Australian Forestry

ISSN: 0004-9158 (Print) 2325-6087 (Online) Journal homepage: https://www.tandfonline.com/loi/tfor20

The evolution and impacts of ACIAR's forestry research program over three decades

A. G. Bartlett

To cite this article: A. G. Bartlett (2016) The evolution and impacts of ACIAR's forestry research program over three decades, Australian Forestry, 79:3, 171-188, DOI: 10.1080/00049158.2016.1184603

To link to this article: https://doi.org/10.1080/00049158.2016.1184603

Published online: 19 Jun 2016.

AUSTRALIAN FORESTRY, 2016
VOL. 79, NO. 3, 171–188
http://dx.doi.org/10.1080/00049158.2016.1184603

The evolution and impacts of ACIAR's forestry research program over three decades

A. G. Bartlett [a,b]

[a]Fenner School of Environment and Society, Australian National University, Canberra, Australia; [b]Australian Centre for International Agricultural Research, Canberra, Australia

ABSTRACT
The Australian Centre for International Agricultural Research (ACIAR) commissions collaborative agriculture, fisheries and forestry research projects in developing countries. Over a 30-year period, ACIAR has invested over AUD 100 million to fund 150 forestry projects and activities in 29 countries, with most of these projects implemented in Indonesia, Vietnam and Papua New Guinea. This article describes the approach that ACIAR uses to develop and implement projects, and reviews the nature of the ACIAR Forestry Program and its achievements during each decade of its existence. About three-quarters of the research projects have focused on aspects of smallholder and community forestry systems. The findings from a series of independent impact assessment studies, which demonstrate generally high returns on the forestry research investment, are reviewed and some examples of different categories of impacts from the research projects are discussed.

ARTICLE HISTORY
Received 26 July 2015
Accepted 4 April 2016

KEYWORDS
Research; international collaboration; impact; forest trees; agroforestry; forest plantations; Australia

Introduction

Agricultural and forestry research have an important role in addressing international development goals related to enhancing food security, reducing poverty and achieving sustainable management of natural resources. Since the 1960s, science for agricultural development has delivered real benefits to farmers, processors and consumers, but many significant challenges remain in developing countries (CGIAR 2005). Australia has more than 30 years of experience in supporting international agricultural and forestry research through the Australian Centre for International Agricultural Research (ACIAR). This presents an important opportunity to examine how ACIAR's forestry research program has contributed to international research for development and how it has changed over the years. This study is not a comprehensive history of all of ACIAR's forestry research activities and achievements nor of its important non-research activities, such as facilitating the establishment of the Center for International Forestry Research (CIFOR).

Until the late 1970s, international rural development programs were focused primarily on increasing agricultural production. Forestry was of interest only if it were thought possible to promote wood production for export or the establishment of domestic industries, or where forests were necessary for water supply or to control erosion (FAO 1981). Assistance to agricultural research scientists in developing countries, including those working on forestry, was neglected (Zethner 1973) compared with other areas of development funding.

In 1975 a group of Australian scientists, businessmen and government officers met to consider whether Australia's aid to developing countries in science and technology would be more effective if it were managed through an independent body. Subsequently the distinguished public servant and vice-chancellor, Sir John Crawford, chaired a committee that assessed the significance of research assistance to development and identified administrative options for Australia's response to this need (ADAB 1981). It concluded that research assistance was one of the most effective ways of helping developing countries achieve economic and social progress and that Australia could do more to assist, especially in South-East Asia and the Pacific. It recommended that the Australian Government should establish an independent agency funded from its aid budget for this purpose.

In late 1977, the Minister for Foreign Affairs established the Consultative Committee on Research for Development to provide advice to the Australian Development Assistance Bureau (ADAB). This committee recognised the role that Australia's network of successful agricultural research organisations and scientific expertise could play in international agriculture. In early 1981, the following deficiencies in Australia's arrangements to assist international agricultural research were identified (ADAB 1981):

- lack of an effective mechanism for systematically identifying agricultural problems of developing countries and the areas of research that warrant Australia's support
- lack of a mechanism for marshalling the collective expertise of Australian research organisations to assist in solving the identified problems
- lack of suitable arrangements to provide training for developing country researchers in practical, problem solving approaches to agricultural research.

After consideration of this advice, the Australian Government decided to establish a statutory authority to commission international agricultural research.

CONTACT A. G. Bartlett Tony.Bartlett@anu.edu.au Fenner School of Environment and Society, Australian National University, Canberra, ACT 0200, Australia

The Australian Centre for International Agricultural Research

In 1982, the Australian Government passed legislation (Commonwealth of Australia 1982) to establish the Australian Centre for International Agricultural Research. ACIAR's mission is to achieve more productive and sustainable agricultural systems for the benefit of both developing countries and Australia through international agricultural research partnerships (ACIAR 2014a). As part of Australia's Official Development Assistance (ODA), ACIAR uses Australia's agricultural innovation system to enhance food security, reduce poverty and contribute to the long-term economic prosperity of developing countries (ACIAR 2014a). In this context, agricultural research includes fisheries and forestry, as well as agricultural disciplines. In accordance with its legislation (Commonwealth of Australia 1982) the functions of ACIAR are to:

- formulate programs and policies with respect to agricultural research for identifying agricultural problems of developing countries and finding solutions to those problems
- commission agricultural research by persons or institutions in accordance with such programs and policies
- communicate to persons and institutions the results of such agricultural research
- establish and fund training schemes related to the research programs
- conduct and fund development activities related to the research programs
- fund international agricultural research centres.

In 1991–92, the Australian Parliament's Joint Committee on Foreign Affairs, Defence and Trade reviewed the effectiveness of ACIAR as an element of Australia's ODA and the desirability of it continuing beyond 1994. The Joint Committee made 21 recommendations including that: ACIAR continue as a statutory authority; that it be responsible for providing Australian funding to the Consultative Group for International Agricultural Research (CGIAR); that projects not be limited to 3 years; and that it be able to undertake pilot programs to extend project results (Parliament of Australia 1992).

Like many other ODA agencies and the CGIAR centres, ACIAR supports Research for Development (R4D) (*sensu lato* Høgh-Jensen *et al*. 2010) that incorporates, where relevant, an understanding of farming systems to ensure that technologies developed meet the needs of farmers (Chambers and Ghildyal 1985). ACIAR projects seek to generate knowledge, technologies and capacity to achieve better decision-making and change agricultural practices and policies that, in turn, generate positive scientific, economic, social or environmental impacts (ACIAR 2014a). In ACIAR terminology, projects generate outputs which, if adopted, lead to outcomes and impacts. Outputs are defined as the products of the research, including technologies, knowledge, enhanced capacity and policy options, that can be adopted or used as inputs for further research; outcomes are changes in practice, products or policies consequent on the adoption of outputs; and impacts are changes in markets, the state of common resources and to individuals or communities that can be attributed to the adoption of the research outputs by the end users of the research (Davis *et al*. 2008).

ACIAR now has over 30 years of experience in implementing agricultural research projects in a wide range of countries and contexts, predominantly from the Asia–Pacific region, but also to a lesser extent in Africa and the Middle East (ACIAR 2014a). In 2014–15, ACIAR received a budget of AUD 123 million, of which AUD 84.4 million was allocated for bilateral and multilateral research projects in 40 countries and AUD 18.9 million was provided as Australia's contribution towards implementation of the 16 CGIAR Research Programs (ACIAR 2014b).

Some defining features, which distinguish ACIAR from many other agricultural and rural development organisations, are:

- its mandate specifically relates to agricultural research rather than to broader areas of international development research
- it commissions research projects as collaborative partnerships between Australian or international scientists and scientists in the partner country and seeks contributions, of time, resources and money, from partners to the project
- projects are formulated to address research priorities identified by the partner country
- projects are designed by research teams with input from the relevant ACIAR Research Program Manager and from three stages of internal and external review
- projects focus predominantly at the research end of the Research for Development continuum, on the expectation that research innovations will be promulgated through national and donor-funded extension and development programs
- many projects have components with the potential to deliver benefits to Australia
- capacity building of research partners is supported in parallel with research activities.

In relation to its capacity-building activities, ACIAR funds postgraduate study and research management training in Australia as well as specific capacity-building activities in each research project. The John Allwright Fellowship scheme, which had 110 active fellowships in 2014–15, supports postgraduate study in Australia for partner country scientists associated with ACIAR projects (ACIAR 2014b). The John Dillon Fellowship program funds short-term research management training (ACIAR 2014a).

ACIAR's approach towards international agricultural research

ACIAR's approach is to identify priorities for research with partner country stakeholders, as the basis for commissioning collaborative research projects (ACIAR 2008). At least 70% of its research activities are implemented through bilateral projects, of three-to-five years duration, commissioned between Australian research institutions and the appropriate national government ministry. The balance are undertaken through multilateral activities of the CGIAR International Agricultural Research Centres (ACIAR 2014a). These research projects can be implemented either in one country or with multiple partner countries and some projects have research activities implemented in Australia. ACIAR also commissions small research activities, each worth less than AUD 150 000. These are generally conducted over shorter time frames than the research projects and are either activities to support the design of new projects, for example scoping of research relevant to teak value chains in Laos (Midgley *et al*. 2012), or stand-alone research studies, for example research on the sustainability of plantation forestry in South-East Asia (Harwood and Nambiar 2014).

The strategic components of ACIAR's approach[1] include:

- focusing on regions and countries in accordance with Australia's overall priorities for ODA
- employing research program managers with a strong technical knowledge and experienced in research management and international development
- conducting periodic consultations with partner countries to identify priorities for future research and identifying those in which Australia has a comparative advantage
- commissioning Australian and international research organisations to implement projects of three-to-five years duration with research partners in developing countries
- conducting technical, social and policy research, but limiting extension activities to those related to proof of concept or understanding of adoption processes
- building capacity of partner country scientists and institutions through joint research activities and postgraduate training in Australia
- communicating the results of ACIAR's research to partners, the scientific community and interested domestic and international stakeholders
- conducting adoption studies and impact assessments of projects and programs several years after completion to establish achievements, lessons learned and the impacts.

ACIAR manages its research activities through discipline-specific research programs, each of which is managed by a research program manager (ACIAR 2014b). The research program managers foster existing relationships, and develop new relationships between research providers, partner government institutions and development agencies. Their expertise is used to identify research priorities and appropriate research partners, develop and manage research projects, and to assess all new research proposals through an internal ('in-house') review process (ACIAR 2008).

While the number and nature of research programs has changed over the years, there has been a Forestry Program since 1982. Analysis of ACIAR's records indicates that the Forestry Program has had relatively stable management over the past 30 years with four forestry scientists[2] occupying the role of the research program manager.

The operational components of ACIAR's approach[3] include:

- employing methods to achieve high quality project design, including scoping studies, internal peer review of preliminary proposals and external review of full proposals
- identifying clear research questions and objectives linked to research activities, articulating the impact pathways and conducting an ex-ante impact assessment
- requiring financial and in-kind contributions from Australian and developing country partner organisations and supporting regular in-country collaborative research rather than full-time technical assistance
- allowing flexibility in project implementation, with project leaders managing within the broad design, and supporting activity variations to improve outcomes
- minimising reporting requirements to annual and final reports
- maintaining professional dialogue between the research program manager and project leaders and conducting mid-term and external end-of-project reviews to facilitate learning and provide accountability.

Once a concept for a new research project is agreed to by ACIAR, the project is designed by partner scientists with input from the research program manager under a two-phase process. This includes consideration of the preliminary proposal business case through the in-house review process, followed by external review and further internal review during the development of the full project proposal.[4] In each project proposal, the objectives, activities and methodology are described together with the expected impacts from the research. ACIAR manages its projects with a 'light touch' relative to many development agencies, monitoring progress through annual reports, occasional visits and mid-term reviews. It also encourages documentation and sharing of lessons to improve future program and project delivery.

ACIAR's approach to conducting international agricultural research, as outlined above, has remained relatively constant throughout its 30-year history. This approach has been the subject of external reviews on four occasions, including in 1992 (Parliament of Australia 1992) and 2013 (Farmer *et al*. 2013). Each external review has noted the effectiveness of ACIAR's approach and recommended that it should continue.

ACIAR has a long history of identifying the impacts of the research it funds, via adoption studies and impact assessments (Davis *et al*. 2008; ACIAR 2014b) and in particular to quantify the economic returns from its bilateral research (Lindner *et al*. 2013). In the lead up to the 1992 Joint Committee review of ACIAR, economic assessments were undertaken on 20 completed projects covering 12 research areas (Davis and Lubulwa 1995). By 2012, ACIAR had published a total of 65 impact assessments, which covered a little less than 10% of ACIAR's investments in bilateral research projects, and was allocating about 0.6% of its budget to impact assessment (Lindner *et al*. 2013).

Adoption studies are undertaken by the project leader on a sample of past projects usually 3 years after completion (Davis *et al*. 2008). These studies identify the level of uptake of project outputs and the extent of the legacy (Pearce *et al*. 2013), through documentation of outcomes at the scientific and community levels in the partner countries and in Australia. The results of these studies are published annually as ACIAR Adoption Series reports and provide a greater understanding of the adoption pathways.

Impact assessments are carried out by independent external consultants once the project results have been taken up by the end users and the results are published as ACIAR

Impact Assessment Series reports (ACIAR 2014b). They provide quantitative estimates of the economic returns from the research investment as well as some qualitative assessments of the project's social and environmental impacts. They provide accountability to stakeholders, a measure of the returns from ACIAR's investments and valuable lessons in the selection, design and delivery of projects (Davis *et al*. 2008). 'Almost all of ACIAR's impact assessments have been ex-post economic cost-benefit evaluations', using a consistent methodology that documents the research undertaken and its costs, the realised and expected take-up of outputs, and quantifies realised and expected benefits (Lindner *et al*. 2013).

Early focus of the ACIAR Forestry Program (1984–1994)

Following the 8th World Forestry Congress in 1978, there was a more widespread recognition of rural communities' dependence on forest goods and services (FAO 1978) and of the potential for forestry to complement agriculture, especially in regards to small farmers (FAO 1981). In the early 1980s, the largest use of forests in most developing countries was for gathering fuelwood (FAO 1981), many people suffered from acute fuelwood scarcity and many forest resources were being overcut (Westoby 1989). Far too little research was being undertaken on the role of trees in agricultural settings (FAO 1978) and it was recognised that forestry interventions should be based on examination of the local context, involvement of local people and the development of new knowledge and skills (FAO 1985). By the late 1980s, scientists were arguing for consideration of sustainability of agricultural systems, both at the local and landscape levels, including impacts on common resources such as forests (Lynam and Herdt 1989).

Australian scientists recognised that there were likely to be many Australian trees and shrubs suitable for community plantings in developing countries to deliver multi-purpose benefits in rural agricultural areas (Boland and Turnbull 1989). Since 1962, the Australian Tree Seed Centre of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) had provided seed from Australian trees to many countries around the world, but some of this seed had not been used effectively due to a lack of expertise in implementing species testing trials in the recipient countries (Boland and Turnbull 1989).

In the early years, the ACIAR Forestry Program had four components (Shepherd 1985):

(1) collecting representative seed samples of potentially useful Australian trees
(2) evaluating the growth of these species in developing countries
(3) researching the propagation and management of these tree species
(4) facilitating adoption of these trees in developing countries.

In selecting partner countries, ACIAR took account of the prevailing foreign aid policy and applied the following criteria (Boland and Turnbull 1989):

- the research must be a high national priority
- the collaborating institution must be of sufficient standard and have the capacity to provide and effective partnership
- the local environment(s) should be sufficiently representative of the region to enable considerable spillover of results to neighbouring countries.

Following 18 months of establishing networks, identifying priorities and then designing projects, ACIAR's first two forestry projects (FST/1983/057 and FST/1983/031) began in late 1984. Both projects were commissioned through CSIRO and involved the growing of Australian trees for fuelwood and nitrogen fixation, with activities in Thailand, Zimbabwe and Kenya. In 1985 ACIAR initiated two forestry projects (FST/1984/058 and FST/1984/057) in China, involving research on wattle tannins and establishing species and provenance trials for promising species of eucalypts, acacias and casuarinas. Subsequently, other forestry projects were developed in China, Thailand, Indonesia, Malaysia, Pakistan and Philippines, and by 1988 the Forestry Program had an annual budget of AUD 1.3 million (Boland and Turnbull 1989). ACIAR's records show that the first forestry project in the Pacific commenced in 1992 and that it focused on nutrition and mycorrhizal requirements of tropical trees in Papua New Guinea, Solomon Islands and Vanuatu.

The first decade of the ACIAR Forestry Program was a period in which some successful long-term collaborative relationships between Australian forestry scientists and partners in South-East Asia, Southern and Eastern Africa and the Pacific were established. Analysis of the ACIAR records shows that during this decade a nominal investment of AUD 21.26 million was made in the Forestry Program. ACIAR worked in close collaboration with CSIRO's Australian Tree Seed Centre, which provided the Australian tree seed to partner countries.

In line with the prevailing global forestry development policies, the research aimed at providing communities with options to address fuelwood and timber shortages under a range of climatic and soil conditions. The projects commissioned focused predominantly on domestication, improvement and silviculture of Australian trees, with a few projects focused on domestication of other trees, agroforestry systems and preservation treatment. The projects did not promote Australian species to the exclusion of local native species, but sought to provide a wide range of multi-purpose species to meet local requirements, including agroforestry, fuelwood production and potential commercial purposes (Boland and Turnbull 1989). Some projects included broader environmental objectives, such as the use of farm trees to assist with rehabilitation of salt-affected sites (Khanzada *et al*. 1998). The research on lesser-known Australian tropical trees produced scientific information on the growing of multi-purpose trees (Boland 1989) and the environmental requirements, cultivation, potential uses and pests and diseases for 166 Australian trees suitable for plantings in the tropics (Doran and Turnbull 1997). It also helped to identify the commercial potential of species such as *Acacia crassicarpa* (Turnbull *et al*. 1988b) and *Eucalyptus pellita* (Hardiyanto 2003) as well at the value of dry-zone acacias such as *A. colei* and *A. difficilis* (Harwood *et al*. 1988).

The research on establishment and management of sandalwood and fuelwood species in northern Australia and Eastern Indonesia (under projects FST/1986/013 and FST/

1990/043), contrasted with the rest of the program, because it included research on non-Australian trees and also led to dramatically different economic impacts in Australia and Indonesia. These projects developed new knowledge on the biology and establishment of *Santalam album* (Harisetijono and Suriamihardja 1991) and the propagation and performance of a range of multi-purpose tree species in Nusa Tenggara Timur. However, 15 years after the completion of the projects, no evidence could be found of the utilisation of any of this knowledge in Indonesia and all the project-funded species and provenance trials were either not maintained or destroyed by fire and weeds (Lindner 2011). In Australia, the research laid the basis for the development of the Ord River sandalwood industry (Henderson and Braidotti 2013), which is predicted to provide benefits with a present value of AUD 766 million to Australia from a combined research investment of AUD 7.5 million (Lindner 2011).

The second decade of the ACIAR Forestry Program (1994–2004)

Around the 1992 United Nations Conference on Environment and Development (UNCED), there was an increase in global policy dialogue about the contribution of forests to global and national development and conservation objectives (Humphreys 2001). Although there was disagreement between developed and developing countries on the substance of an international forest regime, they agreed on the concept of sustainable forest management (Humphreys 1999) and that scientific research should be strengthened through international cooperation (United Nations 1992). During this period, community forestry gained more focus in international forestry development (Gilmour *et al*. 1990; Bartlett 1992) and it was considered that international forestry research required an inter-disciplinary approach involving social, economic and ecological disciplines (FAO-IUFRO-CIFOR 1997).

Analysis of the records shows that during this decade ACIAR made a nominal investment of AUD 27.0 million in the Forestry Program. The program continued research on the development of eucalypts and acacias for plantation forestry in the Asia–Pacific region, but broadened to include research on the utilisation of these species as well as management of their pests and diseases. Research topics on domestication of indigenous trees, impacts of forest and land management practices, and sustainable forest management were introduced.

In 1997 the key priorities for the Forestry Program[5] included:

- development of Australian tree genetic resources to meet community needs for reforestation and agroforestry
- sustainable management practices for tropical plantations of Australian species, particularly soil and water relations, pests and diseases, silviculture and harvesting and processing
- research on forest policy development.

The second decade of the Forestry Program saw an increased number and a considerable broadening of the focus of the research projects commissioned. The inclusion of research on sustainable forest management (SFM) and policy instruments, such as SFM criteria and indicators, partially reflected the broadened focus of global forestry policy and research dialogue. The program continued to focus substantially on technical research associated with the growing, protection and utilisation of trees by smallholders and private companies. There was no research undertaken on community forestry, nor did the nature of the projects designed change to include more inter-disciplinary teams especially with social science skills.

Nevertheless, the focus of the program during the second decade resulted in some very substantial outcomes and impacts from a range of projects. The ongoing collaboration with the Forest Science Institute of Vietnam (under projects FST/1993/118 and FST/1998/096) enabled widespread dissemination of improved *Acacia* and *Eucalyptus* germplasm (Turnbull *et al*. 1988a) resulting in an estimated AUD 129 million of benefits to tree growers and wood fibre product consumers (Fisher and Gordon 2007a). Other substantive outputs included improved understanding of how to better manage soil, water and nutrients to improve the sustainability of tropical plantations (Nambiar and Brown 1997) and on identifying and minimising the impacts of diseases of *Acacia* (Old *et al*. 2000) *and Eucalyptus* (Old *et al*. 2003) in South-East Asia.

According to the impact assessment studies, some projects from this decade have not generated any apparent outcomes or impacts. Research and capacity building on the application of molecular marker technologies for genetic improvement of tropical *Acacia* trees in Indonesia (under project FST/2000/122) generated no apparent impacts (Lindner 2011). Likewise, there were no apparent outcomes or impacts from research and capacity building (under project FST/1998/118) on planning methods for sustainable management of timber from PNG's native forests (Fisher 2011). Whether these findings are true or an artefact of the difficulty of quantifying impacts from capacity building and some scientific and policy research is less clear, because the Indonesian molecular laboratory supported by the ACIAR project is still in operation in 2015.[6]

The third decade of the ACIAR Forestry Program (2004–2014)

During this period, the Non-Legally Binding Instrument on All Types of Forests (United Nations 2007) was negotiated through the United Nations Forum on Forests. It recognises the need to promote the development and application of scientific and technological innovations and to strengthen the contribution of science and research in advancing sustainable forest management. In 2005, the concept of 'Reducing Emissions from Deforestation and Forest Degradation' (REDD+) emerged under the United Nations Framework Convention on Climate Change negotiation forums (Pistorius 2012), generating new forestry research needs.

In the mid-2000s, global deforestation was continuing at a rate of 13 million hectares per annum, although this was partially offset by reforestation and landscape restoration of 5.7 million hectares per annum (FAO 2005b). The contribution of non-wood forest products to the economic benefits derived from forests was recognised, with the global trade in these products increasing 150% over the previous decade. In order to capture the full economic benefits from wood production it was considered necessary to create efficient markets, combat illegal logging and to add value to wood products (FAO 2005a). To meet the multifaceted global expectations on the supply of services and products from planted and natural forests, enhanced multi-disciplinary research was needed, but there was a general lack of interest from ODA for such programs (Bevege 2005).

At the beginning of this period, the Forestry Program was primarily focused on collaborations with countries in the Asia–Pacific region, but by 2013 it included a project in East Africa and one in South Asia. To enhance the contribution that forests make to rural livelihoods the program addressed four themes (Haines 2005):

- silvicultural methods for promising high-value and multi-purpose species
- value-added processing of wood and non-timber forest products
- development of agroforestry systems
- socio-economic impediments to forestry's contributions to rural development.

In 2013 ACIAR updated the strategies for each research program, taking account of priorities identified through recent country consultation processes. The Forestry Program included four strategic themes, each having multiple priority research areas (ACIAR 2013). The four strategic themes were tree growing, sustainable forest management, efficient and sustainable forest industries, and climate change mitigation and adaption.

Analysis of the records shows that during the third decade, ACIAR made a nominal investment of AUD 55.2 million in the Forestry Program and in the 2011–12 financial year, it accounted for 9.2% of ACIAR's investments in bilateral research projects (Lindner *et al*. 2013). During this ten-year period, the individual budgets for the forestry projects were generally in the range of AUD 0.4–2.5 million, with one large regional project covering four African countries having a budget of AUD 5.6 million.

The third decade of the Forestry Program was characterised by a shift towards research on agroforestry and community forestry systems, including improvement and silviculture of high-value species. High-value species include teak, acacias, eucalypts, sandalwood and indigenous trees from the Pacific Islands. A long-term program of value-added wood processing projects in Vietnam, Laos, Papua New Guinea, Indonesia and Fiji aimed at improving the processing and manufacturing of furniture and engineered wood products using small-diameter logs grown by smallholders. The approach of supporting a range of research themes continued with some alignment with global trends, such as the development of REDD+ projects and enhancing economic benefits through value adding of forest products. However, consistent with the approach in the first two decades, most projects related to smallholder and community-based forestry systems.

During this period significant achievements continued to be made on improving the management of *Acacia* plantations in Indonesia (Mendham and Hardiyanto 2011) and on broadening the basis of clonal forestry using the *A. mangium* × *auriculiformis* hybrid (Harwood *et al*. 2015). The research on teak-based agroforestry systems in Indonesia (Roshetko *et al*. 2013) and Laos (Dieters *et al*. 2014) created knowledge on how the existing systems could generate enhanced livelihoods. In the Pacific, good progress was made on developing small-scale agroforestry systems suitable for archipelago nations like Solomon Islands (Blumfield *et al*. 2013) and Vanuatu (Glencross *et al*. 2012; Grant *et al*. 2012; Viranamangga *et al*. 2012).

As with the previous two decades, some of the research showed different achievements in different countries. Research related to the wooden-furniture industries in Central Java (under project FST/2007/119) generated positive economic benefits for the small and medium enterprises that collaborated with the project (Melati *et al*. 2013; Purnomo *et al*. 2014). In contrast, research related to enhancing value-added wood processing in Papua New Guinea (under project FST/2006/120) did not achieve any apparent adoption of project outputs by the private sector (Fisher 2011).

The evolving nature of the Forestry Program over 30 years

The program's investments and major Australian partners

Analysis of the records indicates that ACIAR has invested a nominal AUD 103.46 million over 30 years to commission 150 forestry-related projects. This includes 101 forestry research projects, with a nominal value of AUD 98.93 million, and 49 small research activities. The details of these investments by decade are shown in Table 1, bearing in mind that the financial values have not been adjusted to a common year. Between the first and third decades, the number of research projects commissioned doubled and small research activities had become an important feature.

ACIAR commissions all of its projects through either Australian or international research organisations. While many projects have multiple research organisations involved in the partnership, the commissioned organisation provides the leadership and undertakes the largest proportion of project activities. The analysis of the numbers of projects commissioned through different research organisations in each 10 year period is shown in Table 2.

Over the 30 year period, 17 Australian research organisations and two CGIAR research centres have led ACIAR forestry research projects, with more than one-third of the projects led by CSIRO. During the first decade, there were only four organisations leading projects and 75% of the projects were commissioned through CSIRO. In the second decade, there were 11 commissioned organisations, 45% of the projects were commissioned through CSIRO and collaborations commenced through the CGIAR centres, CIFOR and the World Agroforestry Centre (ICRAF). In the third decade, the number of commissioned

Table 1. ACIAR's investments in forestry research projects and activities.

Decade	Forestry research projects	Nominal investment (AUD million)	Small research activities	Nominal investment (AUD million)	Total nominal investment (AUD million)
1984–94	24	21.13	1	0.13	21.26
1994–04	29	24.76	22	2.24	27.00
2004–14	48	53.04	26	2.16	55.20
Totals	101	98.93	49	4.53	103.46

Table 2. Number of projects commissioned with partner organisations by 10 year period.

Decade	CSIRO	AG BRS	WA CALM	VIC Forestry	QLD Forestry	NSW Forestry	NTU/ CDU	Univ of Qld	ANU	Southern Cross	Univ of Tas	James Cook	Sunshine Coast	Griffith	Charles Sturt	Univ of Melb	Univ of Adelaide	ICRAF	CIFOR
1	18		2		3		1												
2	13	1		1	3		1	2	2	1	2							2	1
3	5				3	1	1	3	6	2	4	5	3	2	1	5	2	3	2
Σ	36	1	2	1	9	1	3	5	8	3	6	5	3	2	1	5	2	5	3

organisations increased to 16, CSIRO's involvement declined and universities such as the Australian National University, James Cook and Melbourne each led five or more projects. The forestry-related CGIAR centres together led five projects, located in countries where they had a presence.

Decisions about the commissioned organisation are made by the Research Program Manager, taking account of factors such as experience in leading projects in developing countries, availability and strength of scientific disciplines needed for the project, value for money and effectiveness of the existing partnership arrangement (for follow-on projects). Over the 30-year period, the number of projects commissioned through CSIRO and state forestry research organisations declined substantially, with the exception of Queensland, reflecting governments' disinvestment in the conduct of forestry research. The increase in number of commissioned organisations reflects the growth in both the number of projects commissioned and the disciplines involved, a conscious effort to seek out new partners, and the need to manage declining availability of Australian forestry scientists.

Countries in which projects have been implemented

Most ACIAR forestry research projects are implemented in one country, although in each decade some projects have involved collaborations with several countries. The selection of countries in which the Forestry Program works is influenced by Australian aid policies, ACIAR policy on the number of countries a program can work in, availability of funding (including government-initiative funding), and the appropriateness of and interest in inter-country collaboration on a research topic. Analysis of the ACIAR records indicates that forestry research projects have been implemented in 29 countries and that the countries have changed over time. The distribution of projects—including projects that have had activities in multiple countries—is shown in Table 3 by country and decade.

The countries that have had the most projects are Indonesia (23), Vietnam (20), Papua New Guinea (19) and Thailand (18). During the first decade there were projects in 15 countries, with the most projects implemented in China, Thailand, Zimbabwe and Kenya. In the second decade there were projects in 17 countries, with the most projects implemented in Indonesia, Vietnam, Thailand and Papua New Guinea. In the third decade projects were implemented in 16 countries, with Indonesia, Papua New Guinea, Vietnam and Laos having most projects.

The program's forestry research themes

In developing projects ACIAR responds to priorities developed collaboratively with partner countries, rather than setting its own priorities. The topics of the 101 completed research projects can be grouped into ten research themes (Table 4).

Analysis of the ACIAR records shows that there have been considerable changes in the nature of the investments over the three decades, including the number of research themes covered and the numbers of projects under a particular research theme, as shown in Figure 1.

Table 3. Number of ACIAR forestry research projects in each partner country by decade.

	East Asia									South Asia				
Decade	Indonesia	China	Vietnam	Laos	Myanmar	Thailand	Cambodia	Malaysia	Philippines	Sri Lanka	India	Bangladesh	Pakistan	Nepal
1	3	9	4	1	1	9		1	2	1	1		2	
2	8	3	8	4		7	1	3	5	1	3	1	1	
3	12	2	8	7		2	1							1
Σ	23	14	20	12	1	18	2	4	7	1	4	1	3	1

	Africa								Pacific						
Decade	Ethiopia	Rwanda	Uganda	Burundi	Ghana	Kenya	Zimbabwe	South Africa	Papua New Guinea	Vanuatu	Solomon Islands	Fiji	Samoa	Pacific Islands	Brazil
1						5	6		1					2	
2					1			1	6					2	1
3	1	1	1	1					12	6	5	3	2		
Σ	1	1	1	1	1	5	6	1	19	6	5	3	2	4	1

Table 4. Themes of ACIAR forestry research undertaken between 1984 and 2014.

No.	Research theme	Comments
T1	Domestication and improvement of Australian trees	Includes domestication and tree improvement principally for *Eucalyptus* and *Acacia*
T2	Silviculture for Australian trees	Includes research on establishment, spacing, site management, growth monitoring and thinning
T3	Domestication and silviculture of non-Australian trees	Includes supply of quality germplasm for native and exotic trees as well as silvicultural systems
T4	Forest health and biosecurity	Includes pests, diseases and forest health systems
T5	Value added processing, timber manufacturing and treatment of wood	Includes wood science, wood processing and manufacturing, furniture and composite products
T6	Agroforestry and community forestry	Improving benefits from agroforestry systems and approaches to community forestry
T7	Non timber forest products	Includes research on growing, processing and adding value to non-timber forest products
T8	Native forest management	Includes yield modelling and improved management systems for native forests
T9	Fire management	Includes use and impacts of fire on land management and systems for managing fire
T10	Forestry and environment policies	Development of policy options, global forestry documents, criteria and indicators and REDD+

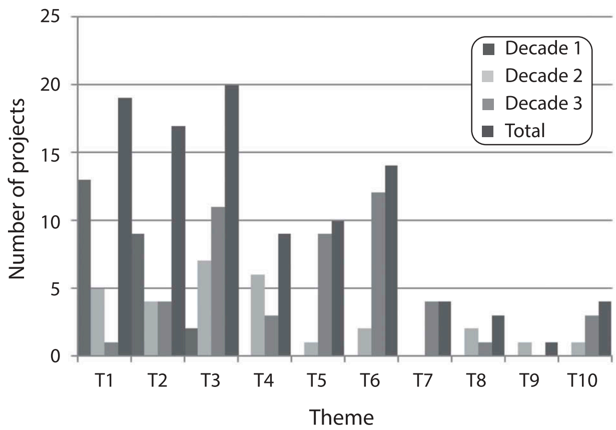

Figure 1. Numbers of research projects by research theme and decade.

In the first decade, there were only three themes covered and 22 of the projects focused on two themes (T1 and T2), which related to domestication, improvement and silviculture of Australian tree species. In each of the subsequent two decades, projects covered nine of the ten research themes. In the second decade, nine projects related to the two Australian tree themes, seven projects related to domestication and silviculture of non-Australian trees (T3), and six projects focused on forest health (T4). In the third decade, the focus shifted significantly towards the research themes related to agroforestry, community forestry (T6), silviculture of non-Australian trees (T3) and value-added processing (T5). In general terms, these thematic shifts parallel the changes in global forestry priorities as outlined in the descriptions of the Forestry Program by decade. Moreover, they reflect the priorities requested by partner countries as well as the perspectives of the incumbent research program manager on the needs, opportunities and best use of the funding provided to the program.

Looking at the program over 30 years, 26% of the research projects have focused on domestication, improvement and silviculture of Australian trees, 20% have focused on domestication and silviculture of non-Australian trees, 14% have focused on agroforestry and community forestry, 10% have focused on value-added processing and 9% have focused on forest health and biosecurity. Almost three-quarters of the research effort by project number has been focused on smallholder and community-based commercial forestry systems (through T1, T2, T3, T6 and T7 themes). This reflects the areas where the program best contributes to ACIAR's aims to enhance food security, reduce poverty and contribute to the long-term economic prosperity of developing countries.

Economic impacts from the Forestry Program

ACIAR puts significant effort into identifying the impacts of the research it funds, particularly through independent impact assessment studies. Analysis of ACIAR's records indicates that there have been ten impact assessment studies undertaken on components of the Forestry Program, nine of which have been published as Impact Assessment Series reports (Lindner *et al.* 2013), and one as an Economic Evaluation Unit Working Paper (Davis and Lubulwa 1995). In aggregate, these impact assessments cover 48 projects, which is nearly half of the completed forestry research projects. For 30% of the completed projects quantitative economic impact assessments have been undertaken. This body of work provides an indication of the overall economic impacts from the Forestry Program and some indication of the differential impacts from various projects.

The results of the impact assessments are summarised in Table 5. They show that the research programs related to the development of plantation forestry systems, based on Australian tree germplasm in Indonesia, Vietnam and China, have all yielded high economic benefits, and therefore have impressive cost-benefit ratios. In each case, the result is strongly influenced by the scale of plantings that have occurred in the three countries. They also indicate that research on tree diseases and non-timber forest products can generate substantial economic benefits. The research on tree planting to facilitate environmental remediation generated positive but low economic benefits, due to the slow growth on these sites.

These impact assessment studies are summarised below and demonstrate the differential benefits within groups of projects studied as well as information on the contribution of forestry research to the overall returns from ACIAR's research investments.

Table 5. Results from impact assessment studies of ACIAR forestry projects.

Impact assessment study	Research costs (AUD million)	NPV of benefits (AUD million)	Benefit-cost ratio	Internal rate of return (%)
Australian trees in China[a]	2.30	122.30	53:1	35.0
Acacia hybrids in Vietnam[b]	1.04	152.00	145:1	N/A
Australian trees in China[c]	18.60	1300.00	57:1	40.0
Australian trees in Vietnam[d]	1.50	129.00	79:1	32.0
Fungal diseases of eucalypts[e]	1.90	65.00	30:1	23.0
Trees on saline land[f]	20.80	23.20	1.12:1	N/A
Plantation forestry in Indonesia and Australia[g]	37.00	11 914.00	322:1	54.4
Galip nuts in Papua New Guinea[h]	7.20	163.00	22.6:1	20.4

[a]ACIAR Impact Assessment Study No. 8 (McKenney 1998).
[b]ACIAR Impact Assessment Study No. 27 (van Bueren 2004a).
[c]ACIAR Impact Assessment Study No. 30 (van Bueren 2004b).
[d]ACIAR Impact Assessment Study No. 47 (Fisher and Gordon 2007a).
[e]ACIAR Impact Assessment Study No. 49 (Fisher and Gordon 2007b).
[f]ACIAR Impact Assessment Study No. 51 (Corbishley and Pearce 2007).
[g]ACIAR Impact Assessment Study No. 71 (Lindner 2011).
[h]ACIAR Impact Assessment Study No. 73 (Fisher 2011), estimates relate to combined program funded by ACIAR, EU and PNG Government.

Australian trees in China

Over a 20-year period—from 1985 to 2004—ACIAR invested AUD 11.8 million on seven forestry projects that primarily addressed the development of high-yielding eucalypt plantations in China. The ACIAR projects included selection trials for 100 eucalypt species, tree improvement for tropical, subtropical and cold-tolerant eucalypts, as well as research on site cultivation techniques, nutrient management, the introduction of mycorrhizal fungi and the water requirements of planted eucalypts (van Bueren 2004b).

ACIAR has conducted two impact assessments on these projects. The first study involved two projects that tested germplasm of *Eucalyptus, Acacia* and *Casuarina* species over an eight-year period and predicted economic benefits worth AUD 122.3 million (McKenney 1998). The second study involved all seven projects, most of which supported research on improving productivity from *Eucalyptus* plantations. It predicted economic benefits worth AUD 1.3 billion, due to both the substantial increase in area of *Eucalyptus* plantations and the tripling of growth rates over 16 years as a result of the research (van Bueren 2004b). It was subsequently recognised that the achievement of such benefits was possible only through the collaboration and coordination of a wide range of research and development activities (Turnbull 2007).

Improving Acacias in Vietnam

Australian tropical *Acacia* species were introduced to Vietnam between 1960 and the late 1980s (Kha and Nghia 1991), but ACIAR's collaboration with Vietnam did not begin until 1993. ACIAR has conducted two impact assessments on *Acacia* tree improvement research in Vietnam (van Bueren 2004a; Fisher and Gordon 2007a).

Between 1988 and 1992, ACIAR funded research (FST/1986/030) into hybridisation and vegetative propagation of tropical acacia species in Malaysia. A scientist from the Forest Science Institute of Vietnam attended the project's final workshop. Access to the knowledge on clonal selection techniques and propagation methods enabled Vietnamese scientists to speed up the development of hybrid *A. mangium* × *auriculiformis* clones for commercial release. The first study found that access to this knowledge generated benefits worth AUD 152 million for Vietnam (van Bueren 2004a). It is an example of spill-over benefits, whereby research conducted in one country benefited another country.

During the period 1993–2004, ACIAR funded two global forestry projects (FST/1993/118 and FST/1998/096) related to the provision and domestication of Australian tree germplasm and which included collaboration between CSIRO and the Forest Science Institute of Vietnam. Seed of various *Eucalyptus, Acacia* and *Melaleuca* trees potentially suitable for Vietnam was provided. The projects involved capacity building in tree breeding and supported the establishment of seed production areas, seedling seed orchards and clonal seed orchards for ten Australian tree species (Fisher and Gordon 2007a). The second study calculated benefits worth AUD 129 million from the projects, from greater access to improved germplasm of commercial timber species, increased plantation productivity and reduced wood production costs (Fisher and Gordon 2007a). This study estimated that about two-thirds of these benefits flow to consumers via lower prices, with the rest flowing to the producers, including large numbers of smallholder farmers, who have planted the better quality Australian trees.

Reducing the impacts of fungal diseases in eucalypt plantations

Pests and diseases are a growing threat to the productivity of eucalypt plantation species (Wingfield *et al*. 2008). Following the widespread planting of eucalypts in Asia, damaging foliar and stem diseases, particularly leaf and shoot blight pathogens, began to appear (Old and Mohammed 2003). From the mid-1990s, the ACIAR Forestry Program began to include projects on management of pests and diseases in eucalypt plantations.

During the period 1996–2000, ACIAR funded a project (FST/1994/041) aimed at minimising disease impacts in eucalypt plantings in Vietnam and Thailand. An impact assessment study calculated benefits worth AUD 65 million to the smallholders and plantation companies growing *Eucalyptus* through the identification and dissemination of planting material with enhanced disease resistance (Fisher and Gordon 2007b). The study demonstrated that research to improve the productivity of plantations can have significant benefits despite the often long lag times required to realise the benefits.

Growing trees on salt-affected land

Soil salinity is an increasing problem impacting negatively on agricultural productivity in many of ACIAR's partner countries as well as in Australia. From 1994 to 1997, ACIAR funded a research project (FST/1993/016) that increased the range of trees and shrubs suitable for saline sites in Pakistan, Thailand and Australia and developed appropriate establishment techniques for these species.

An impact assessment study predicted benefits worth AUD 23.2 million from research and development activities to treat 7000 hectares of saline sites in Pakistan and 5000 hectares in Thailand (Corbishley and Pearce 2007). This study demonstrated that long-term environmental remediation programs, where tree growth is slow and farmers have little incentive to adopt the technologies without subsidies, generate a relatively low rate of return to the investment.

Plantation forestry research in Indonesia and Australia

Between 1987 and 2006, ACIAR invested in 12 forestry projects with the aim of improving plantation forestry in both Indonesia and Australia. These projects focused on the domestication and silviculture of Australian trees and other multi-purpose trees such as sandalwood. They also undertook research on genetic improvement of plantation trees, control of fungal diseases and insect pests and on policy instruments for sustainable plantation management. Because the nature of these projects varied considerably, the impact assessment (Lindner 2011) grouped related projects into four clusters, but found evidence of impact for only two of the clusters. It could not determine any economic impact from either the pest and diseases or policy research.

For the agroforestry and multi-purpose trees cluster, the study found evidence of impact only in Australia, related to the development of the Ord River sandalwood plantation industry. For the Australian trees cluster, evidence of impact was found only in Indonesia, associated with the expansion and improved productivity of *Acacia* and *Eucalyptus* industrial pulpwood plantations. The study calculated benefits worth AUD 11 914 million from the 12 projects, including AUD 766.48 million in benefits to Australia from two sandalwood projects (Lindner 2011).

Forestry in Papua New Guinea

Papua New Guinea has been an important partner country for the Forestry Program. Collaborations began in 1992 and about 15% of the program budget is spent on projects in Papua New Guinea (ACIAR 2013). In 2011, ACIAR published a thematic impact assessment study that examined 12 Papua New Guinea forestry projects, including two scoping studies (Fisher 2011). These projects were grouped into four clusters: project-scoping studies, sustainable forest management, agroforestry, and processing of timber and non-timber forest products. The study identified the key outputs, outcomes and impacts from each project and estimated economic impacts from three projects supporting development of a new industry based on growing and processing nuts from the indigenous galip tree (*Canarium indicum*).

The study found that adoption of project outputs has been mixed and appeared to have been greatest in projects aimed at local communities and least in the policy-related projects. From the ten research projects, there were no apparent outcomes or impacts from four projects; five projects had generated outcomes but no apparent impacts; and only one agroforestry project demonstrated outcomes and impacts at the time of the study (Fisher 2011). The study concluded that achieving adoption of research and development outputs is a significant challenge in Papua New Guinea. Even with projects aimed at local communities, there are various barriers to adoption, including weak governance, resistance to change, lack of extension services and infrastructure, inadequate supply of tree germplasm and the long time frames to receive benefits. It also found that ACIAR's delivery model is not well suited to addressing governance issues and, for research on downstream processing, commitment to long-term funding and to support marketing activities is needed (Fisher 2011).

The study estimated the expected impacts from three projects related to galip nuts, taking account of investment in related development activities from the European Union and 10 years of further investment in research, development and marketing activities. It calculated projected benefits worth AUD 163 million, of which AUD 51 million was attributed to the three ACIAR forestry projects (Fisher 2011).

Contribution of forestry to the returns to ACIAR's investments

ACIAR has commissioned two reviews of the returns to its investment in bilateral agricultural research: the first reviewing returns from 53 projects in 29 impact assessment studies, which represented 7.8% of ACIAR's total investment in bilateral research over 23 years (Raitzer and Lindner 2005); and the second reviewing returns from 103 projects in 27 studies (Lindner *et al*. 2013). To account for variability in methods applied and the certainty of benefit estimates, these reviews included evaluations of the confidence of the reported estimates of benefits. The first review used five criteria and ten indicators to construct three scenarios of benefit aggregation: potential benefits, plausible benefits and substantially demonstrated benefits (Raitzer and Lindner 2005). The second review developed a set of 14 criteria and a three-level rating score, which, when combined, enabled each assessed benefit stream to be classified as conceivable, plausible or convincing (Lindner *et al*. 2013).

The results from the first review indicated a benefit-cost ratio of 1.33 for the substantially demonstrated benefits and that these benefits arose from projects that represented only 3.0% of ACIAR's total investment in bilateral research over the 23-year period (Raitzer and Lindner 2005). This review included three impact assessment studies (McKenney 1998; van Bueren 2004a, 2004b) that assessed eight forestry projects implemented in China and Vietnam on the domestication and improvement of *Eucalyptus* and *Acacia*. It found that the forestry projects produced the highest economic returns in two of the benefit aggregation scenarios—plausible benefits and substantially demonstrated benefits—and that they contributed 47% of the substantially demonstrated benefits (Raitzer and Lindner 2005).

The results from the second review, which were from projects that represented only 3.9% of ACIAR's total investment in bilateral research over 30 years, indicated a much greater benefit-cost ratio of 51.4 for the almost AUD 23 billion worth of benefits assessed as convincing (Lindner *et al*. 2013). This review included five impact assessment studies (Corbishley and Pearce 2007; Fisher and Gordon 2007a, 2007b; Fisher 2011; Lindner 2011) that assessed 28 forestry projects implemented in Indonesia, Pakistan, Papua New Guinea, Thailand and Vietnam. It found that the Indonesia and Vietnam forestry projects contributed 63% of the substantially demonstrated benefits and that the Indonesian plantation forestry projects achieved the highest benefit-cost ratio (323.9) of any of ACIAR's published impact assessments to date (Lindner *et al*. 2013).

These two reviews demonstrate that the Forestry Program, and particularly the subset of plantation forestry research projects, has made a significant contribution to the overall economic returns from ACIAR's research investments. The calculated economic benefits from the plantation forestry research projects to Indonesia and Australia were AUD 11 148 million and AUD 766.48 million respectively (Lindner 2011). These benefit streams far exceed ACIAR's total nominal investment of AUD 103.46 million in the 150 completed forestry research projects. The estimated economic benefit, to either Indonesia or Australia, from just four of the forestry projects, far exceeds the cost of all the ACIAR forestry projects.

Other impacts from the Forestry Program

While economic impacts resulting from research are important they are not the only impacts that ACIAR projects seek to achieve. Other important impact categories include scientific, capacity building, social and environmental impacts. These impacts are harder to assess than economic impacts but they are equally important for research projects. In addition, the type of impacts that can be achieved will vary depending on the nature of the research undertaken by a project, the existing capacity of partners and the positioning of the project activities in a longer-term program of research and development. For each impact category, some examples of the impacts achieved by ACIAR forestry research projects are described below.

Scientific impacts

Unsurprisingly, there have been a considerable number of impacts arising from the scientific outputs from the 101 completed forestry research projects, including the wide dissemination of this knowledge in scientific journals and the publications of ACIAR and partner organisations, such as CIFOR and ICRAF. Some of these impacts include:

- use of information about the environmental requirements, cultivation, potential uses and pests and diseases for 166 Australian trees (Doran and Turnbull 1997) by scientists to guide tree planting programs in their countries
- sharing of knowledge on the domestication and improvement of tropical acacias (Turnbull *et al*. 1988a; Kha and Nghia 1991; Turnbull 1991) between scientists which led to the development of large areas of fast-growing acacia plantations in Vietnam and Indonesia
- sharing current state of knowledge on the role of eucalypts in Asia including socioeconomics, genetics, nutrition, pest and diseases, environmental impacts and utilisation issues (Turnbull 2003)
- knowledge on the essential oils derived from *Melaleuca, Asteromyrtus* and *Callistemon* (Brophy and Doran 1996) used to facilitate production of essential oils in Papua New Guinea and Indonesia
- research on identifying diseases of *Acacia* (Old *et al*. 2000) and *Eucalyptus* (Old *et al*. 2003) in South-East Asia and minimising their impacts, that led to the availability of more disease-resistant plants (Fisher and Gordon 2007b)
- publication of procedures for working with mycorrhizal fungi (Brundrett *et al*. 1995, 1996) enabled researchers, nursery and plantation managers to introduce them

and then establish plantations of Australian trees on nutrient impoverished soils
- development of polyploid varieties of *Acacia mangium* and the discovery that the tetraploids have significantly longer and wider fibres (Griffin *et al*. 2015), offers potential benefits for paper making
- an analysis of the largest global markets for teak timber in India, China, Vietnam and Thailand, together with information on Solomon Islands' under-utilised teak resource (Midgley *et al*. 2015), assists with development of markets for this timber through global timber traders.

Capacity-building impacts

Skills of research scientists and other stakeholders, including farmers and employees of forestry companies and processing industries, have been enhanced by working directly with the international scientists engaged in the forestry projects. An example of this is the enhanced knowledge of appropriate silviculture for teak growing (Pramono *et al*. 2011). At the completion of the project, 50% of the farmers were adopting the silvicultural practices on their farms, 30% were disseminating this knowledge to other farmers. In neighbouring regions 20% of farmers were adopting the recommended silvicultural practices and 15% were sharing this information with other farmers (Rohadi *et al*. 2012).

Perhaps the most important capacity-building impact from the Forestry Program is the substantial legacy of enhanced scientific capacity in partner countries arising from postgraduate studies under ACIAR's John Allwright Fellowship scheme. By mid-2015, ACIAR had supported 293 developing country scientists to complete postgraduate degrees in Australia. Forty-five scientists associated with ACIAR forestry projects, including 33 male and 12 female scientists, have completed 24 PhDs and 21 Masters degrees. These scientists have come from 12 partner countries as shown in Figure 2, with many of them subsequently contributing substantially to forestry in their countries or globally.

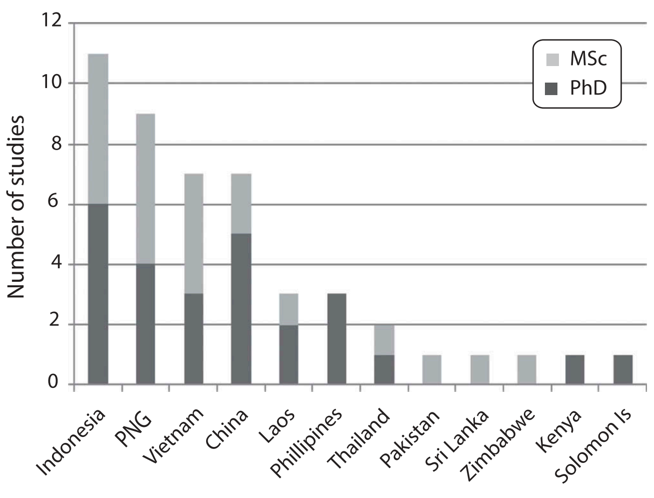

Figure 2. Numbers of forestry-related PhD and MSc studies completed by country.

Social impacts

Enhancing the use of trees and forests in rural development requires consideration of both social and biophysical sciences and often good technical forestry innovations will not succeed without appropriate understanding of the social factors that affect its adoption. While this approach became a significant component of ACIAR forestry projects only in the most recent decade, research under various projects has resulted in a number of important social impacts:

- engagement of farmers and the private sector in research on improving *Eucalyptus* plantation productivity in India facilitated widespread adoption of research outputs which led to 120 000 more jobs in log harvesting and delivery (Mendham 2010)
- knowledge of landholders' attitudes to growing trees and the constraints to them participating in commercial tree growing in Papua New Guinea (Kanowski *et al*. 2014) enabled a more targeted approach to promotion of agroforestry
- understanding of the livelihood assets of different household groups in communities (Oktalina 2015) enabled more effective interventions to foster community-based commercial forestry in Indonesia
- knowledge of how land ownership and labour availability affect different households' ability to integrate tree growing into their farming system, manage the woodlots effectively and maintain plantation ownership until maturity (Newby *et al*. 2014), influenced the design of teak agroforestry systems in northern Laos
- recognition of the importance of decentralised political and administrative structures and existing capacity in the design of REDD+ schemes, enabled local decision-makers to address deforestation causes but increased the risk of leakage (Irawan and Tacconi 2009)
- understanding by donors and policy actors that Nepal's community forestry initiatives have evolved to include governance regimes beyond the local level, with civil society groups engaged in the politics of resource governance has influenced the livelihood and conservation outcomes (Ojha 2014).

Environmental impacts

The expansion of planted forests and the improvement of forest management systems can provide many environmental benefits, but these are often difficult to attribute to research projects. It is also possible that the expansion of planted forests can result in negative environmental outcomes. In Indonesia, about half of the plantations that were established before 2001 were on land that had natural closed forest cleared in the past 20 years (Cossalter and Pye-Smith 2003). Some of the positive environmental impacts from the Forestry Program include:

- research on water use by plantations in China (Lane *et al*. 2004; Morris *et al*. 2004) enabled scientists and plantation managers to predict the impact of new plantations on water availability on different soil

types and suggested options for modifying tree spacing to reduce water use
- information on the recovery of secondary forests following logging (Fox and Keenan 2011) enabled scientists in Papua New Guinea to predict the recovery of merchantable timber volumes and carbon stocks (Fox *et al*. 2011)
- knowledge from a review the sustainability of fast-grown *Eucalyptus* and *Acacia* plantation forestry in five countries in South-East Asia (Harwood and Nambiar 2014) encourages local scientists to develop integrated, science-based operational management systems to improve plantation sustainability
- research on different impacts and alternatives to slash and burn practices in Eastern Indonesia (Russell-Smith *et al*. 2000) provided village communities with skills in strategic burning to protect their agroforestry plots and gardens, which were still being used 7 years after the project finished (Myers *et al*. 2014).

Discussion

Forestry research involves complex systems with biophysical and social elements and requires long timeframes to produce the desired products and, hence, impacts (Henderson 2000). It is apparent from ACIAR's research reports and impact assessment studies that a wide range of positive scientific, capacity, economic, social and environmental impacts have been achieved across the portfolio of completed projects. This highlights the importance of considering the non-economic impacts from research projects when evaluating a program of research projects. It is also apparent that many research projects do not deliver the expected level of impact. What is not so clear, however, is why this occurs and what factors contribute to greater or lesser success of projects in different situations.

Economic impacts differ depending on the theme of the research, the country in which it is undertaken and other factors. In Indonesia, where forestry is important to the economy and comparatively good research capacity exists, very high impacts have arisen from research on domestication and improvement of Australian trees, but only limited impacts from research on control of plantation diseases (Lindner 2011). In Papua New Guinea, where forestry is also important economically but comparatively weaker research capacity exists, it has been difficult to deliver successful research projects across a range of research themes, including tree domestication and improvement (Fisher 2011). While the Western Australian sandalwood industry could not have been developed without the enabling research outputs, the level of plantation expansion was assisted by an enabling tax policy that allowed favourable treatment for forestry Managed Investment Schemes (Lindner 2011).

The focus on smallholder and community forestry

A consistent feature of the ACIAR Forestry Program over the 30 years has been its focus on smallholder and community forestry, particularly research related to enhanced livelihoods from commercial forestry activities, including timber and non-wood forest products. About three-quarters (74%) of the research projects (T1, T2, T3, T4 and T7 from Table 4) related to smallholder and community forestry. This research focus, which includes both technical and social science activities, has supported development of both plantation and agroforestry systems, based on eucalypts, acacias and other trees that produce high-value products.

The arguments for and against fast-growing plantations have been reviewed against published science (Cossalter and Pye-Smith 2003) to conclude that in some situations this form of forestry is undesirable, while in other situations it can yield benefits not just for the economy, but for the environment and local communities. The situation with benefits from smaller-scale agroforestry systems is also complex. The level of adoption of the agroforestry technologies by farmers and the benefits from the particular systems are variable and context-dependent (Mercer 2004; Viranamangga *et al*. 2012; Coe *et al*. 2014).

The ACIAR impact assessment studies clearly show that there have been some substantial economic impacts from this ongoing research focus. This is particularly the case for plantation forestry systems, in situations where there has been a large scale of plantation development and good markets for products. However, these same studies also show that the economic impacts from this smallholder-focused research are not uniformly displayed in all countries, or between projects within countries (Lindner 2011; Fisher 2011). Sustained research on species selection, tree breeding and site management has improved the productivity and profitability of plantations by between 70% and 200% in China (van Bueren 2004b; Turnbull 2007), Vietnam (Fisher and Gordon 2007a; Harwood *et al*. 2015) and Indonesia (Mendham and Hardiyanto 2011).

When two countries collaborate in the same ACIAR projects the outcomes can be very different and these are difficult to predict when the research commences. Vietnam now has 1.1 million hectares of *Acacia* plantations managed for wood production on five-to-ten year rotations, nearly half of which is managed by an estimated 250 000 smallholder growers with woodlots of one to five hectares in size (Nambiar *et al*. 2014). In contrast, in Laos only a small proportion of the estimated 200 000 hectares of plantations consists of *Eucalyptus* and *Acacia* trees and most of this is in concession areas developed by multi-national companies with limited benefit to local communities (Phimmavong *et al*. 2009). Yet both countries collaborated between 1994 and 2004 in two ACIAR forestry projects (FST/1993/118 and FST/1998/096) on domestication and improvement of Australian trees. In Vietnam, the policy settings supported smallholder engagement in forestry, there were very good mechanisms for the production and dissemination of high quality germplasm and strong markets developed for the wood products (Nambiar *et al*. 2014).

Having good forestry technology available to farmers is important, but not sufficient to ensure widespread adoption. Farmers also need secure access to land and rights to the tree products, confidence that their trees can be protected from fire, pests and diseases, as well as a market for the products that is attractive to them (Byron 2001). The level of adoption within a region, where all farmers have access to knowledge and germplasm for an agroforestry system, can also vary. In northern Laos, the degree to which households can participate in growing teak woodlots varies within and between villages, depending on factors such as a household's history of settlement in an area, the age and educational background of the household head, the level of off-farm income and access to enough paddy land to achieve self-sufficiency in rice production (Newby *et al*. 2012).

The situation in Indonesia is complex and depends on the location and nature of the commercial forestry operations.

By 2007 there were an estimated 799 000 hectares of industrial pulpwood plantations based on *Acacia* and *Eucalyptus* species, with most of the economic benefits from these plantations flowing to the plantation companies, but with rural communities benefiting from increased employment opportunities (Lindner 2011). On Java, 1.5 million smallholders manage 444 000 hectares of teak and mahogany-based agroforestry systems. Timber from these systems provides 12% of the average farming household income, with the trees acting as a living savings account (Roshetko *et al*. 2013). In another part of Central Java, where farmers are planting fast-growing *Albizia* trees and collect various non-timber forest products, community forestry contributes an average of 25–32% (USD 590–1200 annually) of household income (Irawanti *et al*. 2014). In Eastern Indonesia, the financial returns to communities engaged in commercial forestry varies considerably, depending on the nature of the system and intercropping outputs, the distribution of costs borne by stakeholders, and the nature of policy settings and government support for community forestry (Nawir 2013).

To date the outputs of ACIAR's smallholder forestry research in Papua New Guinea have not generated the substantial economic benefits for smallholders that have been achieved in South-East Asia. However, there are promising signs from the research about what could be achieved. Financial analysis of five high-value smallholder agroforestry systems showed benefit-cost ratios of between 1.58 and 3.11, with the highest return being for a teak sawlog system (Kanowski *et al*. 2014). Likewise, the estimated net present value from growing galip (*Canarium*) as shade trees in a cocoa agroforestry system was estimated at PGK 10 931 per ha (AUD 4900 per ha), with farmers receiving income from galip nuts after 5 years (Fisher 2011). The achievement of these potential benefits depends on the expansion of processing facilities and development of new markets for the value-added products, which a new ACIAR project that commenced in 2015 will try to address.

An important lesson from this research focus is that to achieve the desired impacts from new forestry technologies, research is also required on value-added processing and pest and disease management. The value chain and wood processing research undertaken in the Jepara region of Indonesia, where there are 12 000 furniture manufacturing businesses and 120 000 workers, has facilitated formation of an industry association and generated additional markets for their furniture products (Purnomo *et al*. 2014). In recent years, fungal diseases, such as *Ganoderma* and *Ceratocystis*, have caused significant death in tropical *Acacia* plantations in Indonesia. Recent research has enabled rapid screening of planting stock for variations in tolerance and/or susceptibility to *G. philippi* (Gafur *et al*. 2015), while preliminary trials on resistance and tolerance to *Ceratocystis* has indicated that the development of resistant breeds will be challenging (Brawner *et al*. 2015).

Challenges of achieving adoption and impact from research projects

ACIAR's 30 years of experience in implementing forestry research projects has shown that there are many challenges in achieving adoption of research outputs and these often have a bearing on the scale of impacts achieved by different projects. An example of the challenges of achieving adoption of research findings for small-scale forestry systems is shown in Box 1.

These adoption challenges are not limited to developing country situations, as is evidenced by the case study described in Box 2. Achieving positive impacts from forestry

Box 1. Challenges for adoption of agroforestry technologies in Vanuatu.

Whitewood (*Endospermum medulosum*), a fast growing high-value native tree of Vanuatu, is highly suited to planting by farmers in small woodlots or agroforestry systems and capable of producing sawlogs in 15 years (Viranamangga *et al*. 2012). Research has shown that in order to control branch size and thereby improve wood quality and value, whitewood stands need to be planted at 800 stems per hectare and then thinned at age 4 years to 400 stems per hectare to maximise individual tree growth (Glencross *et al*. 2012). There has been only limited adoption of this silvicultural knowledge to date, mainly due to the fact that the landowners are unwilling to thin the poorer trees to waste.

Participatory social science research involving 139 landowners on the island of Espiritu Santo, who had collectively established 63 hectares of whitewood plantations, found that almost all of them supported planting whitewood to provide future income. However, only 51% of the landowners were willing to plant additional whitewood, partly due to the lack of reliable markets for the wood products (Aru *et al*. 2012).

Box 2. Challenges for adoption of forest biosecurity research in Australia.

Puccinia psidii (eucalypt rust and, in Australia, also known as myrtle rust) is an exotic rust fungus of South American origin. In the early 2000s, an ACIAR project (FST/1996/206) investigated the susceptibility to eucalypt rust of 129 species of *Eucalyptus* and other Myrtaceae family plants. At the time, this rust was confined to Florida, the Caribbean islands and South America, but was considered a serious threat to eucalypt plantations worldwide and to many natural ecosystems in Australia (Booth *et al*. 2000).

The project found that the impact of rust disease was variable but widespread in the species tested and, of the 58 Australian species tested, 52 had some degree of susceptibility (Glen *et al*. 2007). It developed sensitive detection tests for the rust spores (Langrell *et al*. 2008) and a model to identify potentially high risk areas for *P. psidii* globally and in Australia. The most at-risk areas in Australia encompassed the coastal region from near Sydney northwards to Cape York Peninsula (Booth *et al*. 2000).

Following the completion of the ACIAR project, the project scientists worked with the relevant biosecurity authorities to develop a contingency response plan for an incursion (Carnegie *et al*. 2010). A disease risk assessment method and map for *P. psidii* were produced for the Chief Plant Protection Officer and these were used in a ministerial briefing and a workshop in May 2006 to identify appropriate responses to disease incursion scenarios (Booth and Jovanovic 2012).

An exotic myrtaceous rust was first detected in Australia in April 2010 on the New South Wales Central Coast. It was initially described as *Uredo rangelii*—myrtle rust (Carnegie *et al*. 2010), but later regarded to be *P. psidii* (Booth and Jovanovic 2012). Unfortunately, the contingency response plan was not activated by Australia's biosecurity officials at the time of the incursion and the rust spread rapidly. By late 2011 the rust had spread southwards to Batemans Bay in New South Wales and northwards to Bundaberg in Queensland, with outlier records from plant nurseries in Kingaroy, Chinchilla, Townsville and Cairns. The locations of the 201 sites known to be infected with *P. psidii* in Australia corresponded well with the predicted high disease hazard areas that had been identified following the completion of the ACIAR project (Booth and Jovanovic 2012).

research projects is likely to depend on multiple factors, some of which are likely to be outside the control of a research project. These factors may vary between countries and projects within a country and also could change over time as the local research capacity and policy and development contexts change.

Conclusions

ACIAR has been investing in forestry research in developing countries for over 30 years. Its investment of more than AUD 100 million in 101 forestry research projects, covering ten research themes, and 49 small research activities has resulted in an impressive array of scientific outputs and diverse range of impacts. A total of 29 countries have benefited from these collaborative research projects, most notably Indonesia, Vietnam and Papua New Guinea. In many cases, the projects have led to substantial economic benefits being generated for smallholders, communities and plantation companies.

The strategic and operational components of ACIAR's approach have remained relatively constant over the 30 years, but project designs have incorporated lessons learned from project evaluations to increase the prospects for greater scientific achievements and impacts. The nature of the Forestry Program has evolved and broadened over the three decades. These changes have generally been in line with international forestry research priorities, but it has always maintained its primary focus on research related to enhancing smallholder and community forestry systems. In each decade the number of countries in the program operated was between 15 and 17, but there has been variation in which countries were included in ACIAR projects. The number of partner organisations through which projects are commissioned has grown from four in the first decade to 16 in the third decade.

Over the years there have been many and varied benefits for the partner countries involved in ACIAR forestry projects as well as some significant benefits for Australia. There is now a significant body of knowledge about the growth and management of Australian tree species in tropical and subtropical areas, together with substantial genetic improvement in a number of high-value tree species and enhanced knowledge and capacity to improve the quality and value of timber products from these plantations. Large numbers of smallholders and rural households have had their livelihoods improved by the use of genetic material and silvicultural management practices generated from these projects. Communities have also benefited from employment in the wood processing and manufacturing industries, many of which have also benefited from ACIAR's wood science and processing projects.

Australia too has benefited from this sustained research program. There is improved knowledge of the performance of various Australian trees under different environmental conditions and reliable techniques for growing sandalwood plantations have been developed. The enhanced networks that exist with collaborating partner country scientists facilitate ongoing exchange of scientific information and in the case of forest biosecurity they can assist Australia to monitor the spread of new threats to Australian forestry.

The independent impact assessments conducted on nearly half of the completed projects demonstrate substantial economic benefits from this research investment. They also provide some insights into the variability of outcomes and impacts from individual projects and some of the factors that influence this. These factors include the nature of the research theme and topic, the country where the research is undertaken, the mechanisms that exist to disseminate the research outputs and the linkages that exist to markets for the products and services.

The ACIAR Forestry Program has achieved greater impacts in South-East Asian countries, such as Indonesia and Vietnam, than it has in Pacific countries, such as Papua New Guinea. But clearly, when this 30-year program of forestry research is considered as a whole, it is not clear why one project on a given topic apparently achieves substantially different outcomes and impacts from a similar project in a different location.

Notes

1. Documented by Bartlett 2015 on basis of 5 years of experience as an ACIAR Research Program Manager.
2. Dr John Turnbull, from early 1984 to September 1994; Dr John Fryer, from January 1995 to February 2003; Dr Russell Haines, from September 2004 to June 2010; and Mr Tony Bartlett, from July 2010.
3. Documented by Bartlett 2015 on basis of 5 years of experience as an ACIAR Research Program Manager.
4. The current project development process is described at: http://aciar.gov.au/project_dev
5. Unpublished internal report: ACIAR Forestry Program Strategic Plan 1997–2001.
6. Bartlett, personal observation in June 2015.

Acknowledgements

This research was conducted as part of postgraduate studies while the author was employed as the Forestry Research Program Manager by the Australian Centre for International Agricultural Research. The support and encouragement of ACIAR's Chief Executive Officer, Dr Nick Austin, to undertake postgraduate study and to allow access to all the research project records is gratefully acknowledged. The support and constructive feedback on aspects of this research from my academic supervisors, Dr Lorrae van Kerkhoff and Professor Peter Kanowski (from the Australian National University) and Professor Neil Byron (from the University of Canberra), as well as from two anonymous reviewers, is also gratefully acknowledged.

Disclosure statement

No potential conflict of interest was reported by the author.

ORCID

A. G. Bartlett http://orcid.org/0000-0003-1530-6881

References

ACIAR. (2008) *ACIAR Corporate Plan 2008–12*. Australian Centre for International Agricultural Research, Canberra.

ACIAR. (2013) *Forestry Research Program Strategy*. Australian Centre for International Agricultural Research, Canberra.

ACIAR. (2014a) *ACIAR Strategic Plan 2014–18*. Australian Centre for International Agricultural Research, Canberra.

ACIAR. (2014b) *ACIAR Annual Operational Plan 2014–15*. Australian Centre for International Agricultural Research, Canberra.

ADAB. (1981) *Australian Centre for International Agricultural Research*, Occasional Papers on Development Assistance No. 24. Australian Development Assistance Bureau, Canberra.

Aru, R., Nichols, J.D., Grant, J.C., Leys, A.J., Glencross, K., Sethy, M., Convery, K. and Viranamangga, R. (2012) Constraints to whitewood (*Endospermum medullosum*) plantation development on Santo Island, Vanuatu. *International Forestry Review* **14**, 414–423. doi:10.1505/146554812804715928

Bartlett, A.G. (1992) A review of community forestry advances in Nepal. *Commonwealth Forestry Review* **71**, 95–100.

Bevege, I. (2005) Supplying forest services from natural forests and plantations: can we meet the challenge? In: *Forests, Wood and Livelihoods - Finding a Future for All: Conference Conducted by the ATSE Crawford Fund on* 16 August *2005*. ATSE Crawford Fund, Parliament House, Canberra, pp. 30–43.

Blumfield, T., Bacon, G., Lyons, K., Walters, P., Tutua, S. and Moveni, R. (2013) *Improving Silvicultural and Economic Outcomes for Community Timber Plantations in Solomon Islands by Interplanting with* Flueggea flexuosa *and other Pacific Agroforestry Species*, ACIAR Projects Final Reports No. FR2013-09. Australian Centre for International Agricultural Research, Canberra.

Boland, D.J. (1989) *Trees for the Tropics: Growing Australian Multipurpose Trees and Shrubs in Developing Countries*, ACIAR Monograph No. 10. Australian Centre for International Agricultural Research, Canberra.

Boland, D.J. and Turnbull, J.W. (1989) Australian tree species for fuelwood and agroforestry in China, Kenya, Thailand and Zimbabwe. In: Boland, D.J. (ed.) *Trees for the Tropics: growing Australian Multipurpose Trees and Shrubs in Developing Countries*. Australian Centre for International Agricultural Research, Canberra.

Booth, T.H. and Jovanovic, T. (2012) Assessing vulnerable areas for *Puccinia psidii* (eucalyptus rust) in Australia. *Australasian Plant Pathology* **41**, 425–429. doi:10.1007/s13313-012-0130-x

Booth, T.H., Old, K.M. and Jovanovic, T. (2000) A preliminary assessment of high risk areas for Puccinia psidii (Eucalyptus rust) in the Neotropics and Australia. *Agriculture, Ecosystems & Environment* **82**, 295–301. doi:10.1016/S0167-8809(00)00233-4

Brawner, J., Japarudin, Y., Lapammu, M., Rauf, R., Boden, D. and Wingfield, M.J. (2015) Evaluating the inheritance of Ceratocystis acaciivora symptom expression in a diverse Acacia mangium breeding population. *Southern Forests: A Journal of Forest Science* **77**, 83–90. doi:10.2989/20702620.2015.1007412

Brophy, J.J. and Doran, J.C. (1996) *Essential oils of tropical Asteromyrtus, Callistemon and Melaleuca species*, ACIAR Monograph No 40. Australian Centre for International Agricultural Research, Canberra.

Brundrett, M., Bougher, N., Dell, B., Grove, T. and Malajczuk, N. (1996) *Working with Mycorrhizas in Forestry and Agriculture*, ACIAR Monograph No 32. Australian Centre for International Agricultural Research, Canberra.

Brundrett, M., Dell, B., Malajczuk, N. and Gong, M. (1995) *Mycorrhizal research for forestry in Asia*, Proceedings No. 62. Australian Centre for International Agricultural Research, Canberra.

Byron, N. (2001) Keys to smallholder forestry. *Forests, Trees and Livelihoods* **11**, 279–294. doi:10.1080/14728028.2001.9752396

Carnegie, A.J., Lidbetter, J.R., Walker, J., Horwood, M.A., Tesoriero, L., Glen, M. and Priest, M.J. (2010) Uredo rangelii, a taxon in the guava rust complex, newly recorded on Myrtaceae in Australia. *Australasian Plant Pathology* **39**, 463–466. doi:10.1071/AP10102

CGIAR. (2005) *Science for Agricultural Development: changing Contexts, New Opportunities*. CGIAR Science Council Secretariat, Rome, Italy.

Chambers, R. and Ghildyal, B.P. (1985) Agricultural research for resource-poor farmers: the farmer-first-and-last model. *Agricultural Administration* **20**, 1–30. doi:10.1016/0309-586X(85)90063-9

Coe, R., Sinclair, F. and Barrios, E. (2014) Scaling up agroforestry requires research 'in' rather than 'for' development. *Current Opinion in Environmental Sustainability* **6**, 73–77. doi:10.1016/j.cosust.2013.10.013

Commonwealth of Australia. (1982) *Australian Centre for International Agricultural Research Act, 1982*. Commonwealth of Australia, Australia.

Corbishley, J. and Pearce, D. (2007) *Growing Trees on Salt-Affected Land*, ACIAR Impact Assessment Series Report No. 51. Australian Centre for International Agricultural Research, Canberra.

Cossalter, C. and Pye-Smith, C. (2003) *Fast-Wood Forestry: Myths and Realities*. Forest Perspectives. Center for International Forestry Research, Bogor, Indonesia.

Davis, J., Gordon, J., Pearce, D. and Templeton, D. (2008) *Guidelines for Assessing the Impacts of ACIAR's Research Activities*, ACIAR Impact Assessment Series Report No. 58. Australian Centre for International Agricultural Research, Canberra.

Davis, J. and Lubulwa, G. (1995) *An Overview of ACIAR's Economic Evaluation Activities with a Forestry Program Focus*, Economic Evauation Unit Working Paper No. 18. Australian Centre for International Agricultural Research, Canberra.

Dieters, M., Newby, J., Cramb, R., Sexton, G., McNamara, S. and Johnson, M. (2014) *Enhancing on-Farm Incomes through Improved Silvicultural Management of Teak in Luang Prabang Province of Lao PDR*, ACIAR Final Reports No. 2014-08. Australian Centre for International Agricultural Research, Canberra.

Doran, J.C. and Turnbull, J.W. (1997) *Australian Trees and Shrubs: species for Land Rehabilitation and Farm Planting in the Tropics*. Australian Centre for International Agricultural Research, Canberra.

FAO. (1978) *Forestry for Local Community Development*. Food and Agriculture Organisation of the United Nations, Rome.

FAO. (1981) *Forestry and Rural Development*, FAO Forestry Paper No. 26. Food and Agicultural Organization of the United Nations, Rome.

FAO. (1985) *Tree Growing by Rural People*, FAO Forestry Paper No. 64. Food and Agricultural Organisation of the United Nations, Rome.

FAO. (2005a) *State of the World's Forests 2005*. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO. (2005b) *Global Forest Resources Assessment 2005*. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO-IUFRO-CIFOR. (1997) *New arrangements for forest science*, Discussion paper prepared for the Intergovernmental Panel on Forests, fourth session, New York, Feb 97.

Farmer, B., Duncan, R., Enright, T. and Jarvie, W. (2013) *Independent Review of the Australian Centre for International Agricultural Research (ACIAR)*, ACIAR Corporate Reports No. CP025. Australian Centre for International Agricultural Research, Canberra.

Fisher, H. (2011) *Forestry in Papua New Guinea: A Review of ACIAR's program*, ACIAR Impact Assessment Series Report No. 73. Australian Centre for International Agricultural Research, Canberra.

Fisher, H. and Gordon, J. (2007a) *Improved Australian Tree Species for Vietnam*, ACIAR Impact Assessment Series Report No. 47. Australian Centre for International Agricultural Research, Canberra.

Fisher, H. and Gordon, J. (2007b) *Minimising Impacts of Fungal Disease of Eucalypts in South-East Asia*, ACIAR Impact Assessment Series Report No. 49. Australian Centre for International Agricultural Research, Canberra.

Fox, J. and Keenan, R. (2011) *Assessment, Management and Marketing of Goods and Services from Cutover Native Forests in Papua New Guinea*, ACIAR Final Reports No. FR2011-10. Australian Centre for International Agricultural Research, Canberra.

Fox, J.C., Keenan, R.J., Brack, C.L. and Saulei, S. (2011) *Native Forest Management in Papua New Guinea: Advances* in Assessment, Modelling *and Decision-Making*, ACIAR Proceedings No. 135. Australian Centre for International Agricultural Research, Canberra.

Gafur, A., Nasution, A., Yuliarto, M., Yong, W.C. and Sharma, M. (2015) A new screening method for *Ganoderma philippii* tolerance in tropical *Acacia* species. *Southern Forests: a Journal of Forest Science* **77**, 75–81. doi:10.2989/20702620.2014.999304

Gilmour, D.A., King, G.C., Applegate, G.B. and Mohns, B. (1990) Silviculture of plantation forest in central Nepal to maximise community benefits. *Forest Ecology and Management* **32**, 173–186. doi:10.1016/0378-1127(90)90169-C

Glen, M., Alfenas, A.C., Zauza, E.A.V., Wingfield, M.J. and Mohammed, C. (2007) *Puccinia psidii*: a threat to the Australian environment and economy —a review. *Australasian Plant Pathology* **36**, 1–16. doi:10.1071/AP06088

Glencross, K., Nichols, J.D., Grant, J.C., Sethy, M. and Smith, R.G.B. (2012) Spacing affects stem form, early growth and branching in young whitewood (*Endospermum medullosum*) plantations in Vanuatu. *International Forestry Review* **14**, 442–451. doi:10.1505/146554812804715865

Grant, J.C., Glencross, K., Nichols, J.D., Palmer, G., Sethy, M. and Vanclay, J.K. (2012) Silvicultural implications arising from a simple simulation model for *Endospermum medullosum* in Vanuatu. *International Forestry Review* **14**, 452–462. doi:10.1505/146554812804715874

Griffin, A.R., Chi, N.Q., Harbard, J.L., Son, D.H., Harwood, C.E., Price, A., Vuong, T.D., Koutoulis, A. and Thinh, H.H. (2015) Breeding polyploid varieties of tropical acacias: progress and prospects. *Southern Forests: A Journal of Forest Science* **77**, 41–50. doi:10.2989/20702620.2014.999303

Haines, R. (2005) The contribution of Australian and international forestry research. In: *Forests, Wood and Livelihoods – Finding a Future for All: Conference Conducted by the ATSE Crawford Fund on* 16 August *2005*. ATSE Crawford Fund, Parliament House, Canberra, pp. 74–79.

Hardiyanto, E. (2003) Growth and genetic improvement of *Eucalyptus pellita* in south Sumatra, Indonesia. In: Turnbull, J.W. (ed.) *Eucalypts in*

Asia. ACIAR Proceedings No. 111. Australian Centre for International Agricultural Research, Canberra.

Harisetijono, and Suriamihardja, S. (1991) Sandalwood in Nusa Tenggara Timur. In: McKinnell, F.H. (ed.) *Sandalwood in the Pacific Region*. Proceedings of a Symposium Held on 2 June 1991. Australian Centre for International Agricultural Research, Honolulu, Hawaii, pp. 39–43.

Harwood, C.E., Hardiyanto, E.B. and Yong, W.C. (2015) Genetic improvement of tropical acacias: achievements and challenges. *Southern Forests: a Journal of Forest Science* **77**, 11–18. doi:10.2989/20702620.2014.999302

Harwood, C.E., Kha, L.D., Dien, P.Q. and Thang, L.V. (1988) Performance of Australian dry-zone *Acacia* species on white sandy soil in dry, south-eastern Vietnam. In: Turnbull, J.W., Crompton, H.R. and Pinyopusarerk, K. (eds.) *Recent Developments in Acacia Planting*. ACIAR Proceedings No. 82. Australian Centre for International Agricultural Research, Canberra.

Harwood, C.E. and Nambiar, E.K.S. (2014) *Sustainable Plantation Forestry in South-East Asia*, ACIAR Technical Reports No. 84. Australian Centre for International Agricultural Research, Canberra.

Henderson, J.S. (2000) Evaluating the impact of forestry research for development. *International Forestry Review* **2**, 191–199.

Henderson, W. and Braidotti, G. (2013) *Innovation and entrepreneurs*, Partners, November 2013, 18–19. Australian Centre for International Agricultural Research, Canberra.

Høgh-Jensen, H., Oelofse, M. and Egelyng, H. (2010) New challenges in underprivileged regions call for people-centered research for development. *Society & Natural Resources* **23**, 908–915. doi:10.1080/08941921003671502

Humphreys, D. (1999) The evolving forests regime. *Global Environmental Change* **9**, 251–254. doi:10.1016/S0959-3780(99)00005-9

Humphreys, D. (2001) Forest negotiations at the United Nations: explaining cooperation and discord. *Forest Policy and Economics* **3**, 125–135. doi:10.1016/S1389-9341(01)00039-9

Irawan, S. and Tacconi, L. (2009) Reducing emissions from deforestation and forest degradation (REDD) and decentralized forest management. *International Forestry Review* **11**, 427–438. doi:10.1505/ifor.11.4.427

Irawanti, S., Ginoga, K., Prawestisuka, A. and Race, D. (2014) Commercialising community forestry in Indonesia: lessons about the barriers and opportunities in central Java. *Small-Scale Forestry* **13**, 515–526. doi:10.1007/s11842-014-9268-4

Kanowski, P., Blyth, M., Essacu, F., Holzknecht, H., Jenkin, B., Kuniata, L., Mulung, K. and Rollinson, S. (2014) *Value-Adding to Papua New Guinea Agroforestry Systems*, ACIAR Final Reports No. FR2014-10. Australian Centre for International Agricultural Research, Canberra.

Kha, L.D. and Nghia, N.H. (1991) Growth of some *Acacia* species in Vietnam. In: Turnbull, J.W. (ed.) *Advances in Tropical Acacia Research*. Australian Centre for International Agricultural Research, Canberra.

Khanzada, A.N., Morris, J.D., Ansari, R., Slavich, P.G. and Collopy, J.J. (1998) Groundwater uptake and sustainability of *Acacia* and *Prosopis* plantations in southern Pakistan. *Agricultural Water Management* **36**, 121–139. doi:10.1016/S0378-3774(98)00030-4

Lane, P.N.J., Morris, J., Ningnan, Z., Guangyi, Z., Guoyi, Z. and Daping, X. (2004) Water balance of tropical eucalypt plantations in south-eastern China. *Agricultural and Forest Meteorology* **124**, 253–267. doi:10.1016/j.agrformet.2004.01.015

Langrell, S.R.H., Glen, M. and Alfenas, A.C. (2008) Molecular diagnosis of *Puccinia psidii* (guava rust) – a quarantine threat to Australian eucalypt and Myrtaceae biodiversity. *Plant Pathology* **57**, 687–701. doi:10.1111/ppa.2008.57.issue-4

Lindner, R. (2011) *The Economic Impact in Indonesia and Australia of Investment in* Plantation Forestry Research, *1987–2009*, ACIAR Impact Assessment Series Report No. 71. Australian Centre for International Agricultural Research, Canberra.

Lindner, R., McLeod, P. and Mullen, J. (2013) *Returns to ACIAR's Investment in Bilateral Agricultural Research*, ACIAR Impact Assessment Series No. 86. Australian Centre for International Agricultural Research, Canberra.

Lynam, J.K. and Herdt, R.W. (1989) Sense and sustainability: sustainability as an objective in international agricultural research. *Agricultural Economics* **3**, 381–398. doi:10.1016/0169-5150(89)90010-8

McKenney, D.W. (1998) *Australian Tree Species Selection in China*, ACIAR Impact Assessment Series No. 8. Australian Centre for International Agricultural Research, Canberra.

Melati, Purnomo, H. and Shantiko, B. (2013) *Making Research Work for Small-Scale Furniture Makers: action Research in the Jepara Furniture Industry, Indonesia*, Center for International Forestry Research (CIFOR), Bogor, Indonesia.

Mendham, D. (2010) Adoption study for ACIAR project FST/1995/106. In: Pearce, D. and Templeton, D. (eds.) *Adoption of ACIAR Project Outputs - Studies of Projects Completed in 2005–06*. Australian Centre for International Agricultural Research, Canberra.

Mendham, D. and Hardiyanto, E. (2011) *Realising Genetic Gains in Indonesia and Australian Plantations through Water and Nutrient Management*, ACIAR Final Reports No. FR2011-07. Australian Centre for International Agricultural Research, Canberra.

Mercer, D.E. (2004) Adoption of agroforestry innovations in the tropics: a review. *Agroforestry Systems* **61–62**, 311–328.

Midgley, S., Bennett, J., Samontry, X., Stevens, P., Mounlamai, K., Midgley, D. and Brown, A. (2012) *Enhancing Livelihoods in Lao PDR through* Environmental Services *and Planted-Timber Products*, ACIAR Technical Reports No. 81. Australian Centre for International Agricultural Research, Canberra.

Midgley, S., Somaiya, R.T., Stevens, P.R., Brown, A., Nguyen, D.K. and Laity, R. (2015) *Planted Teak: Global Production and Markets, with Reference to Solomon Islands*, ACIAR Technical Reports No. 85. Australian Centre for International Agricultural Research, Canberra.

Morris, J., Ningnan, Z., Zengjiang, Y., Collopy, J. and Daping, X. (2004) Water use by fast-growing *Eucalyptus urophylla* plantations in southern China. *Tree Physiology* **24**, 1035–1044. doi:10.1093/treephys/24.9.1035

Myers, B., Fisher, R., Pickering, S. and Garnett, S. (2014) Post-project evaluation of the sustainability of development project outcomes: a case study in eastern Indonesia. *Development in Practice* **24**, 379–389. doi:10.1080/09614524.2014.899320

Nambiar, E.K.S. and Brown, A.G. (1997) *Management of Soil, Nutrients and Water in Tropical Plantation Forests*, ACIAR Monograph No. 43. Australian Centre for International Agricultural Research, Canberra.

Nambiar, E.K.S., Harwood, C.E. and Kien, N.D. (2014) Acacia plantations in Vietnam: research and knowledge application to secure a sustainable future. *Southern Forests: A Journal of Forest Science* **77**, 1–10. doi:10.2989/20702620.2014.999301

Nawir, A.A. (2013) Commercial community tree-growing inside state forests: an economic perspective from eastern Indonesia. *International Forestry Review* **15**, 200–217. doi:10.1505/146554813806948558

Newby, J., Cramb, R. and Sakanphet, S. (2014) Forest transitions and rural livelihoods: multiple pathways of smallholder teak expansion in northern Laos. *Land* **3**, 482–503. doi:10.3390/land3020482

Newby, J., Cramb, R.A., Sakanphet, S. and Mcnamara, S. (2012) Smallholder teak and agrarian change in northern Laos. *Small-Scale Forestry* **11**, 27–46. doi:10.1007/s11842-011-9167-x

Ojha, H.R. (2014) Beyond the 'local community': the evolution of multi-scale politics in Nepal's community forestry regimes. *International Forestry Review* **16**, 339–353. doi:10.1505/146554814812572520

Oktalina, S.N. (2015) *Forestry Livelihood Framework: unpublished Report for ACIAR Project FST/2008/030 'Overcoming Constraints to Community-Based Commercial Forestry in Indonesia'*. University of Gadjah Mada, Yogyakarta, Indonesia.

Old, K.M. and Mohammed, C. (2003) Managing diseases of eucalypts in southeast Asia. In: Turnbull, J.W. (ed.) *Eucalypts in Asia*. Proceedings of an International Conference held in Zhanjiang, China. 7–11 April 2003. Australian Centre for International Agricultural Research, Canberra.

Old, K.M., See, L.S., Sharma, J.K. and Yuan, Z.Q. (2000) *A Manual of Diseases of Tropical Acacias in Australia, South-East Asia and India*. CIFOR, Bogor, Indonesia.

Old, K.M., Wingfield, M.J. and Yuan, Z.Q. (2003) *A Manual of Diseases of Eucalyptus in South-East Asia*. CIFOR, Bogor, Indonesia.

Parliament of Australia. (1992) *Review of the Australian Centre for International Agricultural Research: a report of the Joint Committee on Foreign Affairs, Defence and Trade*. Australian Government Publishing Service, Canberra.

Pearce, D., Jilani, A. and Templeton, D. (2013) *Adoption of ACIAR Project Outputs 2013*, ACIAR Adoption Studies No. AS010. Australian Centre for International Agricultural Research, Canberra.

Phimmavong, S., Ozarska, B., Midgley, S. and Keenan, R. (2009) Forest and plantation development in Laos: history, development and impact for rural communities. *International Forestry Review* **11**, 501–513. doi:10.1505/ifor.11.4.501

Pistorius, T. (2012) From RED to REDD+: the evolution of a forest-based mitigation approach for developing countries. *Current Opinion in Environmental Sustainability* **4**, 638–645. doi:10.1016/j.cosust.2012.07.002

Pramono, A.A., Fauzi, M.A., Widyani, N., Heriansyah, I. and Roshetko, J.M. (2011) *Managing Smallholder Teak Plantations: field Guide for Farmers*. Center for International Forestry Research (CIFOR), Bogor, Indonesia.

Purnomo, H., Achdiawan, R., Melati, Irawati, R.H., Sulthon, Shantiko, B. and Wardell, A. (2014) Value-chain dynamics: strengthening the institution of small-scale furniture producers to improve their value addition. *Forests, Trees and Livelihoods* **23**, 87–101. doi:10.1080/14728028.2013.875279

Raitzer, D.A. and Lindner, D. (2005) *Review of the Returns to ACIAR's Bilateral R and D Investments*, ACIAR Impact Assessment Series Report No. 35. Australian Centre for International Agricultural Research, Canberra.

Rohadi, D., Roshetko, J., Perdana, A., Blyth, M., Nuryartono, N., Kusumowardani, N., Pramono, A., Widyani, N. and Fauzan, A. (2012) *Improving Economic Outcomes for Smallholders Growing Teak in Agroforestry Systems in Indonesia*, ACIAR Final Reports No. FR2012-11. Australian Centre for International Agricultural Research, Canberra.

Roshetko, J.M., Rohadi, D., Perdana, A., Sabastian, G., Nuryartono, N., Pramono, A.A., Widyani, N., Manalu, P., Fauzi, M.A., Sumardamto, P. and Kusumowardhani, N. (2013) Teak agroforestry systems for livelihood enhancement, industrial timber production, and environmental rehabilitation. *Forests, Trees and Livelihoods* **22**, 241–256. doi:10.1080/14728028.2013.855150

Russell-Smith, J., Hill, G., Djoeroemana, S. and Myers, B. (2000) Fire and sustainable agricultural and forestry development in Eastern Indonesia and Northern Australia. In: *Proceedings of an International Workshop Held at Northern Territory University, Darwin, Australia*, 13–15 April 1999. ACIAR Proceedings No. 91. Australian Centre for International Agricultural Research, Canberra.

Shepherd, K.R. (1985) Forestry research within the Australian centre for international agricultural research. *Australian Forestry* **48**, 77–78. doi:10.1080/00049158.1985.10674426

Turnbull, J.W. (ed.) (1991) Advances in tropical Acacia research. In: *Proceedings of a Workshop Held in Bangkok, Thailand*, 11–15 February 1991. ACIAR Proceedings No. 35. Australian Centre for International Agricultural Research, Canberra, pp. 234.

Turnbull, J.W. (2003) Eucalypts in Asia. In: *Proceedings of an International Conference Held in Zhanjiang, People's Republic of China*, 7–11 April 2003. Australian Centre for International Agricultural Research, Canberra.

Turnbull, J.W. (2007) *Development of Sustainable Forestry Plantations in China*: A *Review*, ACIAR Impact Assessment Series Report No. 45. Australian Centre for International Agriculture, Canberra.

Turnbull, J.W., Crompton, H.R. and Pinyopusarerk, K. (1988a) Recent developments in Acacia planting. In: *Proceedings of an International Workshop Held in Hanoi, Vietnam*, 27–30 October 1997. ACIAR Proceedings No. 82, Australian Centre for International Agricultural Research, Canberra.

Turnbull, J.W., Midgley, S.J. and Cossalter, C. (1988b). Tropical acacias planted in Asia: an overview. In: Turnbull, J.W., Crompton, H.R. and Pinyopusarerk, K. (eds.) *Recent Developments in Acacia Planting*. ACIAR Proceedings No. 82. Australian Centre for International Agricultural Research, Canberra.

United Nations (1992) *Non-Legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forests*. United Nations, New York.

United Nations. (2007) *Non-Legally Binding Instrument on All Types of Forests*. United Nations General Assembly, New York.

van Bueren, M. (2004a) *Acacia Hybrids in Vietnam*, ACIAR Impact Assessment Series Report No. 27. Australian Centre for International Agricultural Research, Canberra.

van Bueren, M. (2004b) *Eucalypt Tree Improvement in China*, ACIAR Impact Assessment Series Report No. 30. Australian Centre for International Agricultural Research, Canberra.

Viranamangga, R., Palmer, G. and Glencross, K. (2012) Plantation-grown whitewood timber in Vanuatu: challenges and opportunities for export and domestic use. *International Forestry Review* **14**, 486–491. doi:10.1505/146554812804715847

Westoby, J.C. (1989) *Introduction to World Forestry*. Basil Blackwell, Oxford, UK.

Wingfield, M.J., Slippers, B., Hurley, B.P., Coutinho, T.A., Wingfield, B.D. and Roux, J. (2008) Eucalypt pests and diseases: growing threats to plantation productivity. *Southern Forests: a Journal of Forest Science* **70**, 139–144. doi:10.2989/SOUTH.FOR.2008.70.2.9.537

Zethner, O. (1973) Assistance to agricultural scientists in the third world: a neglected field. *World Development* **1**, 53–55. doi:10.1016/0305-750X(73)90112-5