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ADOPTION OF ACIAR PROJECT OUTPUTS

STUDIES OF PROJECTS COMPLETED IN 2002–2003

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Editors: Jenny Gordon and Jeff Davis

August 2007

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

ACIAR seeks to ensure that the outputs of its funded research are adopted by farmers, policymakers, quarantine officers and other intended beneficiaries.

As part of its efforts to monitor the outputs and outcomes of its projects, ACIAR has commissioned project leaders and participants to revisit projects 3 to 4 years after completion, and report back to ACIAR on the medium-term outcomes of the work. This series reports the results of these studies.

Communications regarding any aspects of this series should be directed to:

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Foreword

The Australian Centre for International Agricultural Research (ACIAR) has a funding base of about A$60 million and invests in agricultural research projects that contribute to poverty alleviation.

One of the challenges facing ACIAR and its partner scientists is to ensure that projects leave a legacy—that they continue to benefit the partner countries and communities well after the project itself is completed.

It is not good enough for projects to be delivering benefits only while donor funds are provided. Successful projects impart knowledge and skills and leave in place technology that is sustainable in the long term under local conditions.

Formal independent project impact assessments have always been an important part of ACIAR's accountability process and a means of improving project selection and management. The adoption studies, which form the body of this report, are an important intermediate stage between completion of the projects and these rigorous independent impact assessment studies.

The studies are undertaken 3 to 4 years after each project is completed to assess the level of uptake and the legacy of the project. They provide valuable insights into the uptake of project results and the impact on local communities, and form a basis for the impact assessments.

I particularly want to thank the Australian project participants who undertook the task of revisiting partner countries to gather and collate data and write the adoption statements that form the basis of this publication.

I also want to thank the many project participants in our partner countries who hosted visits, helped with data gathering and provided useful insights on the ongoing impact and effectiveness of these projects. My sincere thanks to each of you for your support.

Peter Core
Director
Australian Centre for International Agricultural Research

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Overview

Jenny Gordon

Introduction

The seven ACIAR projects reviewed in this report demonstrate the diversity of the ACIAR portfolio. They range from policy projects on water management systems in Pakistan to new technology addressing nutrition deficiencies for plantation productivity in Solomon Islands. The reviews demonstrate the opportunities for Australian scientific expertise to add value to the research being undertaking in developing-country partners, and the importance of cooperative research as a modality for technology transfer—in both directions. They also highlight the need to consider adoption pathways carefully when developing ACIAR projects, and emphasise the importance of both policy environment and incentives in encouraging participants to remain engaged and share the outputs of the research with others.

The adoption studies describe the intentions of the research projects and assess the extent to which the outputs and intended outcomes have been achieved. They identify unintended outputs and outcomes that can arise as a result of failure to understand the policy environment and other factors at play, or simply reflect serendipity's role in scientific discovery. Critically, the adoption studies attempt to track the adoption process from project outputs through to the final or end user. This process tends to be very different depending on the nature of the project outputs.

Project outputs

ACIAR identifies three categories of output:

- new technology, practical approaches
- scientific knowledge or understanding (pure or basic science)
- knowledge, models and frameworks to aid policy and decision-making.

Many of the projects delivered outputs that fall across a number of these categories. Table 1 summarises the nature of the outputs for each of the projects reviewed in this report.

Most of the projects delivered the intended outputs. In the case of the Indonesian trade model the emphasis shifted away from the intended focus on the intersection of agriculture, trade and the natural environment. This was in part due to changes in policy priorities with the Asian financial crisis, but also arose from the considerable challenge that such model development presented. Overall, for most projects, the outputs were achievable and were achieved.

Capacity development

The projects also delivered considerable outputs in terms of capacity built. In general the projects incorporated researchers already involved in the field, and in some cases there was considerable exchange of existing knowledge (notably in brassica vegetable IPM in China and the eucalypt rust in Brazil). In a few cases the projects made investments to build the institution's research infrastructure as well as in staff skills and knowledge (notably for insect pathology on white grubs in India and eucalypt rust in Brazil). Table 2 summarises the main capacity built. It also notes the extent to which the capacity has continued to be used. This theme is discussed further in the next section.

Uptake of the R&D outputs—progress along adoption pathways

While research for the knowledge it builds is often of value in its own right, ACIAR undertakes R&D as part of Australia's development assistance program. Thus it is important that ACIAR projects contribute to the development goals of improving agricultural productivity and farmer incomes, sustainable resource use and, as a result, poverty alleviation. ACIAR projects are selected on the basis of the contribution they are expected to make to these goals, as well as the benefits to Australia through improvements in agricultural research. Adoption pathways from research outputs to such desirable impacts must be robust and often need to be actively promoted. The diffuse approach to dissemination of scientific knowledge through academic journals and conferences is rarely speedy and not always effective. The projects in these adoption studies demonstrate the importance of not just building relationships with partner-country researchers, but ensuring that these researchers are directly linked into the final user groups—that is the farmers, processors or other players in the value chain who have to make the changes in behaviour or practice for the output to be adopted.

The projects illustrate a number of adoption pathways:

- Three projects—the Indonesian CGE modelling, Pakistan water management and eucalypt rust projects—provided tools for policy advice or decision-making. These tools were adopted by the next users and, to some extent, by final users, i.e. organisations that have made changes in policies and systems that have much broader impacts. In the case of trade policy modelling, the final users are trade policies that result in improving the allocation of resources and providing market pressure for productivity improvements. In the case of the water management schemes, the decision-making rules of the organisations should, over time, improve management of the water systems and provide benefit for farmers from more equitable and certain water supplies. For eucalypt rust, the project involved the Australian agencies with responsibility for biosecurity. AQIS and Biosecurity Australia are the final users of the diagnostic test, while the beneficiaries range from plantation companies to the community, given the values the community places on Australian native ecosystems.

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Table 1. Project outputs

Project	New technology/ understanding	Scientific knowledge	Knowledge, models for policy
Policy analysis of linkages between Indonesia's agricultural production, trade and the environment			Developed a CGE[a] model for policy analysis
Management of white grubs in peanut cropping systems in Asia and Australia	Control strategies for white grubs; management technologies; insect pathogen	Behaviour, ecology and population dynamics of white grubs	
Improvement of IPM[b] in brassica vegetable crops in China and Australia	IPM for vegetable pests suited for local conditions	Impact of major pests on yield and quality; role of beneficials in suppressing pests; resistance levels to major insecticides	
Assessment of eucalypt rust as a pathogen of *Eucalyptus* spp. and other Myrtaceae, and development of sensitive methods for its detection in germplasm in Australia	Diagnostic techniques for detection of *Puccinia psidii* in seed, tissue-cultured plants or pollen	*P. psidii* DNA-based genetic markers; susceptibility of a range of Australian Myrtaceae	Disease hazard maps for *P. psidii*
Conjunctive water management for sustainable irrigated agriculture in South Asia (Pakistan)	Subsurface evaporation basin construction to alleviate water logging	Hydrologic and hydrogeologic data for the Rechna Doab	Institutional and technical strategies to manage surface and groundwater at a regional scale
Shelf-life extension of leafy vegetables (China)	Techniques for extending shelf life	Identification of physiological factors limiting shelf life	
Nutrition of tropical hardwood species in plantations in the south-western Pacific (Solomon Islands)	Cost-effective methods for addressing nutritional deficiencies		

[a] CGE = computable general equilibrium

[b] IPM = integrated pest management

Table 2. Research capacity built by the projects

Project	Partner-country/ies researchers	Research infrastructure	Capacity used
Policy analysis of linkages between Indonesia's agricultural production, trade and the environment	Development of modelling skills of students and researchers involved; former students now teaching in major universities	WAYANG CGE[a] model publicly available via the web	Use of the model has been requested by the Ministers of Agriculture and Trade; research leaders involved have progressed to high-level government positions
Management of white grubs in peanut cropping systems in Asia (India) and Australia	Skills built in insect pathology and intersection with crop production; capacity also built in farmers involved in the project	Laboratory equipment and facilities developed to support insect pathology research	Laboratories have been closed; researchers have retired or their work has been terminated
Improvement of IPM[b] in brassica vegetable crops in China and Australia	Major improvements in the networking of research and extension staff in China		Research is continuing and skills are being applied to tackle new pest problems
Assessment of eucalypt rust as a pathogen of *Eucalyptus* spp. and other Myrtaceae, and development of sensitive methods for its detection in germplasm in Australia	Scientific skills built in both Brazilian and Australian researchers involved	Improvement in research infrastructure in Brazil	Continued progress in research in the area using the facility and staff in Brazil and ongoing research in Australia
Conjunctive water management for sustainable irrigated agriculture in South Asia (Pakistan)	Facilitated a PhD dissertation and a Masters thesis		While the scientists have progressed in their careers, none continued with the agencies
Shelf-life extension of leafy vegetables (China)	Budgeting and project management skills developed and closer contact with industry gained		Major increase in R&D on postharvest handling due to greater ability to attract investment
Nutrition of tropical hardwood species in plantations in the south-western Pacific (Solomon Islands)	Major improvement in know-ledge, skills and confidence of plantation staff involved		Most researchers have moved to other organisations; indirect use of skills gained

[a] CGE = computable general equilibrium

[b] IPM = integrated pest management

- Three projects, the two in China on vegetables and the white grubs project in India, demonstrate the value of involving the extension services in the project as a means of ensuring early and good adoption. The IPM in China built links between researchers and the state extension services. In southern India the researchers developed training materials and involved the NGO extension and farmer education service to disseminate information on management systems for white grubs. The postharvest handling research on vegetables was quickly adopted by next and final users. The Beijing Vegetable Research Centre worked with the distribution centres, which could dictate practice to growers and support them in improving postharvest practices.
- One project, the Solomon Islands plantation nutrition project, worked directly with the plantation company staff. Uptake was high during the project and most practices were continued by the plantation company involved, but little was transferred to other plantation activities in Solomon Islands or other Pacific countries who participated in workshops. Loss of staff pointed to the need to take succession planning into account. The need for training to go beyond the staff involved to promote adoption is also highlighted by this review. Similarly, while white grub management knowledge is being transferred to farmers in India, the use of formal training courses has excluded the many illiterate or semiliterate farmers from access to this knowledge.
- Final users can also be the researchers involved and other researchers. This use may not have direct impacts as further research must be undertaken before outputs are developed that can be applied to the community. A number of the projects have aspects that may, with additional research effort, yield new technology or policy advice. For example, the eucalypt rust work continues in Brazil and Australia, and is also being used in other countries where plantations have been established. Another example is the insect pathology capacity built in China, which is now being applied to new plant pests.

Table 3 summarises the progress in adoption of the different outputs at the time of the adoption studies. It makes a distinction where the final user is the community, farmer or other supplier in the value chain who also benefits from the change, compared with policymakers or other researchers who, while they may benefit personally from promotion or enhanced recognition of their organisation's achievement, are not the primary beneficiaries.

Overall adoption progress in the projects in this round of reviews has been fairly good. However, the studies suggest that adoption is faster and more complete where the final users are policymakers, or researchers or producers directly involved in the project. This is in part because there are fewer final users in these cases and adoption must be assessed against the potential scale of final users. Where the final user is a farmer, there may be many final users and adoption is almost inevitably slower. It also matters what share of producers the research output is relevant to. Table 3 identified regional impact in several cases, where the adoption had yet to spread to farmers in other regions (in the case of IPM for brassicas, and postharvest handling of vegetables in China) or to less skilled farmers (due to literacy levels as in the case of white grubs in peanuts in India, and dissemination in the case of plantation nutrition technology in the Solomon Islands). This has implications for the impact of the projects.

Table 3. Project outputs and the current progress of adoption

Project	New technology/ understanding	Scientific knowledge	Knowledge, models for policy
Policy analysis of linkages between Indonesia's agricultural production, trade and the environment			NF—policy makers, but yet to have a major impact on the community
Management of white grubs in peanut cropping systems in Asia and Australia	NF—farmers in southern India O—farmers in northern India and Australia	O—researchers in northern India	
Improvement of IPMa in brassica vegetable crops in China and Australia	NF—regions directly involved in project Nf—regions not directly involved	NF—researchers	
Assessment of eucalypt rust as a pathogen of *Eucalyptus* spp. and other Myrtaceae, and development of sensitive methods for its detection in germplasm in Australia	NF—Australian quarantine	NF—researchers	Nf—plantation companies
Conjunctive water management for sustainable irrigated agriculture in South Asia (Pakistan)	N—identified sites not developed	NF—researchers, but not intended water management agencies	NF—model being replicated for water management agencies
Shelf-life extension of leafy vegetables (China)	NF—distribution companies and farmers	NF—researchers	
Nutrition of tropical hardwood species in plantations in the south-western Pacific (Solomon Islands)	Nf—but limited to those involved in the project		

Notes:

Level of uptake is summarised as high, medium, low or none using the following abbreviations:

NF: Demonstrated and considerable use of results by the initial and final users

Nf: Demonstrated and considerable use of results by the initial users but only minimal uptake by the final users

N: Some use of results by initial users but no uptake by final users

O: No uptake by either initial or final users

[a] IPM = integrated pest management

Factors contributing to uptake and project impacts

The impact of each project depends on the relevance of the final use for the community. Where final users are farmers adoption rates are usually good indicators of expected benefits. However, where final users are policymakers or other researchers the links between adoption and impact can be more complex and sometimes tenuous. Thus good adoption is not a necessary measure of a high impact. The impact depends on the size of the community affected by the final use and the size of the benefit to the individuals who are affected. As with adoption rate, impact is affected by the policy and social environment. In assessing the expected return factors, such as the additional costs, market opportunities and the impact on income certainty have to be taken into account as well as any higher yield or quality that might result. The reviews provide some insight into the potential impact of the projects, and the factors that inhibit and enhance adoption and often impact. Table 4 summarises these factors. It follows the categories that have emerged from the analysis of the adoption studies in the previous 3 years[1]. A new category—the continuity of staffing—is added as a result of these reviews. The main types of factors were:

- knowledge of the opportunity—whether potential next and final users know of the outputs and the consequences of use
- benefits accruing to the next and final users—whether they have incentives to adopt the output. This has two aspects. The first is the net return on adopting the output, as adoption can incur costs (e.g. harder work) as well as benefits (e.g. higher productivity); the second is whether the individuals who have to make the change consider it in their best interests to do so, and this in turn may depend on whether they share in the benefits
- compulsion or prohibition—whether adoption is compulsory (e.g. a policy change) or effectively prohibited (e.g. where the imported inputs required cannot be imported at a feasible price)
- capital cost and ability to raise funds—many outputs require additional outlays to make the change. Where the user has limited access to capital to fund such investments, adoption may not be feasible
- complexity to absorb, understand and apply—some outputs are inherently complex and this limits their use. Complexity must be assessed relative to the capabilities of the intended users
- culturally consistent—while linked to relative complexity, there can be barriers to adoption if the output adoption requires changes that are not consistent with the culture of the country
- risk and uncertainty—where the adoption of the output raises the risk even if the expected return is much higher, adoption is unlikely to occur unless other risk management mechanisms are in place
- continuity of staff—where the output is embedded in the skills and knowledge of staff or researchers, ensuring that they are retained in the organisation or a strategy for transferring the knowledge and skills is pursued is important for adoption.

The analysis reinforces the well-known finding of the value of a supportive policy environment and effective extension services for adoption and impact. It also reinforces the importance of the final users' perceptions of need for adoption to occur. It illustrates the value of involving the final users wherever possible in the research itself or directly addressing information dissemination through active engagement rather than indirect means. This includes tailoring communication products to the capabilities of the final users. An additional lesson is the need to manage publicly funded knowledge to the benefit of the widest

[1] The categories are set out in 'ACIAR impact assessment: guidelines for practioners', J. Gordon and J. Davis (working draft), 2007.

Table 4. Factors influencing adoption and impact—analysis of the reviews

Factors contributing to uptake	Factors inhibiting uptake
Knowledge of the opportunity	
▪ Involvement of senior researchers who have moved into policymaking positions in the Indonesia CGE modelling project and appreciate the use of the policy analysis tool ▪ Involvement of the farmer training NGO in white grub management has seen the knowledge embedded in training materials for farmers and extension services ▪ The hydrological dataset developed during the Pakistan water management project is being well used by the scientists involved in the research	▪ The DNA fingerprint has not yet been published for *P. psidii*, which is restricting further use in research ▪ There has been a failure to communicate with subsequent development projects and hence avoid reinventing the wheel for plantation nutrition in Solomon Islands
Benefits accruing to the final user	
▪ Distribution centres in China had a vested interest in adoption of the postharvest technology as it improved their profit through lower losses and higher quality, with access to the premium market ▪ IPM was important for farmers to continue to access markets as consumers (and regulators) were increasingly aware of residue issues in brassica vegetables	▪ Policy change has to be supported by the political powers. In Indonesia, as elsewhere, some policies have populist appeal and are difficult to change regardless of high-quality analysis ▪ Workers in plantations in Solomon Islands may not share the benefits of higher productivity in the plantation and returns take time to be realised
Compulsion or prohibition	
▪ The water management agency structures embedded the project outputs into the legal framework for the agencies ▪ Trade policy changes as a consequence of the use of the model are binding where the policy is effective	
Capital cost and ability to raise sufficient funds	
▪ The plantation project in Solomon Islands was very careful in developing lower cost solutions to raise nutrition, in addition creating local opportunities for income-generating activities	▪ Funding for researchers to continue to train students and use policy analysis models is often a limiting factor in their use. This had little impact in the Indonesian trade model, but far more serious implications for insect pathology in Pakistan
Complexity and capacity to absorb, understand and apply	
▪ The two vegetable projects on IPM and postharvest handling both communicated at the right level with farmers to achieve good adoption rates	▪ Information transmission in the white grub management project required farmers to be literate

Table 4. (continued)

Factors contributing to uptake	Factors inhibiting uptake
Culturally consistent	
no examples	
Risk and uncertainty	
▪ The eucalypt rust project developed tests that reduced risk through low-level identification of pathogens in imported seed, plant material and pollen	▪ The time lag in returns to improved productivity in plantations may be an impediment to adoption
Continuity of staff	
	▪ The plantation technologies, while not complex, needed the ongoing presence of trained staff to ensure that they continued to be undertaken

number of users. Several of the projects did not have the expected adoption and follow-on due to the loss of the staff involved to other activities. The Indonesian project demonstrated that this can have a positive effect where the researchers involved moved to positions of greater influence. But for other projects, such as plantation nutrition in Solomon Islands and water management in Pakistan, the effect was negative.

An issue that needs to be addressed in adoption studies in the future is the counterfactual—what would have happened in the absence of the ACIAR projects. Such considerations help in the assessment of impact. For example, in regard to postharvest handling of vegetables in China, there is a question as to the extent to which the technology transfer would have been undertaken in the absence of the ACIAR project. This cannot be assessed from the information available in the adoption study, although the study did note that demand was rising for improved postharvest handling, especially from fast food chains in Beijing. Such considerations would also be useful in assessing whether the closure of the insect pathology research laboratories in northern Pakistan was likely in the absence of the ACIAR project, and whether the project had the potential to have changed this unfortunate outcome.

Lessons

The lessons that emerge from the adoption studies about likely impact are as follows:

- Building research capacity and the capacity to attract ongoing research contributes to a higher impact. Organisational governance is important for attracting research funding, and ACIAR processes can contribute to developing the needed processes in a partner research organisation. Investment in research infrastructure in a development partner research agency can play an important role in building capacity for research, but commitment is needed to maintain and continue to use the infrastructure. The long-term future of any organisation should be considered when support is provided to build up laboratory capacity, knowledge and staff skills. The ownership of intellectual property also needs to be considered. Where key knowledge remains the property of a private company, this can limit the advance of research.

- Partnership with agencies that promote extension is an effective approach to improve adoption and overall effectiveness, and hence impact. The successful example of partnership with an NGO in Pakistan and the failure to involve such groups in Solomon Islands, resulting in reinventing solutions to the same problems, demonstrate the value in this approach. Such organisations have often developed methods for providing information in forms that are accessible to local farmers. But, given the often tight resources, the cost of developing and providing such material into the future should be included in the project design. The motivation for workers to continue practices that have longer term pay-offs needs to be addressed where a culture that rewards labour productivity does not exist.
- Changing mindsets for policy reform is a long-term process, but returns when it happens are often very big. Technical tools that are mastered by the partner-country government agencies and trusted research suppliers are a very acceptable approach to assisting policy change. However, expectations of policy change need to be adjusted based on the political process in place in the country. The time needed for the merit of quality technical analysis to be appreciated needs to be understood.
- Benefits to Australia come from a diversity of sources. Research undertaken in a development partner can have ongoing benefits for Australia, especially when it addresses common risks. There is considerable opportunity presented for Australian researchers to learn from partner research agencies, suggesting that with some countries the model is moving toward collaborative research. Collaboration on projects can also build relationships between the country and Australian researchers that continues to see technical-level engagement even when engagement at the political level becomes difficult.

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Policy analysis of linkages between Indonesia's agricultural production, trade and environment (ADP/1994/049)

Randy Stringer

Collaborating organisations	Australian National University (ANU), Australia; Ministry of Agriculture (MOA), Indonesia; Centre for Strategic and International Studies (CSIS), Indonesia
Project leaders	Prof. Kym Anderson (University of Adelaide (UA)), Dr Achmad Suryana (MOA), Dr Mari Pangestu (CSIS)
Related projects	ANRE/1989/023, ANRE/1990/022, ANRE/1990/038, ANRE/1992/028, ANRE/1994/09, EFS/1988/038
Principal researchers	Dr Erwidodo (Centre for Agro-Socioeconomic Research (CASER, today know as ICASEPS)), Dr Tahlim Sudaryanto (ICASEPS), Prof. Randy Stringer (UA), Dr Tubagus Feridhanusetyawan (CSIS), Prof. Peter Warr (ANU), Dr Ray Trewin (ANU)
Duration of project	1 January 1996 to 30 June 1999, extension 1 July 1999 to 31 December 2002
Total ACIAR funding	$1,003,473

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Project objectives	The key objective of this project was to assess the production, consumption, trade, income distributional, regional, environmental and welfare effects of structural and policy changes as they affect Indonesia's agricultural sector over the next 5–10 years. By using an appropriate framework that can be reused readily by analysts in the Indonesian Government and research institutes, a major spin-off will be capacity building in the country. The project was extended to establish long-term, in-country capacity for Indonesian researchers to: ▪ use the WAYANG CGE model for a wide range of policy analysis applications well into the future ▪ be able to train others in the use of WAYANG ▪ upgrade and modify the model as circumstances change and opportunities for improvement evolve.
Location of project activities	South-East Asia

Overview

Launched in Bogor on 7 September 1996, ACIAR PN 9449 strove to improve agricultural trade and economic policy formation in Indonesia. Over the following 6 years the project's team developed and adapted an economic modelling framework that Indonesian analysts could reuse, update and maintain to address evolving development issues and policy priorities.

The project also initiated a capacity-building strategy to foster policy dialogue and help integrate Indonesia's diverse agricultural policy community, including universities, research centres and government agencies. This capacity-building strategy focused on training a new generation of users, and linking the Indonesian researchers with international researchers to improve, sustain and evolve these analytical policy tools.

In its early stages the economic modelling framework began assessing the efficiency, distributional, environmental and welfare effects of structural and policy changes on agriculture within Indonesia. The policy changes analysed included the trade impacts on agricultural production, the food consumption impacts on poverty and the environmental impacts on the natural resource base from regional and global trade agreements. Understanding and quantifying the economic impacts of agricultural growth and trade expansion were high priorities in the mid 1990s as many of Indonesia's policies were being questioned, especially in relation to their impact on the natural environment.

To address these concerns, the project introduced an important set of analytical tools that involved what was, at that time, a relatively new focus for the Ministry of Agriculture on the interactions between agriculture, other sectors, trade, income distribution, poverty alleviation and food security.

In particular, the project developed a national computable general equilibrium (CGE) model that could be linked and supported by a global CGE model, the Global Trade Analysis Project (GTAP) model. The GTAP model allowed researchers to analyse potential impacts due to evolving trade agreements and the rapid export-oriented growth of China and other reforming economies. In addition, these modelling tools helped enrich the policy debate about the environmental linkages between agricultural practices and natural resources impacts on soils, forests, water and the atmosphere.

While the project kept these objectives in mind throughout its life, the immediate research focus shifted rather abruptly. The financial, economic and political events which led eventually to the resignation of Indonesia's President Soeharto, in May 1998, compelled the participants to evaluate how PN 9449 could assist policymakers adapt to the impacts on poverty and food security caused by the economic crisis. The extent of the crisis resulted in refocusing the modelling and training efforts so as to also address more immediate agricultural, employment and food policy concerns faced by the country's policymakers.

The project team included representatives of a mix of institutions, each bringing a particular bundle of expertise to the project. The team was chosen to build on and broaden previous collaborations between the Centre for Agro-Socioeconomic Research (CASER, today know as ICASEPS) and the Economic Division of the Research School of Pacific and Asian Studies (RSPAS) at the Australian National University (ANU), and between the Centre for Strategic and International Studies (CSIS) in Jakarta and the Centre for International Economic Studies (CIES) at the University of Adelaide. The team included a valuable mix of disciplinary skills, in particular economic policy analysis, trade and environmental skills. A number of students from both Australia and Indonesia were also involved in the project.

Project achievements

The project established new economic modelling tools and a new generation of researchers who today better understand and can better explain to policymakers the strengths, benefits and weaknesses of CGE modelling. The project's model simulations and policy research efforts achieved three interrelated outcomes. First, the project provided timely new knowledge, exploring the implications of the economic crisis on the agricultural and food sector in Indonesia, and on how the various trade and other policy responses could diminish the negative impacts of the crisis.

Second, the project built up the capacity in research centres and universities to manage, train and disseminate the results of CGE models developed by the project as well as newer generations of these models. Importantly, three of the students who participated in training components of the project, using the project's CGE models for their postgraduate studies, are now teaching at universities in Bogor, East Timor and South Kalimantan.

Third, the economic modelling results were used to promote debate and develop a broader understanding of how alternative agricultural and food policy reforms that underpin Indonesia's agricultural development strategy enhance production and employment of key agricultural sector products in line with national development goals and with the Asia Free Trade Agreement, the Asia Pacific Economic Cooperation trade agreements and the World Trade Organization.

The difference the project has made

How has the project contributed to improvements or changes in the local community? This should focus on users of the new knowledge/approaches and answer the question 'so what?' For example, the smallholder farmers who have implemented the new water management regime have reduced water use by 30%, freeing up this water for use in the local village and increasing environmental flow.

Overall, this ACIAR project has made a number of important contributions to agricultural policy formation and policy analysis capacity in Indonesia. One example is the way in which the project has raised awareness about the importance of recognising and understanding the economic interactions between agriculture and other sectors, and the implications of those interactions on trade, income distribution, poverty alleviation and food security.

Today, an increasing number of policymakers now know how to obtain agricultural and trade policy analysis based on quantitative measures of the production, consumption, trade, welfare and distributional consequences of current versus alternative policies. In particular, the Ministry of Agriculture and the Ministry of Trade consistently request and draw on the results from the analytical tools promoted by the project.

These types of analyses are important in ensuring the sustainability of agricultural development in Indonesia, in securing access to international loans, and in reducing the risk that multilateral and regional trade negotiations are not frustrated by unsubstantiated or exaggerated claims about adverse distributional effects of agricultural development and trade.

The project has also made a difference by enhancing the capabilities of research centres and universities in Indonesia to model the economy-wide effects of economic growth, structural changes and policy developments at home and abroad on agricultural production, trade and income distribution. A related capacity-building contribution is the country's long-term capacity to independently undertake subsequent empirical policy analysis and to communicate their analysis to the broader development community.

Project impacts

This section describes the flow-on effects of the project and the impacts on the community, researchers etc. as a result of the difference the project has made. These should include any community, capacity-building and scientific impacts and are a summary of question 3 in the second report. For example, the local researchers are now conducting training workshops in the surrounding districts.

The project has made an impact on the agricultural and economic research community in Indonesia by encouraging new networks of research centres and universities. These local and international research networks have grown and matured over time. A related impact is the improvement in the country's long-term capacity to independently undertake and communicate subsequent empirical policy analysis.

Three of the project's research team are presently in powerful policymaking positions in Indonesia. The project leader of CSIS was appointed Minister of Trade in 2004, and one of the major project participants from ICASEPS was named Director General of the Trade Research and Development Agency in the Ministry of Trade. Similarly, the Director General of the Indonesian Agency for Agricultural Research and Development (IAARD) from the Ministry of Agriculture was formerly a project leader from ICASEPS.

The project's concepts, ideas and policy tools are now used in a variety of ways by both the Ministry of Trade in its global trade negotiations and national level policy dialogue, and by the Ministry of Agriculture to evaluate the production and poverty implications of proposed food policy options.

One of the most important scientific impacts of the study was the development of the 3-region, 65-sector, multiple-household WAYANG CGE model of the Indonesian economy. The WAYANG model was made publicly available via the web for both medium-term crisis-related policy research and long-term research on agriculture, trade and environmental linkages. A modelling feature unique to WAYANG at that time was the inclusion of 10 household groups based on income levels and production activities. This innovation allowed researchers and policymakers to understand, for the first time, the distributional consequences of policy-, market- and trade-related economic changes in a CGE framework for Indonesia.

From: Gordon, J. and Davis, J. (eds) 2007. Adoption of ACIAR project outputs:
studies of projects completed in 2002–2003. ACIAR: Canberra.

From: Gordon, J. and Davis, J. (eds) 2007. Adoption of ACIAR project outputs: studies of projects completed in 2002–2003. ACIAR: Canberra.

Management of white grubs in peanut cropping systems in Asia and Australia (CS2/1994/050)

John Rogers

Collaborating organisations	▪ Farming Systems Institute—Queensland Department of Primary Industries and Fisheries (QDPIF), Australia ▪ All India Coordinated Research Project on White Grubs, Rajasthan Agricultural University (RAU), India ▪ Department of Zoology and Entomology—The University of Queensland (UQ), Australia (until 30 June 2000) ▪ International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India; Agriculture Man Ecology (AME), India
Project leaders	Dr D. John Rogers (QDPI), Prof. C.P.S. Yadava (RAU)
Related projects	CS1/1992/016; CS1/1994/039
Principal researchers	Dr D. John Rogers (QDPI), Dr John Wightman (ex-ICRISAT), Mr Mans Lanting (AME), Prof. C.P.S Yadava (RAU), Dr David Holdom (UQ), Dr Anitha Reddy (ICRISAT)
Duration of project	1 July 1997 to 30 June 2001; project extension 1 July 2001 to 31 October 2002
Total ACIAR funding	$1,039,796

From: Gordon, J. and Davis, J. (eds) 2007. Adoption of ACIAR project outputs:
studies of projects completed in 2002–2003. ACIAR: Canberra.

Project objectives	The overall aim of the project was to improve the management of white grubs, a key insect pest of peanut (groundnut) in India and Australia. This was achieved through a series of specific objectives: ▪ Clarify the distribution and identity of white grub species damaging peanuts in southern India and Australia. ▪ Develop appropriate techniques and technology for the robust production of the insect pathogen *Metarhizium anisopliae* in India. ▪ Study the behaviour, ecology and population dynamics of white grubs on groundnuts to provide the biological information necessary for developing improved management processes. ▪ Determine the damage potential of key white grubs on groundnut in India and Australia. ▪ Extend, test and modify control strategies developed in India to Australian conditions. ▪ Isolate and identify semiochemicals such as sex-attractant pheromones and develop technology for using semiochemicals for the management of white grub adults in India. ▪ Strengthen linkages with and between appropriate extension agencies to enhance the transfer of technology.
Location of project activities	Hyderabad–Bangalore region (the Deccan region of Andhra Pradesh, Karnataka and Tamil Nadu) and Jaipur, India; and Kingaroy and Brisbane, Australia.

Overview

The project's scientists developed methods of reducing the yield loss caused by white grubs to peanut (groundnut) crops growing in Asia and Australia, and most especially in India. The improved management technology, which included options for both pesticide-free management and the use of minimal amounts of pesticide, is more effective than previous approaches. On-farm surveys and management trials were integral parts of the project and were organised in partnership with NGOs.

Peanut is a major crop in the tropics and semitropics and ranks 13th in the world's most important food crops. It is the fourth most important source of edible oil and the third most important source of vegetable protein, a combination that makes groundnut one of the most important crops in the developing world. It is particularly important in Asia, which produces 24 million tonnes of the global annual production of 36 million tonnes. Developing countries account for 96% of production area and 92% of global production. In India it is a major crop, with 5.7 million ha producing approximately 4.7 million tonnes of peanuts. The southern Indian states of Andhra Pradesh, Karnataka and Tamil Nadu grow 60% of India's peanuts. The Anantapur district of Andhra Pradesh alone grows three-quarters of a million hectares of groundnut. In

these southern Indian states groundnut is produced primarily under rainfed conditions and often under close-to-monoculture conditions by poor and marginal farmers. Peanuts are often the only source of cash income for these farmers, so core family health and educational outcomes hinge on successful production of the crop. Additionally, the haulms (vegetative plant parts) provide high quality hay for the small livestock that are an essential part of the farming system for these poor and marginal farmers.

White grubs, the soil-dwelling larvae of scarab beetles, feed on the groundnut plant's roots and pods, killing seedlings and sometimes older plants, as well as reducing drought tolerance and crop yield. This project sought to develop a better understanding of the white grub problems in the peanut-growing areas of India and Australia, leading to improved control strategies and reduced crop losses from the pest. The researchers also investigated the ecology, biology and behaviour of larvae and adults, and the relationship between crop loss and pest density, and tested improved control methods for the pest. Additionally, the team studied fungal pathogens of white grub larvae, especially *Metarhizium anisopliae*. They discovered strains with enhanced pathogenicity, and improved the production, formulation and application technology of the pathogen as a potential control agent. The efficacy of management techniques involving adult attractants, both insect sex pheromones and plant volatiles, was also assessed.

In southern India the project team extended the knowledge base required for the identification and effective management of white grubs on groundnut. This included pest identity and distribution, adult preferences for food-tree species, crop damage potential and minimal-rate chemical management techniques. This knowledge was developed with strong support from, and close collaboration with, NGOs (especially AME) and farmer groups. These collaborative linkages have enabled appropriate management information to reach a growing pool of poor and marginal farmers during the project, and subsequently through the FAO-funded Agriculture Man Ecology Foundation (AMEF) Farmer Field School Program, but much more remains to be done. In the Raichur, Madanapalle, Chittoor and Bellary districts, where farmers have embraced seed treatment and the use of good-quality organic matter, white grubs are now much less of a problem than they were 5–10 years ago. However, they still cause problems in neighbouring 'non-intervention' areas in these districts. In addition, the Kolar district has substantially changed over to vegetable production from groundnuts because of Bangalore's expansion, and white grubs are causing problems in vegetable crops there.

Meeting between the research group and farmers with major white grub problems

During the February 2007 visit to assess adoption, there was a series of specific and unsolicited requests from farmers' groups and NGOs for additional support for adoption/communication activities on groundnut white grubs, especially targeting illiterate and marginally literate farmers. An additional comment received at the same time was that the project had been terminated before it could achieve its maximum impact with growers. This indicates that project impact could be markedly enhanced with the input of additional investment in communication activities in southern India.

At the beginning of the project, considerable investment in equipment and facilities was made at Jaipur to facilitate research activities, especially for insect pathology. The insect pathology group at Jaipur established the requirements of a *Metarhizium anisopliae* product for use against the groundnut white grub *Holotrichia consanguinea* in northern India. High levels of pathogenicity were confirmed in several pathogen strains, and solid-state grain-based and liquid production methods were evaluated using local grains and additives, as were clay-based spore and mycelial formulations for field application. Optimum placement strategies for a soil-applied biopesticide for white grubs based on *M. anisopliae* were defined. Because of withdrawal of support from the lead agency, Queensland Department of Primary Industries and Fisheries, the project was terminated before this research could progress to pilot-scale production and larger scale field evaluation. However, the knowledge developed during the project remains highly relevant to the development of any fungal pathogen for an insect pest in India, be it a white grub, a caterpillar pest or a sucking pest. Other studies at Jaipur showed that the physiological effects of white grub damage mirrors the effects of water stress on the groundnut plant. Bioassays of leaf extracts from the host trees of *H. consanguinea* showed that neem and khejari were the best sources of plant attractants for adults. This research was terminated before any specific chemicals were identified as attractants.

Project achievements

The project team in southern India established close linkages with a major (nodal) NGO, AME, and through AME with a range of local NGOs. This ensured that the work program was closely connected to the needs of the final users, namely poor and marginal groundnut farmers. This arrangement also enabled effective two-way communication between the research team and end users throughout the project, ensuring that the researchers remained focused on important problems and that the farmers had access to new information as it became available. To December 2000, the total outreach of the AME groundnut participatory technology development (PTD) program was 9,000 farm families. Information and training on white grubs was provided by the project team, as required, in the AME programs with these farmer groups.

During the project an information booklet 'Why are my groundnut plants dying?' was published jointly by the project team and AME in English, Tamil, Kannada and Telugu. This booklet was the basis of communication and extension efforts by the project team and the collaborating NGOs in southern India. A total of 2,000 copies were printed on heavy-grade glossy paper to ensure longevity when used by farmer groups in the field. AME staff ensured that the printing plates of the booklet were preserved by the printer to allow economical reprinting, if required. The booklet was distributed to 'master farmers' in PTD groups and, in one training program alone, hundreds of farmers in Kolar district of Karnataka received copies.

It is still being used by farmers in Farmer Field Schools and by trainees in facilitator training programs. However, while supplies of the booklet are essentially exhausted, demand is ongoing. Existing copies are fragile and much valued.

All of the major findings of the project have been published in peer-reviewed, mostly international, scientific journals, ensuring that the key biological and management information from the project is available to other scientists in India, throughout Asia and elsewhere. Key project outputs included in refereed papers are in the areas of:

- white grub identity, distribution and management in southern India
- identification of the sex pheromone of a key Indian white grub species
- the damage potential of Indian and Australian pest species, leading to establishment of provisional economic thresholds
- the population ecology of Australian peanut white grubs
- information essential to the production and formulation of *M. anisopliae* as an insect pathogen using grains and additives locally available in India.

The difference the project has made

The project has delivered technology to provide better control of groundnut white grubs in southern India with minimal quantities of chemical insecticide. If it were to be fully implemented in this region, then the knowledge generated by the project would deliver significant economic, environmental and community benefits to one of the largest groundnut-producing regions of the world and, in the process, benefit millions of poor and marginal farming families. While there are some observable positive impacts from the project, to a large degree this potential benefit remains unrealised at the time of this adoption study. This is as a result of the timing of project termination and the absence of an appropriate follow-up communication/extension process.

The improved knowledge of white grub management has been incorporated by 'project farmers' into their practices, with different groups adopting different components of the management package to suit their preferences and world view. Farmer groups who wish to avoid/minimise chemical inputs are using collections of white grub beetles from trees at the start of the monsoon season to suppress white grub problems on groundnut, while more chemically oriented farmers use chlorpyrifos seed treatment as well as *Rhizobium* and *Trichoderma* inoculation of seed. Both types of farmers are now aware of the key aspects of white grub biology relevant to their preferred management options. For example, those groups using adult collection are aware of the connection between the appearance of the beetles on the trees at the beginning of the monsoon and the resulting larvae causing crop damage, and which tree species are hosts for the beetles in their locality. They are therefore able to focus their collecting efforts on those trees in the knowledge that the beetle collection activity will reduce damage to the subsequent groundnut crop. The experience of the farmer groups that met in February 2007 was that favourable seasons were associated with high white grub populations and poor years with reduced white grub incidence. Deep ploughing before the start of the monsoon to create a loose soil surface to reduce rainfall runoff is also widely recognised by 'project farmers' as contributing to white grub control because it exposes the pupae to bird predation.

Based on meetings with farmer groups and Dr A.R.V. Kumar from the University of Agricultural Sciences, Bangalore, during the February 2007 visit, the impact of farmyard manure (FYM) and other forms of organic matter on groundnut white grub incidence is a topic that requires further research. During the project small-pot experiments examined the impact of FYM on white grub growth and plant damage. For *Holotrichia serrata* the addition of FYM had little or no effect on larval growth or plant mortality on heavier soils, but on lighter soil it reduced both larval growth rate and plant damage. Additionally, FYM-enriched soil was preferred by *Holotrichia reynaudi* adults for oviposition in small-scale choice tests, but this effect was not apparent under no-choice conditions. Project funding finished before the impact of organic matter could be studied in more detail.

The observations of a number of farmer groups reported in February 2007 were that 'poor quality' organic matter/FYM was associated with an increase in groundnut white grub problems, and Dr Kumar supported this view. However, other groups indicated that 'good quality' organic matter was beneficial. What constituted 'poor' and 'good' quality was not clear, however, but the latter appeared to involve a mixture of cow dung and urine, plant biomass, phosphate-solubilising bacteria and soil mixed together and incubated for some time to produce high-quality compost. Additionally, some groups indicated that they now have sufficient knowledge of white grub identity and biology to be able to distinguish between plant-feeding white grubs and those that feed on FYM. Farmer groups who previously resisted adoption of practices such as FYM use have adopted composting, vermiculture and organic matter use, with benefits to water infiltration and storage and crop nutrition, and reductions in soil-borne plant disease incidence. This diversity of experience and belief, and the limited amount of experimental data generated during the project, indicates that additional research is required on this topic and is of critical importance to the overall farming system's sustainability.

A farming-system change being promoted in parallel with the increased use of organic matter is a diversification of the cropping system from a groundnut monoculture to one that includes dryland horticultural tree crops, pigeon pea, cowpea, millet and vegetables intercropped with groundnut. This increase in crop diversity, together with the increased use of organic matter, is working to produce a more ecologically and economically sustainable farming system. Thus, the white grubs project has provided a trigger for a cascade of broad-based positive changes in the cropping system for at least some farmers.

Project impacts

With the Indian project leader, Prof. C.P.S. Yadava, leaving the university, and other changes of staffing in Jaipur, long-term impacts from the project appear to be minimal at RAU. No information has been received directly from Jaipur despite a series of information requests between November 2006 and February 2007. Informal information sources indicate that all insect pathology research has ceased and the staff have retired or their work has been terminated. The white grub research laboratories are closed and locked pending the retirement of the current officer-in-charge, and white grub research at Jaipur has effectively ceased. This is disappointing given the capital expenditure in Jaipur and the degree of operational funding support received during the project.

Since 2000 a series of drought years has reduced groundnut plantings in southern India, and reduced white grub populations as well. This is a normal pattern of events for this region—a high proportion of drought years alternate with relatively few drought years on an approximately 30-year cycle. However, the adoption study visit in February 2007 indicated that pockets of damaging populations of white grubs remain. Farmers indicated that a return to average-to-good seasons would see both trends reverse, that is they would increase their groundnut area and there would be higher and more widespread white grub populations. An additional consequence of the series of drought years was increased migration of farm families and farm labourers away from the drought areas.

A post-project impact assessment was conducted in 2004 by T.S. Vamsidhar Reddy and Mans Lanting from ETC Consultants, India, using residual project funds. They found that farmers who were involved in project surveys and on-farm trials have retained their knowledge of the problem and are selecting white grub management strategies and tactics consistent with their farming philosophy. Some groups were using adult-collection procedures to reduce pest pressure without chemical insecticides, while other groups have adopted chlorpyrifos seed treatment as their tactic of choice. However, Vamsidhar Reddy and Lanting concluded that the lack of an extension mechanism after the primarily research phase of the project had impacted negatively on more broad-scale adoption at the time of the 2004 study. The February 2007 visit found that the trends identified in 2004 have continued.

Since 2005 information on the management of white grubs in southern India has been incorporated into the sustainable agriculture Farmer Field School and participatory technological development programs now being conducted in groundnut production areas by AMEF and associated local NGOs with funds from FAO. Additionally, the information has been included in the AMEF facilitator training programs and the Fellowship Course in Sustainable Agriculture course run by AMEF. Another communication method used was painted signs on walls in prominent locations in villages to display messages about sustainable agriculture. These activities establish ongoing communication of the outputs of the white grubs project on an increasing trajectory, as new farmer groups are established and more farmer-facilitators and NGO staff are trained.

One specific concern raised by the farmer groups in February 2007 was that the available white grub information is targeting only literate farmers, and that the needs of illiterate and marginally literate farmers have not been met. Posters and video/DVD presentation of information were specifically requested to meet the training needs of the illiterate and marginally literate farmers. Such a presentation would complement the sustainable groundnut production video/DVD project, which is currently well advanced within the AMEF. In May 2004 a scoping workshop for a video-based white grub training package was held in Kingaroy, Australia. Funding came from the Foundation for Development Cooperation, Brisbane, the Crawford Fund and the ACIAR Communications Program. The workshop was attended by a core group who had been involved in the white grubs project. This workshop identified key components of a video presentation, including the timing schedule for filming in India and key script components. Between 2004 and 2007, what is left of the white grub project team developed *pro bono* several proposals for communication projects to a range of potential funding bodies including ACIAR. All of these proposals have been unsuccessful. However, despite this lack of success, and based on the unsolicited requests received from farmer groups and NGOs during the February 2007 visit, the project team remains convinced that there would be significant potential for greatly increased adoption of project outputs in southern India if more training resources were available. The February 2007 visit only served to reinforce this belief.

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Improvement of integrated pest management of brassica vegetable crops in China and Australia (CS2/1998/089)

Myron Zalucki

Collaborating organisations	Queensland Department of Primary Industries (QDPI), Australia; University of Queensland (UQ), Australia; Zhejiang Department of Agriculture, China; Shanghai Academy of Agricultural Science (SAAS), China; Zhejiang University (ZU), China; Zhejiang Academy of Agricultural Science (ZAAS), China
Project leaders	Prof. Myron Zalucki (UQ), Prof. Liu Shu-Sheng (ZU)
Related projects	CS2/1992/013
Principal researchers	Bronwyn Holding (QDPI), Prof. Liu Shu-Sheng (ZU), Jian-xin Wang, Zhejiang Department of Agriculture; Mr Dong-Sheng Wang (SAAS), Guo Shi-jian (ZAAS)
Duration of project	1 July 1999 to 30 June 2002; project extension 1 July 2002 to 30 June 2003
Total ACIAR funding	$830,366

From: Gordon, J. and Davis, J. (eds) 2007. Adoption of ACIAR project outputs:
studies of projects completed in 2002–2003. ACIAR: Canberra.

Project objectives	The overarching objective of the project was to develop and implement sustainable management strategies for insect pests in brassica vegetable crops that significantly reduce pesticide hazards and are acceptable to growers in the Changjiang River Valley, China, and Queensland, Australia. To achieve this objective, several subobjectives were addressed through research directly linked to practical implementation: ▪ Complete investigations of the major quantitative factors affecting numerical changes in pest abundance in brassica crops in the field, and particularly the role that beneficials (parasitoids, predators and pathogens) play in suppressing pest populations. ▪ Determine the impact of major pests on yield and quality loss in major brassica crops and varieties under field conditions. ▪ Investigate on-farm strategies for improvement of insecticide application, particularly those options that promote the use of 'soft' insecticides and reduce the total input of insecticides. ▪ Assess the performance under farmer–field conditions of different pest management strategies, particularly those which enhance natural control agents. ▪ Establish resistance levels to major insecticides used in the brassica production system. ▪ Improve the methodologies previously developed for promoting implementation of integrated pest management (IPM) in brassica vegetable production, and apply these as widely as possible in the target areas.
Location of project activities	China and Australia

Overview

An integrated pest management (IPM) program was developed and implemented, resulting in reduced pesticide use, higher profits for farmers and safer vegetables in the project areas. The project provided increased infrastructure for agricultural extension and added to existing capacity in entomological research.

From: Gordon, J. and Davis, J. (eds) 2007. Adoption of ACIAR project outputs:
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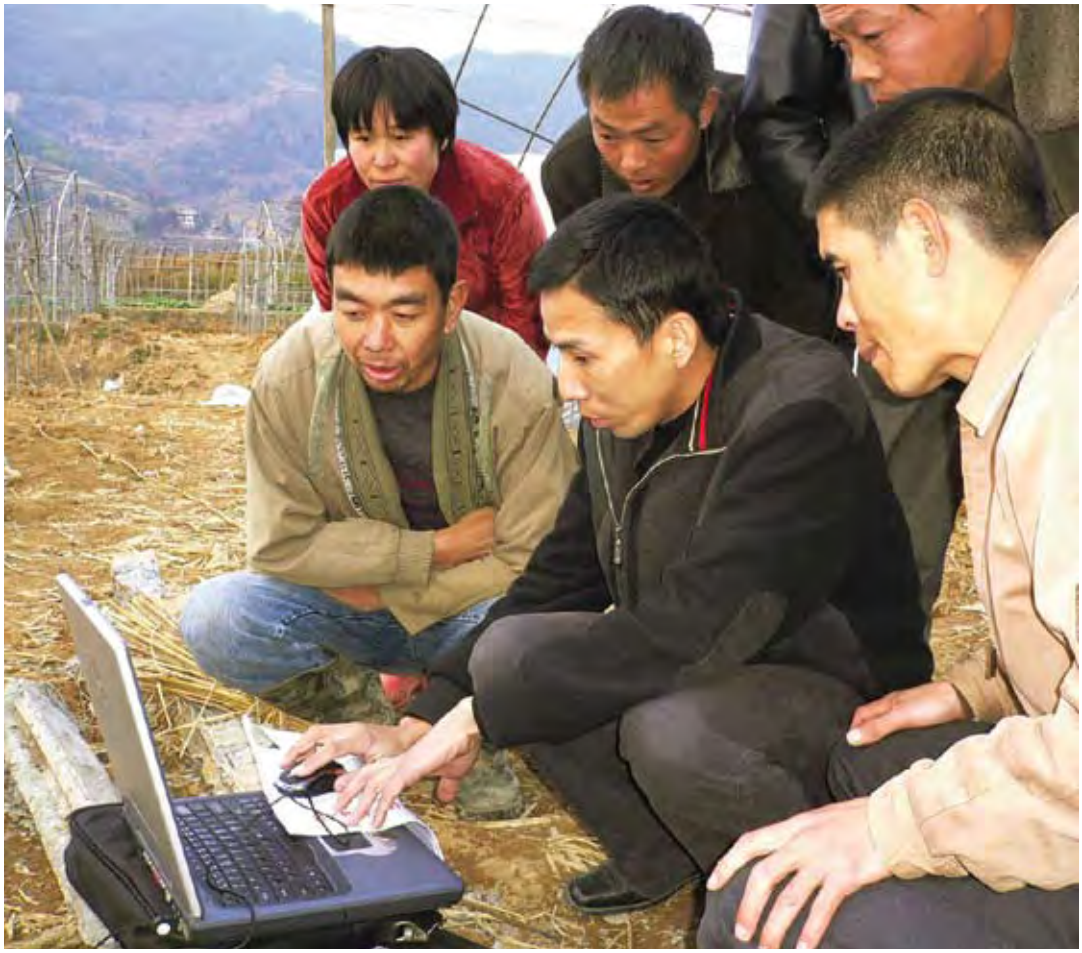
Project achievements

A comprehensive IPM package for vegetable pests was developed for local conditions. This package was underpinned by extensive research and trials, and was widely disseminated for use by local extension workers and farmers during the project. At the end of the project 68% of farmers in the project areas took a positive attitude towards IPM, compared with 48% in the non-project areas. Also, 36% of farmers in the project areas took the approach of 'precaution first, less pesticides, more non-chemical methods', compared with 22% of farmers taking this approach in the non-project areas. In the project areas 38% of farmers were found to have more frequent contacts with, and advice from, local extension services, compared with 16% in the non-project areas. Since the completion of the project, nearly all commercial growers, through ongoing extension work, have become aware of the need to use IPM, resulting in virtually no pesticide residue violations in the project areas.



Professor Liu Shu-Sheng demonstrates the IPM package information to farmers in the project area.

There were significant reductions in pesticide use. As a consequence, farmers saved money and there were fewer residue violations of pesticides on brassica vegetables. Over the life of the project there was a significant increase in the capacity, both in terms of personnel and infrastructure, of the collaborating institutions to undertake research in pest management. The project generated considerable scientific outputs in terms of published papers and conference presentations. A follow-up project has also produced a user-friendly product—an interactive CD for brassica pest management in Chinese that will continue to benefit local extension workers and farmers in both the project areas and further afield. As a result of the research skills developed and the findings from this project, follow-up projects have been developed in the Democratic People's Republic of Korea (DPRK) and the South Pacific that seek to further extend this approach to brassica pest management to other countries and communities.

The difference the project has made

Growers using the approach developed in the project use, on average, one to three fewer insecticide sprays, achieving comparable or higher yields than 'conventional' farmer practice. On average, growers save about RMB30 per crop. Farmers now generally apply insecticides that are targeted at specific pests, resulting in fewer pesticide residue violations. In the project areas there have been no pesticide residue violations in recent years, compared with an average of about 5% of produce registering violations in non-project areas. The resulting safer vegetable production, at a reduced cost, has ensured that deaths of consumers and growers due to pesticide toxicity have virtually ceased. There have been no poisonings or deaths reported from pesticides on vegetables since 2003.

Perhaps one of the biggest differences the project has made is that research and extension services are now much better networked in Zhejiang province.

Project impacts

The project led directly to the development and production of an interactive CD that captured the approach developed for pest management of brassica pests. This CD will provide long-term benefit to extension workers as it enables them to access and readily present the information generated by the project. The CD has been used in training workshops for growers—in 2006 alone it was used in 200–300 workshops in Zhejiang province, each reaching 40–50 growers. This is over and above the success of workshops and field days in extending the IPM package to farmers during the life of the project itself. The enhanced research capacities of the project group and leader have been recognised nationally and internationally through scholarly publications and invitations to present project findings at major scientific meetings and to tackle new pest problems as they arise, for example the recent *Bemisia* whitefly invasion, now a major pest in China. The project developed a strong network, and a working relationship between researchers at Zhejiang University and the Zhejiang Department of Agriculture, that have meant more effective response to pest problems.

From: Gordon, J. and Davis, J. (eds) 2007. Adoption of ACIAR project outputs: studies of projects completed in 2002–2003. ACIAR: Canberra.

Assessment of eucalypt rust as a pathogen of *Eucalyptus* spp. and other Myrtaceae, and development of sensitive methods for its detection in germplasm in Australia (FST/1996/206)

Ken Old

Collaborating organisations	CSIRO Forestry and Forest Products and CSIRO Plant Industry, Australia; Federal University of Vicosa (UFV), Brazil; The Forestry and Agriculture Biotechnology Institute (FABI); University of Pretoria, South Africa
Project leaders	Ken Old (CSIRO Forestry and Forest Products) July 2000 – June 2002, Dr Inez Tommerup (CSIRO Forestry and Forest Products) July 2002 – June 2003
Related projects	FST/1993/118, FST/1994/041
Principal researchers	Dr Inez Tommerup (CSIRO Forestry and Forest Products), Dr Trevor Booth (CSIRO Forestry and Forest Products), Prof. Acelino Alfenas (UFV), Dr Jeremy Burdon (CSIRO Plant Industry)
Duration of project	1 July 2000 to 30 June 2003
Total ACIAR funding	$598,373

Project objectives	■ Test the susceptibility of a comprehensive range of Australian Myrtaceae, drawn from many native genera tree and shrub species, to *P. psidii*. Particular emphasis was given to the economically important genera *Eucalyptus, Melaleuca and Syzygium* ■ Assess pathogenic and life-cycle variation in collections of the rust from various hosts through detailed cross-inoculation trials and population studies of the rust using DNA-based genetic markers ■ Prepare maps indicating eucalypt-growing areas of high, medium and low risk from *P. psidii* using climate interpolation and disease hazard mapping methods ■ Develop molecular diagnostic techniques for detection of *P. psidii* in seed, tissue-cultured plants or pollen
Location of project activities	Australia and Brazil

Overview

All plants, including trees, are subject to infection by many species of fungi, some of which cause diseases of roots, stems and leaves. In most instances the plant species that make up native vegetation have evolved in company with their major pathogens, and in undisturbed plant communities epidemic disease is unusual, although not unknown. *Eucalyptus* spp. belong to the large and diverse Myrtaceae family, and with a few exceptions are native only to Australia. Some eucalypts have proved to be very successful plantation species and are grown as exotics in many parts of the world, especially in the southern hemisphere, for pulp, paper and, increasingly, solid wood products. Genera of Myrtaceae are major components of Australia's native vegetation and occur as indigenous species and plantation crops throughout South-East Asia, where they are often grown for wood, spices, medicinal oils and fruits.

South America also has a diverse myrtaceous flora. Unlike Australia, where eucalypts have no known rust pathogen, a major disease of Myrtaceae is present in South America. *Puccinia psidii* (often called guava rust) has probably evolved on indigenous species but has somehow transferred to eucalypts and other exotic Myrtaceae. Over the latter half of the 20th century Brazil became pre-eminent in the southern hemisphere as a producer of pulp and paper based on intensively managed, very fast growing eucalypt species. Although *P. psidii* had been formally identified on eucalypts in Brazil decades earlier, the first serious outbreak in plantations occurred in the 1970s. The problem has been largely solved for the pulp and paper companies, however, through selection of clones that are highly resistant to rust.

The rust has been found to have a wide host range across many genera of Myrtaceae. It has also shown a capacity for international spread, for example to Jamaica in the 1930s, where it disrupted the allspice industry based on *Pimenta dioica*. The rust was also reported on this host in Florida in 1979 and spread to other species, including the important woody weed *Melaleuca quinquenervia*, a species native to Australia.

For many years *P. psidii* has been regarded as a threat to Australian native vegetation, and quarantine measures have been in place to reduce the chances of incursions by the pathogen. Pathologists have recognised the danger of a situation where Australian native Myrtaceae have evolved in the absence of a potentially serious and damaging pathogen. Information on the host range and biology of the fungus and possible incursion pathways was, however, limited to outcomes of research and field observations made in South America, primarily Brazil, rather than being tailored to Australia's needs. For example, there was no information on which parts of Australia and countries to our north would be at greatest risk from rust epidemics following an incursion of the pathogen. Identification of the rust in the event of an incursion into Australia would be based on spore morphology and host symptoms, whereas recent advances in molecular taxonomy have made possible the development of a rapid diagnostic test.

The project was initiated in 1999 through a request by CSIRO Forestry and Forest Products to ACIAR to support a research team from Australia, South Africa and Brazil to assess *P. psidii* as a threat to Australian plant communities and to eucalypts grown as plantations in Australia and elsewhere. A further objective was to develop a reliable DNA-based detection technique for this rust. Research was carried out in three main areas:

- The susceptibility of species of Myrtaceae native to Australasia (mostly eucalypts and *Melaleuca* spp.) and a small number of South African species to *P. psidii* was investigated. Seed samples were sent to Brazil in accordance with that country's importation regulations, and seedlings were inoculated under controlled conditions at the Federal University of Vicosa (UFV), Minas Gerais province.

The late Dr John Fryer, ACIAR Forestry Research Program Manager January 1995 to December 2004, discusses the eucalypt rust project with a graduate student in the greenhouse facilities of the Federal University of Vicosa, Brazil.

- A DNA-based 'fingerprint' was developed for the unequivocal identification of *P. psidii* and its detection at very low concentrations in plant material and as a contaminant of other substrates. This method was successfully used to detect the rust at low levels in plants and samples of pollen and seed.
- Through bioclimatic modelling, regions were identified in Australia and other parts of the world where the rust could be expected to cause severe epidemics in native vegetation and plantations of susceptible species. In Australia the areas most at risk include high rainfall areas of the east coast from the Victorian border to Cape York with some outliers in the Northern Territory.

At the time of inception of the project, this disease was known to occur only in the Americas; however, during 2005, *P. psidii* was reported in Hawaii, an indication of its capacity for international spread and the timeliness of these investigations.

Project achievements

The susceptibility or resistance to *P. psidii* of 58 species of Myrtaceae, including major plantation species of *Eucalyptus and Melaleuca* and a range of other economically and ecologically important species, was tested in Brazil. Many species were represented by several seed lots from different provenances. Reliable data obtained for more than 120 seed lots indicated a range of resistance or susceptibility to rust (Tommerup et al. 2003). Seed lots of some genera, including both rainforest trees and understorey species, proved to be difficult to germinate in sufficient numbers to provide enough seedlings for rigorous testing, but some indication of their likely susceptibility to rust was obtained.

For eucalypts, large differences in susceptibility to rust were found between and within species; for example, a higher proportion of *E. grandis* seedlings from New South Wales provenances were rust resistant than were those from Queensland. *Eucalyptus brassiana* provenances from Queensland and Papua New Guinea were consistently rust resistant, as were several species of *Corymbia*. The commercially important *Melaleuca alternifolia* and *M. cajuputi*, sources of tea-tree and cajuputi oils, were found to be highly susceptible, whereas *M. ericifolia* proved to be highly resistant to *P. psidii*. Rust susceptibility varied greatly across other genera found in Australia; for example, brush box (*Lophostemon confertus*) was highly resistant, whereas *Syncarpia glomulifera* (turpentine tree) proved to be relatively susceptible (Tommerup et al. 2003). *Heteropyxis natalensis*, native to South Africa and a non-myrtaceous species, was also found to be susceptible (Alfenas et al. 2005).

The highly sensitive polymerase chain reaction (PCR)-based detection assay developed for *P. psidii* was able to detect a single rust spore on its own or four spores on small pieces of plant tissue. The validated assay reliably detected the rust in naturally infected leaves, flowers, fruits, pollen, seeds, stems and wood, and in asymptomatic plants, as cryptic infections. A survey of 77 commercially prepared pollen and seed sources from various regions of Brazil detected rust contamination in samples form all locations using the above assay.

Earlier work had suggested that, as with many other fungi, pathogenic variation was present in rust populations. Three distinct races of *P. psidii* were identified using a standard series of test clones, confirming significant pathogenic variation. This finding has important implications for plant quarantine

and disease management in the event of an incursion by the rust, as pathogen variability makes it difficult to predict impacts on natural vegetation and plantations. In addition, the success of selection for rust-resistant clones or families of trees becomes less certain.

Disease hazard models for eucalypt rust were developed to map potentially high risk areas for *P. psidii* throughout eucalypt-growing regions of Australia, Africa and Asia (Booth et al. 2000; Glen et al. 2007b). The maps are based on climatic data from localities in South America where rust epidemics occur matched with similar climates elsewhere. In Australia the region most at risk encompasses most of the higher rainfall areas of the east coast, especially north of Sydney. These forested areas include national parks, state forests and hardwood plantations, coastal *Melaleuca* stands and tea-tree plantations.

Following the recommendation of an external reviewer of the project in 2003, an international workshop was held in Bangkok in October 2004, supported by ACIAR and FAO. The theme was 'Development of an Asia–Pacific strategy for eucalypt rust' and the event was organised through the Asia Pacific Forestry Commission. The workshop provided an opportunity to pass on the outcomes of the ACIAR/CSIRO project to a wider audience. Most of the research team made presentations, with further contributions from staff of the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF), concerned with quarantine, biosecurity and plant protection. The workshop, generally judged as successful, was attended by tree health specialists from most South-East Asian countries and the Indian subcontinent.

Young *Eucalyptus grandis* heavily infected with eucalypt rust in Brazil

The difference the project has made

Unlike most projects to receive ACIAR funding, the benefits cannot be immediately identified and attributed to one or a few collaborating countries. In Brazil, the major partner, *P. psidii* has been a problem for eucalypt plantations for decades, but has largely been solved through the efforts of forest pathologists and tree breeders working with the pulp and paper companies. For Australia, South Africa and many other southern hemisphere and South-East Asian countries, future invasion of eucalypt plantations and susceptible components of native plant communities by *P. psidii* would have major and damaging economic and environmental impacts.

The ACIAR project brought together an international team of leading eucalypt pathologists to share their experience, knowledge and skills. The research outcomes have increased knowledge of the genetics and epidemiology of eucalypt rust in Brazil, and have provided tools to assist in the exclusion of *P. psidii* from parts of the world which are free from the pathogen. In addition, awareness campaigns, especially in Australia, based partly on project outcomes and conducted by research team members and the Australian Quarantine Inspection Service (AQIS), have raised the appreciation of the threat to a high level of readiness. An additional incentive has been the discovery in 2005 of *P. psidii* in Hawaii on the indigenous tree, ohia (*Metrosideros* sp.), the first authentic record of the pathogen outside the Americas.

Project findings have been communicated at many levels during and since the completion of the project. As a consequence, DAFF and Plant Health Australia (PHA), the peak NGO concerned with pest and disease impacts, have been quick to use outcomes and assist with their implementation. A National Diagnostic Standard for *P. psidii*, prepared by CSIRO, has been partially funded by PHA. Although not yet formally accepted, the standard will be incorporated into the National Plantation Timber Biosecurity Plan. The Office of the Chief Plant Protection Officer (an office within DAFF) has also been proactive in the publication of an awareness leaflet and the development of an Incursion Contingency Plan for *P. psidii*. Aspects of the plan were workshopped with a wide range of stakeholders from state and federal agencies and the plantation industry in April 2006. The plan would be activated in the event of a future incursion by the rust.

Australia's enhanced capacity to respond to the threat has already been tested through the detection by AQIS in 2005 of rust spores on a consignment of wood from Brazil. Samples provided to CSIRO for testing with the newly developed diagnostic DNA sequences proved positive for *P. psidii*. Furthermore, a proportion of the spores were still viable, presenting a real threat of incursion. AQIS responded immediately by imposing a ban on timber from Brazil and other countries harbouring the pathogen, thereby closing a potential loophole in our quarantine barrier.

Responses to the outcomes of the project have not been limited to Australia. Following information presented by the project team at an International Congress of Plant Pathology in Christchurch in 2003, the European Plant Protection Organisation has prepared a pest risk assessment (PRA) for *P. psidii*. In New Zealand there is concern that the rust may be able to infect indigenous myrtaceous plants such as pohutukawa and rata, and a PRA for *P. psidii* is being undertaken by Biosecurity New Zealand. Diagnostic laboratories have also collated the available information for use in case of a suspected incursion. In South Africa Professor Wingfield has published an awareness leaflet and web message on behalf of the South Africa Tree Protection Cooperative Programme.

Project impacts

The project outcomes have already assisted in the prevention of incursions by *P. psidii* into Australia and in the planning of feasible and cost-effective responses. The interception of eucalypt rust by AQIS in 2004 has shown the project's value in terms of rapid diagnosis and response. By keeping the pathogen out of Australia and other countries where Myrtaceae are present, very large economic and environmental benefits will accrue. Such benefits, even if limited to Australasia, are extremely difficult or impossible to quantify. They would, however, be significantly large for a pathogen with such a wide host range (Glen et al. 2007a). Impacts on other countries would vary depending on the status of Myrtaceae in native vegetation and their importance as plantation crops.

Immediate social impacts in countries where the rust is not present are limited to heightened quarantine vigilance at airports and docks, and bans on the importation of risky materials, as in the case of suspension by AQIS of all trade in commercial Myrtaceae timber from 'guava rust' countries.

Until the initiation of this project, there was little or no firsthand knowledge of *P. psidii* among pathologists in Australia. Assembly of the international team with ACIAR support has profoundly changed this situation, through assisting in the reciprocal flow of expertise from Brazil to Australia and South Africa. The CSIRO team made regular visits to Brazil and gained an in-depth knowledge of the rust, its impacts and its biology. In return, the high level of expertise of the CSIRO group in detection and diagnosis of extremely small amounts of fungal biomass, and their skills in disease hazard mapping, have been transferred to Professor Alfenas's team at UFV.

A young UFV postgraduate student, Edival Zauza, was given major responsibility for the research carried out in Brazil. This was a significant career opportunity for him, achieving co-authorship, so far, on five research articles and a UFV–supported visit to Bangkok via Portugal to participate in the FAO/ACIAR-sponsored workshop.

Following the return of Dr Langrell to Europe, project funds were used to support a Murdoch University postgraduate student, Dr Morag Glen, who has since moved to Dr Mohammed's lab in Hobart, now a part of Ensis. Dr Glen has worked on the National Diagnostic Standard and the Incursion Contingency Plan, and has recently published a comprehensive review of *P. psidii* (Glen et al. 2007a).

The scientific impacts of the project have been considerable. Prior to 1998, research on *P. psidii* was largely restricted to scientists based in Brazil, with papers often published in Portuguese and not readily accessible to Australian scientists. The ACIAR project was the first to direct sufficient funds and scientific expertise to carry out key research in Brazil aimed primarily at *P. psidii* as an exotic threat to Australia and other countries where Myrtaceae are grown. Through the research and linkages established within the team, Australian, Brazilian and South African scientists who participated in the project have published a series of journal articles, with additional papers currently being submitted to prestigious international journals. Other researchers have picked up on gaps in the research; for example, a detailed study has recently been published on the taxonomy of rusts of Myrtaceae by research staff of Biosecurity Australia (Simpson et al. 2006).

The science of DNA-based detection and diagnosis of plant pathogens in germplasm or small amounts of host tissue, or as spores, has been advanced to a high level and applied to several tree pathogens in addition to *P. psidii*, for example leaf blotch of eucalypts caused by *Mycosphaerella* spp. (Glen et al. 2007a). Similar techniques are being used by the FABI group to determine the phylogenetic position of *P. psidii* within the Uredinales.

Of particular importance is the demonstration that rust spores are commonly present within seed and pollen samples. There is an international trade in such materials as plantation companies worldwide seek to improve their planting stock to increase growth rates and improve wood quality. Although risks from pollen had been suggested previously, this is the first unequivocal evidence with regard to this form of eucalypt germplasm.

It could be argued that increasing global movement of passengers and commodities and the widespread cultivation of Australian native species, especially eucalypts, as exotic plantations will inevitably result in future incursions of *P. psidii* into Australia. This project has provided knowledge and tools to assist in preventing such an occurrence, as well as information on those species, plant communities and geographic areas most at risk from rust epidemics. There is also an enhanced state of preparedness in organisations and agencies with responsibility for maintaining the health and ecological sustainability of Australian forests and plantations of susceptible species.

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Conjunctive water management for sustainable irrigated agriculture in South Asia (LWR1/1997/016)

S.A. Prathapar

Collaborating organisations	CSIRO Land and Water, Australia; International Water Management Institute (IWMI), Sri Lanka; Pakistan Council for Research on Water Resources (PCRWR), Pakistan
Project leaders	Dr S.A. Prathapar (IWMI), Dr Vilma Horinkova (IWMI), Dr Asad Sarwar Qureshi (IWMI), Dr Waqar A. Jehangir (IWMI)
Related projects	LWR1/1996/190
Principal researchers	Dr Shafqat Ejaz (IWMI), Mr Kaleem Ullah (IWMI), Dr Mobin ud din Ahmad (IWMI), Dr Evan Christen (CSIRO Land and Water), Dr Shahbaz Khan (CSIRO Land and Water), Mr Gul Muhammad Shah (PCRWR), Mr Hafiz Nafeez Ahmad (PCRWR)
Duration of project	1 July 1998 to 30 June 2001, extension 1 July 2001 to 31 March 2003
Total ACIAR funding	$625,818

From: Gordon, J. and Davis, J. (eds) 2007. Adoption of ACIAR project outputs:
studies of projects completed in 2002–2003. ACIAR: Canberra.

Project objectives	Identify combinations of institutions and technical strategies to manage surface and groundwater at the regional scale to promote environmental sustainability and maximise agricultural productivity of water ('crop per drop'), initially in the Rechna Doab in Pakistan and the Murrumbidgee region in Australia. Key outputs and outcomes were: ▪ a methodology to determine appropriate combinations of institutional mechanisms and technical tools to improve conjunctive water management ▪ guidelines to irrigation department officials and Area Water Board members for effective conjunctive water management at the regional scale in the Rechna Doab and the Colleambally Irrigation Area (CIA).
Location of project activities	South Asia

Overview

The Indus Basin Irrigation System is the largest contiguous irrigation system in the world. Water from the Indus River and its tributaries is diverted into 16 million ha of lands via 45 main canals. This ACIAR project was formulated at a time when major reforms in the Indus Basin Irrigation System were initiated. The reforms were a major part of the National Drainage Program (NDP), which was sponsored by the World Bank, the Asian Development Bank and the Government of Japan. Reforms at provincial level were to take place from 'top to bottom' and 'bottom to top'. As a top-down measure, Provincial Irrigation and Development Authorities (PIDAs) were legislated in all provinces in 1997. The next level of organisation was the formation of Area Water Boards (AWBs) at the primary canal level, followed by Farmer Organisations (FOs) at the secondary canal level. This ACIAR project was designed to complement ongoing research projects addressing irrigation sector reforms at IWMI Pakistan, funded by the NDP.

During the first phase of the NDP, only 4 out of 45 canal commands were to be managed by AWBs. One of the four is within the Rechna Doab, the ACIAR project site.

Expected outputs were:

- a methodology to determine appropriate combinations of institutional mechanisms (rules, regulations and by-laws for AWBs and FOs) and technical tools to improve conjunctive water management (a computer model)
- guidelines to irrigation department officials and AWB members for effective conjunctive water management at the regional scale in the Rechna Doab.

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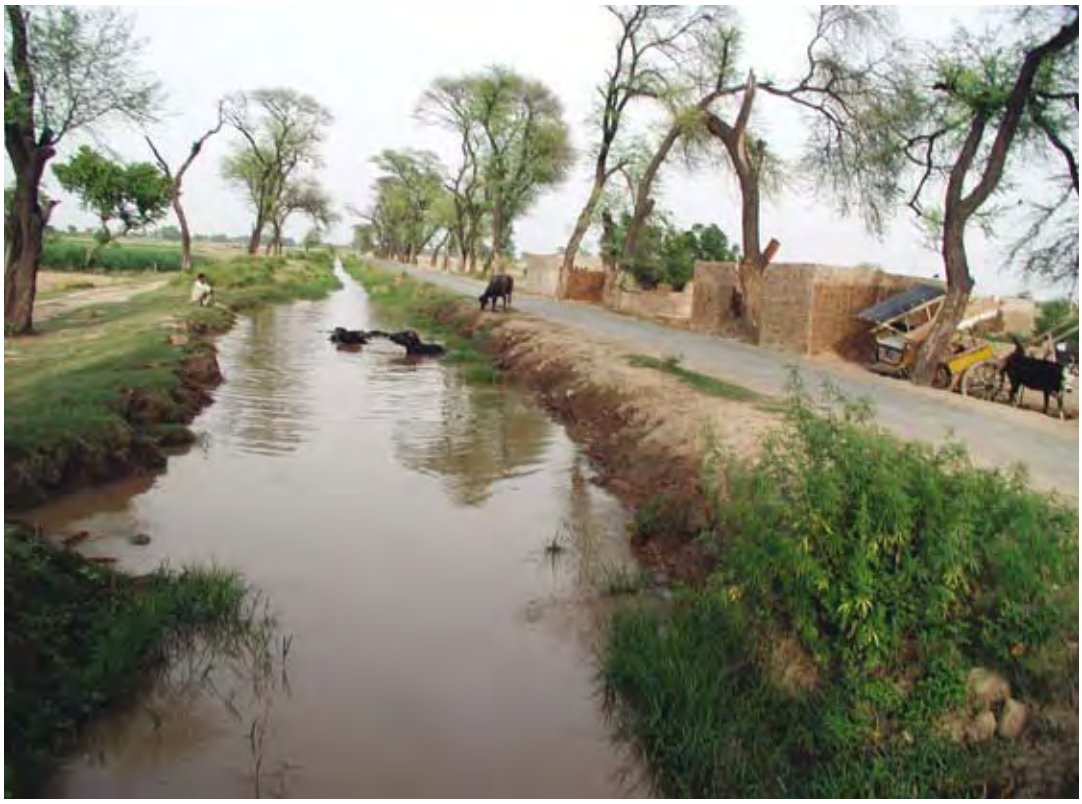
Project achievements

The project delivered all planned outputs, which are listed below:

- Provide consultation to the Punjab Irrigation & Drainage Authority to develop rules, regulations and by-laws which would govern the AWB, its members and the FOs (output 1). Drafted rules, regulations and by-laws for the AWB have been adopted by Irrigation and Drainage Authorities in Punjab and Sind provinces, following revisions made by respective provincial governments. However, not all credit can be ascribed to this project. There were other projects funded by the NDP of Pakistan and the Dutch Government which had similar objectives. But the fact that the ACIAR project scientists actively contributed to the first draft of rules, regulations and by-laws is significant, and duly recognised by the PIDA.
- Compile hydrologic and hydrogeologic data for the Rechna Doab (output 2). This ACIAR project improved existing hydrologic and hydrogeologic databases at IWMI Pakistan. In particular, it was for the first time historic piezometric datasets available at the Water and Power Development Authority (WAPDA) were entered electronically into GIS and relational databases. The end user of this output was this project itself; therefore, its adoption rate was 100%.



Multipurpose use of irrigation canals in Punjab irrigation areas of Pakistan

- Unfortunately, the following outputs, although delivered by the project, were not adopted by the intended end user, namely the PIDA:
  - the conjunctive water management model and recommendations to the PIDA (output 3)
  - the subsurface evaporation basin, constructed to minimise regional drainage requirements in waterlogged areas (output 4)
  - identification of sites where recharge basins could be constructed to recharge the aquifer when surplus canal water is available, especially during monsoon months (output 5).

The difference the project has made

- Since four AWBs in Pakistan (one in Punjab and three in Sind province) have adopted revised forms of the original rules, regulations and by-laws to which this project contributed, and all 45 AWBs in future will also be governed by the same, the adoption rate for output 1 is very high. This is an important development. It is noted, for example, that the LCC East AWB in Punjab province consists of 87 FOs and the three AWBs in Sind province consist of 369 FOs. The three AWBs in Sind cover 1.82 million ha (32% of all irrigated areas in Sind), and the total number of FOs planned for Sind is 1,300.
- Output 2 has served the initial purpose, which was the development of the groundwater model for the ACIAR project. This database is being continuously improved and used by researchers in IWMI and elsewhere. Therefore, the adoption rate for this output is very high and current users are:
  - IWMI's Integrated Data Information System (IDIS), which has 450 thematic layers of geo-referenced data
  - the Rice Wheat Consortium (RWC) of the Indo-Gangetic Plains (CGIAR Initiative) has several ongoing projects in the Rechna Doab. The database provided valuable information to RWC projects in this region
  - project scientists of CGIAR's Challenge Programs on Groundwater Governance, who have consulted this database to assess the extent of groundwater use along the boundaries of surface irrigated catchments
  - university students at the Center for Excellence, University of Engineering, Lahore
  - IWMI's Basin Kit for the Indus Basin
  - IWMI's project on upscaling productivity at the basin scale.
- Output 3 probably used most of the project funds and involved training for several IWMI staff in Australia. However, the model and the recommendations from the modelling study have not been adopted by provincial agencies.
- Output 4 has served its purpose at the site where it was installed. In combination with other factors, the subsurface evaporation basin has alleviated waterlogging at the project site. Another research agency in Pakistan, the Nuclear Institute of Agricultural Biology, is planning to implement the technology at their project sites.

- Output 5 has the potential to be developed into a development project but requires consultation with PIDA and funds for installation. In an era when surface storage of sufficient water is not feasible, and surplus water for recharge is available only occasionally, it is imperative that artificial recharge structures are in place to collect, store and recharge aquifers. AusAID may consider developing this output further in consultation with Punjab Irrigation Department.

Project impacts

This ACIAR project contributed to the establishment of the first AWB, which can be considered as the pilot AWB. Currently, one AWB in Punjab province and three in Sind province are functional, and another in Punjab is expected to function soon. At the end of the reforms all 45 canal commands will be managed by AWBs. Therefore, the flow-on effect of the contribution made by the project will be very high and potentially affect 2 million farmers living in the Indus Basin Irrigation System.

The subsurface evaporation basin (output 4) is the only on-ground activity of the project, and has helped in alleviating waterlogging in the area. Therefore, the project had a positive environmental impact.

The project has had no quantifiable economic impacts so far.

The project facilitated a PhD dissertation and a Master's thesis during its life. Unfortunately, none of the Pakistani project scientists at IWMI Pakistan and PCRWR are with respective agencies at present. However, all have progressed in their professional careers. Many of them contributed to this report and are grateful to ACIAR for providing an opportunity to advance their professional skills.

From: Gordon, J. and Davis, J. (eds) 2007. Adoption of ACIAR project outputs:
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Shelf-life extension of leafy vegetables (PHT/1994/016)

Timothy O'Hare

Collaborating organisations	Queensland Department of Primary Industries and Fisheries (QDPIF), Australia; Agriculture Victoria (now called DPI Victoria), Australia; University of Adelaide (UA), Australia; Hangzhou Institute of Commerce (now called Zhejiang Gongshang University (ZGU)), China; Beijing Vegetable Research Centre (BVRC), China; Zhejiang University (ZU), China
Project leaders	Dr Timothy O'Hare (QDPI), Li Wu (BVRC)
Related projects	-
Principal researchers	Mr Bruce Tomkins (Agriculture Victoria), Dr Andreas Klieber (UA), Prof. Shen Lian-Qing (Hangzhou Institute of Commerce)
Duration of project	1 July 1998 to 30 June 2001, extension 1 July 2001 to 31 December 2002
Total ACIAR funding	$893,898

Project objectives	■ Assessment of existing Chinese handling systems and quantification of existing handling problems for Chinese cabbage, pak choy, broccoli and oriental bunching onions ■ Optimisation of environmental conditions to extend shelf life ■ Identification of inherent physiological factors limiting shelf life Although a major part of the project was to identify issues that limit shelf life in the Chinese handling systems, and the development of fundamental knowledge of vegetable physiology controlling senescence, part of the project was aimed at testing potential means of increasing shelf life through novel postharvest treatments or handling systems. It was expected that some of these would be effective and some would not be feasible.
Location of project activities	China

Overview

Project PHT/1994/016 involved working with two groups in different localities with different issues and differing postharvest handling systems for leafy vegetables. Researchers from these groups used postharvest handling system methodology to analyse the existing handling systems and identify limitations and where losses were occurring. Based on this, and on techniques introduced from Australian industry, several improvements in handling chains were achieved, not only in Beijing and Zhejiang provinces but also in surrounding areas and, in some cases, in other major distribution centres that had linkages to industry in the project area.

Although the project concentrated on specific vegetables (i.e. Chinese cabbage, pak choy, bunching onions), many of the improved handling techniques have been transferred to other vegetables, most of which are of higher intrinsic value and constitute up to 80% of total vegetable production. Considering the size of these industries (relative to Australia), there has been considerable monetary benefit.

Apart from direct benefit to industry, benefits also accrued to the research groups, which have received considerable recognition from both government and industry. Project PHT/1994/016 in many ways acted as a catalyst for postharvest research in these provinces, resulting in further research projects in collaboration with government and industry.

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studies of projects completed in 2002–2003. ACIAR: Canberra.

Project achievements

Project PHT/1994/016 successfully introduced forced-air cooling and refrigerated transport into the Beijing distribution centre handling systems, which handle 10.75% of vegetables in the Beijing region. In addition, the use of returnable stackable crates (to reduce mechanical injury to vegetables and subsequent rotting) for growers and collectors is now widespread. Moisture loss from leafy vegetables, which causes wilting and weight loss, has been significantly minimised through the use of plastic film liners in the stackable crates that can be wrapped over vegetables.

Losses in stored bunching onions have now been reduced through the introduction of refrigerated storage for 20% of production, while 40% of those still stored using ambient storage conditions now use insulated foam-rubber blankets to minimise freezing injury.

Reduction of mechanical damage of Chinese cabbages that are bulk transported in the Zhejiang region (80–90% of production) has been implemented by a modification of the outer leaf removal procedure. Further mechanical damage and rotting has been reduced for more valuable products (the remaining 10% of the Chinese cabbage industry, pak choy, most other vegetables grown) through the widespread use (in 60–70% of entire vegetable industry) of plastic-mesh bags supported by metal frames.

Reduction of mechanical damage and subsequent rotting in summer has also been implemented in the pak choy industry through the use of controlled moisture loss, with 75-80% of the industry (where workshops were performed) adopting this practice.

Numerous extension workshops have been carried out by BVRC in Beijing, concentrating especially on the four large major distribution centres. Workshops in the Zhejiang region, where distributors tend to be smaller and are often growers themselves, have been directed at growers (including the Nanjing military region) via the local agriculture extension networks.

Plastic film liners used in these stackable crates for bok choy help reduce moisture loss.

The difference the project has made

Adoption of forced-air cooling combined with refrigerated transport by Beijing distribution centres has enabled them to extend the shelf life of produce such that high-quality produce can be presented to consumers through high-quality stores. Consumers pay more for this produce so there is increasing profitability to the distribution centres, which maintain ownership of product in supermarkets until it is sold to the public. The distribution centres pass some of this profit on to growers in the form of an annual bonus. The basis for this is so that the distribution centres remain on good terms with good growers. Similarly, the use of returnable stackable crates and film overwraps has decreased mechanical damage during handling, and moisture loss where wraps are used. This results in both a reduction in loss of saleable weight and an increase in quality. Both these factors increase profit with negligible outlay because the initial cost of the reusable crates is borne by the distribution centres. Increased (gross) profit by the four distribution centres over the last 3 years is estimated at approximately Y5.3 million (~A$900,000).

In regard to improved storage of bunching onions, refrigeration has eliminated freezing injury and insulation blankets have reduced freezing losses, which were originally about 40% of stored product. Therefore, more product is available to be sold by growers and collectors, and, as with the stackable crates, the blankets are reusable.

Protective leaves are left on broccoli to help reduce damage during field handling.

In the Zhejiang region growers also tend to be the distributors, so directly accrue benefits where losses have been reduced. Reduced damage to Chinese cabbages transported in bulk, as well as reduced damage to higher value vegetables packaged in plastic-mesh bags supported by metal frames, has led to a direct increase in return to growers in the order of 10–20%. Plastic mesh can be reused and easily repaired by growers. Controlled moisture loss (for pak choy only) reduces leaf turgor, and thus petiole damage and subsequent rotting during packing and handling. This is a relatively simple procedure that costs the grower virtually nothing, and moisture loss can be regained once transported to the marketplace.

Project impacts

Apart from direct impacts on the supply chains in the Beijing and Zhejiang regions, other impacts included flow-on savings to distribution centres and collectors in other main centres (Guangzhou, Shenzhen, Kunming, Shanghai). The reduction in loss has been estimated to be approximately Y131 million (~A$21 million) over the last 3 years.

The impact of the project itself on BVRC research staff has been substantial. Closer contact with industry has resulted, and better budgeting and staff/project management skills have secured more projects from the Chinese government (to the value of Y2.8 million). The BVRC postharvest group has the highest funding of all groups at BVRC. In recognition, BVRC has also had a direct advisory role on vegetable supply during the Beijing Olympics in 2008. The project has been described as a catalyst for the group, with increasing interest from both government and industry. A direct impact of the project was recognition of the potential for fresh-salad and stir-fry packaged fresh-cuts (from the Australian component of the project), resulting in a Y1.8 million research project. It has been recognised that the direction of research has had to change to areas of growth and potential.

In Zhejiang the project had an accelerating effect on the development of postharvest technology at the Zhejiang Gongshang University (ZGU) and resulted in the development of a postharvest laboratory in a new university (Zhejiang University of Science and Technology). A number of students involved in the project are now employed as lecturers in these two universities. The postharvest handling systems assessment section also developed considerably closer ties with the extension arms of the many countries in which the research results were extended in workshops. The research methodology relating to improved handling practices is still being promoted by these groups.

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studies of projects completed in 2002–2003. ACIAR: Canberra.

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Nutrition of tropical hardwood species in plantations in the south-western Pacific (FST/1996/085)

Richard Pauku

Collaborating organisations	Ministry of Agriculture, Sugar and Land Resettlement (MASLR), Fiji; Ministry of Agriculture, Forests, Fisheries and Meteorology (MAFFM), Samoa; Kolombangara Forest Products Ltd (KFPL), Solomon Islands
Project leaders	Dr Paul Reddell (CSIRO Land and Water), Dr Kuldeep Singh (MASLR), Mr Malaki Iakopo (MAFFM), Mr Wayne Wooff (KFPL)
Related projects	FST/1994/025, FST/1995/103, FST/1995/106, FST/1996/05
Principal researchers	Dr Richard Pauku (KFPL), Tevita Bevu (Fiji), Tolusina (Samoa)
Duration of project	1 January 1998 to 31 December 2000, extension 1 January 2001 to 30 June 2002
Total ACIAR funding	$848,586
Project objectives	▪ Species nutritional requirements and criteria for detection of deficiencies ▪ Fertiliser strategies ▪ Nutrient removal during harvesting ▪ Training ▪ Extension
Location of project activities	South Pacific and Papua New Guinea

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Overview

Production of sawlogs and other timber products is a major contributor to the export earnings of many of the larger Pacific island nations. Most of this timber is still harvested from natural forests, and there are significant questions as to the environmental and social sustainability of these activities and to the value and fairness of benefits received by local communities.

Plantations of tropical timber trees offer an attractive alternative to natural forest harvesting because of the potential for much greater long-term benefits to the local economy and communities. At a time when a number of commercial plantation projects were being established by government and private enterprise in the region, this ACIAR project was developed to provide scientific support relating to the nutritional aspects of establishment and sustainability of plantation trees, and to build research capacity in local staff.

The primary collaborator in the project was Kolombangara Forest Products Ltd (KFPL), a joint venture between the Commonwealth Development Corporation (CDC), the Investment Corporation of Solomon Islands and the traditional landholders. KFPL was selected because it was a leader in the development of forest plantations in the region, and had a strong commitment of staff and resources to the research and extension activities that were underpinning its plantation establishment and harvesting operations.

Improved plantation establishment methods that were developed during the project are now incorporated into routine operations of the company. Initial work in the project identifying nutrient and water issues associated with sustainability of production from these plantations contributed to Forest Stewardship Council certification of the company's operations from 2002. The benefits of this 'green labelling' continue to flow to the company in terms of premium pricing and market access in Europe.

Benefits of the research to the local community arise through direct and indirect employment associated with the company's operations, royalties and lease payments to traditional landholders, and reduced environmental impacts. Spillover benefits of this technology to other plantation companies and smallholder growers are less clear due to structural problems in the forestry sector in many parts of the region; limited availability of resources to scientific and technical staff in other private and government forestry organisations; and a high level of political and social instability in many parts of the region, which limits the confidence of private sector investors in relatively long-term activities like plantation forestry.

Project achievements

The project had significant achievements in four areas:

- identifying the previously unrecognised extent and severity of nutrient limitations to productivity of timber plantations in much of the region
- providing novel and cost-effective solutions to improve establishment of plantation trees
- contributing to Forest Stewardship Council certification of the KFPL plantations by identifying and quantifying nutrient budgets associated with the continuing sustainability of these plantings
- enhancing the capacity and skills of researchers from a number of countries throughout the region.

The project identified that deficiencies of one or more nutrients were widespread. This affected the establishment and productivity of fast-growing tree species at a wide range of sites suitable for timber plantations in Solomon Islands, Fiji and Samoa. The extent and severity of these limitations on productivity in these areas had not been recognised previously. In response, a simple, robust framework for identifying the likelihood and severity of occurrence of specific nutrient deficiencies was developed for use in assessing likely problems that could occur on sites on similar soil types and parent materials throughout the region.

To address the major nutritional problems that had been identified, the project developed novel and cost-effective methods to improve the quality and health of nursery stock available for planting, and more effectively deliver nutrients within the root zone of planted stock during the critical early phases of their establishment in the field. Planting stock produced using the new practices had superior survival (>90%) and higher growth rates in the crucial first 9 months after planting out into the field. This superior performance reduced maintenance and weeding costs and eliminated the need for broadcast fertiliser to be applied during the first 12 months of plantation establishment. The technology reduced plantation establishment costs for KFPL by approximately US$30 per ha. In addition, the use of coir as the basis of potting media resulted in the establishment of a new industry, creating income opportunities for women in local villages where coconut husks were previously a waste product of no commercial value.

Clonal *Gmelina arborea* at Kolombangara Forest Products Ltd nursery, Solomon Islands

The project generated estimates of site nutrient budgets for mature plantations at KFPL. This allowed assessments to be made of the net effects of harvesting and other plantation management operations on long-term site nutrient capital. This information contributed to the Forest Stewardship Council independently certifying the compliance of KFPL with best industry sustainability practice. This 'green labelling' of plantation produced timber allows KFPL greater market access and attracts a premium price on their products in Europe.

Capacity building was a fundamental achievement of this project. Research and technical staff from KFPL, the Solomon Islands Forestry Division, the Fiji Department of Forestry and the Samoan Ministry of Agriculture, Fisheries and Forestry were involved in locally appropriate and focused in-house training, together with regional workshops in scientific writing, data analysis and interpretation. One of the Solomon Islands project staff was a recipient of an ACIAR scholarship and completed his PhD studies in Australia in 2005.

The difference the project has made

The project has had a major impact on the day-to-day operations in KFPL's more than 15,000 ha of plantation. It has also increased the level of research skills of staff in other partner countries. The four areas in which the project has made the greatest difference are listed below.

Improved nursery production techniques

The project fundamentally changed the nursery production system used by KFPL. Coir produced from grated, composted coconut husks replaced soil collected in the field as the substrate for the nursery potting medium. This, combined with the careful incorporation of slow-release fertilisers throughout the mix, significantly increased the survival, growth rate and general health of cutting- and seed-grown material. Coir-based potting media are also lighter to transport into the field and adhere better to the root systems of young plants, causing less damage on planting out. Potting media based on coir and slow-release fertilisers were developed for four important plantation species used in the region, namely *Gmelina arborea*, *Tectona grandis* (teak), *Swietenia macrophylla* (mahogany) and *Eucalyptus deglupta*.

As a direct consequence of these improved nursery techniques, KFPL's two nurseries produce better quality planting stock in a shorter time and have increased flexibility in producing the 125,000 clonal *Gmelina arborea* cuttings, 7,000 *Eucalyptus deglupta* seedlings and 3,000 *Tectona grandis* seedlings that are required each month for the company's planting program.

Communities surrounding the KFPL estate have also benefited directly from this technology. It has provided an opportunity to generate additional income (especially for village women) by preparing and selling coir. Coir is made from husks that were previously considered waste from coconut and copra production. KFPL purchases coir from these villagers at SBD50 per 200L coir. In addition, KFPL has increased their capacity to supply planting stock to outgrowers—villagers planting trees on their own land, either as woodlots or using agroforestry concepts. At the time of this adoption study, there are 32 such outgrowers with a total plantation area in excess of 50 ha.

Improved field establishment techniques

Prior to this project, KFPL had been using standard industry practice for applying fertilisers during plantation establishment. These methods involved adding fertilisers to planting holes and broadcasting additional inorganic fertilisers during the first 6 months of planting out. This process is costly and environmentally unsound because of invariably high rates of leaching beyond the root zone. It is also inefficient because of the higher competitive ability of weeds in capturing applied nutrients compared to the establishing trees, and difficult to manage operationally.

This project developed a totally different approach to delivery of nutrients to plants during the critical first 9 months of establishment in the field. The approach involved incorporating long-term slow-release nutrients (9–12 month release time) in the coir potting medium used in the nursery, and completely eliminated the need for any fertiliser to be applied in the field during plantation establishment. The slow-release fertiliser used was in addition to shorter release-time fertiliser that was required for good growth and productivity in the nursery. The method worked because it provided a more targeted delivery, becoming available in the immediate proximity of the roots of the establishing plants. KFPL adopted this method as routine practice in all its plantings in 2002, and it continues to be part of their routine nursery operations. The benefits of this more targeted method of delivering nutrients to the establishing trees are increased survival and growth rates following planting out, earlier canopy closure (with consequent savings in weed management treatments) and elimination of the need for field-applied fertiliser early in the life of the plantation. The cost savings to the company from adopting this approach have been estimated at US$30 per ha of new plantation established.

More sustainable timber production practices

The ability to maintain long-term timber production with minimal environmental impact is an important aspect of sustainability for both timber producers and timber buyers. Increasingly, access to key markets in Europe and elsewhere is dependent on demonstrating sustainability, and this has given rise to a number of schemes for independent certification or 'green labelling' of sustainably produced timber products. KFPL recognised this market opportunity and applied for Forest Stewardship Council certification for its products.

This project contributed technical information that was critical to an important component of the certification process associated with assessing impacts of plantation activities on site nutrient capital, and implementing management practices to minimise these impacts. The research produced estimates of site nutrient budgets and tracked the amount of nutrient lost from the site during harvesting operations through log removal, erosion and leaching. Because of its high content in wood and bark, calcium was found to be the nutrient most critically affected by harvesting. From this data recommendations were produced for management of harvest residues, on-site debarking of logs and long-term fertiliser inputs to overcome this problem.

The Forest Stewardship Council certified KFPL's operations in 1997.

Better trained staff

Over the course of the project, participants from Solomon Islands, Fiji and Samoa received focused, in-house training relevant to their particular roles in the project. For example, KFPL staff gained knowledge and skills of methods and techniques to diagnose specific nutrient deficiencies and work out ways to improve nutrition of plantation species. They also learned approaches to estimate site nutrient budgets.

In addition, project participants were involved in a series of regional workshops that improved their skills in scientific writing, and in experimental design and data analysis and interpretation.

Project impacts

Impacts on KFPL and the community

Forestry projects focusing on generating export income differ significantly from those in much of the agricultural sector. The timeframes for return and the scale of operations required to be internationally competitive invariably require a company to invest in and manage the forestry process. Thus, impacts on the community will generally flow from the impacts on the company's operations and its level of adoption of new technologies. In these situations benefits to the community are derived from:

- improved direct and indirect employment opportunities associated with the company's operations
- payments to traditional landholders for long-term lease of land
- royalties and dividends on product sales paid to shareholders and government
- improved environmental quality associated with more sustainable management practices.

This project had a range of impacts on KFPL's operations, which in turn benefited the community.

The improved nursery production system developed in this project directly reduced operating costs for the company's two nurseries. At the same time it increased their annual production capacity, reduced environmental damage by eliminating the need to collect soil for potting media from surrounding forest areas, and created a new industry (producing coir) that was of special benefit to women in local villages.

The improved field establishment techniques markedly increased survival and growth rate of planted stock, resulting in earlier canopy closure and reduced need for weed control. These techniques also eliminated the need for field-applied fertiliser. Adoption of these establishment techniques had both financial (higher plantation productivity for reduced costs) and environmental (no leaching of broadcast applied fertilisers) benefits.

The identification and adoption of more sustainable plantation management practices in relation to nutrients contributed to KFPL being granted Forest Stewardship Council certification. Benefits of this 'green label' certification for KFPL include increased market accessibility and premium pricing for products in Europe. For the community the additional benefits in the adoption of more sustainable harvesting practices were reduced rates of erosion and of nutrient loss into streams and waterways.

Spillover benefits of this research to rural communities in other forest plantation areas are less clear. Many of the technical innovations made by KFPL in this project do not appear to have been adopted elsewhere despite the project involving researchers from government agencies within Solomon Islands and from other countries in the region. For example, a recent community forestry project in Solomon Islands supported by international donors has taken no account of the potential of the improved nursery production system developed at KFPL to benefit smallholder growers. This perhaps reflects a problem in lack of coordination in the aid area. New projects are often initiated in ignorance of previous activities, new consultants are brought in from outside, and 'corporate memory' is lacking in government and other local agencies due to the small critical mass and relatively high turnover of within-country technical experts.

Capacity building and scientific impacts

The project resulted in a discernable increase in knowledge, skill and confidence of staff that were involved from the participating partners. Many of the staff have moved to other organisations or into management positions in government agencies. One project participant from Solomon Islands was awarded an ACIAR Fellowship and completed a PhD at James Cook University in Cairns in 2005. Since completing his studies, this former student has established a private consultancy firm in Solomon Islands providing technical advice in agriculture, forestry, agroforestry and environmental issues for the South Pacific region. He is

Eucalyptus deglupta in root trainers filled with a mixture of coir and slow-release fertiliser at Kolombangara Forest Products Ltd, Solomon Islands

currently collaborating with the National Agriculture Research Institute (NARI) of Papua New Guinea on the domestication and commercialisation of *Canarium indicum*, and running in parallel a similar but smaller project in collaboration with the Solomon Islands College of Higher Education and the Department of Agriculture and Livestock in Solomon Islands.

This project generated a number of significant scientific impacts. Rapid diagnostic tests for nitrate and phosphate sufficiency using cheap and readily available test strips were found suitable for use in nursery stock and field plants. Visual symptoms of nutrient deficiency were described and photographed in a number of species and compiled in a book published by ACIAR. A number of invited book chapters and publications in scientific journals also resulted from this project. Regular articles highlighting key research findings were published in the regional Forests and Trees newsletter published by the South Pacific Commission. Oral and poster presentations by project participants were made at a number of national and international conferences.

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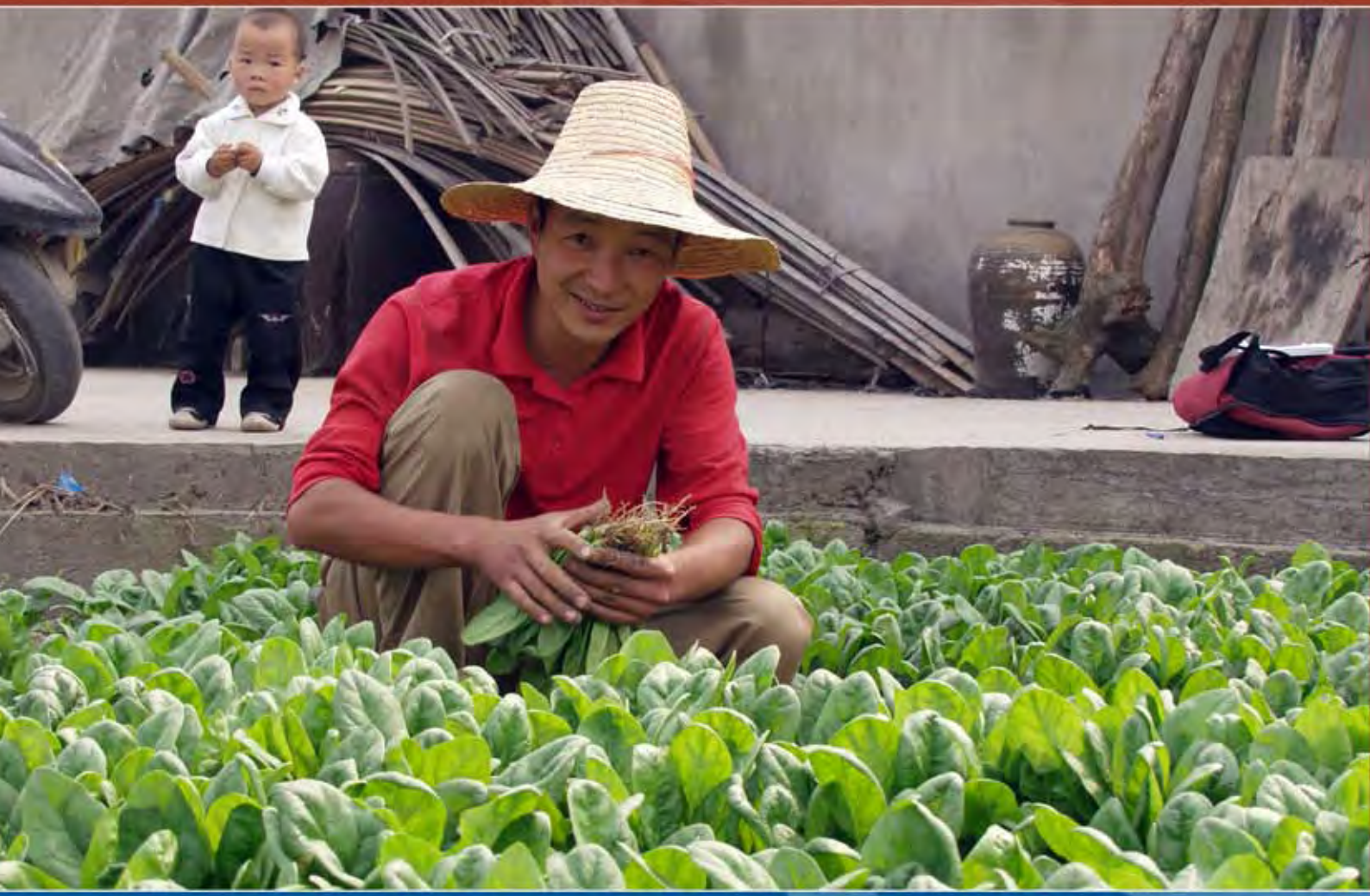

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