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Returns to ACIAR's investment in bilateral agricultural research

ACIAR IMPACT ASSESSMENT SERIES 86

Research that works for developing countries and Australia

Returns to ACIAR's investment in bilateral agricultural research

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Research that works for developing countries and Australia

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The Australian Centre for International Agricultural Research (ACIAR) was established in June 1982 by an Act of the Australian Parliament. ACIAR operates as part of Australia's international development cooperation program, with a mission to achieve more productive and sustainable agricultural systems, for the benefit of developing countries and Australia. It commissions collaborative research between Australian and developing-country researchers in areas where Australia has special research competence. It also administers Australia's contribution to the International Agricultural Research Centres.

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ACIAR IMPACT ASSESSMENT SERIES

ACIAR seeks to ensure that the outputs of the research it funds are adopted by farmers, policymakers, quarantine officers and other beneficiaries. In order to monitor the effects of its projects, ACIAR commissions independent assessments of selected projects. This series of publications reports the results of these independent studies. Numbers in this series are distributed internationally to selected individuals and scientific institutions, and are also available from ACIAR's website at <aciar.gov.au>.

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Foreword

Since the early years of the Australian Centre for International Agricultural Research (ACIAR), a hallmark of its program has been the systematic way that it has assessed the research outcomes arising from the projects it commissions. A primary vehicle for this assessment has been its Impact Assessment Series (IAS) of reports, in which each study has documented the research, its costs and outputs, the adoption pathway, and the realised and expected take-up of research outputs as the basis for quantifying realised and expected benefits. Together, these assessments have enabled the estimation of aggregate benefits and costs across the suite of research activities.

This study is a retrospective view of 27 impact assessment reports, starting with IAS 36. It follows on from a study in 2005 (IAS 35) that reviewed all the IAS reports completed at that time (up to IAS 34). In this subsequent study, the authors have sought to establish whether the sum of economic benefits documented in the 27 assessments exceeded the investment in research, and so justified the total funding allocated to it.

Another objective was to rate these studies by their transparency and analytical rigour to arrive at a lower-bound estimate of the efficiency with which ACIAR uses resources. Across the 27 assessment studies, and the 103 bilateral research and development (R&D) projects they covered, the assessors identified 38 separate benefit streams. They then drew on the literature on impact assessment and valuation to develop criteria for rating each benefit stream evaluation as 'conceivable', 'plausible' or 'convincing'.

From the 38 benefit streams established, a subset of 15 was classified as 'convincing'. It is gratifying to note that, in present value terms, the realised benefits attributable to ACIAR from these 15 convincing benefit streams alone generated estimated benefits of $2.4 billion. The analysis suggests a small number of highly successful projects 'carried' the rest. Three areas in particular—the use of Australian germplasm in Indonesian forestry, pig breeding in Vietnam and integrated pest management in stored grain in the Philippines—accounted for 55% of all conceivable benefits, 80% of plausible benefits and 87% of convincing benefits. This supports the common finding that many low-return (yet worthwhile) projects are carried by the few projects that pay off handsomely.

While these high returns are a desired outcome, they are only one aspect of the benefits emanating from the research. We continue to see ACIAR's partners profit from new knowledge and capacity building, while communities gain social, health and environmental benefits that are rarely quantified in impact assessment studies.

Nick Austin
Chief Executive Officer, ACIAR

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Abbreviations

ACIAR	Australian Centre for International Agricultural Research
ADIA	ACIAR Database for Impact Assessments
IAS	Impact Assessment Series
CIE	Centre for International Economics
PV	present value
R&D	research and development

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The people we received advice and assistance from in the course of this analysis included Deborah Templeton, the program manager responsible for impact assessment at ACIAR, Simon Hearn from ACIAR, David Pearce from the Centre for International Economics (CIE), who reviewed one of the reports and provided access to the ACIAR Database for Impact Assessments maintained by the CIE, and Jeff Durkin, Economic Research Associates, who assisted with data manipulation.

Executive summary

The Australian Centre for International Agricultural Research (ACIAR) is unique among Australia's development institutions because the principal way it contributes to the overall development assistance program is to commission and support collaborative agricultural research between Australian scientists and developing-country scientists. The impacts of successful research occur both in Australia and in the developing countries, and are usually sustainable for long periods after the funding is completed.

A hallmark of ACIAR's research program is the systematic way research outcomes and impacts have been assessed. A primary vehicle for this assessment is the Impact Assessment Series (IAS) of reports, almost all of which have been carried out with a consistent methodology based on the economic surplus approach. Each study documents the research, research costs and outputs, adoption pathway and realised and expected take-up, and quantifies realised and expected benefits. As such, they indicate the likely overall benefits and costs associated with ACIAR's research activities based on an assessment of aggregate benefits and costs from the sample of research activities subject to impact assessment. Less than 10% of ACIAR's bilateral research program is subject to assessment and reported in the IAS reports.

This study reports the findings of a review of 27 IAS reports (covering 103 projects) in which economic impacts were quantified, starting with IAS 36. The focus was on ACIAR projects involving bilateral investments in collaborative research, and the objective was to determine whether the sum of economic benefits exceeded those investments and so justified the total funding allocated to them.

Another objective was to rate the studies by their transparency and analytical rigour to derive a lower-bound estimate of the efficiency with which ACIAR uses resources. Across the 103 bilateral research projects that were assessed in the 27 IAS reports, 38 separate benefit streams were identified. Drawing on the available literature on impact assessment and valuation, we developed a set of criteria that enabled each benefit stream to be classified as 'conceivable', 'plausible' or 'convincing'. The evaluations involved two reviewers independently reading each study and scoring it against the stated criteria.

Of the 38 separate benefit streams, the associated benefits were rated as conceivable for all 38, as plausible for 28 of those, and as convincing for a smaller subset of 15 benefit streams.

All cost and benefit streams for the bilateral projects were brought forward to 2012 present values, and the relative contribution by ACIAR, its research partners and other agencies to funding the projects was calculated from available budget and cost data. Since its inception in 1982, ACIAR has invested a total of $2,517 million in bilateral research, of which $151 million was ACIAR's investment in the set of projects that formed the study pool for this review. Realised and projected benefits were also expressed as 2012 present values. The attribution of benefits to ACIAR and other agencies was done on the basis of their relative contributions to costs.

The aggregate present value (in 2012 Australian dollars) of benefits from the 38 benefit streams assessed as conceivable was estimated at $30,170 million, while the total investment in the 103 projects by ACIAR and partners was estimated to be $448 million, giving a benefit:cost ratio of 67:1. Furthermore, around $13,195 million of the total of conceivable benefits was attributable solely to ACIAR. That amount is 5.2 times ACIAR's total investment of $2,517 million in all bilateral research since 1982.

Plausible and convincing ratings for benefit streams were stricter tests, so fewer benefits were counted as plausible, and even fewer as convincing.

For the 28 plausible and 15 convincing benefit streams, estimated total benefits were $24,987 million and $22,995 million, respectively. Relating those benefit streams to the combined cost of all evaluated projects gave benefit:cost ratios of 56:1 (for plausible) and 51:1 (for convincing). Of those benefits, $10,771 million (for plausible) and $10,098 million (for convincing) were attributed to ACIAR, which gave benefit:cost ratios of 4.3:1 and 4.0:1, respectively, relative to its total investment in all bilateral research since inception.

For each benefit stream there was a mix of realised and projected benefits. Realised benefits were those already realised at the time the impact assessment was undertaken. They were realised because at that time there had been adoption and there was evidence of uptake of research outputs and associated benefits .

If we counted only benefits attributable to ACIAR that were both convincing and realised, the estimated benefits were $2,358 million, a little less than ACIAR's investments since 1982. Clearly, though, this was a gross underestimate of the ultimate impact from the 15 convincing benefit streams. While projected future convincing benefits of $7,741 million were subject to a degree of possible forecasting error, nevertheless the estimate that convincing benefits ultimately realised will be about $10,098 million was based on compelling evidence. This implies that even the lower-bound (convincing) estimate of benefits from the study-pool projects will exceed all ACIAR's investments to date in bilateral agricultural research by a ratio of about 4:1.

Moreover, this estimate ignored the benefits from research projects evaluated in Raitzer and Lindner (2005), which was the first ACIAR review of returns from bilateral investments and the forerunner to this analysis. When we added the substantially demonstrated estimate of benefits of $2,234 million from that stocktake to the $10,098 million of convincing benefits estimated in this study, we arrived at a lower-bound estimate of returns to ACIAR's investment in its bilateral program since 1982 from the two studies of about $12,332 million, and a benefit:cost ratio of 5:1.

Our findings that the returns to ACIAR's investment in bilateral research are high is consistent with the findings of Raitzer and Lindner (2005) and with analyses by the Centre for International Economics of the benefits to Australia from the bilateral research program. They are also consistent with a large body of cost–benefit analyses at the project level (reviewed in Productivity Commission 2011) and econometric studies at the aggregate level (Alston et al. 2010 for the United States and Sheng et al. 2011 for Australia) that indicate that overall returns to agricultural research are high. A common finding in this literature is that many low-return projects are 'carried' by the few projects that pay off handsomely.

This well-established pattern was repeated here. A small number of highly successful projects carried the rest. In particular, three benefit streams—from the use of Australian germplasm in Indonesian forestry, pig breeding in Vietnam and integrated pest management in stored grain in the Philippines—accounted for 55% of all conceivable benefits, 80% of plausible benefits and 87% of convincing benefits. Also reflecting the body of existing research on agricultural returns, these big pay-off projects are difficult to identify ex ante.

It also needs to be remembered that no attempt was made in any of the impact assessment studies to comprehensively quantify all possible benefits. In particular, benefits from new knowledge and capacity building were typically not estimated[1]; nor were social, human health and environmental benefits quantified.

[1] Except in four IAS reports by Brennan and Quade (2004), Fisher and Gordon (2008), Gordon and Chadwick (2007) and Longmore et al. (2007)

1 Introduction

Background

Australia's foreign aid program helps alleviate poverty through sustainable economic development and aid-for-trade initiatives that build livelihoods, provide jobs and grow economies that can then support communities.

The particular focus of the aid program is in Australia's own region (in the Indian Ocean and Asia–Pacific region), while continuing to take into account countries where Australia has an enduring interest, such as Afghanistan, Pakistan and in Africa.

The aid program supports Australia's national interest for greater growth and equity, and consequent peace and prosperity, in the region.

The Australian Centre for International Agricultural Research (ACIAR) was established in 1982 as a relatively small statutory authority within the Australian Government's Official Development Assistance (aid) program. It was founded on the belief that developing countries and Australia all had much to gain from fostering partnerships between Australian and developing-country scientists. The main focus of ACIAR's activities is on sustainable economic development.

ACIAR is unique among Australia's development institutions because the principal way that it contributes to the overall aid program is to commission and support collaborative research between Australian scientists and developing-country scientists. The aim is to develop more productive and sustainable solutions to mutual problems in agriculture, forestry and fisheries and to build scientific capacity in developing countries. If the research is successful, its impact occurs in both countries and is usually sustainable for long periods after the funding is completed.

ACIAR's mission is:

> To achieve more productive and sustainable agricultural systems, for the benefit of developing countries and Australia, through international agricultural research partnerships.

The key question to be addressed in this study was whether the estimated sum of quantitative economic benefits assessed to flow from bilateral investments in collaborative research exceeded and so justified the total funding for such investments.

Because some successful research project clusters generated more than one research output, each with its logically distinct pathway to adoption and consequent creation of economic impacts, the stream of benefits over time, or benefit stream for short, associated with each adoption-ready innovation forms the basis for the assessment of the credibility of estimated economic impacts in this report.

ACIAR's investments in bilateral research

ACIAR has invested about $2,517 million (present value (PV) in real 2012 A$) in bilateral research support (usually including some capacity building) since its foundation. In 2011–12, ACIAR's total expenditure was $103.2 million, allocated as follows:

- bilateral projects $71.4 million
- multilateral projects $23.0 million
- building research capacity $5.1 million
- communicating research results $0.7 million
- measuring research impacts $0.6 million
- research program support $2.6 million.

Clearly, the core of ACIAR's investments has been in in bilateral research projects that involve Australian agricultural scientists working with scientists in developing countries on projects likely not only to benefit those countries, but also contribute to productivity gains in Australian agriculture. Multilateral projects encompass Australia's contributions to international agricultural research centres and projects administered by them. Building research capacity incorporates short- and long-term professional development opportunities, usually in Australia, for scientists from developing countries. Communicating research results encompasses activities to publish the results from ACIAR-funded research. Measuring research impacts encompasses a range of activities, including the assessment of the economic impacts of research, which is the focus of this report.

ACIAR research activities are organised into the following management units:

- Economics and Social Sciences
  - Agribusiness
  - Agricultural Systems Management
  - Agricultural Development Policy
- Crops
  - Horticulture
  - Pacific Crops
  - Cropping Systems and Economics
  - Crop Improvement and Management
- Natural Resources Management
  - Forestry
  - Land and Water Resources
  - Soil Management and Crop Nutrition
- Livestock and Fisheries
  - Animal Health
  - Fisheries
  - Livestock Production Systems
- Australian International Food Security Research Centre (established in 2011 to address food security initially in Africa)
- Impact Assessment.

These units manage the multilateral, capacity-building and communication programs as well as the bilateral program. Bilateral research projects are developed within a framework reflecting the priorities of Australia's aid program as well as its national research strengths, together with the agricultural research and development (R&D) priorities of partner countries.

The proportion of the 2011–12 budget allocated to each of the sub-themes is illustrated in Figure 1. The largest proportion went to research into field crops. A listing of current projects can be found in Appendix 4 of ACIAR's 2011–12 annual report (ACIAR 2012).

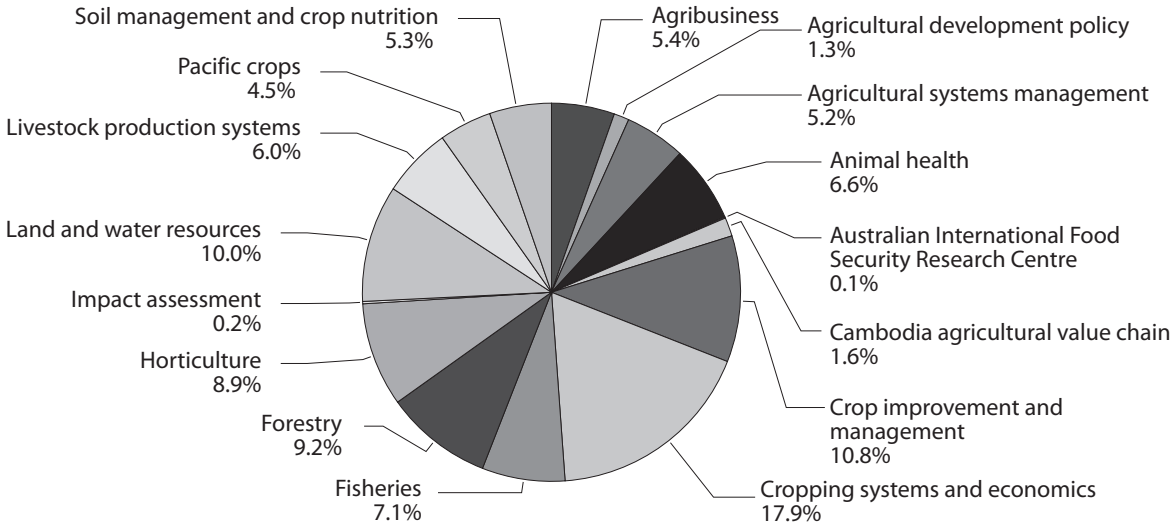

Figure 1. Research focus of ACIAR bilateral investments in 2011–12. Source: ACIAR (2012)

Currently, ACIAR has bilateral research projects in Papua New Guinea and Pacific island countries; Indonesia, East Timor and the Philippines; the Mekong countries and China; South and West Asia; and Africa. The regional allocation of the budget in 2011–12 is shown in Figure 2. Investment in Africa has been the big mover in recent years.

ACIAR's impact assessment program

Since its inception, ACIAR has been committed to demonstrating the effectiveness and impact of its research investments, with particular emphasis on quantifying the economic returns to bilateral research. To that end, it has devoted considerable resources to understanding and measuring the contribution of the research to economic development. In 2011–12, expenditure on measuring research impacts was $0.6 million in a total budget of $103.2 million (almost 0.6%), which is likely to be large relative to other research institutions. The goals of these activities include assistance in priority setting, resource allocation and project development and, significantly, in accounting to stakeholders for ACIAR's use of funds.

Initially, the focus of this work was on quantifying potential impacts to support priority setting and the allocation of resources across commodities and regions of interest, as well as to enhance ACIAR's public accountability. ACIAR has developed a multiregional economic surplus traded goods model covering more than 80 products, more than 100 countries or regions and more than 100 production environments that accounted for spillovers between countries and regions (Davis et al. 1987).

In the late 1980s, 12 ex-post impact assessments, subsequently published as the Economic Assessment Series, were undertaken to demonstrate the high returns to funds invested. Anecdotally, that work was a strong factor in the decision to extend ACIAR's life and increase its budget. Impact assessment studies have been a regular feature of the measuring research impacts program ever since, and are the focus of this report.

As research efforts have matured, more attention has been focused on quantifying the returns on those investments by assessing adoption and impacts. Currently, the measuring research impacts program has two main 'product' groups. First, for a selection of research projects, ACIAR commissions follow-up studies of adoption 3–4 years after completion to not only quantify the level of adoption and ACIAR's contribution, but also to develop an understanding about how and why adoption has been achieved (or not).

Second, ACIAR also commissions impact assessment studies that are primarily economic cost–benefit evaluations. These ex-post economic evaluations are published in Impact Assessment Series (IAS) reports.

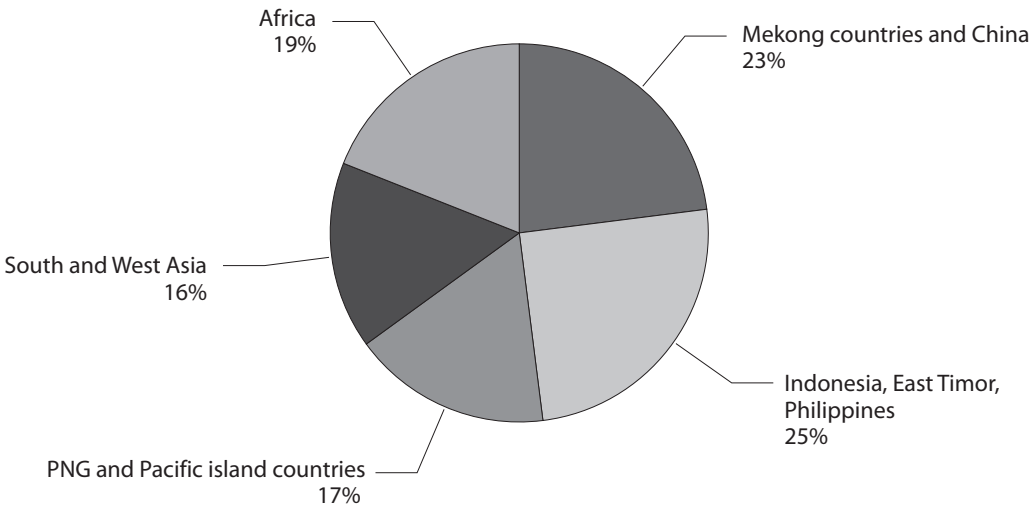

Figure 2. Regional focus of ACIAR bilateral investments in 2011–12. Source: ACIAR (2012)

The objective of such studies is to provide a quantitative estimate of the economic benefits flowing from the adoption of new technologies (or policy change) that can be attributed to individual ACIAR-funded research projects or to groups of related projects. In these studies, the impact pathway for some completed research outputs is analysed, both in partner countries and in Australia, to provide an 'in-depth analysis of the contextual environment, key stakeholders, pathway linkages, changes that have occurred, and actions that could be undertaken within the projects or program to increase the likelihood of the ultimate goals being reached' (ACIAR 2012, p. 50). Normally, social impacts (including gains to scientific capacity and social capital and human health impacts) and environmental impacts are described qualitatively.

Most assessments are conducted by economists who are independent of ACIAR and the partners in the research program under evaluation, and who are experienced in the application of welfare economics to the assessment of the impacts of new technology. Such studies provide estimates of the returns to the investment in the research area of interest, and are used by ACIAR to account to stakeholders, as well as to support improved decision-making and management of its funds.

At the time of writing, there were 82 reports in the IAS, the first published in January 1998. ACIAR also published an Economics Evaluation Unit Working Paper series (33 publications from 1994 to 1999) and an Economic Assessment Working Paper series (14 publications from 1999 to 2004), all of which are available on the ACIAR website. These series included ex-ante evaluations of research programs (using the guidelines published in Davis et al. 2008), ex-post evaluations (forerunners to the current impact assessments), and some papers on methodological issues in economic evaluation of research.

In 2005, out of the 34 reports in the IAS completed by that time, ACIAR commissioned a review of 29 impact assessment studies that attempted to quantify the benefits from 53 individual research projects. The findings, published in IAS 35 (Raitzer and Lindner 2005), are described in more detail below.

Since the publication of IAS 35, ACIAR has continued to implement changes to its impact assessment program to improve the quality of impact assessment studies. For instance, in order to improve the consistency of methods in impact assessment studies, it published a set of previously developed guidelines for independent assessors to follow when conducting the studies. It also sought to address claims that it was 'cherrypicking' only obviously successful projects for impact assessment by commissioning some thematic impact assessment studies of large clusters of cognate research projects, as well as by a trial of random selection of projects to study (announced in the foreword to IAS 55). For example, during 2006–07, ACIAR used a small random sample approach to choose four projects to be the core of its impact assessment studies at that time.

ACIAR also introduced some methodological studies into the impact assessment program that focused mainly or exclusively on providing a basis for assessing more difficult to measure components of overall research impacts, such as capacity building and poverty alleviation.

By the end of 2012, a further 46 impact assessment studies had been completed, including another 31 studies that quantified benefits generated by ACIAR's investments in bilateral research, so it is timely to update the previous study by Raitzer and Lindner (2005).

Objectives of this study

The purpose of this study was to update the first stocktake of quantitative assessments of ACIAR's investment in bilateral research, which was reported in IAS 35. The terms of reference required:

- an appraisal of best-practice methods for ex-post impact assessment
- the development of criteria to evaluate the credibility of quantitative estimates of economic impacts of research
- a review of 31 IAS reports commissioned by ACIAR since IAS 35 that quantified benefits from investment in bilateral research
- aggregation of the benefits estimated in those reports into three categories based on the level of their credibility
- the preparation of this report for ACIAR.

2 A review of past studies of the benefits from ACIAR research

ACIAR has funded two lines of analysis to aggregate the economic benefits of its bilateral research program through time and to relate them to its investment.

Aware that previous impact assessment reports had varied in their plausibility, ACIAR commissioned Raitzer and Lindner (2005) to review the IAS reports completed by that time. The aim was to rate them for their plausibility, and then to identify a subset of reports in which the estimates of benefits were especially convincing. In their report, Raitzer and Lindner argued that an aggregate of the convincing benefits provided a lower-bound estimate of the returns to ACIAR's bilateral research activities.

The second line of analysis was contained in a series of reports prepared by the Centre for International Economics (CIE) (IAS 39, IAS 63 and an unpublished update of IAS 63) using the ACIAR Database for Impact Assessments, which is maintained by CIE for storing the results from impact assessments (IAS 60) and providing regular summary information in a consistent manner across reports.

Several general comments can be made about the IAS. First, it covers only a small proportion of the research projects funded by ACIAR (less than 10% of the bilateral program budget).

Second, the reports focus on quantifying economic or industry impacts, so that environmental and social impacts usually go unmeasured (although they are identified qualitatively in most studies). Moreover, and of particular pertinence, is the fact that the gains in scientific capacity and knowledge, in which Australian scientists and research institutions share, are difficult to measure and hence usually go unquantified.

Also, ACIAR activities should contribute to poverty alleviation and often make an important contribution to this central goal of Australia's foreign aid program. This kind of benefit is likely to have additional value to society over and above economic impacts.

Third, ACIAR has a separate program for building research capacity (about 5% of total budget), and the benefits to Australia from that component of ACIAR activities also go unmeasured.

Fourth, research areas commonly chosen for impact assessment are those expected to have been successful, so the average return from research subject to impact assessment is likely to have been higher than that from the rest of the portfolio. The fact that the returns to the sample of projects subject to impact assessment have well exceeded the cost of all ACIAR's investment in bilateral research lessens concerns about often choosing only successful projects for impact assessment.

Fifth, the IAS analysts generally first identified the total impact of the new technology or policy change. Then they attributed a share of those total benefits to the activities of ACIAR and its partners. Some then identified benefits attributable to ACIAR alone, usually on the basis of ACIAR's share of the total budget. The CIE reports generally focused on the benefits attributable to ACIAR and partners and referred to them as total benefits, while Raitzer and Lindner (2005) were particularly interested in benefits attributable to ACIAR alone.

The IAS studies report streams of benefits and costs through time. To aggregate benefits and costs over time, all of the overviews of impact assessment analysis have used the Consumer Price Index (CPI) to convert those streams to a common year (the year the analysis was

conducted), and then applied a discount rate of 5% to compound past benefits and costs forward and to discount future benefits and costs back to the common year. This procedure allows benefits and costs to be aggregated in a consistent manner (in this report, all monetary values are expressed in 2012 dollars).

The Raitzer and Lindner study

At the time of the Raitzer and Lindner (2005) study, 34 reports had been published in the IAS, but only 29 of them made quantitative estimates of economic impact. The 29 studies, covering 53 individual research projects, formed the study pool for Raitzer and Lindner, who rated each study according to two overarching criteria—transparency and analytical rigour. They assigned the reports to one of three nested classes:

- 'potential'—which encompassed all 29 reports
- 'plausible'—a subset of 'potential' requiring some degree of adoption and reasonable levels of transparency and rigour
- 'substantially demonstrated'—a subset of 'plausible' for which there was a high degree of certainty attached to the estimated benefit stream.

Up to the time of the Raitzer and Lindner study, ACIAR had invested $2,062 million in its bilateral program, 7.8% of which was accounted for by the 29 IAS reports (the CPI factor to return to 2004 A$ is division by 1.25 and the compounding factor is 1.48). Total potential benefits from the 29 (attributable to ACIAR alone) were estimated to be $6,310 million, giving an overall benefit:cost ratio of slightly more than 3:1, which fell to 1.3:1 if only realised total benefits were considered (most IAS reports identified benefits that had been realised at the time of the report and benefits of an ex-ante nature). Raitzer and Lindner estimated that of the $6,310 million of total benefits attributable to ACIAR, $877 million (14% of the total benefits) accrued to Australia. This was higher than the estimate by Pearce et al. (2006), but Raitzer and Lindner's attribution process and differences in the study pool make comparisons difficult.

Only 12 of the 29 IAS reports met Raitzer and Lindner's criteria to join the 'plausible' group, but the total benefits from that group ($2,989 million) still exceeded total investment by ACIAR since its inception. Australia's share remained at 14% ($419 million).

The most conservative group, the 'substantially demonstrated' group, comprised just seven studies and delivered benefits attributable to ACIAR of $2,709 million and a benefit:cost ratio of 1.3:1 against ACIAR's total bilateral investment since inception. Australia's share of benefits from this group rose to 17.2% ($466 million). Nearly 90% of the benefits in this group came from three projects:

- Eucalyptus improvement in China
- Banana skipper biocontrol in Papua New Guinea
- Pig genetic improvement in Vietnam and Australia.

Other research areas in the 'substantially demonstrated' group included:

- Acacia hybrids in Vietnam
- Increased efficiency of straw utilisation by buffalo and cattle
- Pigeonpea improvement
- Control of footrot in small ruminants in Nepal.

Other research areas in the 'plausible' group included:

- Australian tree species in China
- Controlling *Phalaris minor* in the Indian rice–wheat belt
- Genetics of and breeding for rust resistance in wheat in India and Pakistan
- Water and nitrogen management in wheat–maize on the North China Plain
- Identifying the sex pheromone of the sugarcane borer moth.

Other research areas delivering large benefits attributable to ACIAR but in the 'potential' group included:

- Conservation tillage and controlled traffic in China and Australia
- Development of vaccines for Newcastle disease in Africa and Asia.

The CIE studies

The first of the CIE studies (IAS 39, Pearce et al. 2006) primarily addressed the benefits to Australia from ACIAR-funded research. This study used a very similar pool of IAS reports to the earlier Raitzer and Lindner (2005) report, but also included seven analyses that pre-dated the IAS reports. Of the studies reviewed, 28 produced benefits to Australia, at least qualitatively, and 16 (covering 29 projects) provided quantitative estimates of those benefits.

Total benefits to Australia and partner countries (from the 35 impact assessments) were $11.8 billion, and net benefits after ACIAR and partner-country investments were deducted came to $11.2 billion. Pearce et al. (2006) found that 62% of projects quantified benefits to both Australia and the partner countries, while 85% identified both quantitative and qualitative benefits to Australia. They estimated that, from the set of 16 studies, total benefits to Australia were $1,115 million or 9.4% of all benefits from the set of 35. They noted that, at the time of their report in 2006, cumulative investment by ACIAR since its inception was about $2.2 billion.

Pearce et al. analysed a further five case studies (research areas), and were able to quantify impacts in three of them. They estimated an additional $264 million in benefits to Australia from the three case studies.

The quantified Australian benefits came from productivity gains (both on- and off-farm), trade gains, and protection from exotic pests and diseases, either on incursion or before Australian borders were reached.

Following IAS 39, the CIE developed a database for storing the results from impact assessments (IAS 60) and providing summary information in a consistent manner across reports—the ACIAR Database for Impact Assessments (ADIA). The first review of impact assessments using ADIA was IAS 63 by Harding et al. (2009), who reported on the appropriateness, effectiveness and efficiency of ACIAR's program and presented data on the benefits from bilateral research as reported in the IAS. The Harding et al. analysis did not include the seven pre-IAS studies used by Pearce et al.

At the time of the Harding et al. report, there had been 59 reports in the IAS, but for those reports only 37 streams of quantitative estimates of benefits were recorded in the database. Total benefits (attributable to ACIAR and partners) were $16,834 million from a total investment of $312 million. Benefits and costs attributable to ACIAR (on the basis of a cost share of about 54%) were $9,077 million and $171 million, respectively. In both cases, the benefit:cost ratio was 54:1. Total benefits flowing to Australia were estimated to be $1,569 million (about 9.3% of total benefits), considerably exceeding the total investment in the 37 projects.

An unpublished update of the Harding et al. (2009) analysis using ADIA was provided to ACIAR by CIE in December 2011. At the time of the update, 75 reports in the IAS series had been published, 48 of which reported quantitative estimates of benefits (not including earlier reports subsequently updated). Total investment by ACIAR and partners in projects covered by the 48 IAS reports was $439 million, and by ACIAR alone, $219 million. Total benefits (attributable to ACIAR and partners) were $37,002 million and benefits to ACIAR (based on a 50% cost share) were $18,459 million, giving a benefit:cost ratio of 84.2:1. Total quantified benefits to Australia amounted to $2,549 million or about 7% of total benefits. At the time of the unpublished update, CIE estimated that ACIAR had invested $3.1 billion since its inception, giving a minimum benefit:cost ratio of 6:1.

3 Methods

The rate of return to agricultural research is a much studied topic, and overwhelmingly the finding has been that rates of return are very high. Nevertheless, many observers and commentators remain sceptical. Indeed, as Alston et al. (2000) noted more than a decade ago, there is a disconnect between the widespread decline in public funding for agricultural research and the seemingly strong evidence that it pays off handsomely (a review of recent Australian experience is in Mullen 2011). Reasons for this apparent paradox include the possibility that many policymakers do not find the empirical evidence credible. Another possible explanation for the paradox could be that, even though politicians know that returns would be high, the returns are not likely to be realised during their political careers, so they would rather invest in areas where the returns are faster—and more noticeable—even if smaller.

While the consistent empirical evidence of high returns comes from a large number of studies that employed a variety of methodologies, the only available evidence that might justify ACIAR's investment in its bilateral research program comes from commissioned impact assessment studies that used the economic surplus approach to estimate the benefits from a subset of projects evaluated in the centre's impact assessment studies. Since the pioneering study by Griliches (1958), the economic surplus approach has been the most widely used and fruitful way to assess the economic impacts of investments in agricultural research. Furthermore, all studies in the IAS were ex-post impact assessments in the sense that more or less adoption-ready research outputs developed from the projects could be identified by the time that the impact assessment was carried out, although the level of adoption may have been small.

In practice, there is wide variation in the process for tracing the impact pathway, in the data used and assumptions made, and in the methods employed to calculate quantitative estimates of research costs and benefits. Due to such disparities, ex-post impact assessments differ markedly in their perceived credibility. Furthermore, it is well known that realised returns to research are very uneven—most projects yield modest returns at best. On the other hand, 'cherrypicking' a sample of research projects that, ex post, are known to be successful and then estimating benefit:cost ratios for such a sample can give a very misleading impression of overall returns to the investment in research.

As in most such studies, the approach taken to address these twin problems in the initial stocktake by Raitzer and Lindner (2005) was to assemble lower-bound estimates of economic benefits from ACIAR's ongoing investments in bilateral research that were highly believable, and then observe whether they exceeded the total cost of the research program. We followed a similar approach in this study.

To do so, we had to identify a study pool of previously published IAS reports containing quantitative estimates of economic benefits from the uptake of bilateral research project outputs. Next, the information and methods used to derive the estimates had to be rated as more or less credible, and then assembled into aggregate estimates of decreasing magnitude but increasing credibility. All identified estimates were rated against criteria for good practice in ex-post impact assessment, and then classified as 'conceivable', 'plausible' or 'convincing'. The lower-bound estimate of highly credible research benefits was assumed to comprise only those benefits rated as convincing.

The following sections:

- outline the common approach to estimating economic surplus employed in the IAS reports

- explain the selection of the set of IAS reports that form the study pool for this review and provide some information on its characteristics
- discuss the rationale underlying the criteria chosen to rate the credibility of the findings in the various the IAS reports
- explain the procedure and criteria used to rate the credibility of estimates of benefit streams
- outline some technical issues relating to measuring quantitative estimates of benefit streams and ensuring that they are commensurate
- states some caveats that need to be considered in reaching conclusions from the findings of this study.

Ex-post impact assessment

The framework for ex-post impact assessment outlined in Davis et al. (2008) was developed by ACIAR to formalise the application of the economic surplus approach to the evaluation of its research projects and programs. The underlying structure of the impact assessment studies in the study pool followed those guidelines. Within this framework, the initial focus is on identifying research outputs that are the deliverables from the research projects. Davis et al. defined three broad categories of outputs: technologies, scientific capacity and policy. While some outputs are ready for adoption, others need to be commercialised and many others—including, in particular, new knowledge and other types of new capacity—are inputs into further research.

In practice, the estimation of quantitative benefits in impact assessment studies is usually restricted to the analysis of impacts from the uptake of adoption-ready innovations, which might be new and better products or production processes, but might also include policy analysis and/or recommendations of direct relevance to policymakers. While the prototype for technology innovations remains productivity-enhancing process innovations, such as hybrid corn that reduces the per unit cost of production, the outputs from other types of research might include new defensive or maintenance innovations that reduce the risk and/or magnitude of avoidable losses (such as a decline in productivity or damage from a pest incursion), and natural resource management and other management innovations that have the potential to improve the efficiency of resource use.

A successful research project typically generates only a single adoption-ready innovation, but it is possible for a single project to produce multiple innovations that are adoption-ready but dissimilar in important ways that pose different challenges in tracing pathways to adoption, as well as in quantifying the consequential benefit streams. Furthermore, in recent years, it has become more common for the scope of a single impact assessment study to assess the impacts of a cluster of research projects. Hence, the analytical framework used in this study made provision for separate benefit streams for each innovation within a single study.

Even technologies that are adoption ready can require more transformations before they can be used, so a critical step in an impact assessment study is to trace the early stages of the impact pathway to determine whether the research has produced one or more outputs that have been adopted by potential users, or are likely to be adopted, and to determine both the spatial and temporal dimensions of any uptake of project outputs. Also important at this stage is the estimation of expected cost reduction from the new technology at the firm level, often referred to as the 'k shift' (or 'demand shift' in some cases).

Where adoption has occurred, or if there is strong evidence that it will occur, the focus then becomes the estimated industry outcomes from adoption. Quantification of the economic surplus is based on identifying all relevant project costs and measuring the benefits to both producers and consumers (combined producer and consumer surplus). These data are then used to estimate the net present value (PV) of the research project and the associated benefit:cost ratio and internal rate of return.

As recommended in the ACIAR guidelines, benefits in most IAS studies are estimated by building from the bottom up, first estimating the productivity change at the farm level. Then, based on the actual and/or expected spatial and temporal take-up rate of research outputs, estimates of the annual stream of surplus benefits to industry are produced.

Comprehensive impact evaluations are also required to identify wider economic benefits of research that arise through adjustments in factor and/or product markets, as well as impacts on broader socioeconomic outcomes such as equity, poverty alleviation, environmental quality, food safety, and health and nutrition. Most of the IAS studies in our study pool attempted to do some of this, but usually only in qualitative terms, and attempts at quantification were rare.

Definition of the study pool

At the time of this study, ACIAR had published 81 reports in the IAS since the series began in 1998. Following the classification described in the 2011–12 ACIAR annual report, the breakdown of the 81 impact assessment studies into focus areas and regions is depicted in Figures 3 and 4, respectively.

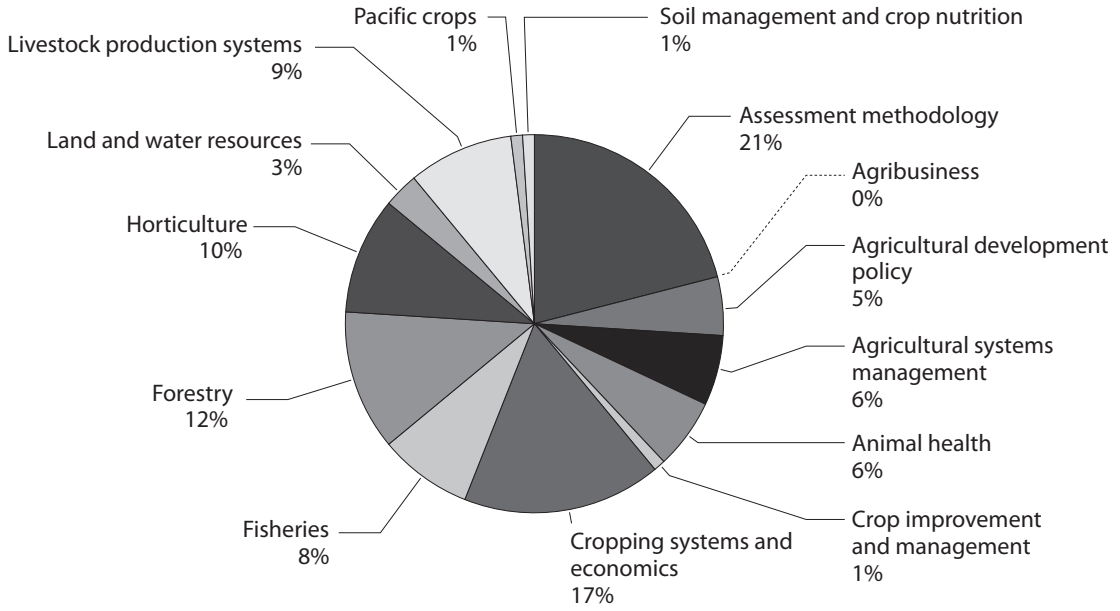

Figure 3. Research focus of all published impact assessments

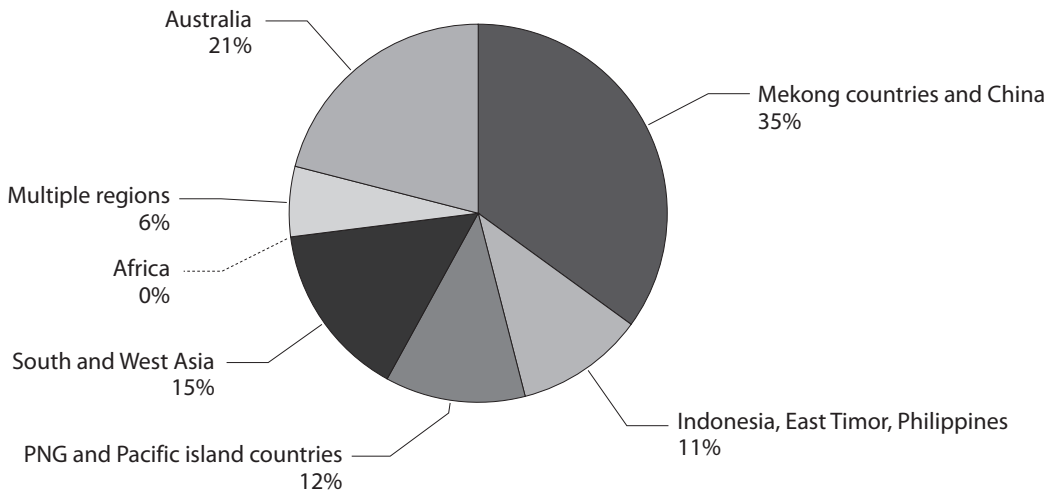

Figure 4. Regional focus of all published impact assessments

Some of these studies (21% of all IAS reports) related to the internal management of ACIAR's impact assessment operations and its allocation of funding to research projects. Those studies are shown in Figure 3 as being for Assessment methodology and in Figure 4 as Australia-specific.

Since the 2005 study by Raitzer and Lindner, a further 46 impact assessment studies were completed by late 2012. However, 15 of them were dedicated to a continuing review of management practices, frameworks and methodology, and were therefore excluded from the prospective study pool for this follow-up study.

The remaining 31 studies formed the preliminary study pool for this review. However, a further three studies were removed to avoid double-counting benefits of bilateral research projects that were assessed in more than one IAS report. Also, in IAS 40, which focused on poverty, the only economic outcomes quantified were the poverty impacts for a subset of the population, so it was excluded as well.

Consequently, the final study pool comprised 27 impact assessment studies, in which quantitative estimates of economic impacts of 103 bilateral research projects were reported. By comparison, the Raitzer and Lindner review was based on 29 impact assessment studies in which, generally, the economic impacts of only one or two bilateral research projects were estimated, so that it covered only 53 individual projects in total. Hence, the scope of the current study pool was considerably broader, in that benefits from nearly double that number of projects were estimated. The distributions between research and regional focus areas of the impact assessments in the study pool for the current review are charted in Figures 5 and 6, respectively.

The main reason for the broader scope of ACIAR's impact assessment program since the publication of IAS 35 was a deliberate attempt to mitigate the perception that successful projects were cherrypicked for assessment, and thereby to provide a more balanced picture of the overall economic impacts of the bilateral research program. One way this was achieved was to commission some thematic studies, which assessed the economic impacts of a cluster of cognate research projects. For instance, the disparate impacts of a total of 17 projects were estimated in the assessment of ACIAR's overall investment in fruit-fly research, while the scope of an assessment of benefits to Indonesia and Australia from investment in plantation forestry research encompassed 12 projects.

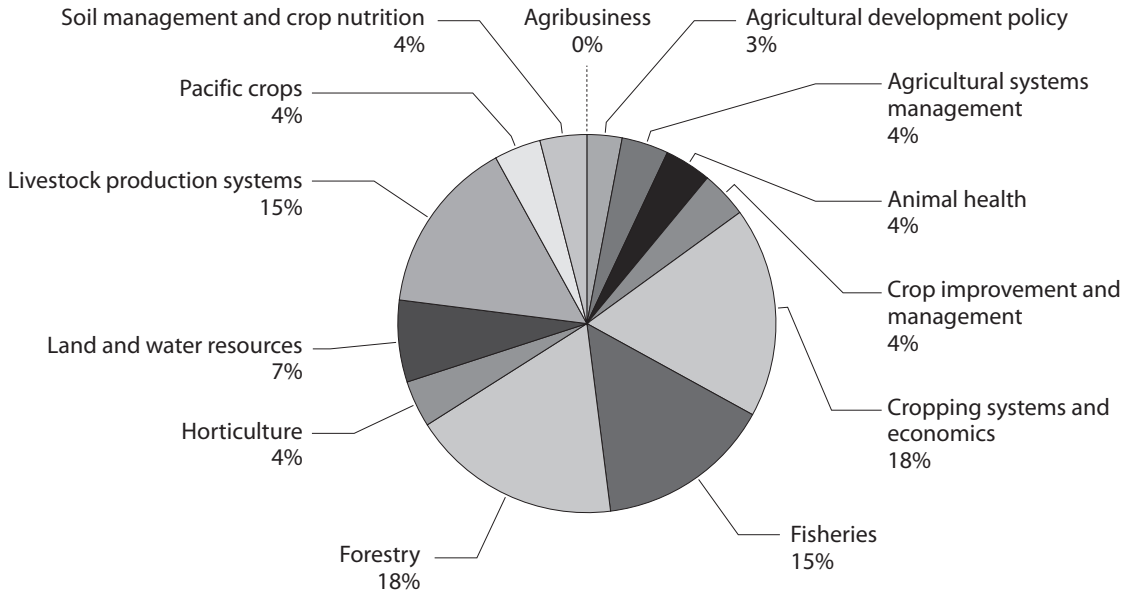

Figure 5. Research focus of impact assessments in the current study pool

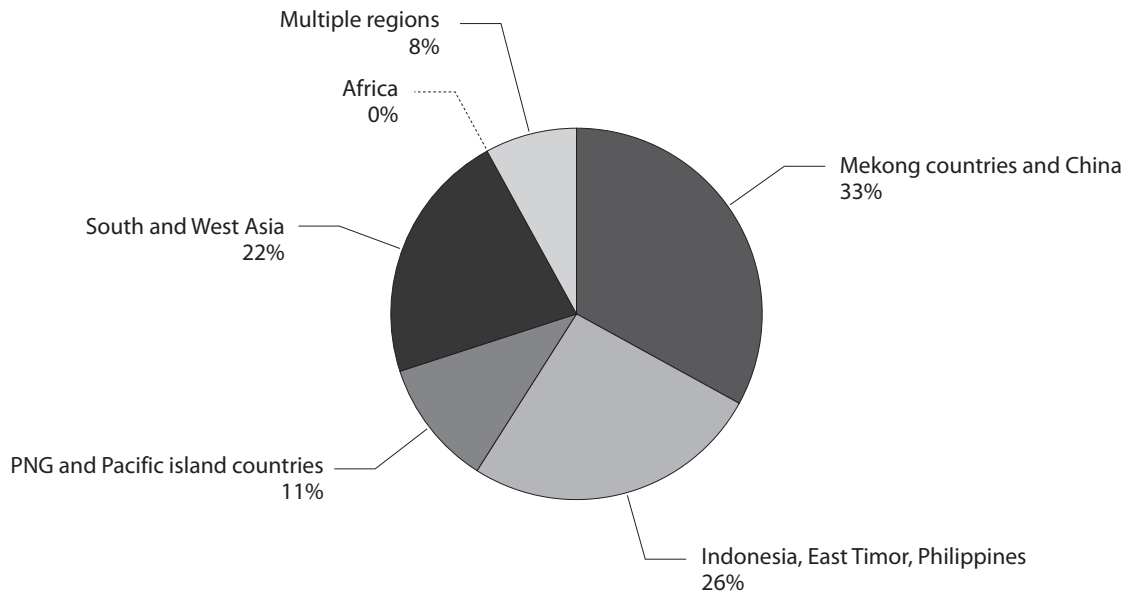

Figure 6. Regional focus of impact assessments in the current study pool

Partly as a consequence, some studies identified more than one distinct type of research output, and with a separate impact pathway from research outputs to outcomes and impacts. For instance, in the fruit-fly impact assessment study, independent research outputs were identified that had distinctly different impacts on biosecurity in Pacific island countries, on biosecurity in Australia, and on field control of fruit fly in several countries that mitigated damage and thereby either reduced production costs or enabled access to new markets. Other outputs also enabled access to new markets, either from innovations in postharvest disinfestation techniques or by establishing host-free status to the satisfaction of importing countries.

Equally disparate were the challenges in quantifying estimates of economic impacts for each impact pathway, so it is quite possible that some estimates of benefit streams are more credible than others. Hence, the unit of analysis in this study was neither the impact evaluation per se, nor the individual projects assessed in any given IAS report. Instead, the unit of analysis was the estimated quantitative stream of benefits consequential on the uptake of a particular adoption-ready research output, or cognate group of outputs, that shared a unique impact pathway. For those impact assessment studies in which diverse research outputs with dissimilar impact pathways were identified, the associated quantitative estimates of benefit streams were rated separately.

In the ultimate study pool for the current study, 38 independent quantitative estimates of streams of benefits were specified. Each was rated as either conceivable, plausible or convincing using the criteria described below.

Basis for evaluation of credibility

While the application of the economic surplus approach outlined above was common to the IAS reports in the study pool, the credibility of the final estimates of rates of return in the reports depends to a considerable degree on the details of how the assessed impacts were quantified. To rate the suite of assessments published as IAS reports, we developed a procedure that was consistent with good practice in ex-post impact assessment as outlined in the literature and in accord with our considerable experience in conducting such studies.

The following discussion about the key determinants of the credibility of ex-post impact assessment studies that employ the economic surplus methodology draws on

some of the key publications from the quite small body of literature that is pertinent to this topic, including Alston et al. (1995), Davis et al. (2008), Maredia et al. (1999), Raitzer and Lindner (2005) and Walker et al. (2008). In particular, Maredia et al. (1999) identified several key elements that should be present for a fruitful and believable impact assessment. They include:

- Clearly defined projects with information on:
  - direct project research costs
  - allocation of complementary research costs
  - allocation of staff and overhead costs for hosting research and extension agencies.
- Information on the research outputs:
  - clear articulation of the research product either as new knowledge or new technology
  - clear articulation of the pathway by which uptake leads to productivity improvements.
- Quantification of the k factor[1]
  - The k factor is central to most research impacts.
  - Its quantification should be assessed using the accepted methodology for estimating supply curve shifts.
  - The spatial and inter-temporal dimension of the k factor improvement should be identified.
- Clear articulation of the counterfactual scenario:
  - State the without-research case, in comparison with the with-research case (consequential scenario).
  - Even without research, some productivity improvements are likely to occur, either because equivalent research would have been funded by other agencies or because producers would have found alternative pathways to productivity gains.
  - At one extreme, without the research, no improvement would have occurred. At the other extreme, without the project, equivalent research would have occurred through other channels without any significant loss of benefits.
  - In some cases, the counterfactual scenario may simply be that the research and subsequent productivity improvement would be delayed. In this case, the benefit may be in bringing the impacts forward in time.

In their initial stocktake of ACIAR's investment in bilateral research, Raitzer and Lindner (2005) found that a significant number of the IAS reports departed substantially from one or more of the above good-practice guidelines. Since the publication of IAS 35, ACIAR has developed guidelines for its impact assessment program, culminating in the publication of Davis et al. (2008), but notable differences in the application of this framework still exist in the 27 more recent IAS reports that formed the pool for this study.

In part, this is because it took time to develop guidelines to improve the consistency of the methods and parameter values used by independent consultants, but it can be ascribed mainly to more intractable issues. They include differences in the availability, completeness and reliability of data sources, especially information about the uptake of research outputs and the consequential productivity improvement. Even more notable, however, are disparities in predictions about future trends in those measures. Last, and arguably even more important, are the validity, rationality and logical consistency of the assumptions made in framing an appropriate and likely counterfactual scenario.

Given such inherent scope for lack of exactitude in ex-post impact assessment, credible assessments of benefit streams must use transparent and consistent processes. Hence, the main focus in the choice of criteria to rate benefit estimates was on the key determinants of the credibility of ex-post impact assessment discussed above. Specifically, we rated the benefit streams on an assessment of the data, assumptions and rigour of the methods used to derive them. This allowed us to identify a subset of benefit streams for which it was possible to have a high degree of confidence.

The assessment criteria

Estimates of quantitative measures of the economic impacts of technology or policy shocks cannot be completely objective. Nevertheless, it is still desirable for

[1] In the impact assessment literature, the k factor is defined as the reduction in average cost of production. Clearly, both cost reductions per se and improvements in input:output ratios co-determine the reduction in average costs.

the evaluation process to be consistent between benefit streams and to be based on criteria selected to reflect best practice in ex-post impact assessment. To that end, individual IAS studies were rated on the criteria described below by two assessors, neither of whom was an author of the particular IAS reports they reviewed.

First, it was essential that the estimation procedure be transparent. If a reasonably intelligent reader could not understand what assumptions had been made and what methods were employed to derive the estimated benefit stream, such estimates would have no credibility. In other words, a necessary condition for credibility was transparency, and any impact assessment study that did not satisfy that criterion could not be included in any set of credible benefit estimates. There could be cases in which the estimates would be credible *if* the information in the report had been adequate for the reader to determine credibility.

Likewise, it was essential that the procedure used to estimate economic impacts be free of any obvious methodological or logical errors. It was also essential that the evidence that research had produced one or more adoption-ready innovations be objective and convincing. Furthermore, for any impact assessment study to be credible, it had to describe an explicit pathway for the adoption of the innovations.

Hence, as a prerequisite, the procedure used to estimate each benefit stream had to satisfy the following four necessary conditions for the benefit stream to be classified as conceivable:

- The IAS report provided a clear and understandable description of all assumptions and methods used to derive benefit estimates.
- The approach used to estimate economic impacts contained no critical methodological or logical errors.
- The report described objective and convincing evidence that outputs of the research projects included one or more adoption-ready innovations.
- The report described an explicit impact pathway that demonstrated the likelihood of uptake of adoption-ready outputs from the research projects.

All four necessary criteria were rated as *yes* or *no*. Failure to satisfy one or more of them resulted in a benefit stream being rated as inconceivable and excluded from further consideration.

All benefit estimates that were rated as conceivable were then evaluated against a further three necessary binary (yes/no) conditions for plausibility:

- Benefit estimates were derived from a comparison of outcomes between a clear and unambiguous consequential (with-research) scenario and a clear and plausible counterfactual (without-research) scenario.
- Postulated uptake of at least one innovation in the consequential scenario was based on evidence or on explicit reasoning of a strong potential for significant take-up.
- The postulated k shift in the consequential scenario was based on evidence or on explicit economic analysis.

Again, these were necessary criteria, so failure to satisfy even one of them resulted in that estimated benefit stream being rated as merely conceivable, but not plausible. However, satisfying all three criteria was not sufficient to establish plausibility, and certainly not sufficient to establish a benefit stream estimate as convincing.

Those benefit estimates that satisfied all of the necessary criteria for both conceivability and plausibility were also rated against the following seven numerical criteria:

- The plausibility of the counterfactual scenario was justified by explicit and convincing reasoning that recognised the possibility of the development of substitutable innovations from other research, other timing issues and/or mitigating factors, and other changes due to exogenous causes (10% weighting).
- The realised uptake of project innovations was based on objective and convincing evidence or on evidence-based reasoning (25% weighting).
- The postulated per unit cost reduction (the k shift) was based on objective and convincing evidence or on evidence-based reasoning (25% weighting).
- The predicted future take-up of project innovations was based on objective and convincing evidence or on evidence-based reasoning (25% weighting).

- There were no significant omissions in estimates of research costs (5% weighting).
- There were no significant errors in the application of economic surplus methodology (5% weighting).
- The quality of analysis was adequate (5% weighting).

For each criterion, a score of 0 was assigned if the criterion was deemed to not be satisfied, a score of 1 if it was partially satisfied and a score of 2 if it was fully satisfied.

In applying these credibility criteria, the assessors were asked to re-read those IAS reports for which their scores differed markedly.

An overall rating score was then computed by averaging the weighted average scores for each assessor, and multiplying by 150% so that the range of the overall rating score was from 0 to 3. This approach ensured that assessments were focused on the main criteria identified as best practice in impact assessment.

The sufficient condition for a benefit stream to be categorised as *conceivable* was that its estimation satisfied all of the necessary criteria for conceivability.

The sufficient conditions for a benefit stream to also be categorised as *plausible* were that its estimation satisfied all of the necessary criteria for conceivability and plausibility, and that it had an overall rating score greater than 1.5 for credibility.

The sufficient conditions for a benefit stream to also be categorised as *convincing* were that its estimation satisfied all of the necessary criteria for conceivability and plausibility, and that it had an overall rating score of at least 2.5 for credibility.

In addition, any given benefit stream can notionally be split into two parts. The first part, termed 'realised benefits', was defined in this study as the subset of the benefit stream estimated for the period preceding the date of publication of the IAS report. Realised benefits can supposedly be inferred from observed evidence on the values of the key determinants of economic impacts: the extent and speed of uptake of research outputs, and per unit cost reductions.

The second component comprised benefits yet to be realised at the time of the impact assessment ('projected benefits'). Necessarily, estimations of projected benefits are based, at least in part, on predictions about uncertain events. Clearly, estimates of the realised benefits portion are more credible than the projected benefits subset of the same benefit stream.

Quantitative estimates of benefit streams

While investment by ACIAR was the common thread running through all assessed bilateral research projects, other Australian and developing-country project partners also contributed complementary funding for the development of adoption-ready innovations. Furthermore, other aid agencies and even private firms also supplied part of the costs in some cases. Arguably, ACIAR funding was necessary for many of the estimated impacts of these projects, although in more than one IAS report the author(s) judged that if ACIAR had not funded the research, other agencies would have done so, albeit some years later.

As was the case in the first review of returns to ACIAR's investment in bilateral research, many impact assessment studies did not attempt to partition the proportion of quantified benefits that could be attributed to ACIAR from those attributable to partner organisations. Rather, most impact assessments simply sought to quantify the total economic impacts from the combined investment by ACIAR and all other contributing funders, and then set those collective benefits against total research costs.

However, one of the main aims in the current study was to investigate whether the subset of convincing benefits, which are a lower-bound estimate of highly believable total benefits, could justify the aggregated cost of ACIAR's investment in bilateral research since the agency's inception. To do so, it was necessary to estimate the share of total assessed benefits that could reasonably be attributed solely to ACIAR's investment. Consistent with the method used in other studies that also needed to apportion estimated benefits between complementary sources of funding, we used a variety of sources to calculate ACIAR's share of the total investment in the projects assessed for each IAS report (in some cases, the report contained enough information to calculate ACIAR's share of total project costs; in others,

we obtained comparable information from the CIE database or from project documents). This share of costs was then used to attribute to ACIAR the same share of total benefits assessed from the projects considered in the particular IAS studies, and those attributed benefits were then aggregated up over all IAS reports in the study pool.

Not all IAS reports made the same assumptions about the duration of the benefit streams. Earlier studies tended to estimate benefits only for 30 years from a defined starting point, which was usually the first year of the ACIAR research investment (ACIAR's contract guidelines at that time specified that future benefits be calculated over a 30-year period). Later studies tended to follow the guidelines published in IAS 58, which recognised that benefits from many types of research output reach a steady state and then continue indefinitely. Hence, the annuity value for future benefits (and any costs) should be used in the final year of the impact assessment period.

Because the quantitative estimates of benefit streams from each impact assessment were made at different times by disparate independent consultants, they had to be standardised before they could be aggregated. Converting them to a common basis first involved deflating all annual benefits (and costs) with an appropriate price deflator so they were expressed in constant 2012 dollars. Then the flows of costs and benefits were aggregated over time by discounting or compounding from the year of incidence to calculate their 2012 PV.

Some caveats

One caveat concerns the possibility that returns to a few bilateral research projects might be negative, or at least less than research costs. For instance, significant costs may be incurred in enabling the uptake of new technologies that then fail to deliver expected benefits. Also, the take-up of research outputs may result in negative external effects. Such unintended consequences are considered very unlikely, but it is possible that certain problems (such as exotic pest introductions) may be due to some research activities. Also unlikely, but not impossible, are certain negative social and/or environmental consequences indirectly attributable to agricultural innovations. These possibilities could only be ruled out by an exhaustive study of all impacts of all bilateral research projects, which is simply not feasible.

Offsetting such caveats are several reasons why the approach adopted in this study was very conservative. First, only a small fraction of ACIAR's research program has been subject to impact assessment, and the scope of this study was limited to a subset of those projects that have been assessed. Furthermore, while many of the projects that have not been assessed might have generated only modest benefits, it is likely that a few such projects did produce significant returns that have not been quantified.

More importantly, virtually all impact assessment studies documented positive economic as well as non-economic impacts that could not be quantified, but were no less valid for that difficulty. Notable examples included more knowledge, enhanced research capability and other capacity building, and poverty alleviation. As a result, measures of aggregate benefits reported in this analysis exclude many probably important impacts.

Last, there was little or no opportunity to clarify ambiguities with most authors of the assessments in the study pool. As a result, assumptions sometimes had to be made on the basis of the reviewers' experience when the methodology of the analysis was not clear from the explanation provided in the impact assessment study. Those assumptions may have resulted in estimated benefit streams being over- or underestimated, and it is possible that some studies rated here as being only conceivable might actually have delivered a strong stream of benefits, which should have been rated as plausible or convincing. Similarly, there might be other cases where the reverse was true.

It also must be understood that because we were rating the credibility of how the benefit streams were estimated, there may have been some benefit streams that were rated as plausible or convincing but delivered small benefit streams or even no benefits. One example was IAS 59, which concluded that there had been no uptake in the Philippines of the outputs from research into grain-drying technology, and that this was likely to remain the case. Although this outcome was disappointing, the assessment that there were no quantifiable benefits was highly credible.

4 Results

Observations on the study pool

The study pool for this review comprised 27 impact assessment studies in which at least some of the economic impacts of 103 bilateral research projects were quantified by a panel of independent consultants. The 2012 PV of cumulative expenditure from 1982 to 2012 by ACIAR alone on the 103 projects was $151 million. These values exclude some earlier investment before the establishment of ACIAR and exclude a very small amount of future investment in these projects that is predicted to be spent in 2013 and 2014. For a small number of very large multi-country projects, only that part of the total cost of investment deemed to have been focused on countries included in study-pool IAS reports was included in study-pool costs.

When expenditure by partners was taken into account, the corresponding combined investment by ACIAR and partner organisations was estimated to have been $448 million. The estimate was necessary because information about contributions by organisations other than ACIAR and project partners was skimpy.

By 2012, the PV of cumulative investment by ACIAR on all bilateral research since the inception of the agency in 1982 was $2,517 million. The time profile of that investment is illustrated in Figure 7, together with the estimated total cost of the study-pool projects and of ACIAR's contribution to that cost. Cumulative investment by ACIAR in the study-pool projects increased from less than 3% of its total investment in bilateral research in the early years to more than 6% in recent years. Figure 7 also depicts the time profile of convincing benefits up to 2012.

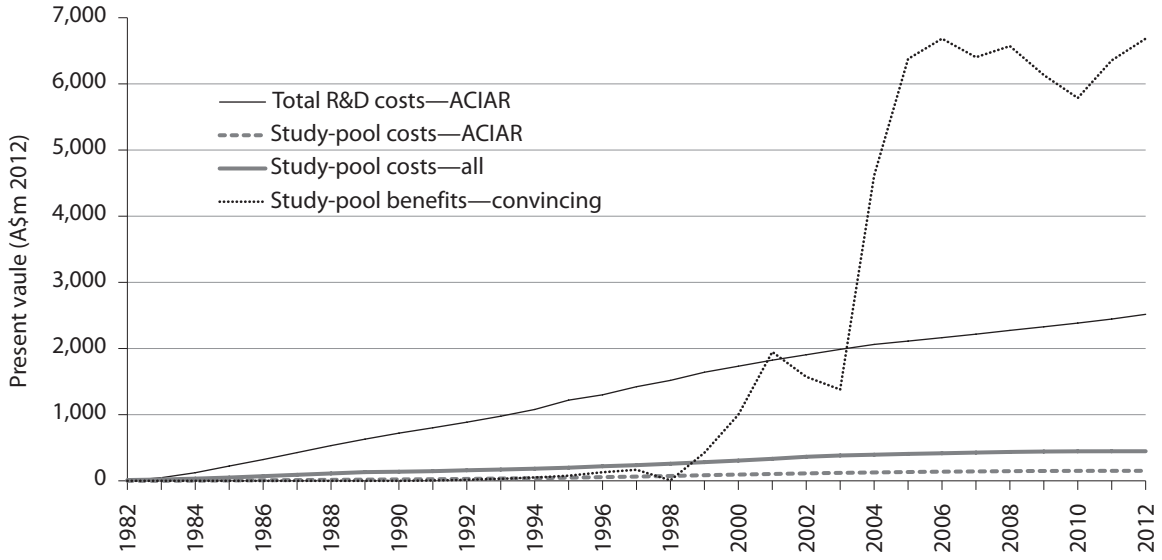

Figure 7. Return on investment by ACIAR in bilateral research, 1982–2012

The distribution of the combined investment by ACIAR and its partner organisations between research focus areas and regions across the 103 bilateral research projects is illustrated in Figures 8 and 9.

For study-pool projects, the dominant focus areas by level of research investment were crop improvement and management, followed by forestry, and then by livestock production systems. Table 1 compares this breakdown by research focus area with the allocation of total expenditure on bilateral research by ACIAR for the 2011–12 financial year. It was not possible to compare the allocation of bilateral R&D expenditure by research focus area for the study-pool with that for cumulative expenditure by ACIAR because data on the latter were not available.

Research areas in which the share of 2011–12 expenditure substantially exceeded the share of investment of study pool projects included agribusiness, agricultural systems management, cropping systems and economics, animal health, land and water resources, and soil management and crop nutrition, while the reverse was true for crop improvement and management, livestock production systems, and forestry.

The regional focus of investment in study-pool projects was dominated by South and West Asia (34.4%); Indonesia, East Timor and the Philippines (28.1%); and the Mekong countries and China (24.6%)(Figure 9). By comparison with the regional allocation of bilateral research expenditure in 2011–12, South and West Asia were over-represented in the study-pool projects, while Africa was under-represented.

The other notable feature of the study pool was the considerable variation in the magnitude of the investment among the 27 impact assessment studies. Five of the 27 study-pool impact assessments (IAS 44, 51, 52, 56 and 71) accounted for 69% of the total expenditure by ACIAR and other agencies on study-pool research topics. Moreover, ACIAR funding for the projects assessed in those five assessments accounted for 50% of ACIAR's investment in study-pool projects. Among the clusters of research projects, the combined investment by various agencies on pigeonpea plant breeding (assessed in IAS 44) was the largest and accounted for 23% of all related expenditure on bilateral research projects in the study pool. However, the two ACIAR projects on pigeonpea plant breeding were estimated to have made up less than 5% of the total cost of this extended program of plant breeding research. On the other hand, ACIAR's investment in the 17 fruit-fly research projects assessed in IAS 56 comprised 23% of the centre's funding for all study-pool research projects.

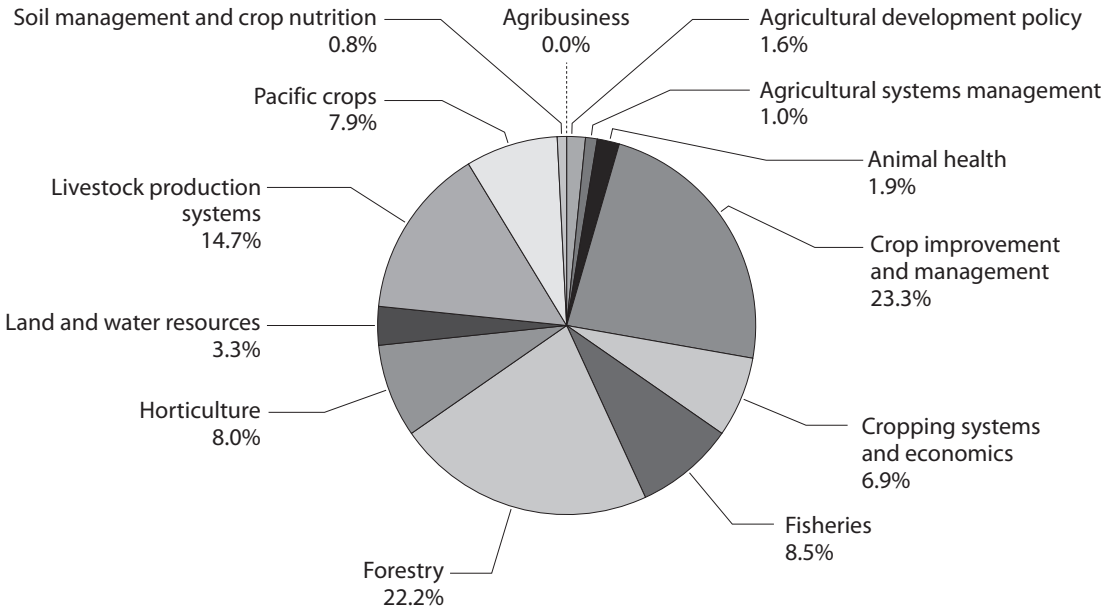

Figure 8. Research focus in the study pool, by 2012 present value of combined cost of research projects

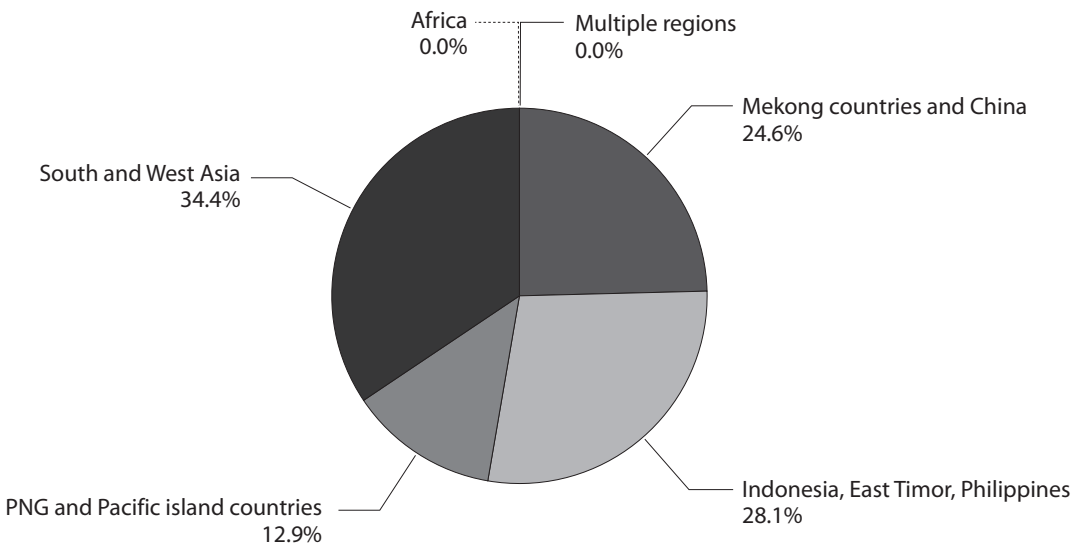

Figure 9. Regional focus of research projects in the study pool, by 2012 present value of combined costs

Table 1. Share of bilateral research investment, by research focus area

Research focus area	Share of total bilateral research cost (%)	
	2011–12	Study-pool projects
Agribusiness	5.4	0.0
Agricultural development policy	1.3	1.6
Agricultural systems management	5.2	1.0
Horticulture	8.9	8.0
Pacific crops	4.5	7.9
Cropping systems and economics	17.9	6.9
Crop improvement and management	10.8	23.3
Animal health	6.6	1.9
Fisheries	7.1	8.5
Livestock production systems	6.0	14.7
Forestry	9.2	22.2
Land and water resources	10.0	3.3
Soil management and crop nutrition	5.3	0.8
Australian International Food Security Research Centre	0.1	–
Impact assessment	0.2	–
Cambodia agricultural value chain	1.6	–

While most of the 38 benefit streams were assessed to continue in perpetuity, there were five cases in which the duration of the estimated benefit stream was both finite and short. For two such cases, the reason for truncating the period of the benefit stream was a judgment by the assessor that, without the ACIAR investment, the innovation would have been developed with alternative funding from another source, albeit some years later. Hence, the sole impact of ACIAR funding was to bring the realisation of benefits from uptake of the innovation forward in time. Another two cases involved a policy innovation, the uptake of which was deemed to be ephemeral, while in the remaining case there was no take-up.

For five benefit streams, the fact that estimated benefits in some years were assessed to be negative also requires some comment. Three were tree-growing projects for which direct costs associated with the uptake of research project outputs were incurred in early years, while revenue from harvesting was only received several years later. The other two involved the take-up of policy innovations, which, depending on exogenous events, might mean that net benefits for the counterfactual scenario exceed those for the consequential scenario in some years.

As was the case for investments in study-pool projects, there is huge variation in the magnitude of the PV of estimated benefits for the 38 benefit streams. This is illustrated in Figure 10, which displays both realised and projected benefits for each benefit stream.

Clearly, the uptake of innovations from the Indonesian forestry projects assessed in IAS 71 delivered the largest flow of benefits, accounting for nearly 37% of the estimated total PV for all 38 benefit streams. Moreover, the five largest benefit streams accounted for more than 77% of total benefits. In the case of the benefit stream from sandalwood research assessed in IAS 71, realised benefits were negative because none of the trees had been harvested at the time of the impact assessment study.

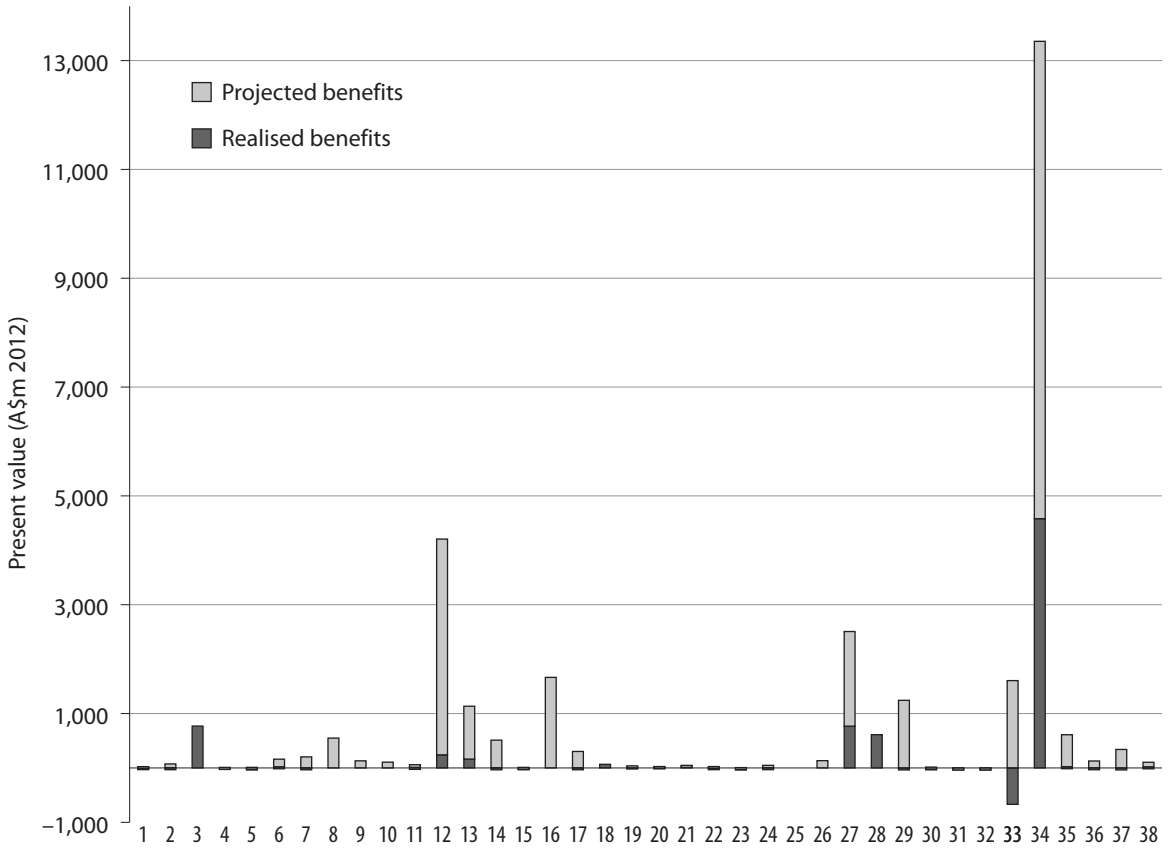

Figure 10. Present value (PV) of realised and projected benefits for 38 benefit streams

Conceivable benefits

All 38 quantified estimates of benefit streams satisfied all four necessary conditions for conceivability, and consequently all 38 were rated as conceivable benefits. In contrast to some studies in the previous stocktake, all studies in the current study pool were executed in a professional way and were methodologically sound. Almost all conformed closely to the guidelines developed by ACIAR on good practice for impact assessment, even though the guidelines were not published until 2008.

In aggregate, the 2012 PV of all conceivable benefits was estimated to be $30,170 million, of which $6,733 million was realised (in the sense that evidence on which to base their estimation was available when the impact assessment study was carried out). Overall, the ratio of total conceivable benefits to combined investment in study-pool projects was 67:1, while the benefit:cost ratio for realised benefits alone was 15:1.

Of the quantified level of conceivable benefits, it was estimated that $13,195 million could be attributed to funding from ACIAR. This exceeds the centre's cumulative investment of $2,517 million in all bilateral research since its inception, so the corresponding benefit:cost ratio was 5.2:1. Indeed, realised conceivable benefits attributable to ACIAR of $2,729 million alone could justify ACIAR's cumulative investment in all bilateral research.

Figure 11 shows the magnitude of quantified realised and projected conceivable benefits by research focus area. Figure 12 shows the relative magnitude of the benefits for the same focus areas. Benefits from forestry projects clearly were the single largest source, followed by benefits from livestock production systems, cropping systems and economics, and fisheries projects. Only around 9% of total benefits came from projects in all other research areas.

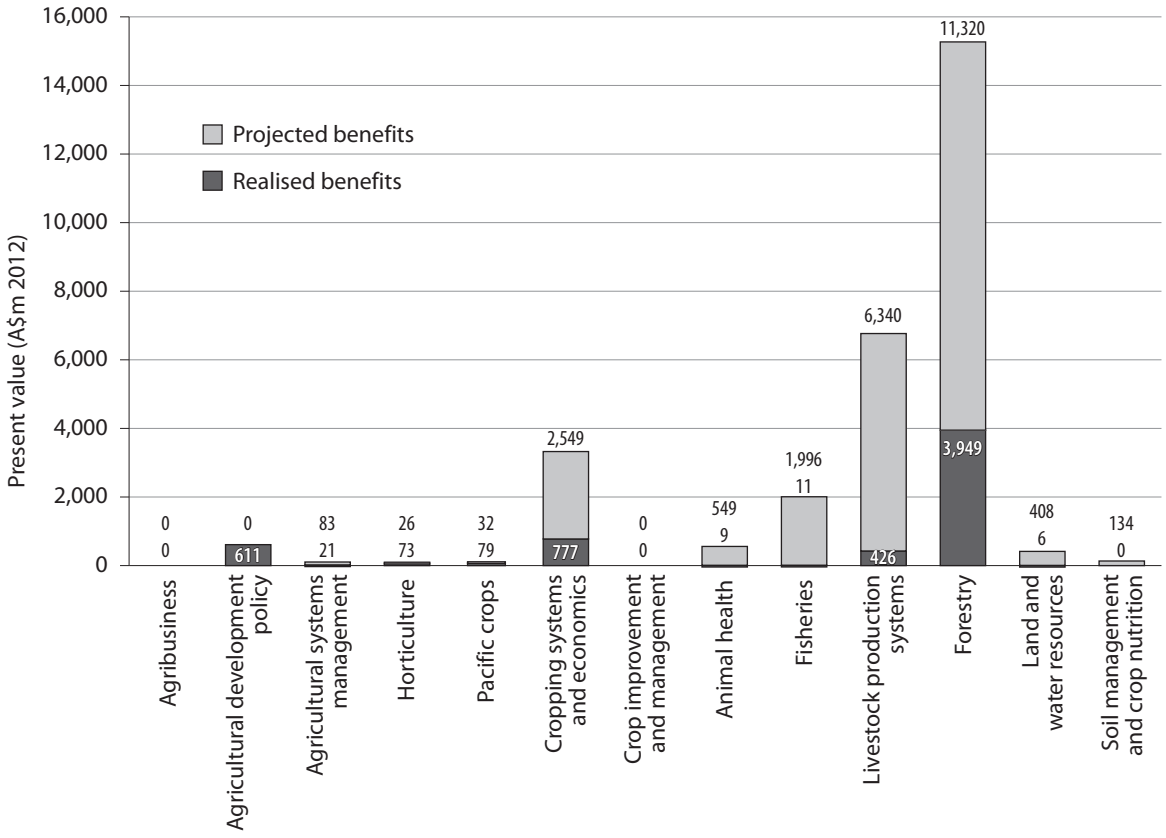

Figure 11. Research focus of benefits rated as conceivable

Figure 13 illustrates the regional distribution of realised and projected conceivable benefits, and the proportion of conceivable benefits for each region is shown in Figure 14. The benefits to Australia amounted to $1,232 million (realised benefits of –$652 million and projected benefits of $1,884 million) or 4.1% of total conceivable benefits, which is over half the total investment by ACIAR in bilateral research.

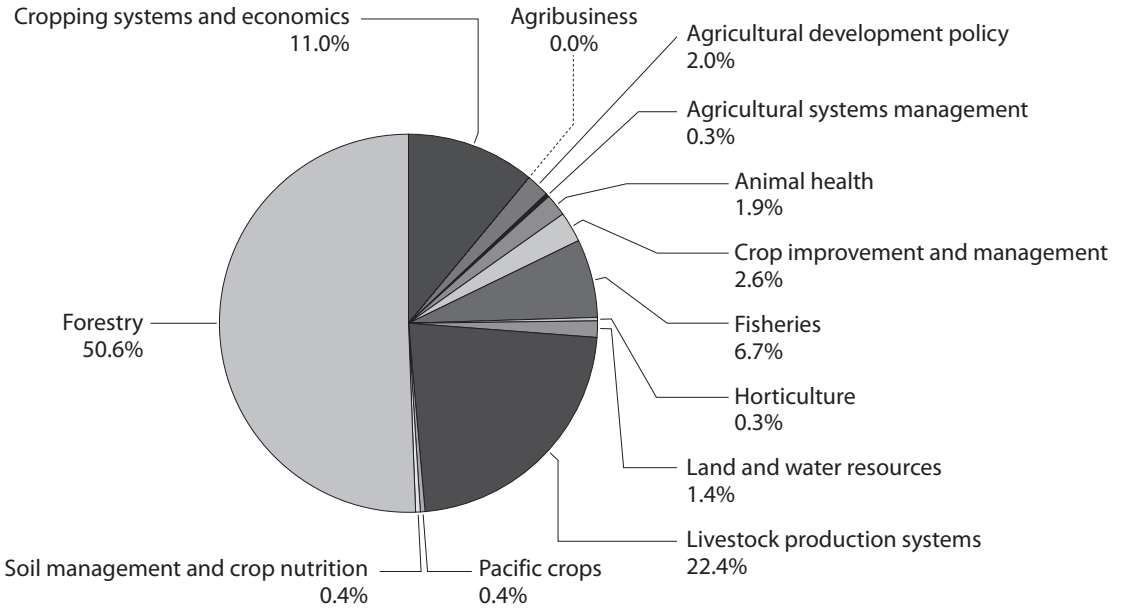

Figure 12. Proportion of conceivable benefits, by research focus area

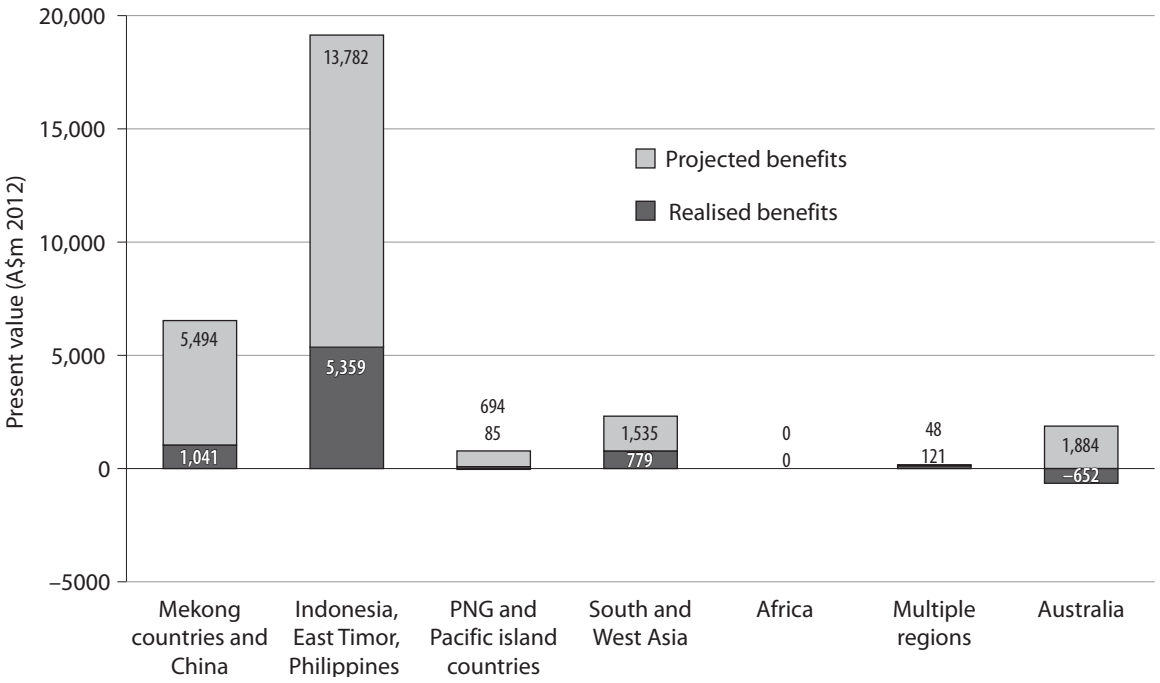

Figure 13. Regional focus of benefits rated as conceivable

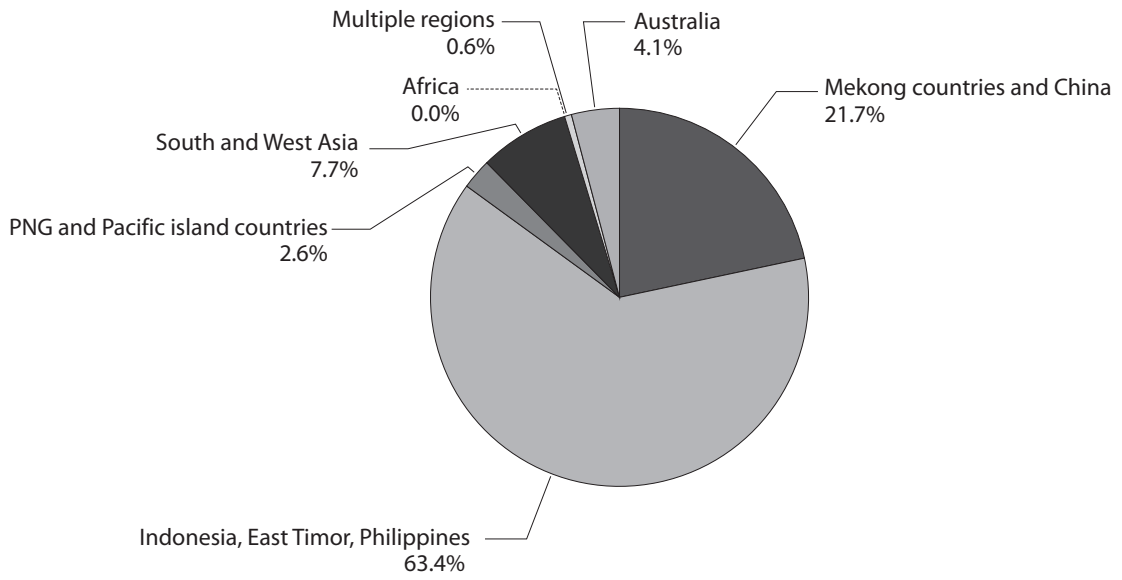

Figure 14. Proportion of conceivable benefits, by regional area

Plausible benefits

Of the 38 conceivable benefit streams, three did not satisfy all of the necessary conditions for plausibility and so were rated as only conceivable. Potentially, the remaining 35 benefit streams could be rated as plausible, or even convincing, provided the scores for the numerical criteria for credibility were sufficiently high. However, a further seven benefit streams received an average score of less than 1.5, which was the critical cut-off score to be rated plausible or better. Hence, only 28 benefit streams were rated as being at least plausible.

The 2012 PV of benefits rated to be plausible was estimated to be $24,987 million, which was approximately one-third less than the PV of all conceivable benefits. Nevertheless, total plausible benefits still exceeded the combined cost of all study-pool projects by a ratio of 56:1. Using cost-based attribution of benefits, the subset of plausible benefits attributable to ACIAR was estimated to be $10,771 million, which was 4.3 times larger than all investment by ACIAR in bilateral research projects since 1982.

Figure 15 depicts the magnitude of realised and projected plausible benefits by research focus area, while Figure 16 shows the relative magnitude of the benefits for the same focus areas. Again, forestry projects were the single largest source of plausible benefits, followed by livestock production systems and cropping systems and economics projects. Fisheries projects, which were a sizeable component of conceivable benefits, were a negligible component of plausible benefits because two very large benefit streams that were rated as conceivable were not rated as plausible. Benefits from projects in other research areas were also minor components of plausible benefits.

Figure 17 illustrates the regional distribution of realised and projected plausible benefits from the study-pool projects. The benefits to Australia that were classed as plausible amounted to $1,232 million (realised benefits of –$652 million and projected benefits of $1,884 million) or 4.9% of total plausible benefits.

Figure 18 shows the proportion of plausible benefits by region.

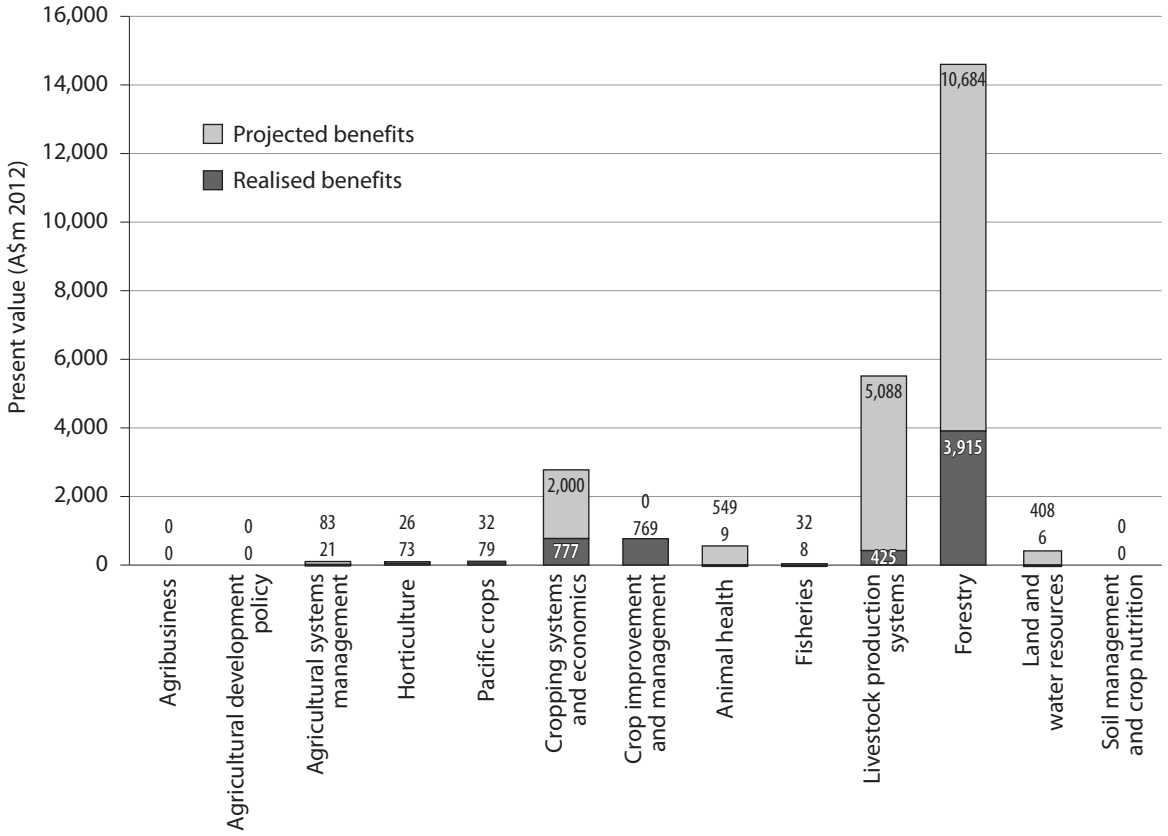

Figure 15. Research focus of benefits rated as plausible

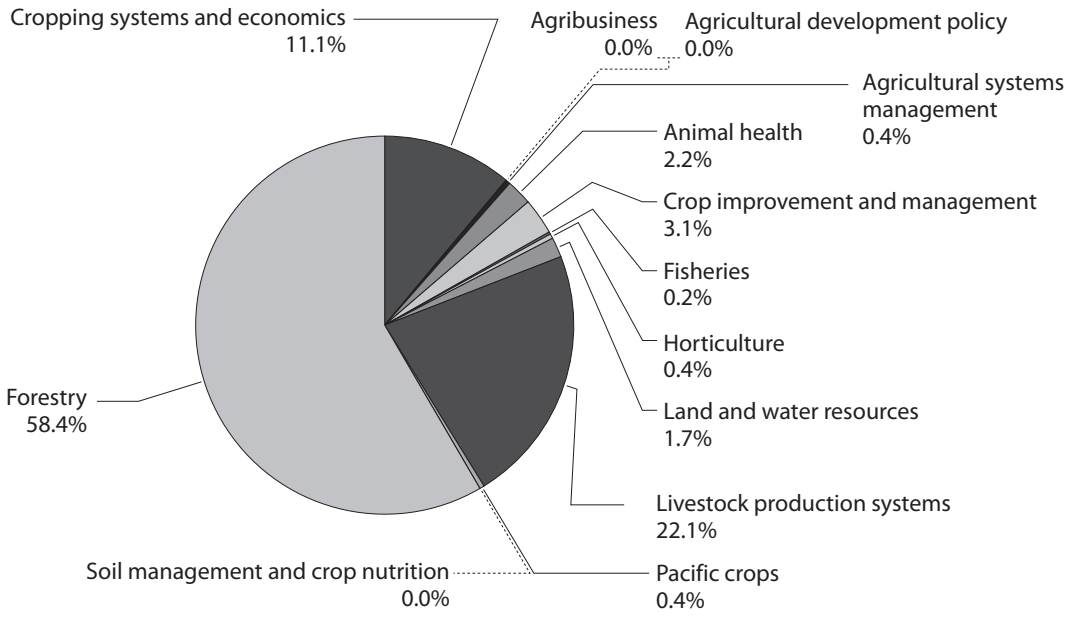

Figure 16. Proportion of plausible benefits, by research focus area

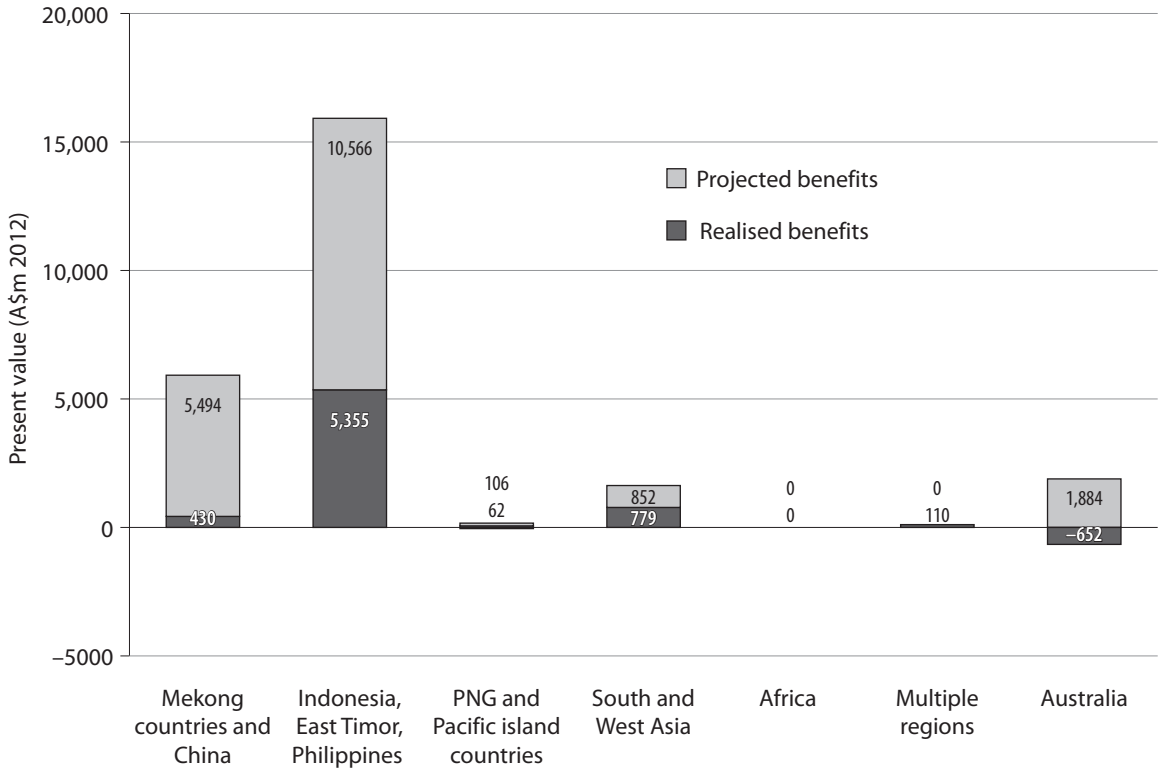

Figure 17. Regional focus of benefits rated as plausible

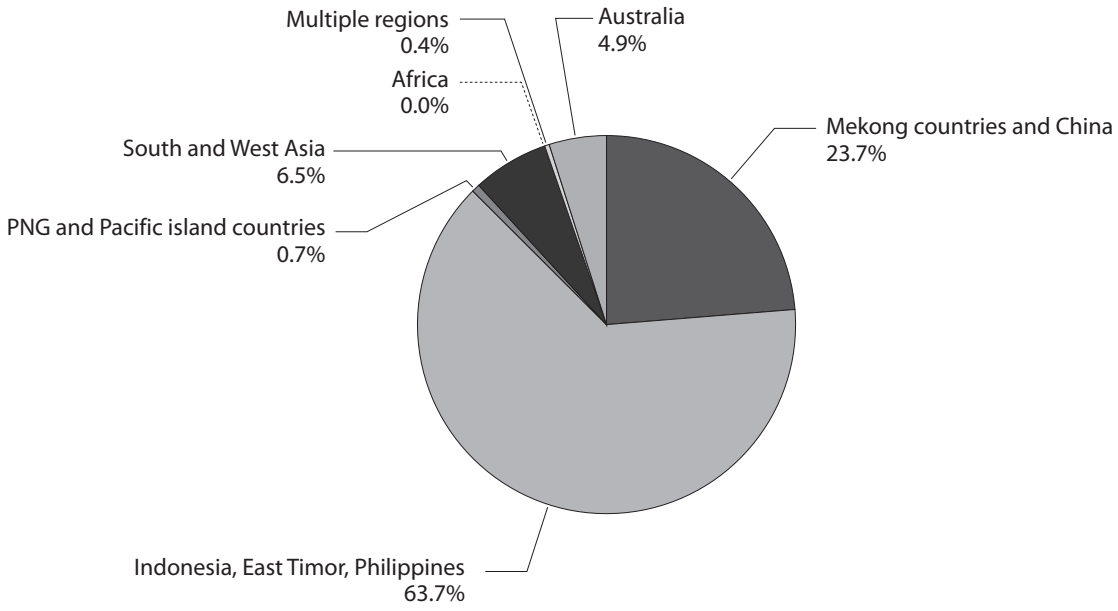

Figure 18. Proportion of plausible benefits, by regional area

Convincing benefits

Of the 28 benefit streams rated as being plausible, only 15 received an average score for the numerical criteria of more than 2.5, which was the critical cut-off score to be rated as convincing.

The total PV of convincing benefits was estimated to be $22,995 million, which was only slightly smaller than the estimate of $24,987 million for plausible benefits, even though the number of convincing benefit streams was much smaller than the number of plausible benefit streams. Clearly, the 13 benefit streams rated as plausible, but not convincing, were generally considerably smaller than those rated as convincing.

In fact, the first, third and fifth largest benefit streams, which accounted for 55% of all conceivable benefits, were rated as convincing. Those three streams were equal to 80% of plausible benefits and 87% of convincing benefits. Just as striking is the fact that for these three benefit streams, a 2012 PV of $5,303 million, or 79% of all realised conceivable benefits, was assessed as already realised by the time of the impact assessment. Furthermore, the clusters of bilateral research projects that generated these benefit streams also generated another two distinct streams that were also rated as convincing, so the estimated PV of convincing benefits from these three clusters of research projects was $22,138 million, which almost equalled the PV of all convincing benefits.

Overall, the ratio of total convincing benefits to combined investments in study-pool projects was 51:1, and the benefit:cost ratio for realised benefits alone was 12:1. The combined realised plus prospective convincing benefits that could be attributed to investment by ACIAR was estimated to be $10,098 million. Relative to the PV of total investment by ACIAR in all bilateral research projects since inception, the benefit:cost ratio was 4:1. Moreover, those benefits realised at the time when the impact studies were completed almost equalled that cost base. This is a striking result.

Figures 19 and 20 depict the magnitude and proportion of assessed realised and projected convincing benefits by research focus area.

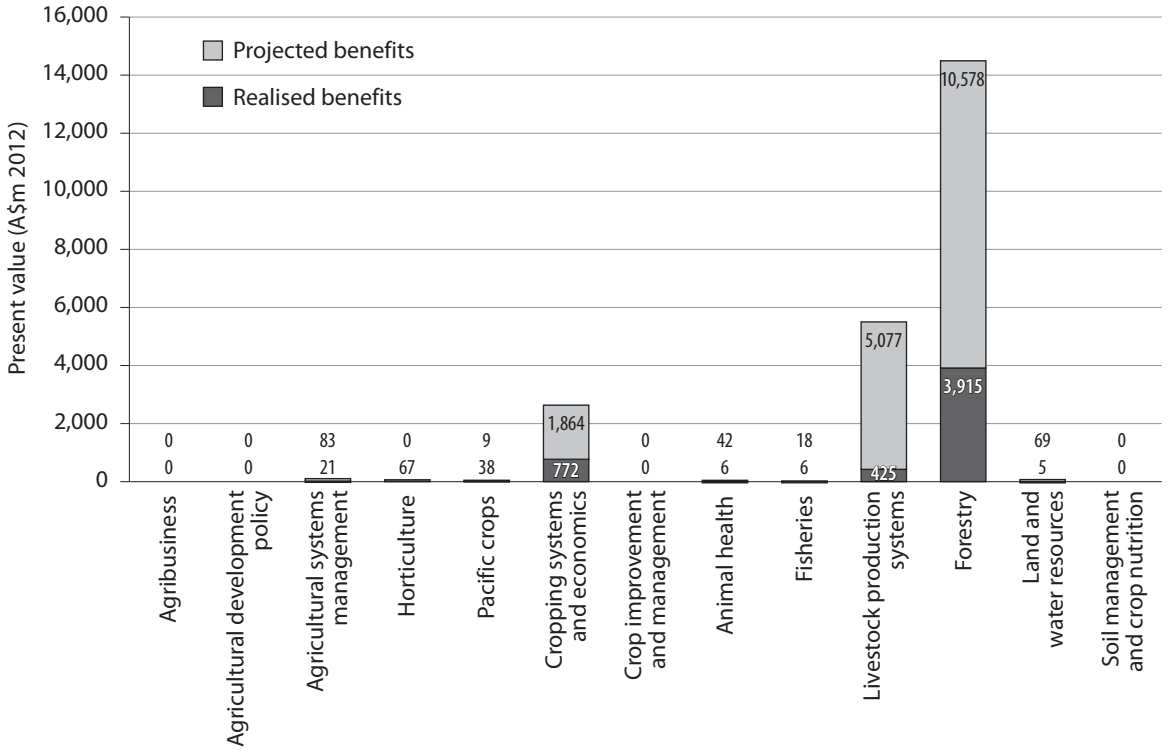

Figure 19. Research focus of benefits rated as convincing

Figure 21 shows the regional focus of convincing benefits, while Figure 22 shows the proportions of convincing benefits, by region. The net flow of benefits to Australia classed as convincing amounted to $1,101 million, or 5.1% of total convincing benefits (realised benefits of –$652 million and projected benefits of $1,753 million).

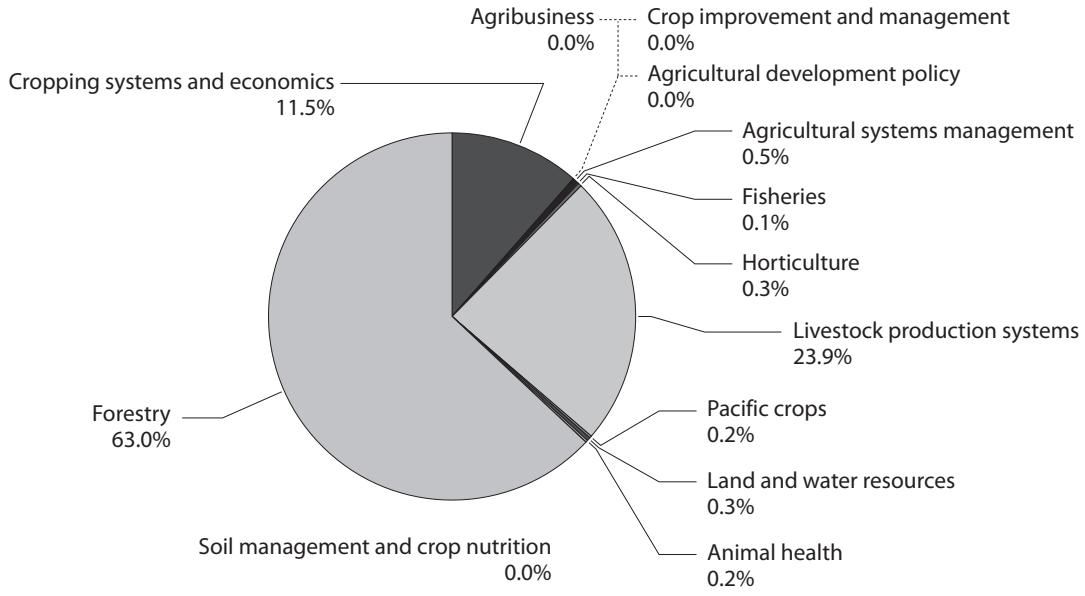

Figure 20. Proportion of convincing benefits, by research focus area

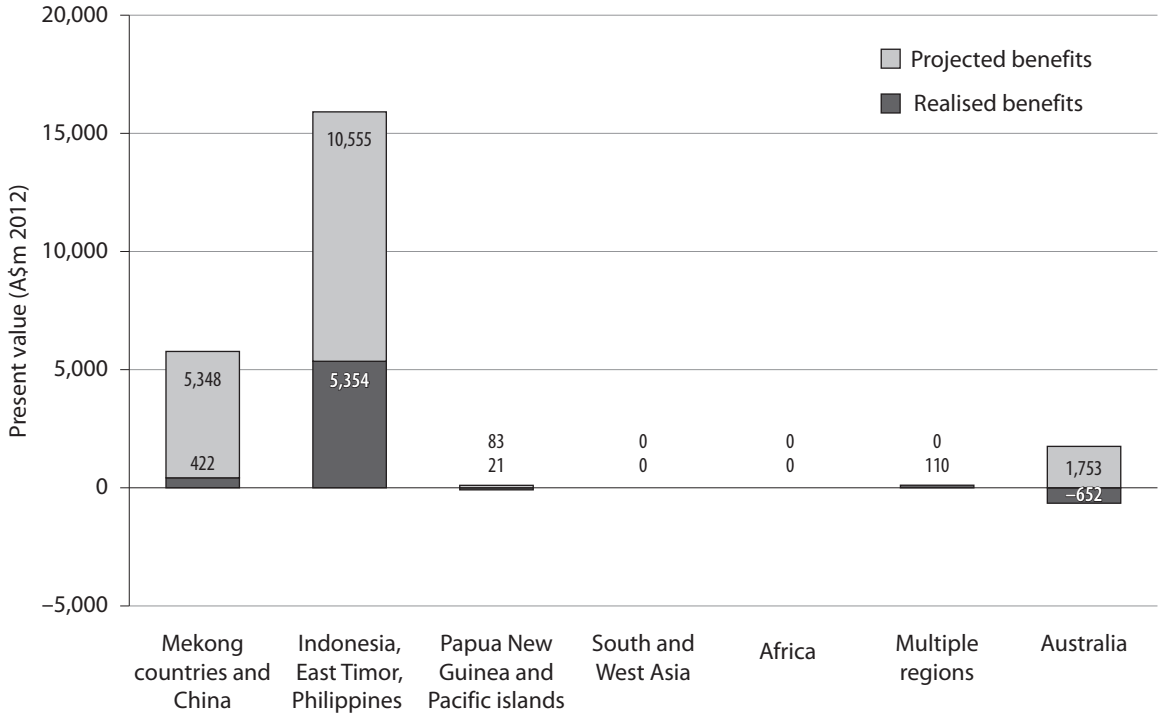

Figure 21. Regional focus of benefits rated as convincing

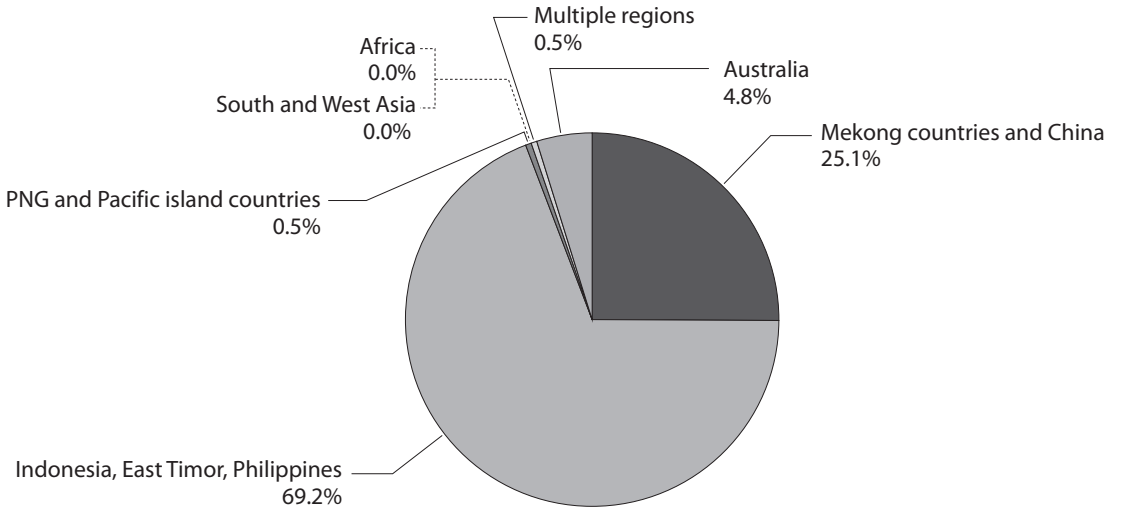

Figure 22. Proportion of convincing benefits, by regional area

Benefits to Australia

Four streams delivered benefits to Australia:

- Biosecurity gains from understanding mite pests of honey bees (IAS 46) ($161 million)
- Incorporation of ICRISAT germplasm in Australian sorghum breeding program (IAS 48) ($131 million)
- Access to Japanese mango market through post-harvest treatment of fruit fly (IAS 56) ($4 million)
- Development of the sandalwood industry in Ord River (IAS 71) ($936 million).

Only one of these benefit streams, sorghum germplasm, was not classed as being convincing but, rather, plausible. The total flow of benefits to Australia classed as convincing was estimated to be $1,101 million. While only about half of ACIAR's investment in bilateral research since 1982, it easily exceeded ACIAR's investment of $448 million in the set of IAS reports under review here.

Discussion

In aggregate, ACIAR and partner organisations invested a sum of $448 million in the 103 bilateral research projects assessed in the study pool of 27 impact assessments. Out of all possible economic impacts resulting from the uptake of outputs from those projects, the sum of benefits that could be quantified in formal impact assessments was estimated to be $30,170 million. Furthermore, all of those benefits were rated as conceivable.

The ratios of conceivable benefits to costs for each impact assessment in the study pool are shown in Figure 23. They are highly disparate, with one negative and one zero value, although the ratio exceeds 5:1 for another 20 impact assessment studies, and it even exceeds 100:1 for eight of them. The weighted average of the 27 benefit:cost ratios was 66:1.

Two preliminary inferences can be made from these findings. Returns to collaborative research projects between Australian scientists and overseas counterparts can be very high indeed, but, ex ante, it is difficult to pick the 'gushers' from the 'dry holes'. At the time of commissioning, ACIAR presumably did not expect any of these projects to yield negligible returns, let alone negative returns.

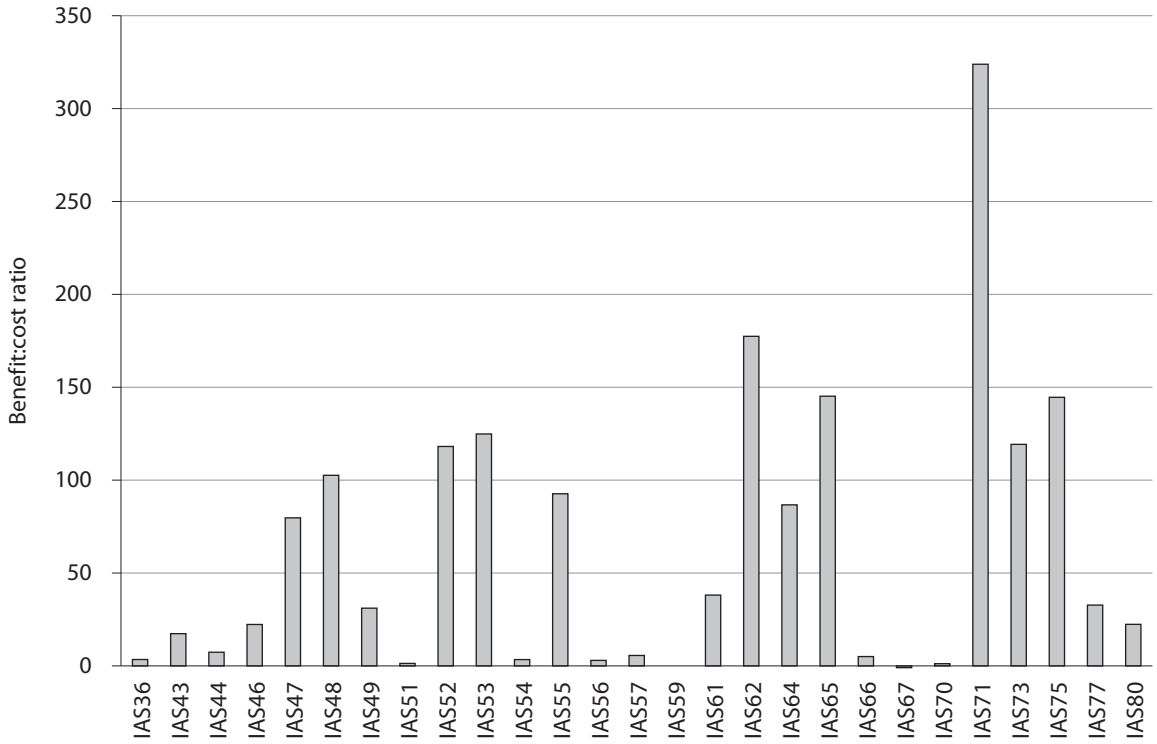

Figure 23. Assessed conceivable benefit:cost ratios for 27 impact assessment studies

However, in this evaluation of the credibility of estimated benefits, only a subset of the conceivable benefits above were rated as being plausible, and only a subset of plausible benefits were rated as being convincing. Specifically, out of the estimate of $30,170 million in conceivable benefits, only $22,995 million was rated as convincing.

Table 2 provides details of the benefits, costs and benefit:cost ratios for those benefit streams that were rated as convincing. For each of IAS 52, IAS 56 and IAS 71, two of the benefit streams were rated as convincing. The two streams had to be aggregated to calculate a combined benefit:cost ratio for each IAS.

Additionally, within the stream of convincing benefits, the subset of realised benefits was more credible than projected benefits. While the former were based on observable evidence available at the time the impact assessment was conducted, the latter had to depend, at least to some extent, on predictions about levels of uptake and consequential outcomes long after the completion of the impact assessment. Of the $22,995 million of convincing benefits from the study-pool projects, $5,303 million was already realised when the impact assessment studies were carried out, and $17,692 million was projected to be realised in subsequent years.

Figure 24 shows the individual benefit:cost ratios broken down into realised and projected components. If anything, convincing benefits were even more highly disparate than conceivable benefits. Overall, convincing benefits of $22,995 million were 52 times the $448 million invested in all study-pool projects, but 109 times greater than $210 million, which was the cost attributed to only those projects that generated convincing benefits.

Overall, estimated benefits from investments in just three clusters of cognate research projects completely dominated total benefits regardless of whether they were rated as convincing, plausible, or merely conceivable.

Table 2. Benefits, costs and benefit:cost ratios for study-pool benefit streams rated as convincing

IAS no.	Benefit stream	Benefits ($m)		Costs ($m)		B/C ratio
		Total	ACIAR	Total	ACIAR	
36	Mudcrab hatchery technology in Vietnam	24	8	7.0	2.3	3.4
43	Irrigation water management in Vietnam	74	50	4.3	2.9	17.4
46	Bee mite pest control in Australia	161	108	8.2	5.5	19.7
47	Improved tree species in Vietnam	203	111	2.6	1.4	79.7
52	Pig breeding in Vietnam	4,206	1,648	45.2	17.7	118.1
52	Pig feeding in Vietnam	1,135	445			
56	Fruit-fly biosecurity benefits to Australia	67	30	70.8	32.0	1.6
56	Fruit-fly biosecurity benefits in Pacific and Australia	47	21			
57	Endoparasite control in goats in the Philippines	48	4	8.5	0.7	5.6
59	Grain drying in the Philippines	0	0	6.0	3.9	0
62	Integrated pest management in stored grain in the Philippines	2,508	1,812	14.1	10.2	177.4
71	Indonesian forestry—sandalwood in Australia	936	373	44.1	17.6	323.9
71	Indonesian forestry—Australian trees in Indonesia	13,354	5,320			
75	Rice yields in Laos	128	105	0.9	0.7	144.6
80	Oil palm in Papua New Guinea	105	64	4.7	2.9	22.4
	Total	**22,995**	**10,098**	**216.0**	**98.0**	**103.0**

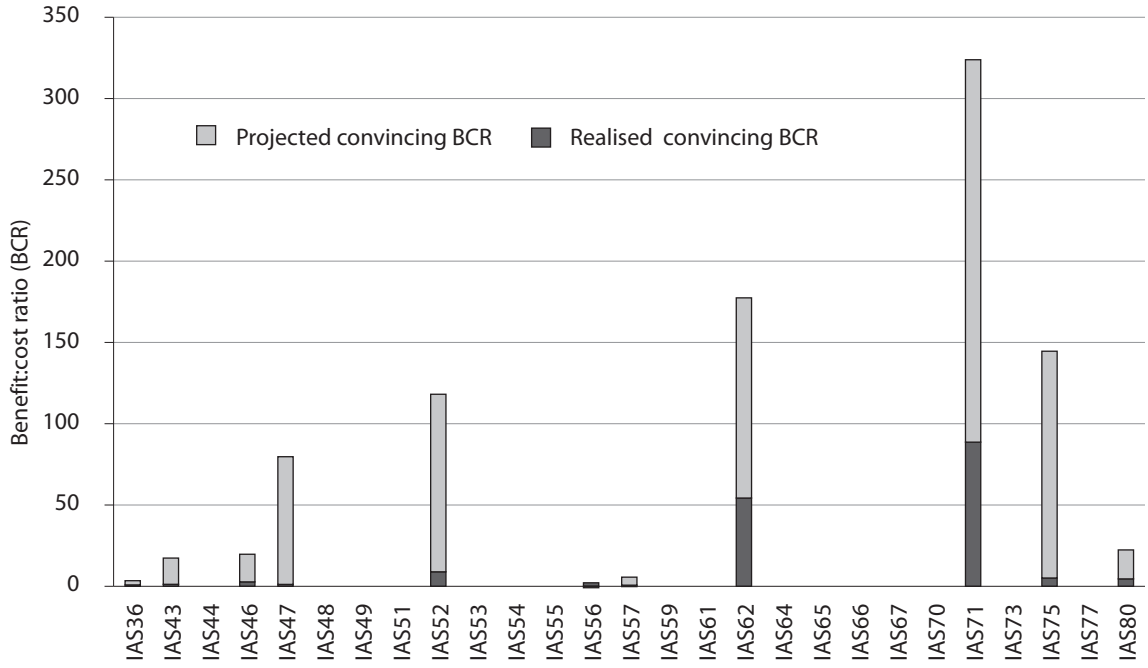

Figure 24. Assessed realised and projected benefit:cost ratios for 11 convincing estimates of economic impacts

Undoubtedly, the outstanding source of financial returns was the investment in a cluster of multi-country research projects that sought to domesticate Australian hardwood species through genetic enhancement and improved plantation management to raise the productivity of forestry plantations. In IAS 71, the Indonesian component of those projects was assessed to have produced two distinct outputs: improved germplasm based on Australian hardwoods and related management practices for pulpwood plantations in Indonesia, and novel technology to grow Indian sandalwood in plantations in the Ord River Irrigation Area in Australia. The combined PV of the benefit streams from take-up of those two innovations was estimated to be $14,290 million ($13,354 million and $936 million, respectively). Furthermore, in other impact assessment studies, uptake of a similar set of innovations from the same cluster of forestry research projects was estimated to have also generated substantial benefits in Vietnam and China. The key driver of the outstanding returns to forestry research was the widespread take-up of research results over very large areas.

Next, in IAS 52, take-up of outputs from a single pig breeding and feeding project was estimated to have generated $5,341 million of benefits. Again, the key driver of the high returns to the project was widespread uptake of research results that were applicable to huge numbers of pigs in small herds owned by most Vietnamese households.

The third most important source of study-pool benefits was uptake of innovations for insect pest management in stored grain that were developed by a series of research projects in the Philippines. The new pest management regime was based on integrated pest management principles of using chemicals in combination, in rotation, and at the lowest effective dose rates when indicated by pest population monitoring. The new regime overcame an emerging problem of pest resistance to malathion, with an estimated economic impact of $2,508 million. In addition, it lowered the risks to human and environmental health from pesticides.

Altogether, these three clusters of research projects were estimated to have generated $22,138 million of benefits, which accounted for 73% of conceivable benefits, 89% of plausible benefits and 93% of convincing benefits.

The ratings of quantified benefits for study-pool projects are summarised in Table 3 by categories of credibility, together with corresponding benefit:cost ratios using combined costs of study-pool projects as the base.

However, as a guide to the general returns that can be expected from investment by ACIAR in bilateral research, such benefit:cost ratios are potentially misleading. First, no attempt was made in any of the impact assessment studies to comprehensively quantify all possible benefits. In particular, benefits from new knowledge and capacity building typically were not estimated, and social, human health and environmental benefits were not quantified in any of the studies. Likewise, spillover benefits to other commodities, regions or countries were rarely, if ever, estimated.

Second, the bilateral research projects evaluated in the impact assessment reports were only a subset (<10%) of all such projects supported by ACIAR and partners.

Table 3. Summary of quantified benefits for study-pool projects, by credibility category

Total quantified benefits from study-pool projects ($m)			
Benefits	**Conceivable**	**Plausible**	**Convincing**
Quantified	30,170	24,987	22,995
Realised	6,733	6,084	5,303
Projected	23,437	18,903	17,692
Ratio of benefits to combined costs of study-pool projects ($448 million)			
Quantified	67.4	55.8	51.4
Realised	15.0	13.6	11.9
Projected	52.4	42.2	39.5

Moreover, apart from the exceptions discussed above, the selection of most of that subset was based on the perception that they had been successful. Hence, it could be argued that the selection of most of the projects for impact assessment was biased towards those projects that, ex post, yielded higher returns.

Despite such apparent cherrypicking, many research projects in the study pool yielded only very modest returns. Still, because little, if anything, is known about returns to those projects not selected for formal impact assessment, it seems likely that any 'gushers' among the unselected projects would be both fewer and smaller, and that many more such projects would prove to be 'dry holes' or even to have yielded negative returns. However, both the Philippines grain pests study and the Indonesian forestry study were either randomly selected, or commissioned because of the lack of studies undertaken in Indonesia, so the very large pay-offs to these projects were surprising.

A more conservative indication of likely overall returns to research was provided by the ratio of PV of those study-pool benefit streams attributed to ACIAR and rated as convincing to the PV of total investment by ACIAR in all bilateral research projects since inception. To implement this approach, it was necessary to partition total benefit streams into a component attributable to ACIAR and a component attributable to other funders. Typically, all inputs to jointly funded investments are necessary, while none is sufficient on its own. Hence, cost-based attribution was used as the basis for estimating ACIAR-specific benefits for projects classified as conceivable, plausible and convincing.

Table 4 summarises the benefits from all bilateral research projects to date attributable solely to ACIAR, and the corresponding benefit:cost ratios based on all of ACIAR's investments in bilateral research progress for the conceivable/plausible/convincing and realised/projected dimensions.

If we counted only benefits attributable to ACIAR that were both convincing and realised, the estimated benefits were $2,358 million, a little less than ACIAR's investments since 1982. Clearly, though, this would be a gross underestimate of the ultimate impact from the 15 convincing benefit streams. While projected future convincing benefits of $7,741 million were subject to a degree of possible forecasting error, nevertheless the estimate that convincing benefits ultimately realised would be about $10,098 million was based on compelling evidence. This implies that even the lower bound to highly credible estimates of benefits from the study-pool projects would exceed all ACIAR's investments to date in bilateral agricultural research by a ratio of about 4:1.

Table 4. Quantified benefits attributed to ACIAR from study-pool projects

Quantified benefits attributed to ACIAR from study-pool projects ($m)			
Benefits	**Conceivable**	**Plausible**	**Convincing**
Quantified	13,195	10,771	10,098
Realised	2,729	2,410	2,358
Projected	10,465	8,361	7,741
Ratio of benefits to ACIAR's investment in all bilateral research projects ($2,517 million)			
Quantified	5.2	4.3	4.0
Realised	1.1	1.0	0.9
Projected	4.2	3.3	3.1

Comparison with previous studies

It is natural to ask how the results presented here compare with the findings of the earlier CIE analyses and the Raitzer and Lindner (2005) analysis, which was the forerunner of this analysis. The two sets of studies are consistent in their assessment that the returns to ACIAR's bilateral research program have been high. Investment in the projects assessed in the IAS reports was easily exceeded by the stream of total benefits (by a multiple of 80, according to the updated (unpublished) Harding et al. analysis and the present analysis), and even by realised total benefits. Moreover, the benefits, both in total as well as those attributable to ACIAR, exceeded the total investment in the bilateral research program since 1982 even when benefits were restricted to those that were 'substantially demonstrated', in Raitzer and Lindner's terms, or 'convincing' in this report.

Nevertheless, it was difficult to assess the level of consistency between these studies. One reason for this was that the CIE and the Lindner studies (comprising Raitzer and Lindner and this present study) separately assembled data on benefits and costs from the IAS reports, and it is likely that small differences have arisen. An important difference is that Harding et al. (2009, updated) derived an ACIAR cost share of 50%, whereas here the average cost share of an admittedly smaller sample was 34% (Raitzer and Lindner did not report an average cost share). One reason is that the CIE studies focused on total benefits across all countries and total benefits to Australia, whereas in Raitzer and Lindner (2005) as well as in this study the focus is on whether benefits attributable to ACIAR could justify its total investment in all bilateral research projects. This report also presents estimates of total benefits as well as benefits to Australia, but those measures are less easily identified in Raitzer and Lindner (2005).

Another problem is that some research projects have been assessed in more than one IAS report, so simply summing across studies would result in some double counting of benefits and costs. Harding et al. (2009) do not disclose how they treated double counting. With the exception of our 'convincing' and Raitzer and Lindner's 'substantially demonstrated' subset, we have not attempted to aggregate benefits and costs over the two reports. To do so would have required us to rework the Raitzer and Lindner analysis to remove benefit streams reestimated in the set of IAS reports reviewed here.

The flow of benefits attributable to ACIAR from the seven benefit streams classed by Raitzer and Lindner (2005) as 'substantially demonstrated' amounted to $2,709 million (compounded forward and expressed in 2012 dollars). In this study, 15 benefit streams were classed as 'convincing' and delivered $10,098 million in benefits attributable to ACIAR. The two classes of benefit streams cannot simply be aggregated because the benefits of pig breeding and feeding research in Vietnam are included in both streams. In IAS 17, the estimated benefit of this project was $475 million (2012 dollars), and the net value of substantially demonstrated benefits in Raitzer and Lindner (2005) after deducting that sum was $2,234 million. When this net amount attributable to ACIAR is added to this study's estimate of $10,098 million of 'convincing' benefits, the aggregate value of highly credible benefits is $12,332 million, which exceeds ACIAR's total investment in bilateral research ($2,517 million) by a factor of 4.9:1. In our view, this represents a lower-bound estimate of the returns to ACIAR's investment in bilateral research since 1982.

5 Conclusion

We were commissioned by ACIAR to review the 27 IAS reports (covering 103 projects) in which economic impacts were quantified, starting with IAS 36. We identified 38 separate benefit streams from the set of 27 IAS reports. The key objectives of this review process were to assess the credibility of those benefit flows and identify a subset that were convincing and hence provided a lower-bound estimate of the returns to ACIAR's investment in bilateral research. Since its inception in 1982, ACIAR has invested $2,517 million in bilateral research and $151 million in this set of projects.

In a manner similar to Raitzer and Lindner (2005), we rated the methodology used to estimate the economic impact of each benefit stream by its transparency, plausibility and analytical rigour. The benefit streams were classified as conceivable (38), a plausible (28) subset of conceivable and a convincing (15) subset of plausible.

Reflecting the rigour that ACIAR guidelines now require in impact assessment, all 38 benefit streams were rated as conceivable—evidence that the efforts ACIAR has made to improve impact assessment processes, particularly in developing the guidelines reported in IAS 58, have been fruitful.

It is worth stating again that we were rating the credibility of how the benefit streams were estimated. Hence, there may be some benefit streams that were rated as plausible or convincing but that delivered small benefit streams, or even no benefits. Moreover, it is possible that some studies rated here as being only conceivable might have delivered a strong stream of benefits that should have been rated as convincing. ACIAR could aim for even greater transparency by asking for greater detail about how conceptual models to estimate economic impact are implemented and empirical results are derived.

Turning to the efficiency with which ACIAR uses resources, the flow of conceivable benefits from the 38 benefit streams amounted to $30,170 million (PV 2012), of which $13,195 million was attributable to ACIAR. These benefit streams can be related to the combined investment by ACIAR and partners in the 103 study-pool projects ($448 million), or to the total investment in ACIAR's bilateral research program since 1982 ($2,517 million), giving benefit:cost ratios of 67:1 and 5.2:1, respectively. The latter ratio is particularly notable, given that research projects assessed in the IAS cover only a small proportion of ACIAR's total bilateral research program.

We rated 15 benefit flows as being convincing, with total benefits of $22,995 million, of which $10,098 million was attributable to ACIAR. For convincing benefits, the benefit:cost ratios, calculated as above (for total and ACIAR-attributed figures) were 51:1 and 4:1, respectively. The realised benefits attributable to ACIAR from the 15 convincing benefit streams amounted to $2,358 million, a little less than ACIAR's investments since 1982.

The flow of benefits from the seven benefit streams classed by Raitzer and Lindner (2005) as 'substantially demonstrated' amounted to $2,709 million (compounded forward and expressed in 2012 dollars). After netting out some double counting, the estimated value of substantially demonstrated benefits from Raitzer and Lindner was $2,234 million. Hence, the aggregate value of highly credible benefits ('substantially demonstrated' plus 'convincing' benefits) attributable to ACIAR from all research projects assessed to date was $12,332 million, which exceeds ACIAR's total investment in bilateral research of $2,517 million by a ratio of 4.9:1.

As has been found in previous studies, a small number of highly successful projects 'carried' the rest. Three benefit streams—the use of Australian germplasm in Indonesian forestry, pig breeding in Vietnam and integrated pest management in stored grain in the Philippines—accounted for 55% of all conceivable benefits, 80% of plausible benefits and 87% of convincing benefits. Two other smaller benefit streams associated with these same clusters of cognate research projects—sandalwood in the Ord and pig feeding in Vietnam—were also convincing. Hence, nearly all convincing benefits derived from these three research clusters. Unfortunately, there is no science allowing the identification of potential 'gushers' ex ante.

Our finding that the returns to ACIAR's investment in bilateral research are high is consistent with Raitzer and Lindner (2005), the forerunner to this analysis, and with the CIE analyses of the benefits to Australia from the bilateral program. They are also consistent with a large body of cost–benefit analyses at the project level reviewed by the Productivity Commission (2011), and with econometric studies at the aggregate level by Alston et al. (2010) for the United States and by Sheng et al. (2011) for Australia.

It also needs to be remembered that no attempt was made in any of the impact assessment studies to comprehensively quantify all possible benefits. In particular, benefits from new knowledge and capacity building were typically not estimated, and social, human health and environmental benefits were not quantified in any of the impact assessments that comprised the study pool. Likewise, spillover benefits to other commodities, regions or countries were rarely, if ever, estimated.

Appendix 1: Study pool of economic impact assessment studies and assessed research projects reviewed for this report

No.	Title	Projects
36	Impacts of mud crab hatchery technology in Vietnam	FIS/1992/017, FIS/1999/076
43	Water management in public irrigation schemes in Vietnam	LWR1/1998/034, LWR2/1994/004
44	Impact assessment of capacity building and training: assessment framework and two case studies	CS1/1982/001, CS1/1985/067, LWR2/1994/004, LWR1/1998/034
46	Mite pests of honey bees in the Asia–Pacific region	AS2/1990/028, AS2/1994/017 AS2/1994/018, AS2/1999/060
47	Improved Australian tree species for Vietnam	FST/1993/118, FST/1998/096
48	Assessment of capacity building: overcoming production constraints to sorghum in rainfed environments in India and Australia	CS1/1994/968
49	Minimising impacts of fungal disease of eucalypts in South-East Asia	FST/1994/041
51	Growing trees on salt-affected land	FST/1993/016
52	Breeding and feeding pigs in Vietnam: assessment of capacity building and an update on impacts	AS2/1994/023
53	The impact of increasing efficiency and productivity of ruminants in India by the use of protected-nutrient technology	AH/1997/115
54	Impact of improved management of white grubs in peanut-cropping systems in India	CS2/1994/050
55	ACIAR fisheries projects in Indonesia: review and impact assessment	FIS/1997/022, FIS/1997/125, FIS/2000/061, FIS/2001/079, FIS/2002/074, FIS/2002/076, FIS/2005/169, FIS/2006/144
56	A review and impact assessment of ACIAR's fruit-fly research partnerships—1984–2007	CP/1997/079, CP/2001/027, CP/2002/086, CP/2007/002, CP/2007/187, CS2/1983/043, CS2/1989/019, CS2/1989/020, CS2/1994/003, CS2/1994/115, CS2/1996/225, CS2/1997/101, CS2/1998/005, CS2/2003/036, PHT/1990/051, PHT/1993/87, PHT/1994/133
57	Management of internal parasites in goats in the Philippines	AS1/1997/133
59	Two-stage grain drying in the Philippines	PHT/1983/008, PHT/1986/008, PHT/1990/008

No.	Title	Projects
61	Salinity reduction in tannery effluents in India and Australia	AS1/2001/005
62	Integrated management of insect pests of stored grain in the Philippines	PHT/1983/009, PHT/1983/011, PHT/1986/009, PHT/1990/009
64	Reform of domestic grain markets in China: a reassessment of the contribution of ACIAR-funded economic policy research	ADP/1997/021, ANRE1/1992/028
65	ACIAR investment in research on forages in Indonesia	AS2/2000/103, AS2/2000/124, AS2/2001/125, LPS/2004/005, SMAR/2006/061, SMAR/2006/096
66	Extending low-cost fish farming in Thailand: an ACIAR–World Vision collaborative program	PLIA/2000/165
67	The biology, socioeconomics and management of the barramundi fishery in Papua New Guinea's Western Province	FIS/1998/024
70	Extending low-chill fruit in northern Thailand: an ACIAR–World Vision collaborative project	PLIA/2000/165
71	The economic impact in Indonesia and Australia from ACIAR's investment in plantation forestry research, 1987–2009	FST/1986/013, FST/1990/043, FST/1993/118, FST/1995/110, FST/1995/124, FST/1996/182, FST/1997/035, FST/1998/096, FST/2000/122, FST/2000/123, FST/2003/048, FST/2004/058
73	Forestry in Papua New Guinea: a review of ACIAR's program	FST/1994/033, FST/1995/123, FST/1998/118, FST/2002/010, FST/2004/050, FST/2004/055, FST/2004/061, FST/2006/048, FST/2006/088, FST/2006/120, FST/2007/078, FST/2009/012
75	Extending rice crop yield improvements in Lao PDR: an ACIAR–World Vision collaborative project	CIM/1999/048, CS1/1995/100, PLIA/2000/165
77	Rice–wheat cropping systems in India and Australia, and development of the 'Happy Seeder'	LWR/2000/089, LWR/2006/132, CSE/2006/124
80	Oil palm pathways: an analysis of ACIAR's oil palm projects in Papua New Guinea	ASEM/1999/084, ASEM/2002/014, ASEM/2006/127, CP/1996/091, CP/2007/098, PC/2004/064, PC/2006/063

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IMPACT ASSESSMENT SERIES

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

IMPACT ASSESSMENT SERIES <CONTINUED>

No.	Author(s) and year of publication	Title	ACIAR project numbers
24	Palis F.G., Sumalde Z.M. and Hossain M. 2004.	Assessment of the rodent control projects in Vietnam funded by ACIAR and AusAID: adoption and impact	AS1/1998/036
25	Brennan J.P. and Quade K.J. 2004.	Genetics of and breeding for rust resistance in wheat in India and Pakistan	CS1/1983/037 and CS1/1988/014
26	Mullen J.D. 2004.	Impact assessment of ACIAR-funded projects on grain-market reform in China	ADP/1997/021 and ANRE1/1992/028
27	van Bueren M. 2004.	Acacia hybrids in Vietnam	FST/1986/030
28	Harris D. 2004.	Water and nitrogen management in wheat–maize production on the North China Plain	LWR1/1996/164
29	Lindner R. 2004.	Impact assessment of research on the biology and management of coconut crabs on Vanuatu	FIS/1983/081
30	van Bueren M. 2004.	Eucalypt tree improvement in China	FST/1984/057, FST/1987/036, FST/1988/048, FST/1990/044, FST/1994/025, FST/1996/125 and FST/1997/077
31	Pearce D. 2005.	Review of ACIAR's research on agricultural policy	
32	Tingsong Jiang and Pearce D. 2005.	Shelf-life extension of leafy vegetables—evaluating the impacts	PHT/1994/016
33	Vere D. 2005.	Research into conservation tillage for dryland cropping in Australia and China	LWR2/1992/009 and LWR2/1996/143
34	Pearce D. 2005.	Identifying the sex pheromone of the sugarcane borer moth	CS2/1991/680
35	Raitzer D.A. and Lindner R. 2005.	Review of the returns to ACIAR's bilateral R&D investments	
36	Lindner R. 2005.	Impacts of mud crab hatchery technology in Vietnam	FIS/1992/017 and FIS/1999/076
37	McLeod R. 2005.	Management of fruit flies in the Pacific	CS2/1989/020, CS2/1994/003, CS2/1994/115 and CS2/1996/225
38	ACIAR 2006.	Future directions for ACIAR's animal health research	
39	Pearce D., Monck M., Chadwick K. and Corbishley J. 2006.	Benefits to Australia from ACIAR-funded research	AS2/1990/028, AS2/1994/017, AS2/1994/018, AS2/1999/060, CS1/1990/012, CS1/1994/968, FST/1993/016 and PHT/1990/051
40	Corbishley J. and Pearce D. 2006.	Zero tillage for weed control in India: the contribution to poverty alleviation	CS1/1996/013
41	ACIAR 2006.	ACIAR and public funding of R&D. Submission to Productivity Commission study on public support for science and innovation	
42	Pearce D. and Monck M. 2006.	Benefits to Australia of selected CABI products	
43	Harris D.N. 2006.	Water management in public irrigation schemes in Vietnam	LWR1/1998/034 and LWR2/1994/004
44	Gordon J. and Chadwick K. 2007.	Impact assessment of capacity building and training: assessment framework and two case studies	CS1/1982/001, CS1/1985/067, LWR2/1994/004 and LWR2/1998/034

IMPACT ASSESSMENT SERIES <CONTINUED>

No.	Author(s) and year of publication	Title	ACIAR project numbers
45	Turnbull J.W. 2007.	Development of sustainable forestry plantations in China: a review	
46	Monck M. and Pearce D. 2007.	Mite pests of honey bees in the Asia–Pacific region	AS2/1990/028, AS2/1994/017, AS2/1994/018 and AS2/1999/060
47	Fisher H. and Gordon J. 2007.	Improved Australian tree species for Vietnam	FST/1993/118 and FST/1998/096
48	Longmore C., Gordon J. and Bantilan M.C. 2007.	Assessment of capacity building: overcoming production constraints to sorghum in rainfed environments in India and Australia	CS1/1994/968
49	Fisher H. and Gordon J. 2007.	Minimising impacts of fungal disease of eucalypts in South-East Asia	FST/1994/041
50	Monck M. and Pearce D. 2007.	Improved trade in mangoes from the Philippines, Thailand and Australia	CS1/1990/012 and PHT/1990/051
51	Corbishley J. and Pearce D. 2007.	Growing trees on salt-affected land	FST/1993/016
52	Fisher H. and Gordon J. 2008.	Breeding and feeding pigs in Vietnam: assessment of capacity building and an update on impacts	AS2/1994/023
53	Monck M. and Pearce D. 2008.	The impact of increasing efficiency and productivity of ruminants in India by the use of protected-nutrient technology	AH/1997/115
54	Monck M. and Pearce D. 2008.	Impact of improved management of white grubs in peanut-cropping systems in India	CS2/1994/050
55	Martin G. 2008.	ACIAR fisheries projects in Indonesia: review and impact assessment	FIS/1997/022, FIS/1997/125, FIS/2000/061, FIS/2001/079, FIS/2002/074, FIS/2002/076, FIS/2005/169 and FIS/2006/144
56	Lindner B. and McLeod P. 2008.	A review and impact assessment of ACIAR's fruit-fly research partnerships—1984–2007	CP/1997/079, CP/2001/027, CP/2002/086, CP/2007/002, CP/2007/187, CS2/1983/043, CS2/1989/019, CS2/1989/020, CS2/1994/003, CS2/1994/115, CS2/1996/225, CS2/1997/101, CS2/1998/005, CS2/2003/036, PHT/1990/051, PHT/1993/87 and PHT/1994/133
57	Montes N.D., Zapata Jr N.R., Alo A.M.P. and Mullen J.D. 2008.	Management of internal parasites in goats in the Philippines	AS1/1997/133
58	Davis J., Gordon J., Pearce D. and Templeton D. 2008.	Guidelines for assessing the impacts of ACIAR's research activities	
59	Chupungco A., Dumayas E. and Mullen J. 2008.	Two-stage grain drying in the Philippines	PHT/1983/008, PHT/1986/008 and PHT/1990/008
60	Centre for International Economics 2009.	ACIAR Database for Impact Assessments (ADIA): an outline of the database structure and a guide to its operation	
61	Fisher H. and Pearce D. 2009.	Salinity reduction in tannery effluents in India and Australia	AS1/2001/005

IMPACT ASSESSMENT SERIES <CONTINUED>

No.	Author(s) and year of publication	Title	ACIAR project numbers
62	Francisco S.R., Mangabat M.C., Mataia A.B., Acda M.A., Kagaoan C.V., Laguna J.P., Ramos M., Garabiag K.A., Paguia F.L. and Mullen J.D. 2009.	Integrated management of insect pests of stored grain in the Philippines	PHT/1983/009, PHT/1983/011, PHT/1986/009 and PHT/1990/009
63	Harding M., Tingsong Jiang and Pearce D. 2009.	Analysis of ACIAR's returns on investment: appropriateness, efficiency and effectiveness	
64	Mullen J.D. 2010.	Reform of domestic grain markets in China: a reassessment of the contribution of ACIAR-funded economic policy research	ADP/1997/021 and ANRE1/1992/028
65	Martin G. 2010.	ACIAR investment in research on forages in Indonesia	AS2/2000/103, AS2/2000/124, AS2/2001/125, LPS/2004/005, SMAR/2006/061 and SMAR/2006/096
66	Harris D.N. 2010.	Extending low-cost fish farming in Thailand: an ACIAR–World Vision collaborative program	PLIA/2000/165
67	Fisher H. 2010.	The biology, socioeconomics and management of the barramundi fishery in Papua New Guinea's Western Province	FIS/1998/024
68	McClintock A. and Griffith G. 2010.	Benefit–cost meta-analysis of investment in the International Agricultural Research Centres	
69	Pearce D. 2010.	Lessons learned from past ACIAR impact assessments, adoption studies and experience	
70	Harris D.N. 2011.	Extending low-chill fruit in northern Thailand: an ACIAR–World Vision collaborative project	PLIA/2000/165
71	Lindner R. 2011.	The economic impact in Indonesia and Australia from ACIAR's investment in plantation forestry research, 1987–2009	FST/1986/013, FST/1990/043, FST/1993/118, FST/1995/110, FST/1995/124, FST/1996/182, FST/1997/035, FST/1998/096, FST/2000/122, FST/2000/123, FST/2003/048 and FST/2004/058
72	Lindner R. 2011.	Frameworks for assessing policy research and ACIAR's investment in policy-oriented projects in Indonesia	ADP/1994/049, ADP/2000/100, ADP/2000/126, AGB/2000/072, AGB/2004/028, ANRE1/1990/038, ANRE1/1993/023, ANRE1/1993/705, EFS/1983/062 and EFS/1988/022
73	Fisher H. 2011.	Forestry in Papua New Guinea: a review of ACIAR's program	FST/1994/033, FST/1995/123, FST/1998/118, FST/2002/010, FST/2004/050, FST/2004/055, FST/2004/061, FST/2006/048, FST/2006/088, FST/2006/120, FST/2007/078 and FST/2009/012
74	Brennan J.P. and Malabayabas A. 2011.	International Rice Research Institute's contribution to rice varietal yield improvement in South-East Asia	
75	Harris D.N. 2011.	Extending rice crop yield improvements in Lao PDR: an ACIAR–World Vision collaborative project	CIM/1999/048, CS1/1995/100 and PLIA/2000/165
76	Grewal B., Grunfeld H. and Sheehan P. 2011.	The contribution of agricultural growth to poverty reduction	

IMPACT ASSESSMENT SERIES <CONTINUED>

No.	Author(s) and year of publication	Title	ACIAR project numbers
77	Saunders C., Davis L. and Pearce D. 2012.	Rice–wheat cropping systems in India and Australia, and development of the 'Happy Seeder'	LWR/2000/089, LWR/2006/132 and CSE/2006/124
78	Carpenter D. and McGillivray M. 2012	A methodology for assessing the poverty-reducing impacts of Australia's international agricultural research	
79	Dugdale A., Sadleir C., Tennant-Wood R. and Turner M. 2012	Developing and testing a tool for measuring capacity building	
80	Fisher H., Sar L. and Winzenried C. 2012	Oil palm pathways: an analysis of ACIAR's oil palm projects in Papua New Guinea	ASEM/1999/084, ASEM/2002/014, ASEM/2006/127, CP/1996/091, CP/2007/098, PC/2004/064, PC/2006/063
81	Pearce D. and White L. 2012	Including natural resource management and environmental impacts within impact assessment studies: methodological issues	
82	Fisher H. and Hohnen L. 2012	ACIAR's activities in Africa: a review	AS1/1983/003, AS1/1995/040, AS1/1995/111, AS1/1996/096, AS1/1998/010, AS2/1990/047, AS2/1991/018, AS2/1993/724, AS2/1996/014, AS2/1999/063, AS2/1996/090, AS2/1996/149, AS2/1996/203, AS2/1997/098, CP/1994/126, CS2/1990/007, EFS/1983/026, FST/1983/020, FST/1983/031, FST/1983/057, FST/1988/008, FST/1988/009, FST/1991/026, FST/1995/107, FST/1996/124, FST/1996/206, FST/2003/002, IAP/1996/181, LPS/1999/036, LPS/2002/081, LPS/2004/022, LPS/2008/013, LWR/2011/015, LWR1/1994/046, LWR2/1987/035, LWR2/1996/049, LWR2/1996/163, LWRS/1996/215, LWR2/1997/038, SMCN/1999/003, SMCN/1999/004, SMCN/2000/173, SMCN/2001/028
83	Palis F.G., Sumalde Z.M., Torres C.S., Contreras A.P. and Datar F.A. 2013	Impact pathway analysis of ACIAR's investment in rodent control in Vietnam, Lao PDR and Cambodia	ADP/2000/007, ADP/2003/060, ADP/2004/016, AS1/1994/020, AS1/1996/079, AS1/1998/036, CARD 2000/024, PLIA/2000/165
84	Mayne J. and Stern E. 2013	Impact evaluation of natural resource management research programs: a broader view	
85	Jilani A., Pearce D. and Bailo F. 2013	ACIAR wheat and maize projects in Afghanistan	SMCN/2002/028, CIM/2004/002 and CIM/2007/065
86	Lindner B., McLeod P. and Mullen J. 2013	Returns to ACIAR's investment in bilateral agricultural research	

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