therefore, a 75% increase in yield requires a 110% increase in inputs. Inputs are assumed to increase uniformly.

Source: Centre for International Economics estimates, using parameters from Perdew and Shively (2009)

[1] The results from Perdew and Shivley (2009) have also been used as the basis of a research report—'The 2020 roadmap to sustainable Indonesian cocoa' (www.newforesight.com/wp-content/uploads/2014/06/CSP-Roadmap-Report_here2.pdf)—by NewForesight, commissioned by the Cocoa Sustainability Partnership (CSP). The CSP was established in 2006; it includes a number of private and public members, and includes ACIAR as a partner.

Indicative annual benefits from research and extension

Demand and supply parameters

Calculating the surplus increase from research requires assumptions about supply and demand parameters. The demand parameters are particularly important for determining smallholder gains in the presence of an export tax (as discussed below).

Two recent studies have reported cocoa demand and supply elasticities for Indonesia (ICCO 2008; Permani 2013). The average result from these studies suggests a supply elasticity of 0.4 and a demand elasticity of –1.

The export tax complication

In 2010, Indonesia introduced an export tax on cocoa (up to 10%, depending on the volume). This tax has been controversial, but its effects have been dramatic: before the tax, 75% of exports were raw cocoa beans; by 2012, 76% of cocoa was exported in a processed form (mainly butter), and only 24% was exported as raw beans.

A key effect of an export tax is that it provides a subsidy to local consumers (processors) at the expense of farmers, and possibly foreign consumers. The export tax unambiguously lowers the price to farmers, is likely to lower the price to local consumers, raises government revenue, and may raise world prices and thus tax foreign consumers. In theory, an 'optimal' export tax will increase welfare if the increase in government revenue, and the benefit to local consumers outweigh the lost surplus to producers. This net gain, were it to actually occur, would clearly not be of much comfort to farmers who are paying the price—particularly as there is no guarantee that the tax proceeds go back into the cocoa industry.

In terms of evaluating the impacts of research, a key implication of the export tax is that not all the benefits of research gains accrue to the smallholder producers. Rather, some accrue to domestic consumers (processors), and some accrue to the government in the form of export revenue (some may also accrue to foreign consumers). To deal with this, we present a range of surplus results showing the potential benefit to smallholders, as well as the total potential benefit from the yield increase.

Potential annual benefits

Table 3.4 presents estimates of the increase in economic surplus, assuming a 75% increase in yield and using the underlying net saving parameters from Table 3.3.[2] The table contains four sets of results, one set for each of the lower and upper cost and yield variants, each with two surplus measures (full economic surplus and the surplus accruing to producers only).

For example, using the low-input, low-yield cost variant and looking at the full possible surplus from the research suggests annual benefits of $588 million. This is equivalent to $331 per hectare or approximately $497 per farm (assuming an average farm size of 1.5 ha). Accounting for the fact that some of these benefits will accrue to domestic users and government, the surplus to smallholders is estimated to be $413 million—$233 per hectare or $350 per farm.

Under the high-input, high-yield variant, the benefits are correspondingly lower (reflecting the smaller supply shift calculated in Table 3.3).

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2 For this calculation, baseline production is set at 777,500 tonnes, which is the 2013 value reported by the Food and Agriculture Organization of the United Nations, and just slightly higher than expectations for 2015.

Table 3.4 also shows results at the present value over 30 years (using a real discount rate of 5%). Looking across the full range of benefits, the present value per farm ranges from $4,391 to $7,640. Since the present value of ACIAR funding for the two projects covered here is $5.3 million, this implies that to achieve a benefit:cost ratio (BCR) of 1 (over 30 years) the ACIAR projects need to be responsible for increasing the yields of between 694 and 1,207 farms.

Table 3.4 Potential annual benefits from a 75% increase in cocoa yield, Indonesia

Variable	Full surplus	Producer gain only
Assuming low-input, low-yield variant		
Annual benefits		
$ million	588	413
$/hectare	31	233
$/farm	497	350
Present value over 30 years		
$ million	9,038	6,356
$/hectare	5,093	3,582
$/farm	7,640	5,373
Assuming high-input, high-yield variant		
Annual benefits		
$ million	479	338
$/hectare	270	190
$/farm	405	286
Present value over 30 years		
$ million	7,367	5,195
$/hectare	4,151	2,928
$/farm	6,227	4,391

Note: Real discount rate is 5%.
Source: Centre for International Economics estimates

Potential research gains to 2040

The results in Table 3.4 are the benefits from full adoption of the techniques and inputs required to increase yield in the presence of a variety of pests, the reduction in nutrients and the need to replace ageing trees.

An alternative way to determine the benefits is to construct an adoption profile to 2040, which is 33 years from when the ACIAR-funded projects started in 2007.

Constructing an adoption profile

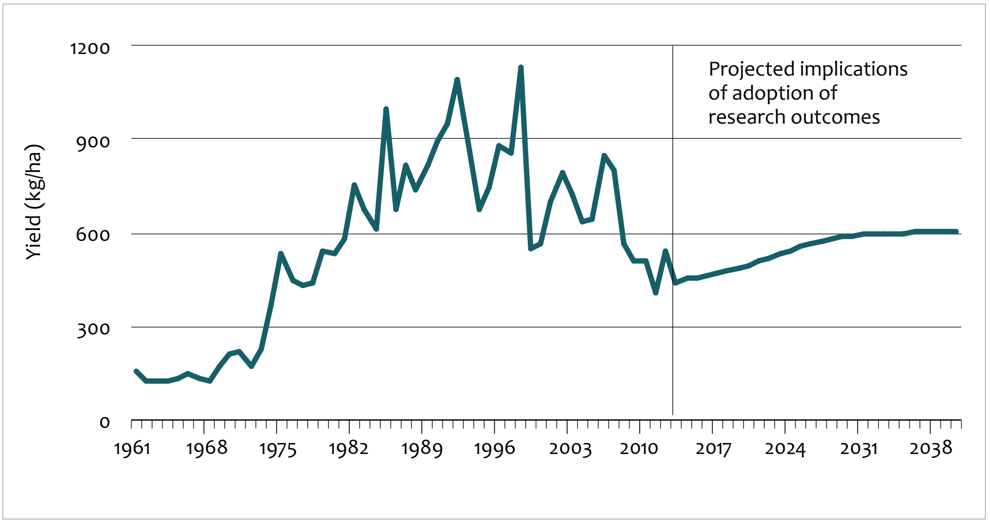
Measuring adoption of improved techniques and inputs is problematic. Despite a large number of projects aimed at disseminating good research practices, there is no systematic estimate of how these outcomes have been adopted over time.

The approach to constructing an adoption profile for the results presented here is as follows:

- First, we assume that the maximum adoption rate will be 50% and that half of this will be achieved by 2022, with the maximum achieved by 2040. This assumption is broadly based on recent experience in Sulawesi, where it is estimated that 30–40% of farmers receiving intensive training adopt new techniques. Over a longer time frame, it is possible (but by no means certain) that 50% of farmers could adopt the improved techniques developed by the ACIAR and related projects.
- Second, the rate of increase within this broad period (the slope coefficient of the S-curve used for adoption) needs to be calibrated. Between 2007 and 2015, around 100,000 farmers have been systematically trained in good farming practices (see de Wolf 2013 and Swisscontact 2015). Assuming that half of these farmers fully adopt the practices (consistent with recent experience), this implies an economy-wide adoption rate of around 5–6% in 2015. This rate is used to calibrate an adoption curve.

Implications of the adoption profile

This adoption rate, when used to estimate aggregate yields, projects a reversal of the recent yield declines and a return to an economy-wide average of around 600 kg/ha (Figure 3.3).



Data source: Food and Agriculture Organization of the United Nations for historical data, Centre for International Economics estimates for projections

Figure 3.3 **Implied yields from assumed adoption rate, Indonesia**

Whereas yield was falling at an average annual rate of 3.5% from 1996, under this adoption profile it increases at an average annual rate of 1.3% from 2015.

In terms of the percentiles discussed before, this would take Indonesia from the 66th percentile to the 87th percentile.

Economic gains from the research and assumed adoption profile

Table 3.5 summarises the present value of the increased economic surplus resulting from the net yield improvement, using the adoption profile discussed above and net benefits from the research.

The benefits reported here are attributable to all the research and extension in Indonesia, not just the ACIAR projects, for the reasons discussed in 'ACIAR projects in context'.

Benefits range from $1,382 million to $2,371 million.

Assuming total costs of $266 million—an estimate only, for the reasons discussed above—then BCRs from the research range from 5 to 9.

Because of the uncertainty surrounding the magnitude of the total costs incurred in all projects to date, these BCR estimates should be treated as very approximate.

Table 3.5 Potential benefits, costs and net benefits: all Indonesian projects

Variable	Low yield, low input	High yield, high input
Benefits (2015A$ million)		
Full surplus	2,371	1,944
Producer surplus only	1,684	1,382
Cost (2015$A million)	266	266
Net benefits (2015$A million)		
Full surplus	2,105	1,678
Producer surplus only	1,418	1,116
Benefit:cost ratios		
Full surplus	9	7
Producer surplus only	6	5
Internal rate of return (%)		
Full surplus	21	19
Producer surplus only	18	16
External rate of return (%)		
Full surplus	7	6
Producer surplus only	6	5

Source: Centre for International Economics estimates

Attribution to ACIAR: cost share versus bringing adoption forward

Further assumptions are needed to attribute benefits to specific ACIAR-funded projects. The analysis below presents the results from two methods of allocating benefits to the ACIAR-funded projects: cost shares and bringing adoption forward.

Method 1: cost share

In the absence of other information, the most common attribution method is to apportion benefits between research projects using individual projects' shares in the total cost of all projects covered. As noted, the ACIAR-funded projects covered in this report account for an estimated 2% of total expenditure (in present-value terms).

Table 3.6 reports the ACIAR-funded project outcomes using this method.

Table 3.6 Results for ACIAR-funded Indonesian projects attributing benefits using cost shares

Variable	Low input, low yield	High input, high yield
Benefits (2015$A million)		
Full surplus	45	37
Producer surplus only	32	26
Cost (2015$A million)	5.3	5.3
Net benefits (2015$A million)		
Full surplus	40	32
Producer surplus only	27	21
Benefit:cost ratios		
Full surplus	9	7
Producer surplus only	6	5
Internal rate of return (%)		
Full surplus	23	21
Producer surplus only	19	17
External rate of return (%)		
Full surplus	7	6
Producer surplus only	6	5

Source: Centre for International Economics estimates

Method 2: bringing adoption forward

A significant proportion of the costs (around two-thirds) of all the recent projects associated with cocoa accrue to the GERNAS project. Field visits to Indonesia indicated very mixed views about the success (or otherwise) of GERNAS. Given some concerns that GERNAS has not achieved its aims (or has not necessarily achieved relative to the level of expenditure), it is possible that the ACIAR-funded projects have generated a return marginally higher than would be indicated by simply apportioning benefits according to cost shares (this could also be true of the other projects, but they are not the focus of analysis here).

One way of getting a sense of this is to examine the implications of bringing adoption from the ACIAR-funded research forward by 1 year (relative to the baseline adoption profile set out above; Table 3.7). Although there is no direct evidence that this has been the case, the assumption that benefits are brought forward by 1 year is not unreasonable, given the nature of the ACIAR-funded research.

The benefits attributed to the ACIAR-funded research are considerably higher under this method. Bringing benefits forward by a year roughly corresponds to 7% of total project benefits, which is clearly greater than the 2% under the cost share method.

Table 3.7 Results for ACIAR-funded Indonesian projects, assuming adoption is brought forward by 1 year

Variable	Low input, low yield	High input, high yield
Benefits (2015$A million)		
Full surplus	168	138
Producer surplus only	120	98
Cost (2015$A million)	5.3	5.3
Net benefits (2015$A million)		
Full surplus	163	133
Producer surplus only	115	93
Benefit:cost ratios		
Full surplus	32	26
Producer surplus only	23	18
Internal rate of return (%)		
Full surplus	63	58
Producer surplus only	55	50
External rate of return (%)		
Full surplus	11.0	10.4
Producer surplus only	9.9	9.2

Source: Centre for International Economics estimates

Sensitivity analysis

The results presented above provide one view of the potential benefits from cocoa research in Indonesia. Given uncertainties surrounding adoption rates and the magnitude of the supply shift, it is important to use systematic sensitivity analysis to understand the full range of potential results. A Monte Carlo analysis is used, where a wide range of input variables (see Table 3.8) are used to produce a large number of output results, giving a picture of the full distribution of outcomes.

In all cases, the ranges for the input variables are assumed to follow a uniform distribution. These variations are designed to represent a range of possible outcomes. The variation in the ACIAR cost share is introduced to simulate uncertainty in both underlying total costs and in the appropriate attribution to ACIAR. The upper bound of the cost share, for example, arises by assuming that the GERNAS project was only half as effective as its overall level of funding would suggest.

Figures 3.4 and 3.5 show the sensitivity of total and producer net benefit outcomes to changes in key underlying assumptions for both the cost share method and the adoption brought forward method, respectively. In each case, the five most important input variables are shown.

These figures illustrate how key outcomes (on the vertical axis) vary as the input variables change over their range. The steeper the relevant curve, the more sensitive outcomes are to that particular variable.

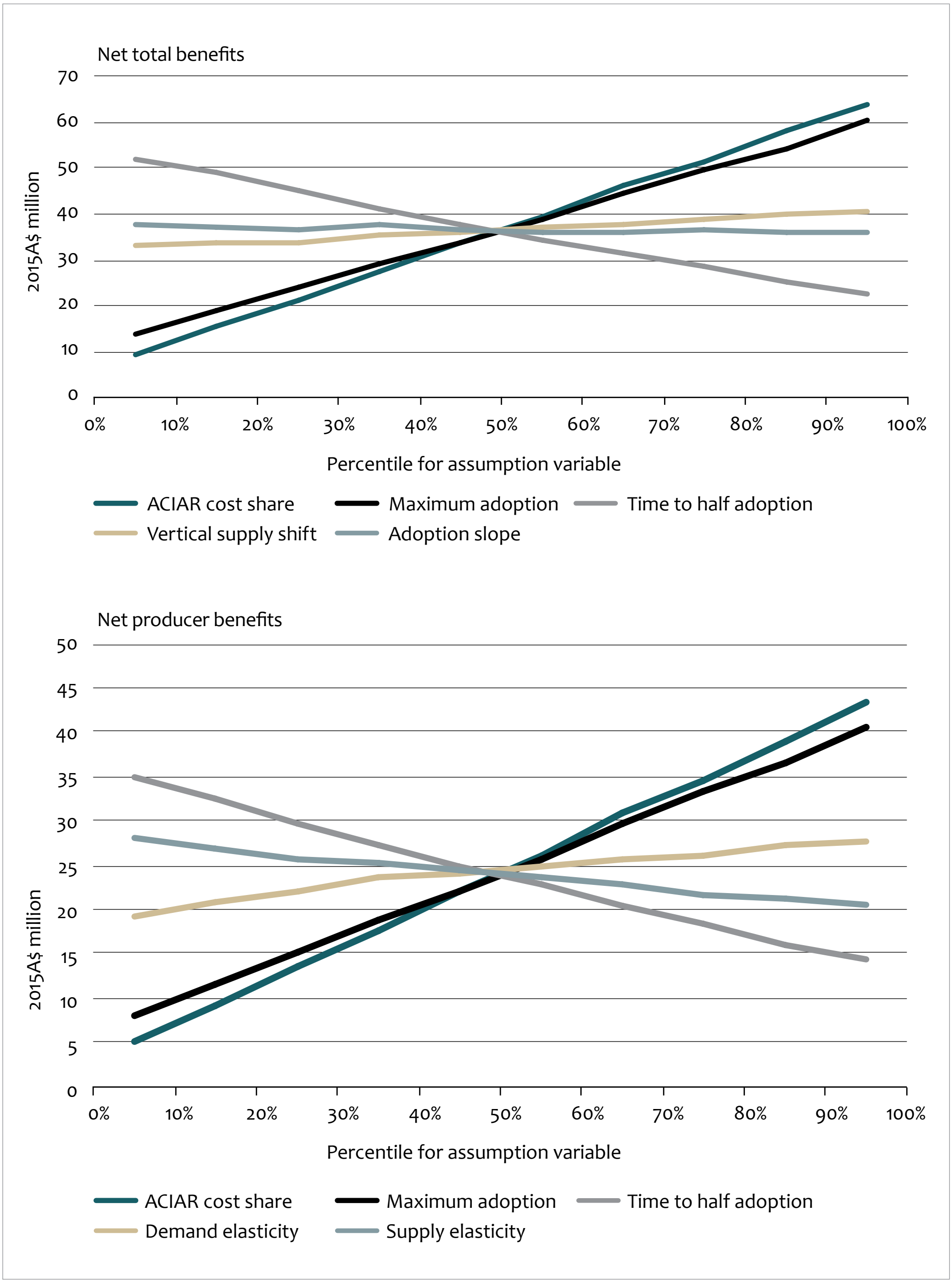
A number of important points emerge from these figures:

- Under the cost share method
    - net benefits are most sensitive to the value of the ACIAR cost share, followed closely by the maximum adoption rate and the time to half adoption
    - the magnitude of the vertical supply shift and the slope of the adoption curve are considerably less important in driving the overall range of results
    - net producer benefits are also determined by the values of the demand and supply elasticities, as these determine the distribution of benefits between producers and consumers.

Table 3.8 Assumptions underlying Indonesian sensitivity analysis

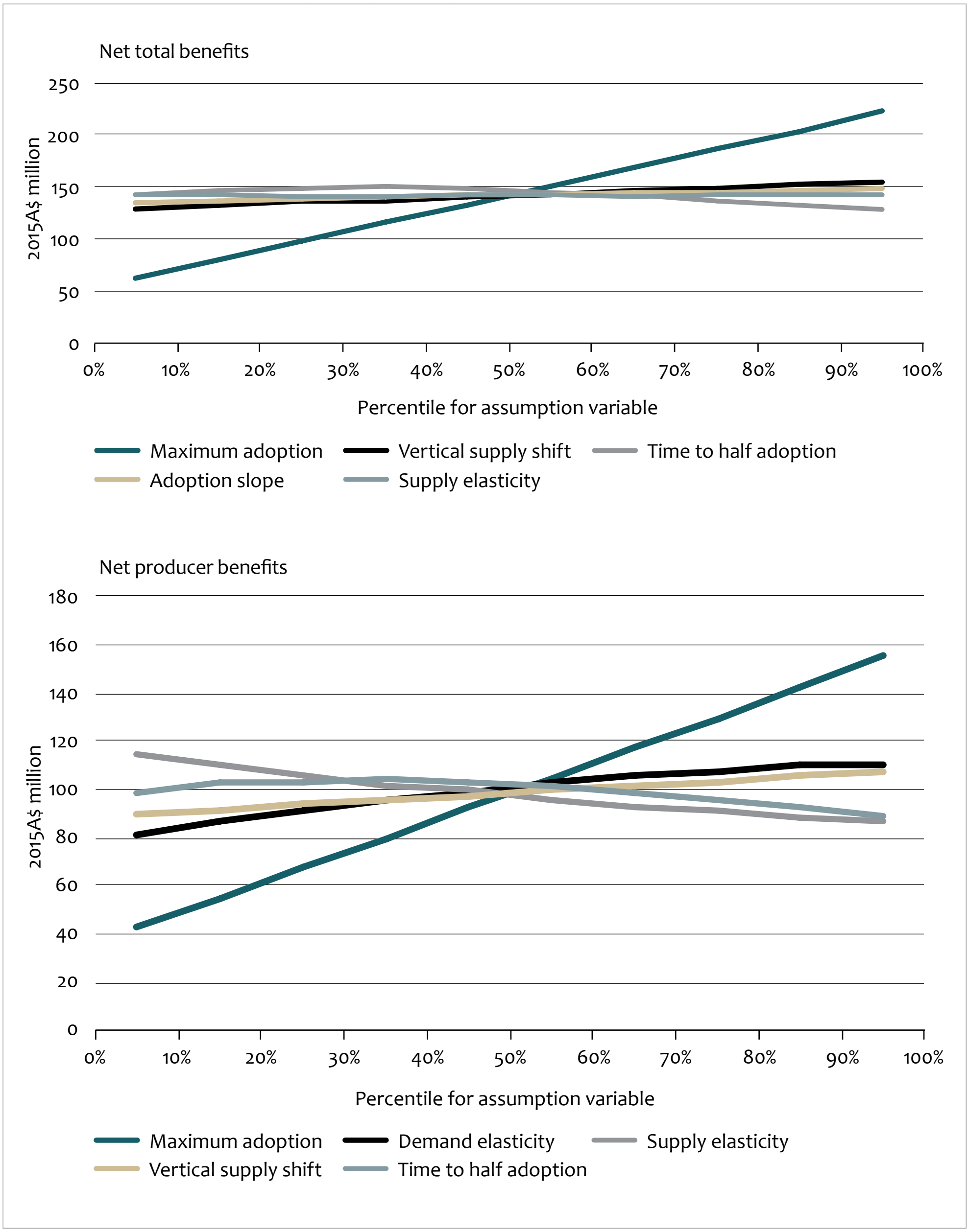
Variable	Lower	Upper
Maximum adoption rate (%)	20	80
Year to half adoption (year)	2017	2027
Adoption slope (unit)	0.24	0.36
Vertical supply shift (Rp/kg)	6071	7377
Demand elasticity	–0.5	–1.5
Supply elasticity	0.2	0.6
ACIAR cost share (%)	0.5	3.5

kg = kilogram; Rp = rupiah
Source: Centre for International Economics estimates



Data source: Centre for International Economics estimates

Figure 3.4 Sensitivity of total and producer net benefits, cost share method, Indonesia

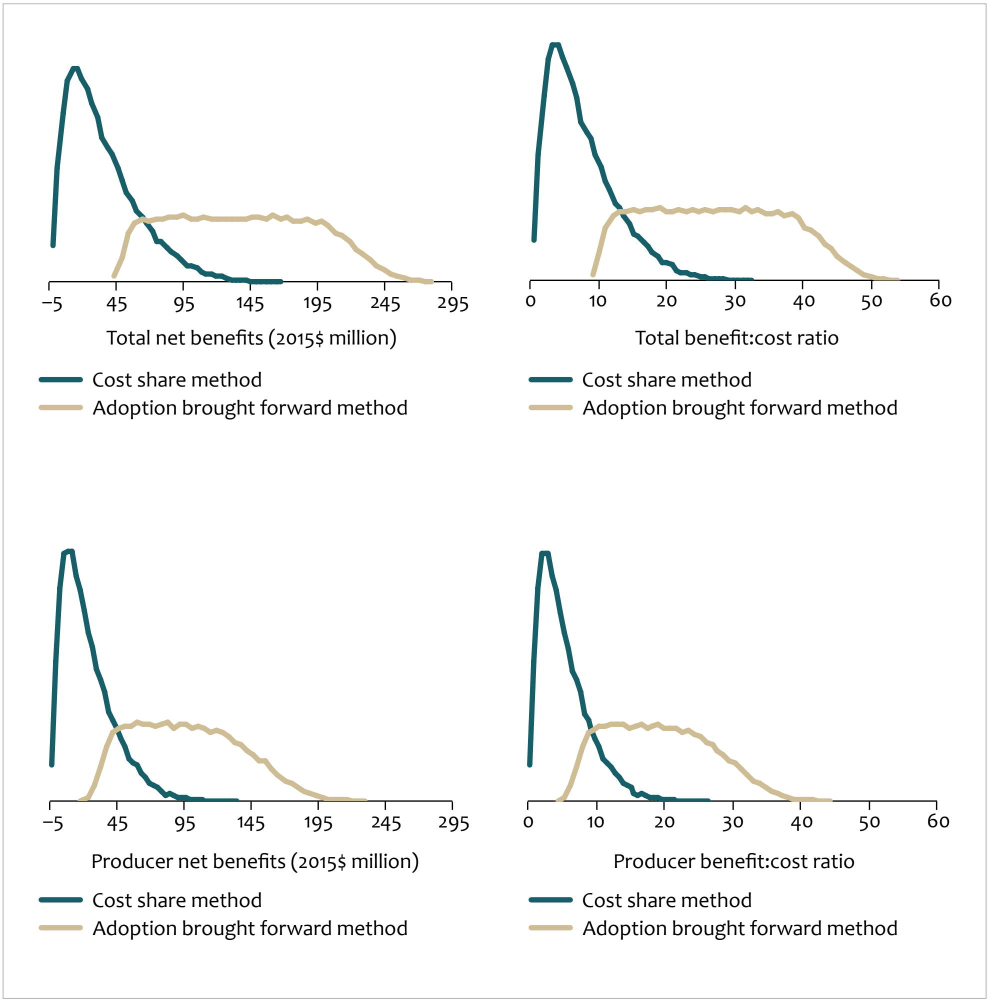


Data source: Centre for International Economics estimates

Figure 3.5 Sensitivity of total and producer net benefits, adoption brought forward method, Indonesia

The probability distributions for the net benefits and the BCRs (total and producer) associated with both methods show (Figure 3.6):

- the two methods generate distinctly different shapes for the probability distribution. For the cost share method, the distribution is narrower and is skewed to the left—a direct consequence of the shape of the adoption curve. For the adoption brought forward method, the outcomes are much more uniform, reflecting an implicitly differently shaped adoption curve
- there is some overlap between estimates generated by the two methods.



Data source: Estimates by the Centre for International Economics

Figure 3.6 Probability distribution for net benefits and benefit:cost ratio, Indonesia

Results from the systematic sensitivity analysis are summarised in Table 3.9 for the cost share method and in Table 3.10 for the adoption brought forward method.

For the cost share method:

- The total BCR range is from 0.5 to 30.7. The BCR is less than 1 in 0.4% of cases and greater than 10 in 28% of cases.
- The BCR based on producer benefits ranges from 0.3 to 25.6. The probability of a BCR less than 1 is 1.8%, while the BCR is greater than 10 in 12% of cases.
- Total net benefits range from –$2.5 million to $157.8 million. These net benefits are negative in 0.8% of cases and greater than $100 million in 2.5% of cases.
- Net benefits based on producer gains range from –$3.6 million to $130.4 million. These net benefits are negative in 1.8% of cases and greater than $100 million in 0.1% of cases.

Table 3.9 Sensitivity analysis results: cost share method, Indonesia

Variable	Minimum	Maximum	Mean	Median	Mode
Benefits (2015$A million)					
Full surplus	2.8	163.1	42.0	36.0	19.7
Producer surplus only	1.7	135.7	29.4	25.1	172
Net benefits (2015$A million)					
Full surplus	–2.5	157.8	36.7	30.7	14.4
Producer surplus only	–3.6	130.4	24.1	19.8	11.9
Benefit:cost ratios					
Full surplus	0.5	30.7	7.9	6.8	3.7
Producer surplus only	0.3	25.6	5.5	4.7	3.2
Internal rate of return (%)					
Full surplus	8.4	152.3	24.0	21.3	18.7
Producer surplus only	5.3	77.4	19.1	17.6	15.2
External rate of return (%)					
Full surplus	–1.9	10.9	5.8	6.0	6.6
Producer surplus only	–3.2	10.3	4.7	4.8	5.1

Source: Centre for International Economics estimates

For the adoption brought forward method:

- The total BCR ranges from 9.2 to 53.5, with only a 12% chance of a BCR less than 15 and a 13% chance of one greater than 40. In most cases (75%), the range is from 15 to 40.
- The producer benefit BCR ranges from 4.5 to 44.8. The chance of a BCR less than 10 is 10%, and the chance of one greater than 30 is 10%. It is between 10 and 30 in 80% of cases.
- For total net benefits, the full range is from $43.4 million to $278.4 million. The chance of net benefits less than $100 million is 27%, and the chance of net benefits greater than $200 million is 17%.
- For net benefits based on producer benefits, the range is from $18.4 million to $232.5 million. The chance of producer net benefits being less than $100 million is 53% and being greater than $200 million is only 0.3%.

Table 3.10 Sensitivity analysis results: adoption brought forward method, Indonesia

Variable	Minimum	Maximum	Mean	Median	Mode
Benefits (2015$A million)					
Full surplus	48.7	283.7	147.3	146.4	194.7
Producer surplus only	23.7	237.8	104.0	101.6	65.6
Net benefits (2015$A million)					
Full surplus	43.4	278.4	142	141.1	189.4
Producer surplus only	18.4	232.5	98.7	96.3	60.3
Benefit:cost ratios					
Full surplus	9.2	53.5	27.8	27.6	36.7
Producer surplus only	4.5	44.8	19.6	19.2	12.4
Internal rate of return (%)					
Full surplus	25.4	102.7	59.2	58.0	48.7
Producer surplus only	18.4	95.9	51.2	49.8	43.5
External rate of return (%)					
Full surplus	6.9	12.8	10.4	10.6	11.5
Producer surplus only	4.6	12.2	9.2	9.4	10.1

Source: Centre for International Economics estimates

4 Papua New Guinea

Dominance of a moth

In 2006, the CPB moth was discovered on East New Britain. CPB is known throughout Asia as a major pest of cocoa trees, and its appearance was a major blow to the PNG cocoa industry. Initial attempts to eradicate the moth—through large-scale destruction of trees—were not successful, and CPB is now established throughout PNG.

Various control techniques for CPB have long been known and used, and it turns out that the IPDM techniques developed as part of project ASEM/2003/115, while not specifically targeted at CPB, were successful in controlling it. Subsequent research (PC/2006/114) further developed options for CPB control within the IPDM framework. This, combined with a better understanding of the factors that lead to adoption (ASEM/2006/127), has provided a sound basis for ongoing control of CPB.

Field visits strongly indicated that, whereas the emergence of CPB created great uncertainty and distress among cocoa farmers (leading many of them to abandon their plots), the development and dissemination of IPDM techniques have led to dramatically increased confidence in cocoa growing. The model farmers have achieved substantial increases in yield, and adoption of the IPDM techniques has extended beyond the original project areas.

These projects are interesting in that they do not just deliver a single technology (although this is present in new planting material and in increased understanding of disease dynamics), they also propose a change in farming practices to achieve better outcomes (particularly yield). These better practices require increased inputs (particularly labour and, in some cases, fertiliser and pesticides). The need for increased inputs creates a particular challenge to adoption, especially in parts of PNG where most cocoa farming is typically very low input (Curry et al. 2007).

A complex economic and social calculation within farming households and communities is involved when considering adopting these practices. The opportunity cost of labour is key here.

Potential yield increase

Field visits suggested that a number of key farmers doubled their yield after adopting outcomes from the ACIAR-funded research.

World Bank research suggests that yield increases of between 150% and 180% are possible (World Bank 2010).

Research within project PC/2006/114 suggests yield increases (relative to low-cost management) of between 80% and 170% (Tuck et al., no date).

Thus, the range of the yield increases is 150–180%.

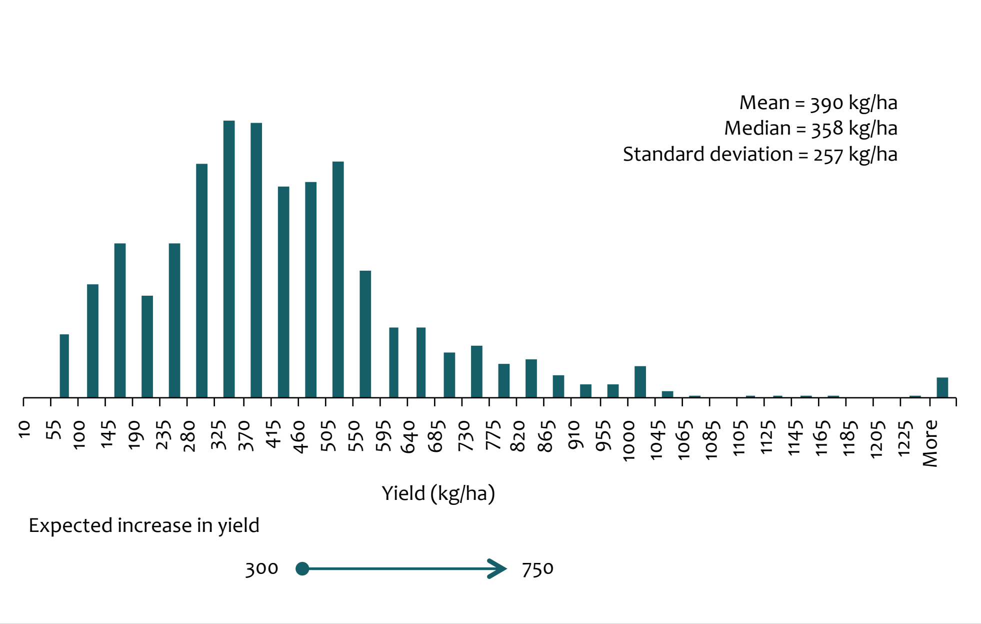
Potential yield increase in context

If the IPDM practices were fully adopted, they would take PNG yield from the 37th percentile to the 93rd percentile (Figure 4.1). The average effect in aggregate depends, of course, on the adoption rate.

Cost structures

Cost structures derived from World Bank and ACIAR project sources have different estimates of underlying costs under both the baseline and with research outcomes. The World Bank analysis provides for two improvement options: one using IPDM and other improved farming techniques on old cocoa trees, and the other using IPDM and other improved farming techniques along with new trees (possibly via grafting; Table 4.1).

The ACIAR project outcomes show three different levels of farming practice, with increasing yield (and costs) for each option (Table 4.2).



Data source: Food and Agriculture Organization of the United Nations, Centre for International Economics estimates

Figure 4.1 **PNG increase in cocoa yield as a proportion of global yield**

Table 4.1 Cost structure from World Bank project outcomes, PNG

Variable	Baseline	Old cocoa improvement	New cocoa improvement
Yield (kg/ha)	300	750	850
Variable costs (kina)	250	704	786
Labour cost (kina)	270	663	768
Selling price (kina/kg)	4.56	4.56	4.56
Revenue (kina)	1,368	3,420	3,876
Labour cost share of revenue (%)	20	19	20
Variable cost share of revenue (%)	18	21	20
Net return (kina/ha)	848	2,053	2,322
Profit share of revenue (%)	62	60	60

ha = hectare; kg = kilogram
Source: World Bank (2010)

Table 4.2 Cost structure from ACIAR project outcomes, PNG

Variable	Baseline	Option 2	Option 3	Option 4
Yield (kg/ha)	260	468	649	699
Cost (kina/ha)	384	720	1,636	1,646
Price (kina/kg)	4.56	4.56	4.56	4.56
Revenue (kina)	1,187	2,136	2,961	3,186
Cost share of revenue (%)	32	34	55	52
Net return (kina/ha)	803	1,416	1,325	1,540
Profit share of revenue (%)	68	66	45	48

ha = hectare; kg = kilogram
Source: Tuck et al. (no date)

Supply shift following research

Results from the World Bank analysis, which are directly derived from the results presented in Table 4.1, suggest a supply shift of between 0.35 and 0.38 of the price (Table 4.3).

When the cost structure from ACIAR project outcomes is analysed, the results suggest a vertical supply shift of between 0.18 and 0.29 of the price (Table 4.4).

Table 4.3 Vertical supply shift implied by World Bank, PNG

Variable	Old cocoa improvement	New cocoa improvement
Vertical shift from yield improvement (kina/t)	2.7	2.95
As proportion of price	0.60	0.65
Cost increase (kina/ha)	847	1,034
Cost increase (kina/kg)	1.13	1.22
Net shift in supply (kina/kg)	1.61	1.73
As proportion of price	0.35	0.38

ha = hectare; kg = kilogram; t = tonne
Source: Centre for International Economics estimates, based on World Bank Productive Partnerships in Agriculture Project

Table 4.4 Vertical supply shift from ACIAR project outcomes, PNG

Variable	Option 2	Option 3	Option 4
Vertical shift from yield improvement (kina/t)	2.03	2.73	2.86
As proportion of price	0.44	0.60	0.63
Cost increase (kina/ha)	336	1,252	1,262
Cost increase (kina/kg)	0.72	1.93	1.81
Net shift in supply (kina/kg)	1.31	0.80	1.05
As proportion of price	0.29	0.18	0.23

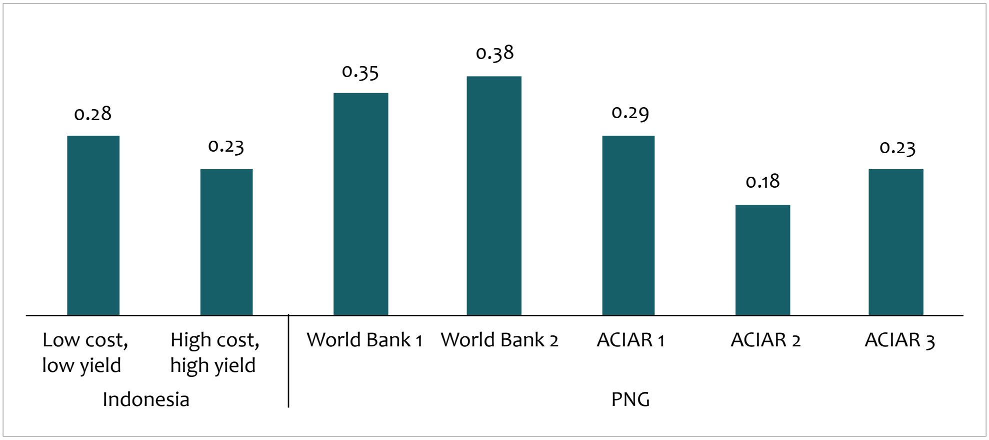
ha = hectare; kg = kilogram; t = tonne
Source: Centre for International Economics estimates, based on ACIAR project documents

Comparing PNG and Indonesian supply shift

A comparison of the vertical supply shifts for the Indonesian and PNG projects indicates that the estimates are similar when the ACIAR estimate is used for PNG, but that the improvement implied by the World Bank estimates is more optimistic (Figure 4.2).

Projected annual benefits from full adoption

Assuming full adoption of the IPDM practices, the potential annual benefits range from $21 million to $35 million, equivalent to between $231 and $388 per farm (Table 4.5). The present value of these benefits over 30 years varies from $325 million to $546 million, or from $3,546 to $5,960 per farm (Table 4.5).



Data source: Centre for International Economics estimates

Figure 4.2 Supply shift as a proportion of price, PNG

Table 4.5 Potential annual benefits, assuming full adoption, PNG

Variable	Lower supply shift estimates	Upper supply shift estimates
Annual benefits		
$ million	21	35
$/hectare	154	258
$/farm	231	388
Present value over 30 years		
$ million	325	546
$/hectare	2,364	3,973
$/farm	3,546	5,960

Source: Centre for International Economics estimates

These benefits per farm are lower than for Indonesia, mostly because of the lower base yield in PNG.

Because the cost of the PNG projects is $6.4 million (in present-value terms), to generate a BCR of 1, the ACIAR projects need to achieve successful yield increases for between 1,070 and 1,800 farms.

Inferring an adoption profile

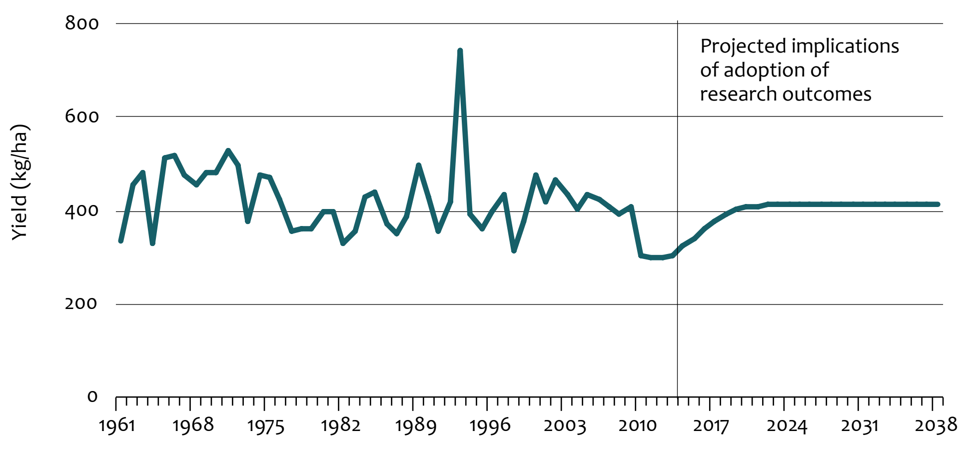
An adoption profile is inferred using results published from the World Bank's PPAP.

The PPAP target is 30,000 farmers by 2019, which is a 20% adoption rate. Coverage achieved by the end of 2014 was around 4%. These two points allow the calibration of a typical S-shaped adoption curve.

Implications of adoption

The broad implication of this adoption profile is that aggregate economy-wide yields cease their recent decline and return to historical averages (see Figure 4.3). Whereas yields were on a steady decline of about 4% per year since about 2002, the projection implied by the adoption rates is for an average annual increase of around 3% until 2022, and remaining steady from then onwards.

In terms of the percentiles discussed previously, this would take PNG from the 37th percentile to the 61st percentile, which is a slightly better relative performance than Indonesia: an increase of 24 percentage points compared with an increase of 21 percentage points for Indonesia. This provides some suggestion that the relative adoption rates (if not the absolute levels) between the two countries are reasonable.



Data source: Food and Agriculture Organization of the United Nations for historical data, Centre for International Economics estimates for projections

Figure 4.3 **Projected aggregate yield following adoption, PNG**

Integration with the World Bank

It is important to note that this adoption profile, and indeed the ACIAR projects themselves, are very closely related to the World Bank's PPAP. The PPAP has a number of components, but an important element is providing support for public–private partnerships to improve smallholder productivity in cocoa and coffee growing.

This means that estimating net benefits of the PNG projects requires the inclusion of the costs associated with the PPAP. Rather than attempting separate attribution of the ACIAR projects, we assume that the outcomes are achieved jointly with the PPAP.

The Centre for International Economics' estimates of the PPAP costs are set out in Table 4.6. These are added to the ACIAR-related costs set out in Table 2.4. Of the total costs, 20% are associated with ACIAR and 80% are associated with the World Bank project.

Table 4.6 Estimated World Bank PPAP costs associated with cocoa, PNG

Year	Nominal (A$ million)	Real (2015A$ million)	Present value (2015A$ million)
2011	0.67	0.72	0.88
2012	1.28	1.35	1.57
2013	1.99	2.05	2.26
2014	2.03	2.04	2.14
2015	4.40	4.40	4.40
2016	6.59	6.59	6.28
2017	3.22	3.22	2.92
2018	2.97	2.97	2.57
2019	2.10	2.10	1.72
2020	0.63	0.63	0.50
Total	**25.88**	**26.08**	**25.23**

PPAP = Productive Partnerships in Agriculture Project
Source: Centre for International Economics estimates, based on PPAP documents

Project benefits

Table 4.7 summarises benefit outcomes using the adoption profiles set out above, and total costs for both the World Bank and ACIAR projects. Results are attributed to ACIAR on the basis of cost shares.

Table 4.7 PNG net benefits, benefit:cost ratio and rates of return

Variable	Rate of return	
	Low	**High**
Results from total cost of ACIAR and World Bank projects		
Present value of benefits (2015A$ million)	54	89
Present value of costs (2015A$ million)	32	32
Net benefit (2015A$ million)	22	57
Benefit:cost ratio	1.71	2.81
Internal rate of return (%)	9.5	15.97
External rate of return (%)	1.63	3.18
Results attributed to ACIAR on the basis of cost shares		
Present value of benefits (2015A$ million)	12	21
Present value of costs (2015A$ million)	6.4	6.4
Net benefit (2015A$ million)	5.8	13.7
Benefit:cost ratio	1.9	3.14
Internal rate of return (%)	9.7	14.0
External rate of return (%)	1.96	3.5

Source: Centre for International Economics estimates

Sensitivity analysis

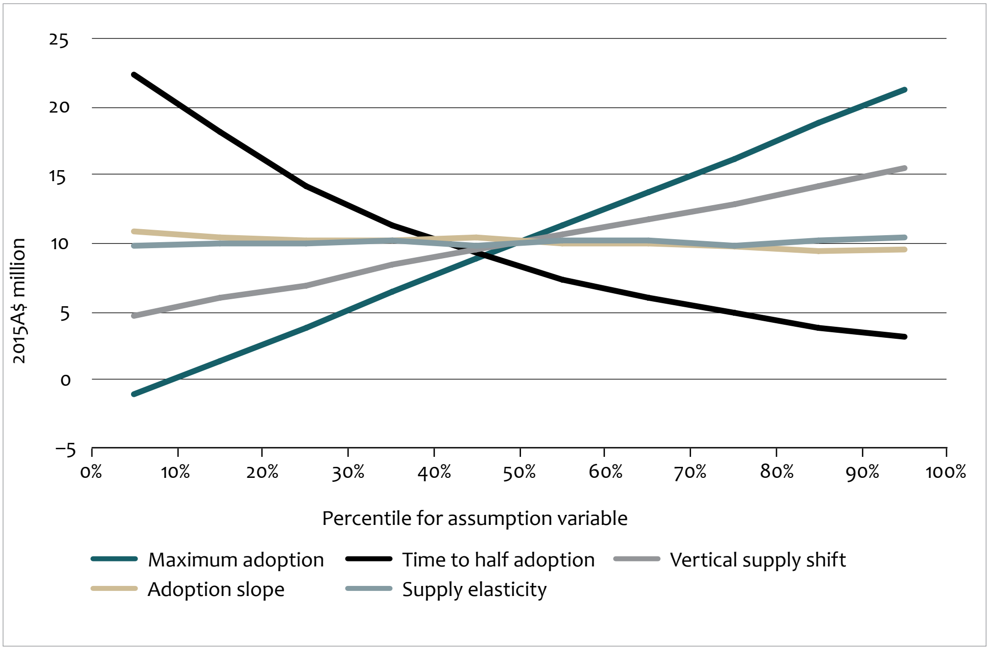
Table 4.8 summarises the ranges used for sensitivity analysis for the PNG outcomes. These ranges are applied to the results attributed to ACIAR on the basis of cost shares.

Figure 4.4 summarises the sensitivity of estimates of net benefits to key assumptions. The maximum adoption rate and the time to half adoption are the key determinants of the range of results, followed by the vertical supply shift. Results are relatively insensitive to the slope of the adoption curve or the supply elasticity.

Table 4.8 Assumptions underlying PNG sensitivity analysis

Variable	Lower	Upper
Maximum adoption rate (%)	5	35
Year to half adoption (year)	2011	2021
Adoption slope (unit)	0.56	0.84
Vertical supply shift (kina/kg)	0.8	1.73
Demand elasticity	–0.5	–1.5
Supply elasticity	0.1	0.5

kg = kilogram
Source: Centre for International Economics estimates



Data source: Centre for International Economics estimates

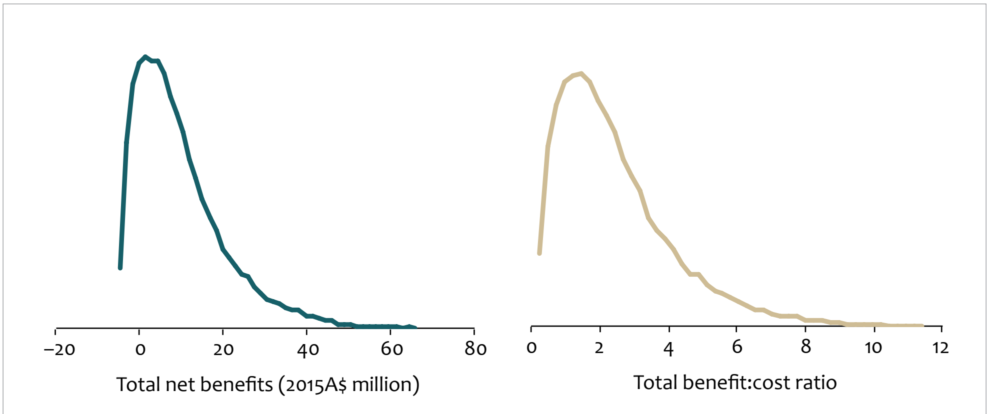
Figure 4.4 Sensitivity of net benefits to key input variables, PNG

When the net benefit and BCR results are analysed, as expected, the probability distribution of these are skewed to the left as a consequence of the shape of the adoption curves (Figure 4.5).

Net benefit results range from –$4.7 million to $66.6 million. There is a 14.5% chance that the net benefits will be less than zero and a 15.6% chance that they will be greater than $100 million.

Systematic sensitivity analysis

Results from the sensitivity analysis for key variables (Table 4.9) show that BCR results range from 0.3 to 11.4. There is a 14.5% chance that the BCR will be less than 1, and a 17% chance that it will be greater than 4.



Data source: Centre for International Economics estimates

Figure 4.5 Distribution of net benefits and benefit:cost ratio, PNG

Table 4.9 Sensitivity analysis results, PNG

Variable	Minimum	Maximum	Mean	Median	Mode
Present value of benefits (2015A$ million)	1.7	73.0	16.5	14.0	11.7
Net benefit (2015A$ million)	–4.7	66.6	10.0	7.6	5.2
Benefit:cost ratio	0.3	11.4	2.6	2.2	1.8
Internal rate of return (%)	–1.7	155.6	14.3	10.7	9.3
External rate of return (%)	–4.0	7.7	2.3	2.4	2.8

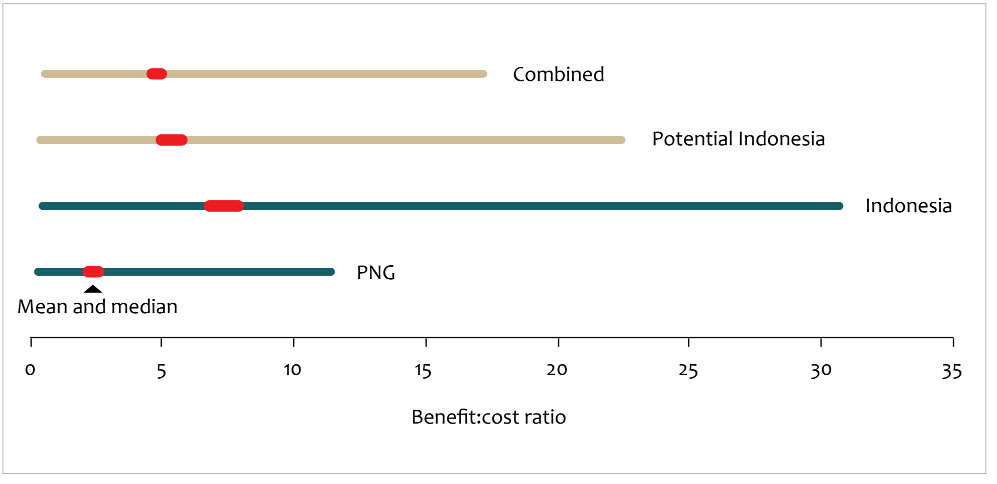
Source: Centre for International Economics estimates

5 Conclusions: combined benefits

Comparing PNG and Indonesia

Analysis of the the range of BCR results for PNG and Indonesia shows that, although there is considerable overlap between outcomes for the two countries, it is clear that the outcomes are generally lower for PNG than for Indonesia (Figure 5.1).

BCRs are useful for this comparison because they are not affected by the relative size of the projects. There are a number of reasons for this, and some care should be taken when comparing outcomes between the two countries.



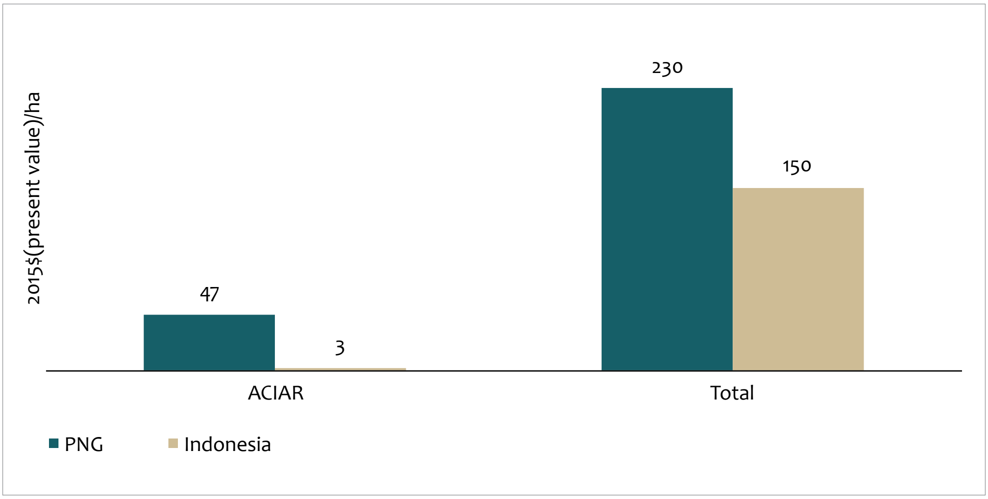
Data source: Centre for International Economics estimates

Figure 5.1 Comparison of benefit:cost ratio outcomes

First, there is an overall scale effect, and the funding per hectare (one means of putting the levels of funding on a comparable basis) is much higher in PNG than in Indonesia (see Figure 5.2). This is particularly the case for ACIAR funding, which is 16 times higher in PNG than in Indonesia. There is also a significant difference in spending per hectare for total project spending, with PNG two times more intensive. A variety of factors underlie this difference, but it reflects that there is an underlying fixed cost to undertaking research and extension, so that research intensity will appear greater in a smaller economy.

Second, the outcomes for PNG include some estimates of future spending, as available from the World Bank PPAP. This is not the case for Indonesia, where such data are not available. However, there are some reports that the Indonesian Government proposes to spend a significant amount in coming years (up to $100 million) to extend adoption. In this case, the BCRs for the Indonesian projects are expected to be lower. This is illustrated in Figure 5.1.

Finally, the available evidence indicates that the expected adoption rate in PNG is lower than in Indonesia. This view may change as more information becomes available. Matching the adoption rates between the two countries removes some, but not all, of the difference in outcomes.



Data source: Project documents, Centre for International Economics estimates

Figure 5.2 Project spending per hectare

Combined evaluation

Although distinct projects were taking place in two very different countries, strong methodological and conceptual links existed between the projects, including material from the PNG projects being used in subsequent Indonesian projects.

For this reason, it is worthwhile considering the benefits of all the projects together as one stream of cocoa research. Table 5.1 presents the range of results from the analyses done for this report, based on the $11.7 million (in real present-value terms) spending associated with the ACIAR-funded projects (Figure 5.1 also illustrates this). The results present the benefits attributed to ACIAR, using a cost share method.

The outcomes reflect a healthy return on the funds invested. Although Table 5.1 indicates a chance of a negative net benefit (or a BCR less than 1), this only occurs in 0.3% of cases. Offsetting this is a 5% chance of net returns greater than $100 million.

Table 5.1 Combined sensitivity analysis results, using cost share method

Variable	Minimum	Maximum	Mean	Median	Mode
Present value of benefits (2015A$ million)	6.8	200.8	58.4	53.3	42.0
Net benefit (2015A$ million)	–4.9	189.1	46.7	41.6	30.3
Benefit:cost ratio	0.6	17.2	5.0	4.6	3.6
Internal rate of return (%)	5.8	138.2	18.9	17.0	14.7
External rate of return (%)	–1.6	9.0	4.6	4.7	5.4

Source: Centre for International Economics estimates

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