Australian Government
Australian Centre for
International Agricultural Research

Adoption of ACIAR project outputs: Studies of projects completed in 1999–2000

Editors: Viv McWaters and Deborah Templeton

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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, policy-makers, 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 three–four years after completion, and report back to ACIAR on the medium-term outcomes of the work. This series reports the results of these studies.

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Foreword

ACIAR has an annual funding base of about A$50 million and invests in agricultural research projects that have a pro-poor focus. About 190 projects are being funded at any one time, with 40–50 projects being completed each year.

In themselves these numbers are not that important. The important point is that the Australian Government provides significant funds to ACIAR as part of its overall international development cooperation program. As such, ACIAR has an obligation to provide evidence that the funds have been employed wisely and have generally benefited the poor.

One of ACIAR's challenges is to ensure that project benefits continue beyond the life of the project. While not applicable to all projects, adoption pathways need to be built into project design. 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.

ACIAR is increasing its investment in ex-post evaluations. One component of this is an initiative to look back on all large projects (>$400 000 outlays by ACIAR) three to four years after their completion. This publication is the first compilation of reports on what has happened in our partner countries after the end of a group of projects' lives. It is a first effort, and one we want to repeat each year. There is much here from which we can all learn, to improve our future joint efforts.

I want to take this opportunity to thank each of the Australian project scientists 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, assisted with data gathering, and helped in numerous other ways. My sincere thanks go to each one of you for your support.

Peter Core
Director

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Overview

Viv McWaters[1] and Debbie Templeton[2]

Introduction

In 2003–04, ACIAR decided to refine the process of measuring the impacts of its projects. It set up a system for Australian project leaders to assess the effectiveness of large projects three years after their completion. The three-year interval takes account of the time required for an agricultural R&D project to start bearing fruit. The assessment process not only analyses the degree of uptake of the project's results, but also examines which factors affect the uptake and why, and whether the project has made a difference to the social, economic and environmental wellbeing of a community.

During 2003–04, ACIAR completed adoption studies for 12 of its projects. While the projects covered a range of scientific disciplines and geographical regions, several common themes are apparent. The purpose of this report is to present these common themes and summarise the lessons learnt. This information can be used to help guide future investment in ACIAR projects.

Broad project categories and adoption levels: a qualitative assessment

The 12 projects covered in this report are divided into three broad categories according to the type of project. They are:

1 new technology, practical approaches;

2 scientific knowledge or understanding (pure or basic science); and

3 knowledge, models and frameworks to aid policy- and decision-making.

[1] Beyond the Edge Pty Ltd.

[2] Impact Assessment Unit Manager, ACIAR.

The classification of each of the projects, as well as a ranking of the level or extent of uptake by key users of the results, is presented in Table 1. Key users are defined as the people who will be using the research findings that result from research project activities. They can be divided into two broad groups: next users (e.g. government agencies such as registration authorities, extension agencies, quarantine services, etc.) and final users (e.g. smallholders, policy-makers, etc.). There are two projects in category 1 and one in category 3 for which there is demonstrated and considerable use of the results by both the next users and the final users of the project results (scored as 'NF' in Table 1). Projects where there is reasonable use of the results by the next user, but little uptake by the final user, are scored as 'Nf'. Once again the projects that fall into this classification are from categories 1 and 3. Projects where there is some evidence of uptake of the results by the next users but none by the final users are scored as 'N'. Both the projects that are in category 2 are scored as 'N', as was one of the projects in category 3. No projects covered in the adoption studies had zero uptake of the results by the next users.

Table 1: Type of projects and uptake of project results since the projects finished

Project categorised by type	Level of uptake*
1 New technology, practical approaches	
Integrated control of citrus pests in China and SE Asia	Nf
Development of improved mud crab culture systems in the Philippines and Australia	N
Development of leading centres for mud crab culture in Indonesia and Vietnam	NF
Ectomycorrhizal fungi for eucalypt plantations in China	NF
Tree production technologies for the Philippines and tropical Australia	Nf
Phosphine resistance in insect pests of stored grain	Nf
2 Scientific knowledge/understanding (pure science)	
Improved diagnosis and control of peanut stripe virus	N
Control of bacterial wilt by agricultural biotechnology	N
3 Knowledge, models and frameworks to aid policy- and decision-making	
Optimal land use in Sri Lanka with particular application to land degradation and plantation industries	Nf
Accelerating growth through globalisation of Indian agriculture	N
Analysis of socioeconomic and agribusiness developments in the Chinese cattle and beef industry	NF
Computer-assisted learning as a tool to improve grain storage pest management in key ASEAN countries	Nf

* Level of uptake is summarised as high, medium or low using the following criteria:

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

Nf: Demonstrated and considerable use of the results by the next user but only limited uptake by the final user

N: Some use of the results by next users and but no uptake by the final users

0: No uptake by either next or final users.

Factors affecting uptake of results: lessons learnt

From the information contained in the adoption studies, it is clear that various factors have either contributed to, or inhibited, the uptake of results of the projects included in this assessment (Table 2).

First, projects with the highest level of uptake by the next users have ongoing participation in the project by a core group of in-country scientists who have local credibility and are committed to the project and its outcomes. This is particularly evident for at least one project in each of the categories, indicating that this success factor holds across all types of projects. Examples include the ectomycorrhizal fungi for eucalypt plantations in China project, improved diagnosis and control of the peanut stripe virus, and optimal land use in Sri Lanka. The current and potential stability of partner organisations and institutions, and their commitment to the research topic, should be assessed at the project development stage when the likelihood that the project results or outputs will be taken up by the next and final users is examined.

Table 2: Summary of factors that have affected the uptake of results

New technology, practical approaches

Factors contributing to uptake

- Government, or commercial enterprises, sharing the risk
- Appropriate and extensive training of users and/or promoters of the new approaches
- Workshops that increase awareness and understanding, especially of local 'champions'
- Trained scientists who can continue the work and help train others
- Publishing results in appropriate languages and in a way that is accessible
- Reputation, and credibility, of the scientists

Factors inhibiting uptake

- Bureaucratic barriers to further development and implementation of project results
- Shortage of essential facilities and/or equipment and/or the expertise to use it
- Limited number of field trails and demonstrations to provide visible 'proof' of the effectiveness of a new approach
- Competition, especially from cheaper alternatives
- Time lag – where the results from implementing a change are not immediately apparent
- No existing domestic market and/or poor infrastructure to support industry development

Scientific knowledge/understanding (pure science)

Factors contributing to uptake

- Involvement of a stable and robust collaborating organisation where staff turnover is likely to be low
- Well educated, committed in-country scientists able and willing to mentor staff and students
- Ownership of, and excitement about, the potential of the project by scientists working on the project which leads to adequate preparatory work with collaborators
- Results that contribute directly to developing practical applications

Factors inhibiting uptake

- The 'pure science' nature of the results that has limited applicability
- Legislative uncertainty regarding further development, especially of GMOs

Knowledge, models and frameworks to aid policy- and decision-making

Factors contributing to uptake

- Good personal relationships where there is a high level of trust between the researchers and decision-makers
- Models that can be used by other researchers to add value to their work
- Academic acceptance and use within universities

Factors inhibiting uptake

- Complex socio-political climates, especially where there is ongoing uncertainty
- Seemingly complex models that require extensive training before they can be used

Second, a varied and comprehensive approach to communication and dissemination activities and extension also contributes to a high level of uptake. Examples include the mud crab aquaculture project in Vietnam, the project looking at mineral oils as an alternative for the integrated control of citrus pests in China and South-East Asia, the optimal land use project in Sri Lanka and the project on the analysis of socioeconomic and agribusiness developments in the Chinese cattle and beef industries. Further, uptake is likely to be enhanced if the extension activities includes a strong training component to make sure that new understanding and skills are passed on and able to be implemented in the field. Again, the mud crab aquaculture project in Vietnam is a shining example of how this approach contributes to uptake. The control of bacterial wilt by biotechnology is an example of a basic scientific project where complex information has been successfully transferred to people who are in a position to use the new knowledge. The ATSE Crawford Fund Master Class program has contributed significantly to this. The project on accelerated growth through globalisation of Indian agriculture is a good example where the outputs of a project are continuing to be used in Indian universities to train students in aspects of agricultural and international economics.

Third, it is important that the transfer activities are developed with the skills and knowledge levels of the target audience in mind so that the target group fully understands the new technology, its benefits, how it should be applied and so on. In fact, evidence from the adoption studies suggests that uptake of good research is most often inhibited by extension or training that is not easily transferable or understood. This is apparent in the case of the project on integrated control of citrus pests in China and South-East Asia. The project on tree establishment and production technologies in the Philippines is another example of a situation where the lack of appropriate information is limiting uptake by the final users. In the case of the project on the development of decision-support tools for managing pests in grain storage, the need for and cost of specialised training courses has limited post-project activity in the Philippines. This limiting factor could be reduced by: (1) including specialist extension staff in the project, even if for only a limited time, to help develop the transfer process; and (2) assessing at the project design stage whether effective plans for extension and transfer throughout the life of the project and beyond are in place.

Fourth, a lack of resources to enhance human capacity and skills, provide equipment, and set up trials or demonstrations can impede the uptake of research results. For example, there has been good uptake of mud crab farming in Vietnam, but the situation is different in the Philippines where the lack of demonstrations has inhibited uptake. Another example is the project on tree establishment and production technologies, where the lack of a seed source and training in nursery management for the introduced species and information on their uses are all factors limiting adoption in the Philippines. This sort of problem can be addressed by ensuring that there is adequate provision in the project proposals for capacity building, equipment, and local demonstrations or trials.

Fifth, the absolute or relative cost of using the project results may be a significant inhibitor to adoption, particularly if immediately cheaper alternatives (albeit socially or environmentally costly in the long term) are available. This is clearly a major factor limiting the uptake of the mineral spray oils developed in the project on integrated control of citrus pests in China and South-East Asia. In this situation, it may be very difficult to convince the local community groups to accept the recommendations of the projects, especially when the competitors have large budgets to promote their products, and the targeted users are poor. Nevertheless, it may be possible to ensure that the policy-makers and government officials are aware of the project activities and results, and the potential social, economic and environmental benefits if the results are taken up.

Finally the socioeconomic, political and legislative climate of ACIAR's partner countries can at times inhibit or slow the progress on a project and, therefore, inhibit or delay adoption of the results. While there has been some success in Sri Lanka with policy change in relation to land degradation, the instability of the political situation makes long-term planning for the environment a low-priority issue for the government.

Further, success with the development of techniques for the control of peanut stripe virus will depend on government decisions regarding the use and transfer of genetically modified organisms. Where possible, careful attention needs to be paid to current or likely future government policies during the project development phase.

Impacts and lessons learnt

At ACIAR, an impact is defined as a *change* that has occurred:

- at the community level;
- at the scientific level; or
- in research capacity.

A community impact should be interpreted as an impact beyond the scientific sphere. It refers to any *change* in social, economic, or environmental conditions due to the uptake of information or technology by individuals or groups (including government) as a result of the project. A capacity building impact is a *change* in the knowledge and skills of researchers (particularly those in the partner country), which has occurred through their participation in the project and its training elements. Capacity also refers to equipment (hardware and software), buildings and infrastructure provided through the project that enables researchers to continue research outside the scope of the project. A scientific impact is a *change* in scientific practices that have occurred *outside* the project because of the findings of the project.

Community impacts

Where relevant and possible, the difference the project made at the community level is described in the adoption studies. A summary of the information contained in the adoption studies about community impacts is given in Table 3. In general, evidence of community impacts is limited. This is not surprising given that the lag from the completion of an agricultural research project to impact is generally longer than three years, and considerably more so in the case of pure scientific research projects that do not directly lead to the development of a new technology or process.

There was significant evidence of community impacts for two research projects that were developed to deliver new technologies or practical approaches. These were: in Vietnam, the mud crab aquaculture project; and in China, the ectomycorrhizal fungi for eucalypt plantations project. In the case of the mud crab project in Vietnam, for example, there was substantial expansion in mud crab hatchery and nursery production, and in the number of grow-out ponds owned and operated by smallholders. As hatchery-produced crablets are cheaper and have a higher survival rate than wild stock, the returns to smallholders from mud crab production increased.

Over the last 20 years, ACIAR has funded seven projects related to the development of high-yielding eucalyptus plantations in China, including the one on ectomycorrhizal fungi for eucalypt plantations. As a result of the substantial investment, China now has a thriving eucalypt plantation industry with about 1.5 million hectares of trees planted. The expansion of the forest industry in China, even into tracts of unproductive land previously considered to be commercially nonviable for eucalypts, has had a positive impact on rural communities by providing employment in rural areas. This is likely to continue into the future.

Table 3: Summary of impacts: what difference the projects have made to the social, economic or environmental wellbeing of a community

Project	Social, economic and/or environmental impacts
New technology, practical approaches	
Integrated control of citrus pests in China and SE Asia	The use of horticultural mineral sprays could result in significant economic and environmental benefits. However, the availability of cheaper synthetic alternatives has been a significant factor limiting uptake and the realisation of these benefits.
Development of improved mud crab culture systems in the Philippines and Australia	There has been very limited impact due to virtually no uptake because of 'wait and see' attitude.
Development of leading centres for mud crab culture in Indonesia and Vietnam	Farmers are realising increased profits as a result of a rapidly growing domestic and export market for mud crabs. Environmental benefits are evident.
Ectomycorrhizal fungi for eucalypt plantations in China	Positive impact due to the use of previously unproductive land and greater commercial investment in eucalypt plantations. Some potential for displacement from other land uses.
Tree production technologies for the Philippines and tropical Australia	In some areas, reforestation is occurring and community-operated nurseries have been established. However, the potential impact is yet to be realised because of industry fragmentation and lack of support.
Phosphine resistance in insect pests of stored grain	Two large grain storage corporations in India have reduced grain losses and labour and fumigant costs by adopting the results of the project.
Scientific knowledge/understanding (pure science)	
Improved diagnosis and control of peanut stripe virus	No community impacts because no transgenic peanuts have been released as a result of the project. Use of the project-developed diagnostic tests for PStV in seed has also been constrained
Control of bacterial wilt by agricultural biotechnology	Community impacts are not expected to be realised until around 2010.
Knowledge, models and frameworks to aid policy- and decision-making	
Optimal land use in Sri Lanka with particular application to land degradation and plantation industries	While it is difficult to identify and measure the impact of a project-induced policy change, it appears that in a number of instances, the project played a role in achieving policy reform that has the potential to reduce land degradation, and increase land viability and economic stability.
Accelerating growth through globalisation of Indian agriculture	Too early for the project to have had any measurable community impacts although there has been considerable uptake of the frontier production function methodology at the academic level.
Analysis of socioeconomic and agribusiness developments in the Chinese cattle and beef industry	Improved efficiency of the beef industry and increased direct investment by Australia and others.
Computer-assisted learning as a tool to improve grain storage pest management in key ASEAN countries	The rate of uptake in the four countries reflects the levels of investment and interaction in the training courses, with Vietnam being by far the highest. In principle, the increase in technical skills of people involved in postharvest technology will, in turn, lead to reductions in commodity losses and treatment costs.

Projects that generate new scientific knowledge or understanding (pure research) are often an important step in the development of new applied technologies but are, by their very nature, well removed from changes by final users or a community impact. Not surprisingly then, the adoption studies found that there were no realised community impacts for the projects on the control of bacterial wilt by agricultural biotechnology and improved diagnosis and control of peanut stripe virus. Nevertheless, the results of these projects either have been taken up or are likely to be by the next users – primarily scientists – so it may be that this early work could ultimately lead to applied research that will develop new technologies or processes that will be taken up by the final users.

There are many factors that influence policy-making and it is difficult to assess the contribution of an individual ACIAR project to changes in policy. Nevertheless, evidence from the adoption studies for the project on the Chinese cattle and beef industries suggests that this project has made a significant difference at the community level. It is also likely that the project on optimal land use has influenced some policy reform in Sri Lanka which has impacted on the wellbeing of some poor producers and consumers.

Capacity-building and scientific impacts

Capacity-building and scientific impacts are often described in terms of products (scientific papers, publications, seminars etc.) rather than improvements in the scientific capability of a country outside the sphere of the project. While a link between the number and types of papers published and capacity-building and/or scientific impact is often made, this link may give a false impression. Skills and knowledge gained within a project (as evidenced by research papers and reports) may or may not be used or drawn upon once the project is finished. Nonetheless, there is considerable evidence contained within the adoption studies which indicates that the projects in general had capacity-building and/or scientific impact.

As an example, teachers, researchers and policy-makers familiar with the results of the ACIAR-funded project on accelerating growth through globalisation of Indian agriculture are of the view that the project has already, and will continue to, strengthen capacity to use the frontier production function methodology and software to analyse productivity levels and allocative inefficiencies in agriculture and other industries in India.

There has also been significant recognition of the work the project scientists undertook, both within and outside the scientific community. For example, scientists involved in the development of mud crab aquaculture in Vietnam have received numerous awards and recognition. Similarly, even though there has been limited uptake of mud crab aquaculture in the Philippines, scientists there have attracted funds for ongoing research and regularly network with other scientists.

The study on ectomycorrhizal fungi for eucalypt plantations in China is an excellent example of how a project can leave a legacy in the form of a group of trained scientists able to carry on further research and with enough credibility to gain more funding. Indeed, the ability of in-country scientists to obtain further funding is a common successful feature in many of the ACIAR projects.

Another significant impact is the use of knowledge and techniques in tertiary education, where students are being attracted to courses in 'newer' sciences such as biotechnology.

On the other hand, factors that inhibit capacity-building and scientific impacts include the transfer of trained scientists to other roles, institutions or projects and, in some cases, the choice by some scientists to move to other countries to further their careers. It is, of course, not known whether these scientists will return to their own countries in the future.

Optimal land use in Sri Lanka with particular application to land degradation and the plantation industries (ADP/1992/012)

Anthony Chisholm

Collaborating organisations:	La Trobe University, Australia (LTU); Ministry of Plantation Industries, Sri Lanka (MPI)
Project leaders:	Prof. Anthony Chisholm & Dr Sisira Jayasuriya (LTU); Dr Anura Ekanayake (MPI)
Related projects:	PN/1992/011, PN/1992/001
Principal researchers:	Dr Jayatilleke Bandara, Griffith University; Dr Ian Coxhead, University of Wisconsin
Duration of project:	1 July 1993 – 31 December 1999
Total ACIAR funding:	$572 116
Project objectives:	The objectives of this research were to formulate a set of policy proposals to develop an improved pattern of land use management, which would increase net social benefits. A CGE model was constructed to account for on-site and off-site interactions; upland and lowland agricultural sector interactions; and intersectoral and economy-wide factors. A number of policy areas were analysed to determine the most efficient combination of policy changes for the desired objectives of improved soil structure on-site and reduced sedimentation off-site, including trade taxes, exchange rate policies and direct soil conservation oriented tax/subsidy measures. Policy recommendations were also made in other relevant areas including land tenure, replanting and land quality mapping.
Location of project activities:	Sri Lanka

Overview

La Trobe University, Australia, and the Sri Lankan Ministry of Plantation Industries (MPI) collaborated on an ACIAR-funded project (ADP/1992/012) to increase understanding of the importance of land degradation in Sri Lanka by policy-makers, administrators and researchers. The project resulted in a number of policy recommendations to control land degradation in Sri Lanka. Implementation of these policies varies and is discussed in detail below.

Project achievements

The researchers needed to gather and analyse data concerning land use and its impact to underpin their policy recommendations. As a result, there is now the most comprehensive collection of biological and economic data and other dispersed material concerning the on-site and off-site effects of soil erosion in Sri Lanka. This includes a GIS-based, detailed map of land degradation in the major Mahaweli catchment (the first map of its kind in the country); the construction of the most up-to-date input/output table for the Sri Lankan economy; and evidence relating to the effects of soil erosion off-site as well as on the yields and financial performances of various perennial and annual crops.

In addition, the construction of a computable general equilibrium (CGE) model, which explicitly takes into account off-site as well as on-site consequences of soil erosion, was a pioneering effort. It is the first time, to our knowledge, that a CGE model anywhere in the world has been adapted satisfactorily to incorporate detailed bio-economic relationships pertaining to land degradation problems.

Much of the research data was published in the proceedings of a national policy forum and technical workshop held in Colombo in December 1997. The 600-page publication *Economic policy reforms and the environment: Land degradation in Sri Lanka* (A Chisholm, A Ekanayake & SK Jayasuriya eds, Ministry of Public Administration, Home Affairs, Plantation Industries and Parliamentary Affairs of Sri Lanka, Colombo, 1999) contains contributions from economists, scientists, engineers and public administrators. The topics cover land degradation and tea and rubber production, the impacts of land degradation on hydropower generation and road systems, and CGE modelling of economy-wide impacts. The publication continues to be the most comprehensive primary reference source on land degradation issues in Sri Lanka. Other publications included papers in the *Australian Journal of Agricultural and Resource Economics*, the *American Journal of Agricultural Economics*, the *Sri Lankan Journal of Agricultural Economics*, the *Proceedings of the Resource Policy Consortium Symposium* (Washington, DC), the *Journal of Environmental Modelling and Software* and the *Journal of Policy Modelling*.

The project also had a significant postgraduate training component. Three Sri Lankan PhD candidates and one Masters candidate did their research on various aspects of land degradation problems in Sri Lanka. All graduated from La Trobe University under the supervision of Professor Anthony Chisholm and Dr Sisira Jayasuriya. The Masters student has since completed a PhD at La Trobe. A further successful PhD candidate in economics at La Trobe returned to Sri Lanka in 2002 to take up a position with the Tea Research Institute. Of the above five PhD graduates, three returned to Sri Lanka, one remained in Australia and one may return to Sri Lanka. Finally, a successful PhD candidate with the Food Research Institute, Stanford University, worked for six months under the auspices of the project. About four months was spent at La Trobe, under the supervision of the project leaders, and two months at the Institute of Policy Studies, Colombo. The outcome was a published paper on institutions (with particular application to land tenure and rural credit) and land degradation in the Sri Lankan hill country.

External influences

The Sri Lankan economy and people have endured a draining civil war for the past 20 years. In the first three and a half years of the 21st century, four Sri Lankan governments have held power. From 1995 to 2000, the main policy platform of the first government in power was liberalisation with a human face. Unemployment was maintained at a low level but the level of government spending, the budget deficit and rate of inflation rose to high levels. The second government held power for only one year from 2001 to 2002 and essentially maintained a similar policy. From January 2002 to April 2004, the over-riding goal of the third government was to curtail the budget deficit. It succeeded in reducing it from 10.5 to 7.8 per cent, and interest rates were reduced from around 18 to 8 per cent. The cut in government expenditure was severe and widespread. This government also adopted a pro-trade liberalisation stance and general trade liberalisation reforms were introduced in December 2003. In April 2004, the fourth government gained power. This government has a poverty alleviation (subsidy-based) stance and is likely to favour smallholder farmers producing agricultural and plantation crops. Government spending and the government budget deficit are likely to increase under the new government. The new government is less sympathetic to trade liberalisation reforms.

Land degradation happens slowly. Timing is not critical in the implementation of policy reforms to combat soil erosion. In the above economic and political setting, it would not be surprising to see a delay in implementation of policies to combat land degradation.

Unexpected outcomes and spin-offs

Dr Anura Ekanayake, the project leader based in Sri Lanka, played a pivotal role in communication with and influence on policy-makers. Over the most crucial years of the project (1995–1998), Dr Ekanayake was in almost daily contact with the Minister of Public Administration, Home Affairs and Plantation Industries and in weekly contact with the Prime Minister. He has an outstanding blend of skills including considerable powers of persuasion, diplomacy and political know-how. Some of our ultimate policy recommendations, such as land tenure reforms and reduced restrictions on potato imports, were being promoted at a relatively early stage of the project and Dr Ekanayake was in a position to play a crucial role. Dr Ekanayake's appointment as a Director of Unilever at the beginning of 1998 was a considerable loss to the Ministry and to the communication of recommended policy reforms to policy-makers.

Whilst not based in Sri Lanka, Dr Sisira Jayasuriya (co-project leader in Australia) made many trips to the country and in the latter stages of the project was working actively at the highest level of government on economic policy. Dr Jayasuriya's expert knowledge of economic policy issues and the plantation industries, combined with his network of high-level government policy contacts, made him a valuable advocate for policy change.

A noteworthy point is that some of the project postgraduate students were experienced in research and held influential positions in departments of collaborating institutions. In particular, Dr P. Samaratunga was an agricultural and resource economist in the Department of Agriculture with an in-depth knowledge and experience of both the agricultural and plantation sectors. Whilst he was in Sri Lanka during his PhD candidature, and upon his subsequent return to the country, he was a valuable advocate for the project. Drs R Jayasuriya and W Somaratne were also good ambassadors for the project during and after their PhD candidature.

The difference the project has made

Trade liberalisation

Our analysis, which explicitly took into account economy-wide interactions, showed that trade liberalisation reforms in Sri Lanka would have a positive impact on land degradation, and other key environmental variables, as well as stimulating growth and enhancing economic welfare. This is in sharp contrast to the widespread speculation that trade liberalisation conflicts with environmental goals.

We therefore recommended that the environmental benefits of trade liberalisation should be taken into consideration in national economic policy formulation.

Import restrictions on potatoes were among the specific trade policy issues we tackled. The results were unambiguous: liberalisation of potato imports helps soil conservation. Import restrictions increase prices to consumers, encouraging cultivation on erosive soils, in turn degrading the valuable land resources of the uplands and reducing the country's irrigation water and hydropower capacity. We recommended that the long-term environmental and economic costs of maintaining restrictions on potato imports are very high and that they should be removed.

For many years, potatoes were a highly protected crop in Sri Lanka, with a complete ban on the import of consumption potatoes from 1968 to 1996. Potato cultivation therefore became very inefficient and yields declined by about 40 per cent. During the import prohibition potato growing was very remunerative, so most potato farmers did not adhere to recommended crop rotation practices. Continuous cultivation of potatoes on the same land led to soil-borne diseases, low yields and severe soil erosion. For these reasons, the cost of production of potatoes in Sri Lanka is extremely high compared to other countries like India and Pakistan.

In 1996, the Government announced that the imports of potatoes would be liberalised and duty waivers would be provided to further bring down prices (Central Bank of Sri Lanka*, Annual Report*, 1997). Imports of consumption potatoes increased more than fourfold from 25 740 metric tons in 1996 to 108 375 metric tons in 1997, and 116 000 metric tons in 1998, of which 86 per cent came from India and Pakistan (Central Bank of Sri Lanka, Annual Report, 1998).

During the early stages of the project (1994–95), we concluded that the high level of protection of the potato industry had a negative impact on aggregate economic welfare and on land degradation. I believe that the ACIAR-funded project played a significant role in achieving the above policy reform. The most important political factor influencing tariff reform was the favourable impact of lower prices on the cost of living. The realisation that potato growing caused land degradation and the goal of rationalising the tariff bans from a large to a small number provided additional support for the political decision. However, there is likely to be considerable political resistance to reducing the tariff below its current level of 35 per cent, partly because the overall tariff makes an important contribution to government revenue, and partly because potato producers are a relatively affluent and politically powerful group who would resist a lowering of the tariff on potatoes whilst the 35 per cent tariff was maintained elsewhere. Insightful discussions of general tariff and trade policy issues in Sri Lanka are contained in *Tariff and trade policy framework for Sri Lanka in 2003* (Centre for International Economics September 2003) and *Trade policies in South Asia: An overview – operational summary, poverty reduction and economic management, South Asia Region, May 2003* (World Bank 2003).

Land tenure and property rights

Land tenure systems play a critical role in decisions involving land conservation practices. Short-term tenure discourages land conservation and encourages land degradation. Existing land policies encouraged land degradation by not regularising or effectively policing encroachment of state lands.

We recommended that short-term leasing of state lands must be strongly discouraged, while existing legal provisions should be used to convert short-term leases to longer term leases (99 years) or to freehold, conditional on adoption of specified soil conservation measures. The granting of these conditional long-term leases should be considered for current 'encroached' lands, when there are no ecological reasons for prohibiting agriculture. In the case of the latter, stronger monitoring and enforcement is essential.

The post-nationalisation management of the tea (and rubber) estates from 1973 to 1991 resulted in widespread mismanagement and neglect, and had a devastating impact on productivity and land degradation. In 1992, short-term (five year) leases were introduced. From the beginning of the ACIAR-funded project, we argued strongly for the period of leases to be increased to 99 years, conditional upon the adoption of appropriate soil conservation measures. In 1995, short-term 5-year leases were converted to 53-year leases. Dr Anura Ekanayake played a crucial role in achieving this policy reform.

Tea and rubber production are long-lived investments. The optimum replacement period for well-managed seedling tea is around 70 years, and for vegetatively propagated (VP) tea about 60 years. The optimum replacement period for rubber trees is around 25 years. Some structural soil conservation measures have replacement periods of 100 years or more. Negotiations are currently taking place between the corporate tea sector (using in part the project policy recommendation) and the government sector to extend the lease term from 53 to 99 years. This is partly because of the long life of some of the structural investments, but is mainly due to the banks' financing requirements. The banks treat 99-year leases as a close substitute for freehold title and consequently are prepared to provide the corporate tea sector with more favourable terms of credit.

The ownership of smallholder tea and rubber lands is now almost exclusively freehold. Appropriate incentives to farm the land carefully are inherent under freehold title, providing that farmers are well informed, have reasonable levels of income, and credit is available at moderate interest rates.

A significant area of Forest/Crown land in Sri Lanka has been occupied by 'squatters', who are usually poor people with limited means of support and whose encroachments are therefore usually tolerated. Lacking any real property rights in, or security to, the land, the encroachers have had little incentive to implement soil conservation measures. Rather, the tendency has been to maximise production in the short run on an area of encroached land and then abandon the degraded land. A new area of land is then encroached upon. The resultant land degradation has been severe. Over the last five years, a policy has been progressively implemented to give security of tenure to selected encroachers by effectively converting the land to leasehold title. Conversion of encroached land to leasehold title is carried out on the basis of selecting potentially good farmers who have built their homes on the land. The term of the lease (permit) is for one year. Providing farmers adopt reasonable conservation measures and undertake no further conversion of forestland to agriculture, the permit is renewed annually. If farmers abide by these conditions, they have effective security of title. If they fail to abide by the conditions, the Department of Forest Conservation has the power to cancel the permit.

Where there are grounds for prohibiting agriculture for ecological reasons, or the encroached area is not the site of the farm family's home, a policy of stronger monitoring and enforcement is now being implemented.

A problem with some encroached forestland that we did not anticipate at the time of the project was one of property rights. In recent years, when the Department of Forest Conservation began to enforce its encroachment policy, some encroachers challenged the right of the Department to stop their farming activities. It became apparent that the boundaries of forestland over which the Department had authority were not clearly defined. A major project involving a clear and indisputable definition of these boundaries has now been almost completed. Following enforcement, the area of encroached forest land on which farming activities will be permitted to continue represents less than 1 per cent of total forest land and will not pose a significant soil erosion threat.

Encroachment can also affect railway land. Encroachers are increasingly cultivating land next to railway lines and planting annual agricultural crops with little, if any, soil conservation measures. Railway authorities claim that they do not have the power to remove encroachers. It is now clear that historically, property rights were not well defined on some important land areas. The main lesson to be learned is that property right issues are nearly always likely to be a significant factor in developing countries. To address problems like land degradation comprehensively, an attempt should be made to identify all areas of land for which property rights are poorly defined.

A further problem relating to property rights, was the current perceived magnitude of off-site soil/sediment problems caused by urban (and rural town) building activities. The most blatant manifestation of the problem is dumping unwanted excavated soil directly into waterways. Under the Soil Conservation Act, the Department of Agriculture has the authority to fine any individuals or firms not undertaking adequate soil conservation measures, wherever their activities may occur. Recently, however, the Department of Agriculture has delegated to local councils its soil conservation powers that relate to urban and rural town building activities. There is some anecdotal evidence that some local councils are reluctant to fully enforce these newly acquired powers because of their concerns about the negative impact on development. The overall quantitative off-site impact of the above 'new' sources of soil erosion and displacement is unknown.

During the project we also recognised the significance of public road development as a potential source of soil erosion. In turn, soil slips and erosion, which commonly arise from inadequate off-site conservation measures, can increase road maintenance costs. The Chief Engineer, Road Development Authority, prepared a research paper for the project. The Road Development Authority now implements strict procedures to prevent undue soil erosion during road construction and upgrading. I was personally impressed to see conservation measures comparable with best practices in a developed country being implemented on a major road development project between Kandy and the high-elevation town of Nuwara Eliya.

Replanting of plantation crops

Our project demonstrated that replanting of tea lands, or rehabilitation through infilling, is very strong on both environmental and productivity grounds if soil conservation measures are properly implemented during replanting. We therefore recommended that replanting and rehabilitation (infilling) of tea, with appropriate soil conservation measures, be actively encouraged and vigorously pursued.

Tea

About one half of the area of tea production occurs in the hilly and high country (up to an elevation of 6500 ft) and the other half in the low country. Soil erosion is not a significant problem in low country tea production.

The case for replanting tea and infilling (i.e. selective replanting in between thriving tea plants) where appropriate, is being vigorously promoted by the Tea Research Institute (TRI), the Tea Small Holdings Development Authority and the Ministry of Plantation Industries (MPI). In 1997, Dr Ekanayake used the findings from the project to support an application to the Asian Development Bank for funding a development project, with a substantial replanting/infilling component. The outcome was a $US94 million concessionary loan to operate over 1999–2005.

The major crops under the auspices of the MPI in the Corporate (Estate) sector are tea (67.5 per cent), rubber (13.8 per cent) and fuel wood/timber (15.9 per cent). About 53 per cent of the tea area is old seedling tea (OST) while 47 per cent is under vegetatively propagated (VP) tea. VP tea yields are around 80 per cent higher than OST. Moreover, VP tea provides excellent plant cover to protect the soil against erosion. Replanting and infilling are a crucial means of increasing tea productivity and controlling erosion. The soil loss from well managed VP tea is around 15 t/ha/year compared with 75 t/ha/year for the degraded areas of OST which are being replaced with VP tea. From 1993 to 2002, the area of replanting in the corporate tea sector was 5674 ha. The estimated abatement of soil erosion attributable to this replanting is 340 440 t/ha/year. Estimates of the area of infilling in the corporate sector are unavailable.

While tea replanting in the corporate sector has made an important contribution to soil erosion abatement, the annual rate of replanting remains well below the optimum. The desirable rate of annual replanting is around 2 per cent of the total tea area. Over the last decade the replanting rate achieved has averaged 0.70 per cent. Of some concern is the fact that the average annual rate of replanting between 1993 and 1998 was 0.88 per cent of the total corporate tea area (81 591 ha), but between 1999 and 2002 the rate of replanting slowed even more to 0.42 per cent. A possible explanation for this slowdown is that the real world price for tea was around 25 per cent lower over the period 1999–2002 compared with 1998. Also, there has been a labour shortage in the last few years in Sri Lanka, which has impacted on the highly labour intensive tea industry. Moreover, unlike the tea smallholdings sector, the corporate tea sector receives no government subsidy for replanting or infilling.

In the tea smallholdings sector there was a small increase in the annual area replanted and infilled between 1999 and 2002. The total area replanted in 2002 was around 0.8 per cent of the total tea smallholdings area (91 669ha). The above estimates of the areas of replanting and infilling in the tea smallholdings sector underestimate the true areas to some degree because they are based on data for the smallholdings that claim the subsidy incentives. These subsidies are conditional upon good soil conservation measures being adopted. Some smallholders choose not to implement the soil conservation measures and are thus not eligible to claim the subsidy.

Finally, recent research at TRI (2002) indicates that while the practice of infilling has an estimated benefit/cost ratio greater than one, the benefit/cost ratio for replanting is less than one, given the present price and cost regime. Our study strongly encouraged the practice of infilling, at the time of pruning, as opposed to uprooting entire blocks of land. However, the proportion of dead and very low-yielding tea plants is often too high to make infilling a practical alternative to replanting. An activity of considerable concern, but understandable in the light of the above research, is the practice adopted by some tea estate managers to lease out tea land to potato-growers.

Rubber

Rubber trees are mostly grown in the mid-country. We found that by the mid-1990s rubber was not a significant contributor to Sri Lanka's overall soil erosion problem. Indeed, the soil loss under well-managed rubber plantations is very low, usually not more than 10 t/ha/year. At the time of the project we did not see the need for a specific policy recommendation for rubber. Following the nationalisation of estates in 1975, rubber production in Sri Lanka declined by around one third between 1978 and 1993. Following privatisation of estates in 1993, production had increased by about 10 per cent to 1996. However, rubber prices peaked in 1995, declined for a short period and then fell dramatically. Between 1999 and June 2002, rubber prices were only one half of the 1995 level. From 2000 to 2002, rubber production was around 20 per cent lower than its 1996 level. Significant areas of rubber land were neglected or poorly managed and soil erosion increased.

At the time of our study, we believed that the relatively low rates of soil erosion were likely to be slowly reduced. We did not anticipate the dramatic fall in rubber prices. There is, however, a silver lining to the rubber story. From June 2003, rubber prices began to rise and they have risen dramatically over the past 12 months. In early June 2004, Colombo rubber prices were the highest ever recorded. In a recent statement, the Additional Secretary, Ministry of Plantation Industries, Mr YG Wijeratna, announced government plans to upgrade rubber research and improve the smallholder sector. Subsidies for replanting and new planting, subject to growers adopting appropriate soil conservation measures, will be increased from A$724/ha to A$14 493/ha, which represents 40 per cent of the total cost of replanting. The new scheme will be mainly financed from a rubber production levy (to be introduced on 1 July 2004). The rubber sector is now viewing the future with considerable confidence and a surge in replanting and new planting of rubber trees is anticipated. A significant beneficial impact on soil conservation is to be expected. Infilling is not a practical alternative to replanting for rubber.

The major lesson to be learned is that large changes in product prices, if sustained for lengthy periods, will have substantial impacts on production and soil conservation. It is noteworthy that unlike the old replanting incentive scheme, the new subsidy scheme incorporates soil conservation measures. The project may have played a small role in the socially beneficial policy change, but the dominant driver of policy change is very high product prices.

Conversion of uneconomic tea and rubber lands to fuel wood and timber plantations

The conversion of poorly managed tree crops or erosion-prone annual crops to well-managed plantation crops (or, depending on specific circumstance, to other perennial crops, forestry and less erosive land use systems) which minimise soil erosion, is more productive, profitable and soil-conserving in the long-run. However, the employment implications of such changes need to be further studied.

We recommended that additional information be urgently gathered on current land use, soil profiles and profitable alternative land use systems, to develop more specific recommendations tailored to particular circumstances.

Up until the late 1990s there was widespread reluctance to admit that some land had become uneconomic for tea and rubber production. The problem of uneconomic eroded tea land in the mid-country has been particularly acute. From 2000 onward, there has been increasing and widespread acceptance by the corporate sector of the need to plant uneconomic tea and rubber land with other soil-conserving perennial crops. The increasing recognition of the need to change the land use of such areas is reflected in a significant

growth in the area under fuelwood/timber production. The fuelwood/timber area in 2002 comprised 15.9 per cent of the total corporate sector land area (TRI, 2003). Most smallholdings are too small to permit viable production of fuelwood/timber. The fuelwood/timber area now exceeds the area of 13.8 per cent under rubber production. Around 78 per cent of the combined fuelwood/timber is estimated to be under fuelwood. Fuelwood cultivation in the up-country has been estimated to yield a benefit/cost ratio significantly greater than one (TRI, 2002).

Our concern about the lower employment opportunities on land used for fuelwood or timber, compared with the labour intensive tea and rubber production activities, is much less relevant at a time of labour shortages.

Soil conservation incentives for smallholders

Whilst trade liberalisation had a positive impact on the environment, our CGE modelling revealed that trade liberalisation measures were still not sufficient to ameliorate the land degradation problem to desirable levels. We concluded that policies that directly encourage soil conservation measures and less erosive land use practices were required.

The major form of assistance for smallholder tea producers is an incentive payment for replanting, infilling and new planting. The incentive payments scheme has been operating for over 20 years. The incentive payment for replanting (per ha) and for infilling (per plant) on smallholder tea lands was substantially increased in 1999. From 1999 to 2002, the annual incentive payment for each of these activities was about 40 per cent higher than for the period 1996–98. The incentive payments are conditional upon smallholders implementing appropriate soil conservation measures. Well-managed replanting and refilling are the major means of combating soil erosion. The incentive payments are a close proxy for direct subsidisation of the soil conservation measures. The main difference is that an unknown number of smallholders choose not to implement all the required soil conservation measures at the time of their replanting and infilling activities and do not claim the incentive payment.

The revenue for the smallholder incentive payments is acquired through a levy (Cess) on total tea exports. The Cess payments also fund the TRI. Through its Cess payments, the corporate tea sector, like the smallholder sector, receives the benefits derived from the research and extension activities of TRI. However, it effectively cross-subsidises the replanting, infilling and new planting activities of the smallholder sector.

Around 60 per cent of rubber production is consumed domestically and 40 per cent exported. Cess payments for the rubber sector were abolished in May 1998, due to very low prices. However, incentive payments for replanting and new planting continued, albeit at lower aggregate levels due to the slump in rubber prices. During the period of the world price slump, the Rubber Research Institute (RRI) budget was severely cut. Following the recent dramatic upsurge in world rubber prices, the Additional Secretary of the MPI announced (June 2004) that Cess payments will be reintroduced, and incentive payments for smallholders for replanting and new planting of rubber will be substantially increased along with the budget of the RRI. These incentives will make a significant contribution to reducing soil erosion, but the major contributor will be high world prices.

Agricultural crops grown in the mid and high country (up-country) are a major contributor to off-site erosion problems. Tobacco growing was potentially a highly erosive activity in the hill country. Fortunately, over the last decade, growing tobacco under irrigation in the low country has been found to be a good substitute for producing it in the higher country. There is now a negligible area of tobacco grown in the up-country.

The soil erosion impacts, particularly off-site, of annual agricultural crop production in the higher hill country continues to be a major concern. The only subsidy for annual agricultural crop production relates to a subsidy on the fertiliser urea introduced by the new government (April 2004), largely in response to lobbying by paddy farmers. The fertiliser subsidy is not conditional upon implementing soil conservation measures. For agriculture, it appears that the overriding industry and government priority is for high output of annual vegetable crops over the short and medium term. Soil erosion, whilst causing damaging off-site impacts, appears not to substantially affect the on-site productive capacity of the land in the short to medium term. With no subsidy incentives or enforced regulations to implement soil conservation measures, hill country farmers largely continue to ignore the off-site impacts of their cropping activities. Consequently, from the viewpoint of society as a whole, the level of soil conservation measures is sub-optimal. The Department of Agriculture, under the Soil Conservation Act, has the legal powers to fine farmers who are not adopting appropriate soil conservation measures. However, these regulations have not been enforced. No farmer has been fined for not adopting appropriate soil conservation measures in the past 30 years. Conservation techniques such as terracing are only compulsory when cropping occurs near major towns (for example, Nuwara Eliya). A more widespread potential force to control high country soil erosion is the combined political power of lowland irrigation farmers if they feel their water supply is threatened by sedimentation of reservoirs.

The continuing production orientation of the agricultural sector, with inadequate allocation of resources to soil conservation, is disappointing, but understandable from a political economy perspective. With the exception of potatoes, the annual food crops are essentially non-traded goods, the production of which is dominated by smallholders. Governments and administrators are extremely reluctant to introduce and enforce legislation, such as compulsory soil conservation measures, which is likely to increase domestic food prices or reduce farmer profits in the short to medium term. Unlike the export-orientated plantation crop sector, the imposition of a production levy to finance soil conservation subsidies in the agricultural food sector appears to be politically unacceptable. Neither does the government currently appear to have the revenue to fund such subsidies itself.

Smallholder access to credit

There is a case for serious consideration of government assistance for land managers to undertake soil conservation measures, and in particular for smallholders whose access to credit is limited. We are very conscious of the constraints on government funds, and the past experience of various subsidised credit schemes. Nevertheless, the nature of the soil erosion problem warrants placing this issue on the agenda. We recommended providing carefully targeted government assistance for land conservation and that consideration be given to making land conservation mandatory to qualify for agricultural subsidies. We also recommended urgent discussion of issues such as the manner in which funds for assistance should be raised, and the specific forms for dispensing such assistance to avoid inefficiency and costly monitoring.

In the tea and rubber smallholdings, the payment of incentive subsidies for replanting, infilling and new planting is now conditional upon farmers adopting appropriate soil conservation measures. In the food crops sector there are no subsidies (carrots) listed with soil conservation measures and there is no evidence of the Department of Agriculture using its power (stick) to fine farmers whose activities are in breach of the Soil Conservation Act.

Various concessionary loans from the Asian Development Bank to rural government agencies have a component which targets soil-conserving practices. As previously mentioned, the project was influential in helping the MPI secure a substantial loan of this type from the Asian Development Bank. However, the over-riding goal of the immediate past government to substantially reduce the government budget deficit precluded any government action to use government revenue to provide easier access to credit for smallholders for soil conservation orientated farm expenditures. Although the new government is likely to be more sympathetic to smallholders, it is too early to judge whether or not it will be more active in this area.

Farm extension

Farmers' perceptions of soil losses under different land use systems and management practices, and their productivity implications, are crucial to adoption of soil conservation practices. While farmers have a very good understanding of the land quality implications of traditional farming systems and practices, this is not the case with newer crops and cultivation systems. We feel that there is a case for an extension effort to provide better information on the long-term effects of land degradation and the productivity implications of specific soil conservation practices to farmers.

The TRI and RRI have strong advisory and extension activities, including the training of officers well qualified in techniques of sustaining high levels of output in conjunction with appropriate soil conservation measures. The TRI owns and commercially operates a tea estate which facilitates the training of extension officers, and is used for tea grower field days as well as being a valuable research resource. The Advisory and Extension Service of TRI has in particular displayed considerable energy and enterprise in recent years. They have communicated with and surveyed every estate in the corporate tea sector. The TRI is currently undertaking a similar exercise for the smallholdings tea sector. An advisory orientated research project on the cost of tea cultivation has recently been completed, including benefit–cost estimates of the return to replanting, infilling, intercropping and fuelwood cultivation (J Jayakody & H Shyamalie, *Cost of tea cultivation*, Tea Research Institute of Sri Lanka, April 2002).

Between 1999 and 2002, the research and extension/advisory activities of the RRI suffered as a result of very low world prices. The recent announcement by the Additional Secretary of the MPI will ensure a substantial increase in the resourcing of both activities.

In the plantation sector, particularly in the up-country tea sector which has a higher potential for erosion, it is apparent that over the last decade, there has been an increasing awareness and understanding of land degradation processes and problems and appropriate conservation measures to combat them. The extension and advisory services in the plantation sector have without doubt contributed to this situation. We believe that the project has also made a contribution. A significant initiative of the project was to prepare 25 000 copies of an extension pamphlet on the national problem of soil erosion. The pamphlets were printed in English, Singalese and Tamil. These were distributed widely to extension personnel and schools.

Of course, to have knowledge of sound conservation measures is a necessary but not sufficient condition for their implementation. TRI is currently undertaking a research project to determine the gap between its recommended practices and actual on-farm practices and attempting to identify the factors contributing to the gap. Clearly, if there are times when farmers' product price expectations and cost estimates point to negative profit expectations for some recommended practices, they are unlikely to be implemented.

The Environment and Forest Conservation Division, Mahaweli Authority, in addition to its GIS mapping activities, has an active Catchment Conservation Program based on inclusive participation. The program involves awareness creation and training and mobilisation of inhabitants of the catchment area for action. Target groups include school children, local political leaders, smallholder farmers, managers of large estates and government and NGO officials at various levels. The use of a soil conservation measure with a high potential, Sloping Agricultural Land Technology (SALT), has been particularly actively promoted. The implementation of SALT has expanded significantly in recent years. The promotion of the protection and scientific management of the catchment by the above Division is technically assisted by the United Kingdom and Germany through their donor arms. This has helped insulate the extension and scientific watershed management activities of the Division from the widespread budget cuts introduced by the previous government.

In the Department of Agriculture in the early 1970s, the positions of about 65 soil conservation extension officers were abolished. The administration of the extension service was decentralised and extension officers became general agricultural advisers. There is some criticism of the current agricultural extension system, especially that extension officers were giving overriding priority to current high production of annual crops and according a low priority to soil conservation.

Cost-effective technologies

Land conservation takes place only when cost-effective technologies are available and when farmers are aware of them. Land conservation methods which ignore potential off-site effects may be attractive from a private point of view, but their overall effects may not be socially desirable. We believe that there is a need for research institutes to actively pursue a program for the generation of cost-effective new technologies which take into consideration the spillover effects of land conservation practices.

Major measures for soil conservation – such as contour banking, terracing, contour and connecting drains, growing and mulching with Guatemala or Mana grass and SALT – have been used for many years, though there is continuous refinement of these techniques. Perhaps the most noteworthy new technology is the TRI work on developing a new clonal variety of seedling tea to plant in conjunction with vegetatively propagated (VP) tea. The VP tea used to replace the old seedling tea (OST) yields about 80 per cent more. Moreover, the VP tea provides a denser cover and more protection to the soil than OST although its leaf quality is lower. The new varieties of seedling tea, expected to be commercially released in the next year or so, have a considerably higher leaf quality than VP tea whilst also providing a level of soil protection comparable with VP tea.

Land quality mapping

As part of the research project, the GIS mapping project being undertaken at Polgolla by the Environment and Forest Conservation Division, Mahaweli Authority, has been instrumental in producing an indicative map of land quality in the important Mahaweli catchment area. We recommended that this work should be continued and expanded and collaboration between the Environment and Forest Conservation Division and agricultural research institutes, commercial plantations and other land use planning bodies should be encouraged.

The GIS map of land quality/degradation in the Mahaweli catchment produced in 1997, under the auspices of the project, has since been extended and refined. Complimentary maps of soil type and of contour and slope were completed in 2000. A land use map of the catchment area is currently being updated. In

2003 the Natural Resource Management Centre, Department of Agriculture, completed a complementary Soil Erosion Hazard mapping exercise for the entire country. The above maps are being used by relevant authorities to prioritise activities to combat land degradation. However, the Natural Resource Management Centre, which charges clients for its mapping services, is disappointed that only a few clients are currently purchasing its Soil Erosion Hazard mapping services.

Project impacts

Many changing factors influence government policy and it is usually very difficult to know the contribution of individual ones. The publicly stated reasons for enacting new policy may bear little relationship to the true reasons. Moreover, there is often a considerable lapse of time between the initial exertion of forces towards a policy change and ultimate government action.

For a project like the Sri Lanka land degradation project, apart from the problem of disentangling the influence of the ACIAR-funded project from the influence of other forces on a particular policy outcome, there is a further challenge, namely, that a number of policy recommendations relating to combating land degradation problems were made. It would be a substantial research task to identify the community impacts (social, economic, environmental etc.) of one policy change. It would be a virtually impossible task to quantify the individual impact of each of a number of policy changes, all of which have some influence on land degradation.

There is no quantitative measurement of the aggregate level of soil erosion over time in Sri Lanka. The best 'guesstimate' is that there was an escalating process of land degradation over the period of nationalisation of the tea and rubber estates (1975–1992). The expansion of the area of erosive annual cropping over this period coupled with increasing land encroachment, as a result of population growth, exacerbated the land degradation problem. Without doubt, over the last decade the *rate of escalation* of land degradation has been substantially reduced. It may now have stabilised. Ideally, continuous measurement of both stream sediment loads and reservoir siltation levels in the high, mid and low country should be undertaken. However, this is a costly process and the existing network of monitoring is patchy. For example, the sediment levels in some major reservoirs have not been measured for over a decade.

Even if accurate information on levels of soil erosion over time were available to help with assessing the impact of policy change, there are other complicating factors. For example, there is some evidence that the rainfall pattern has changed and the incidence of severe erosion-inducing storms has increased. Similarly, changes in world commodity prices will influence the level of land degradation. Obviously, the impact of policy change cannot be determined simply by observing trends in levels of land degradation, even if good quantitative data were available.

The high cost of monitoring some environmental impacts has led some researchers to suggest that the best indicator of sound environmental management may be the nature of the policies or institutions designed to protect the environment. In the reviewer's judgement, there has been a significant improvement in the policies and institutions (taken as a whole) directed toward combating land degradation over the last decade, and in some areas the ACIAR-funded project has been influential in effecting these changes. Of course, apart from the structure and nature of the institutions to combat land degradation, maps showing changes in land use and land quality over time are also valuable indicators. Hopefully, future GIS maps of the Mahaweli Catchment will be able to be compared with the pioneering 1997 map and they will show a decline in the areas of degraded and degrading lands in Sri Lanka.

Accelerating growth through globalisation of Indian agriculture (ADP/1994/026)

Ric Shand

Collaborating organisations	Research School of Pacific and Asian Studies, Australian National University, Canberra, Australia (ANU); Madras School of Economics, Anna University, Madras, India (MSE)
Project leaders	Dr K P Kalirajan (ANU); Professor U Sankar (MSE)
Related projects	ANRE/90/38, ANRE/92/28, EFS/88/38, EFS/90/22
Principal researchers	Dr Richard Shand (ANU)
Duration of project	1 July 1996 – 31 December 1999
Total ACIAR funding	$494 702
Project objectives	The aim of this project was to review existing agricultural policies and identify factors that restrict growth potential. Using computer models, policy changes were made that improve resource allocation and the distribution of benefits of economic growth. This project formulated disequilibrium econometric models that incorporated not only known relationships between supply and demand, but also imperfect information. Using these models, the agricultural, manufacturing, and service sectors of the economy were able to interact. Inefficiencies resulting from organisational and non-price factors as well as policies were also examined.
Location of project activities	States of Bihar, Karnataka, Punjab and Tamil Nadu, India

Overview

As the result of an ACIAR-funded project on accelerating growth through globalisation of Indian agriculture (ADP/1994/026), a number of economists and academics, government agencies and policy-makers in India have the capacity to use the frontier production function approach to analyse agricultural productivity. This project was undertaken by the Research School of Pacific and Asian Studies at the Australian National University (ANU), in collaboration with the Madras School of Economics (MSE), Chennai, India.

The project has led to increased awareness by farmers about the potential to improve yields and to increase agricultural incomes. Farmers and policy-makers also better understand the importance of food-processing and export of processed foods, the role of the WTO in facilitating agricultural growth in developing countries (especially India), and the effects on agriculture of changing some policies such as education expenditure and infrastructure.

Project achievements

Annual project meetings were held in 1997 and 1998 in Madras and in 1999 in Delhi. At these meetings progress was reported by team leaders and discussed with some ten prominent Indian research economists and policy-makers from the Indian Planning Commission; Ministry of Rural Areas and Employment, Government of India; State Planning Commission, Tamil Nadu; Agricultural Economic Research Centre, Delhi; Delhi School of Economics, Rajiv Gandhi Foundation, Delhi; Andhra University and Indian Institute of Technology, Chennai.

The project outputs included two books authored by project participants.

Three workshops were conducted to disseminate the objectives and the final results of the project to policy-makers and economists in India. The first was in 1998 on econometric methods of measuring productivity. Participants were from leading institutions such as the Indian Statistical Institute, Calcutta; Delhi School of Economics; Institute of Economic Growth, Delhi; Institute for Social and Economic Change (ISEC), Bangalore; Centre for Development Studies, Trivandrum; Madurai Kamaraj University, Madurai; Tamil Nadu Agricultural University; and Centre for Economic and Social Studies, Hyderabad. The workshop enabled dissemination of the frontier production function approach to a wide audience.

The second workshop was the project conclusion workshop in 1999 at which the project results and methodologies were critically discussed in relation to project objectives.

The third workshop was an International Conference on Second Generation Reforms in India also held in 1999. At this workshop, project leaders were able to give international exposure to results and methodology of the project. The Proceedings of this workshop were subsequently published in 2003, further disseminating the work of the project internationally.

After the project ended, the state-level and all-India results that came out of the project continued to be disseminated, as detailed below:

- Some 50 copies of the first book (KP Kalirajan, G Mythili & U Sankar eds., *Accelerating growth through globalisation of Indian agriculture*, Macmillan, New Delhi, 2001) were distributed to the Planning Secretaries of the four states included in the project; to senior agricultural economists throughout India and to some libraries of institutions offering courses in agricultural economics. The book is now used as a reference book in agricultural economics courses in a number of universities. Some teachers and researchers said that they were also using Chapters 3–7 in teaching a course on international economics.

- A long and favourable review article outlining the results of the project was published in the *Indian Journal of Agricultural Economics* (April-June 2003, pp. 287–292).

- Professor U Sankar participated in the WTO Cell in Tamil Nadu and transmitted project results. He is also a member of the State Planning Commission, Tamil Nadu. He prepared a Plan Report and had a meeting with the Planning Minister on reforms. Since there were no follow-up mechanisms in the project, the influences and policy responses could not be assessed in the other three states.

- The Agriculture Ministry of the Government of Karnataka invited Professor U Sankar to provide a review of the findings of the project.

- Dr Vijay Kelkar, Adviser to the Minister of Finance, Government of India, appreciated Chapter 4 on 'Measures of protection', and said it could be compact teaching or reference material. The research helped in getting a balanced view (positive benefits and likely adverse effects) of globalisation and for developing coping and facilitating mechanisms at state level.

- Some public sector firms (banks, thermal power stations) sought the help of the researchers and benefited during the workshop on econometric methods of measuring productivity.

The results of the macroeconometric study were published only recently (K Kalirajan & S Bhide, *A disequilibrium macroeconometric model for the Indian economy*, Ashgate Publishing Limited, Aldershot, UK, 2003) and so dissemination is at an early stage. However, the early qualitative evidence from several distinguished Indian economists who are familiar with the manuscript suggests that it will make a seminal contribution to research and policy analysis into interrelationships between sectors both at national and state levels and to identification of the policy variables that determine these interrelationships.

- Dr Radhakrishna (Director, Indira Gandhi Institute of Development Research, Mumbai) stated that he found the book very useful in his teaching, as the econometric methods used were innovative and useful in applied economics.

- Dr KL Krishna (former Professor at the Delhi School of Economics) has judged the work an important contribution to macroeconomic modelling in India. In a review for Ashgate Publishers, he stated '*In this truly unique and innovative macro-econometric study for India, two distinguished economists construct a comprehensive model of agriculture and other major sectors of the Indian economy and draw several important policy conclusions on the basis of simulations. The distinctive features of the study are the incorporation of the frontier production function framework and the analysis of the regional dimension of agricultural performance in the post-reform period. The study abounds in valuable analytical and policy insights*'. Dr Krishna sees a major contribution in methodology.

- In a review in the *Australian Journal of Agricultural and Resource Economics* (vol. 48, no. 3, pages 557–568), Renuka Mahadevan of the University of Queensland's School of Economics said '*The book strikes a good balance in its contribution on both theoretical and empirical grounds, thereby appealing to econometricians and modellers, as well as applied economists and policy makers who may or may not be working on India...On the empirical front, the study is enriching in two ways. The first is the computation of the refined efficiency measures in the agricultural sector for 15 Indian states. The second is the attempt to provide richer outputs in assessing the impact of economic reforms at the state level. These impacts were assessed in terms of fertiliser use, tractor purchase and stock, general efficiency, crop yield, and crop output, some of which were estimated as input demand functions, which is yet another contribution of the study. Such analysis incorporating a regional dimension is important, as across India the states are differentiated by the extent of adoption of modern inputs of*

high yielding seed, fertiliser and machinery, agro-climatic conditions, access to irrigation and markets, and the level of economic development. Therefore, a more accurate picture is seen to evolve for policy prescriptions in contrast to past modelling efforts and simulation exercises, which did not explicitly consider regional variations in production behaviour, thereby masking the impacts at the state level. A noteworthy point on the simulation analysis is that it not only considers specific measures to raise agricultural output but also macroeconomic policies that may have an impact on agricultural output…Overall … this book is extremely interesting and thought provoking in the way the authors model and discuss the empirical results based on various economic issues.'

- The book has been distributed to a wide range of eminent researchers and key policy-makers in India.
- Enquiries have been received in 2004 from the Ministry of Industry, New Delhi, to carry out some sectoral studies using the macroeconometric frontier production function methodology. This work will be done jointly by Dr Shashanka Bhide and Professor Kalirajan.
- Dr Kalirajan gave a series of lectures, including the topic of frontier production functions, at ISEC in September 2003.
- Dr Bhide presented the results of the macro-modelling to a workshop on rural infrastructure in New Delhi in November 2000.
- Dr Bhide made a presentation on the incorporation of the frontier production function in a macro-econometric model (Project LINK) in Oslo, September 2000.

The difference the project has made

There has been considerable uptake of the frontier production function methodology for analysing productivity in agriculture and other industries within the MSE and amongst some economists in ISEC in Bangalore. There are also a number of PhD students in other parts of India who have taken this methodology up in their research work.

Awareness of the frontier production methodology is a major contribution of this project. It therefore makes good sense to undertake follow-up studies, since it expanded research capability in the country and also highlighted some important research issues. Also, India has progressed further in terms of rationalising its tariffs and moving towards globalisation. There have been other issues that have deflected attention from productivity and efficiency but they should be kept in focus for long-term policy.

The project has brought to focus the need for analysis at the state level in a unique way. Although there have been many studies at the state level, the project made a significant effort to focus on the problems at the state level both in the framework of the national economy, as well as in the context of the states' own perspectives. In this sense, the project – the first of its kind – is likely to be recognised as an important benchmark.

The analysis at the state level was restricted by project resource constraints to the use of secondary data. Further valuable analytical insights could be gained from similar research work which could gather and use a primary data base with the methodology.

The project has addressed issues that required considerable analysis at the academic level. Logically, the next step should be to undertake further research work that would distil the findings in order to bring them to the operational level.

In this connection, and from a longer term perspective, there would be much merit in holding a regular annual or biennial conference on agricultural research and policy at two levels: one to bring significant academic research findings to the attention of policy-makers, and the second to bring the research findings to a level of actual implementation. This way the most pressing policy issues in agricultural reform and development could be addressed by researchers and policy-makers in a focused, continuous and coordinated fashion.

Project impacts

Community impacts

It is too early for the project to have had any measurable community impacts.

Capacity-building and scientific impacts

Economists, particularly at MSE, have been continuing their research using the methodology that has been developed, refined and disseminated through this project. Economists at ISEC (e.g. Dr Madheswaran) are also working on data in agriculture using the project methodology.

Several PhD students in universities in India have been working with this methodology. The frontier production function methodology, especially the computer software, has enabled researchers at MSE and other places to apply this approach to measure allocative inefficiencies in agriculture, banking, power, hospital and other sectors.

Those teachers, researchers and policy-makers familiar with this project and its results are of the view that the project has already, and will continue to, strengthen capacity resulting from the adoption of the frontier production function methodology.

Several factors were suggested as to why the impact of the project on academia and policy-makers has not been as strong to date as it deserves:

- Several reports on agriculture and agricultural policy became available at or around the time the project results became public. These included the *Agriculture 2000* report which provided a road map for the agricultural economy, and the Summary Report on Agriculture written for the *Approach to the Tenth Five Year Plan* (Government of India 2001). These commanded considerable publicity and public attention. They had much in common with the content and arguments of Kalirajan, Mythili and Sankar, although there were differences in focus.

- There is a divide in academic opinion as to the appropriate direction for Indian agricultural policy in this current transition period from a highly protected to a more liberalised competitive regime. Three viewpoints have been identified, the proponents of which have been grouped as 'Committed liberalisers', 'Advocates of no-change' and 'Cautious liberalisers'. The project espouses the first viewpoint. Academics supporting the second and perhaps the third viewpoints, who are reportedly numerous in agricultural universities, would likely not be receptive to use of the book in teaching or research.

- The book was launched at a particularly inauspicious time for agriculture and its policy-makers, i.e. when India experienced two consecutive droughts, which indeed in the southern states still continue. Policy concerns were focused on survival and assurance of food and fodder supplies rather than on issues of globalisation and liberalisation.

- The review in the *Indian Journal of Agricultural Economics* was favourable but the journal is not generally read by policy-makers. There were no reviews in the economic newspapers.
- The seminars have been concentrated in the southern states. The project would have benefited from a well-publicised seminar on the final results in Delhi, where it would attract wider attention.

The limits on impact, mentioned above and noted by individual observers, were in fact mostly beyond the control of the researchers, but do usefully illustrate some of the difficulties encountered. Overall, they are far outweighed by the widespread positive impacts of the study.

Analysis of socioeconomic and agribusiness developments in the Chinese cattle and beef industry (ASEM/1995/002)

Colin Brown, Scott Waldron and John Longworth

Collaborating organisations	University of Queensland, Brisbane, Australia (UQ); Ministry of Agriculture, Beijing(MA); Chinese Academy of Agricultural Sciences, Beijing (CAAS); Chinese Academy of Social Sciences, Beijing, China (CASS)
Project leaders	Professor John W Longworth and Dr Colin Brown (UQ); Mr Lu Xiaoping (MA), Professor Zhang Cungen (CAAS), Professor Chen Jiyuan (CASS)
Related projects	EFS/88/11
Principal researchers	Associate Professor Xiong Cunkai; Mr Li Souping, Dr Hu Drughuan, Ms Liu Fang (CAAS); Professor Lin Xiangjin, Associate Professor Liu Yuman, Mr Hu Bin (CASS); Dr Zuo Changsheng, (MA); Mr Scott Waldron (UQ).
Duration of project	1 January 1997 – 30 June 2000
Total ACIAR funding	$669 406
Project objectives	The main aim of this project was to gain a comprehensive overview of substantial changes in the Chinese beef and cattle industry. An important objective was to help Chinese and Australian beef industry officials formulate strategies and policies to take advantage of the developments in the Chinese industry. This was to be achieved by identifying the key policy issues relevant to the economic, social and environmental effects of the changes in production and marketing systems, and by examining the agribusiness and trade opportunities afforded by the latest developments in China. As a result, Sino-Australian cooperation on beef industry matters was expected to be enhanced.
Location of project activities	Central Plains and north-eastern provinces of China

Overview

An ACIAR-funded project to analyse socioeconomic and agribusiness developments in the Chinese cattle and beef industry was undertaken by the University of Queensland in collaboration with the Ministry of Agriculture (MA) in China, the Chinese Academy of Science (CAS) and the Chinese Academy of Social Sciences (CASS). This project has changed the thinking about the cattle and beef industry in China from a 'develop-at-all-cost' approach to a more appropriate 'sustainable development' approach as indicated by recent policy and other industry changes.

The project contributed to several specific changes, as detailed below:

- Households now account for the opportunity (real) costs and benefits of cattle raising.
- Feedlots and abattoirs are more focused on targeting appropriate (especially mid-value) market segments at an appropriate scale.
- There is better coordination of activities between cattle-raising households (local groups) and between industry sectors (especially cattle producers and abattoirs).
- There is improved recognition of food safety as an important social issue and as a source of price premiums.
- The design of projects and strategies has been modified following feasibility studies and other involvement of (Chinese) project staff.
- Ways of integrating economic, social and environmental factors are now being considered.
- There has been a re-evaluation of the design and targeting of poverty alleviation schemes involving ruminant livestock.

Project achievements

The project conducted a comprehensive socioeconomic analysis of developments in the Chinese cattle and beef industry to establish appropriate development strategies for the industry from an economic, social, agribusiness, regional and environmental perspective.

The Chinese beef industry was in a rapid growth phase during the time the project was conducted (1997–2000). Policy makers were intensely interested in the industry and it was supported by several major domestic and international projects. This increased the interest in and potential adoption rate of the project findings both during and after project implementation.

More than 400 interviews were conducted in 15 provinces, cities and/or regions in China. It is believed that 60 per cent of the organisations (including animal husbandry bureaus, agricultural bureaus, local government leaders, market administrators and other government and industry officials) in 60 per cent of the regions were influenced by the research team and preliminary findings from the project.

The theme of the 2000 end-of-project workshop was to build economic, social and environmental efficiency in the Chinese beef industry. This call was mirrored in a major government report and statement by the Vice Minister of Agriculture one month after the workshop. The workshop was attended by 80 Chinese industry officials, who were significantly influenced by the formal presentations and group discussions.

For example, in 'feedback' addresses from the discussion groups to all attendees, there were many instances of speakers saying that their discussions had generated 'new' and 'surprising' findings. In particular, attendees said that the conference encouraged them to think about appropriate rather than just modern approaches to industry development.

Project outputs included two books. All workshop attendees were given a copy (in both English and Chinese) of the Workshop Proceedings, *Efficiency in China's cattle and beef industry* (Zhang Cungen & JW Longworth eds., IAE/CAAS, Beijing, 2000), and about 100 of the key interviewees were sent (gratis) a copy of the Chinese version of *Beef in China* (JW Longworth, CG Brown & SA Waldron, University of Queensland Press, St Lucia, Queensland, 2001). It is believed they all would have incorporated some of the findings into their industry planning and administration practices in one way or another.

Apart from the collaborating scientists for the project, the research team had extensive dealings with four researchers from two leading research institutions in Beijing (Chinese Agricultural University and the Research Centre for the Rural Economy).

After contact with the project team, seven Australian breed societies and/or investors have been substantially influenced in developing their strategies toward the Chinese beef industry.

The difference the project has made

The project influenced the following changes:

- Switch by local level officials from a develop-at-all-costs, production-led approach to a more facilitative, market-led approach to their beef cattle industry development. The research team emphasised the importance of standards (including food safety), quality control and market information. In Heze and Fuyang, where the research team initially spent significant periods of time (several weeks in each), this switch was observed on subsequent return visits.
- Switch to a more circumspect approach to using cattle and beef as a development and poverty alleviation option. Other types of livestock (poultry, dairy cattle, sheep and goats) are now more commonly used in poverty alleviation programs throughout China.
- More rigorous and critical review of beef industry investments and appropriate design. A recent return visit to Zhoukou Prefecture in Henan revealed that rather than building new, large and overcapitalised abattoirs, the locals have chosen to upgrade smaller abattoirs. The prefecture has also emphasised the development of household-based cattle-raising associations rather than large corporatised feedlots, an outlook that was advocated by the research team.
- Switch to assessing beef industry development from production/output orientation to integration of economic, social and environmental perspectives.
- Switch to realising the need to access mid-value markets rather than relying on local markets (of marginal profitability) and high value markets (that are largely unattainable and crowded-out).

Project impacts

Community impacts

The economic returns of the project are estimated to be around $30 million per annum with an additional one-off return of $11.5 million:

- **Improved efficiency of beef cattle industry in China** with an approximate turnover of $10 billion at 15 per cent efficiency gain at 2 per cent attributed to direct and indirect project involvement (excluding specific involvements discussed below) (= $30 million)
- **Improved design of international development programs** (World Bank, 'Straw for Ruminants' and 'Advantaged Area'): $150 million at 50 per cent potential gain at 10 per cent uptake (= $7.5 million)
- **Direct investments in Chinese beef industry by Australian interests** potentially worth $20 million. Savings in terms of either opportunities identified, losses avoided, or improved efficiency conservatively estimated at 20 per cent (= $4 million).

These aggregate impact figures are based on the actual outputs and realistic detailed assessments of the adoption and practice changes (outlined above). The parameters in the calculation of the figures such as efficiency gain and uptake levels are considered to be very conservative.

There is enormous diversity among Chinese cattle producers and so the impact of the project upon them also varies in magnitude and form. For instance, the project identified that for some unspecialised households, raising cattle could result in negative returns to management of around Rmb900 when household resources were properly valued. (Annual per capita household incomes can be as low as Rmb2000.) Raising awareness of this issue among these households and among officials promoting cattle is clearly important. Conversely, for some groups of specialised households, the impact of the project is associated with higher returns and efficiency gains.

Capacity-building and scientific impacts

The project helped raise the profile of collaborating scientists – especially from the Institute of Agricultural Economics and the Rural Development Institute – within the Chinese beef cattle industry, and of Chinese livestock economists within international agencies such as ILRI, IFPRI, World Bank and FAO.

There are now improved linkages between Australian and Chinese industry participants. For example, after introduction through the research team, various Australian organisations (Department of Agriculture, Forestry and Fisheries, Meat and Livestock Australia, CRC for Beef, the Agricultural Business Research Institute, BreedPlan, various breed societies and companies) now have ongoing contact with collaborating scientists in China (the Institute of Agricultural Economics, the Rural Development Institute and the China Animal Husbandry Association, the Ministry of Agriculture, the China Meat Association).

Project collaborators are major actors in the Chinese Economist Society of Forestry, Animal Husbandry and Fishery (CESFAHF) and the Special Economist Committee of the Beef and Cattle Industry (SECBCI), both of which are active in beef-related conferences, publications and project funding on an ongoing basis.

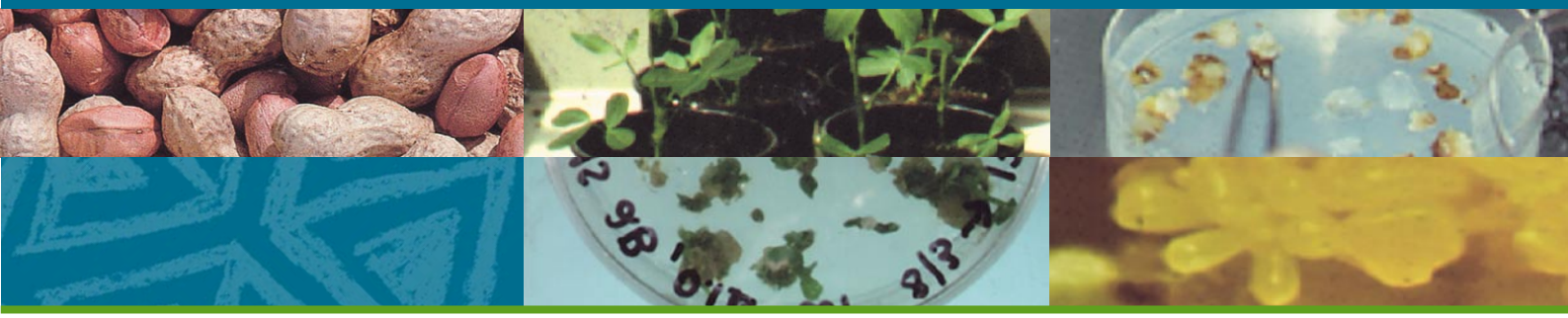
Within China, there are now improved linkages between industry participants on vertical and horizontal levels, as well as between technical scientists and livestock economists. This has improved the capacity for briefings and projects on the beef industry and the impacts of China's WTO accession on its agricultural/ livestock sector.

There have been four student projects conducted at UQ directly related to the Chinese beef industry (Dominic Smith, Lu Xiaoping, Yan Dong, Megan Collins). Dominic Smith, following his PhD study directly associated with the project, went on to establish Agrifood Consulting International, which conducts livestock research in Asia.

Other Australian researchers associated with the China beef project, such as Ralph van Gelder and Ian Jarratt, have since been involved in various activities concerning livestock in Asia. The experiences, networks and insights gained from in-depth research on the ACIAR-funded beef project proved invaluable for these subsequent Asia livestock activities.

The project created linkages with or impacts on the following ACIAR, international agency and Chinese projects, including:

- ACIAR project on livestock development on red soils in Jiangxi and Hunan provinces (various meetings with Dr Neil McLeod who is the economist working on the project, and who is currently using the household model from this project to run various scenarios)
- Proposed ACIAR China grasslands project
- Proposed ACIAR projects on beef grading
- World Bank grasslands project in Xinjiang and Gansu
- World Bank beef project
- The 'Straw for Ruminants' program of the Ministry of Agriculture
- 'Advantaged Area' (for beef and mutton) program of the Ministry of Agriculture
- Agribusiness development project in the 10th Five-year Plan (in 1996–2000)
- ILRI project on 'Research to Increase Productivity of Crop–Livestock Systems in South-East Asia'
- Responses to many email requests from other researchers.



Improved diagnosis and control of peanut stripe virus (CS1/1994/039)

Ralf Dietzgen

Collaborating organisations	Queensland Department of Primary Industries (QDPI), University of Queensland (UQ), Brisbane, Australia; Institut Pertanian Bogor (IPB), Research Institute for Food Crops Biotechnology (BRIFC), Bogor, Indonesia; Oil Crops Research Institute (OCRI), Chinese Academy of Agricultural Sciences (CAAS), Wuhan, China
Project leaders	Dr Ralf Dietzgen (QDPI); Dr Sudarsono (IPB); Dr H Jumanto (BRIFC); Dr Xu Zeyong (OCRI)
Related projects	CS1/1990/015, CS1/1992/016, CS1/1990/017
Principal researchers	Dr R G Birch (UQ); Mr A Cruickshank, Mr J R Tattnell and Mr P R Trevorrow (QDPI); Dr Roechan M, Mr M Muhsin (BRIFC); Ms Zhang Zongyi, Mr Chen Kunrong (OCRI)
Duration of project	1 January 1996 – 31 December 1999
Total ACIAR funding	$889 259
Project objectives	Previous research had suggested that genetic engineering was the only possible option for producing commercial peanut lines resistant to peanut stripe virus (PStV). The main aim of this project was to develop further the gene transfer system from CS1/1990/017 and be able to produce PStV-resistant peanuts by inserting a coat protein gene from the virus into commercial cultivars. Expression of coat protein genes in genetically transformed plants has yielded protection against a range of polyviruses (the family to which PStV belongs), but systems for producing transgenic peanut plants had not been available.
Location of project activities	Wuhan province, China; Java, Sumatra and Irian Jaya regions of Indonesia; Kingaroy/Mareeba, Queensland, Australia

Overview

An ACIAR-funded project on improved diagnosis and control of peanut stripe virus (CS1/1994/039) was undertaken by the then Queensland Department of Primary Industries (QDPI) and the University of Queensland, in collaboration with the Institut Pertanian Bogor (IPB), the Research Institute for Food Crops Biotechnology (RIFCB) and the Oil Crops Research Institute (OCRI) of the Chinese Academy of Agricultural Sciences (CAAS). This project was a continuation of previous research into peanut stripe virus and aimed, in particular, to develop a commercial peanut cultivar resistant to the virus. Such a cultivar would increase yield and quality, and entice growers back into planting peanuts as a valuable cash crop. An additional goal was to develop and use improved diagnostic assays for peanut viruses to help in the early detection and monitoring of infection and in the selection of virus-tested seeds for planting.

Peanut stripe virus (PStV) seriously affects the yields and quality of peanuts in Indonesia and China and is a serious quarantine threat to Australia. Indonesian peanut farmers used to regard symptoms of PStV infection as part of the natural development of peanut. This was probably because PStV was present in almost all peanut plantations in Indonesia. There were no PStV-resistant cultivars that could have been used in comparison to show the negative effects of PStV infection on peanut yield and quality. This project clearly demonstrated the negative agronomic effects of PStV and generated improved peanut lines that are PStV resistant. These resistant lines can now be used to demonstrate to growers that symptoms of PStV infection are indeed pathogenic effects. This can change their view and help them to identify and control the disease.

Induction of somatic embryogenesis in peanut used to be a difficult task for scientists and students. It is now a routine and simple procedure. In the past, end users used to think that tissue culture could only be used for micropropagation (clonal propagation). With the results from this project, peanut tissue culture is now being used to induce somaclonal variation and generate novel peanut germplasm.

Project achievements

Previous work showed that classical breeding approaches incorporating host plant resistance proved unsuccessful, despite exploring the entire world peanut germplasm collection (over 11 000 accessions). Resistance to peanut stripe virus has been identified among wild *Arachis* relatives, but crosses to introduce this trait have not been successful due to incompatibility between species. Therefore, genetic engineering offers the opportunity to improve existing cultivars by selectively adding specific new traits such as virus resistance.

This project on peanut stripe virus was able to develop a practical and efficient genetic transformation and regeneration system for cultivars in both botanical types of peanut, and reporter and viral resistance genes were introduced into peanut using particle bombardment technology in Australia and China. An alternative *Agrobacterium*-mediated transformation system was investigated.

Four modified versions of PStV coat protein (CP) sequences were engineered and assessed in transgenic *Nicotiana benthamiana* plants for protection against PStV infection. The untranslatable construct CP2 gave immunity to infection in about 70 per cent of the lines following mechanical challenge inoculation. Immune lines were protected even against isolates with the highest sequence divergence in the CP gene.

Seven transgenic peanut lines of cultivar *Gajah* (Spanish market type) carrying CP2 or CP4 constructs were identified as resistant or immune to infection to the homologous virus in glasshouse trials in Australia.

In Australia, China and Indonesia, scientists developed non-radioactive probe hybridisation for PStV, and reverse transcriptase-PCR assays for detecting and identifying seed-borne peanut viruses (peanut stripe and peanut mottle potyviruses, and cucumber mosaic and peanut stunt cucumoviruses).

A study of the biological and genetic variability of PStV isolates in Indonesia, Thailand and China found geographically related groups with wide symptom diversity. Indonesian isolates of PStV were identified as intra-species recombinants and Chinese strains of peanut stunt virus were shown to differ sufficiently from strains in other locations, suggesting that they may form a third taxonomic subgroup of the species. This information is significant for future diagnostic tests.

Scientists in collaborating institutes in Indonesia and China working on peanut transformation and regeneration and diagnostics benefited from the project through the provision of equipment and the opportunity to participate in training with the Australian team. The scientists also took part in project coordination visits and a two-week workshop in Indonesia.

Several scientific papers were published in peer-reviewed international journals, local journals in China and Indonesia, and in newsletter and conference proceedings. A popular ACIAR Technical Report was published on peanut transformation and regeneration technologies (CM Higgins & RG Dietzgen, *Genetic transformation, regeneration and analysis of transgenic peanut*, Tech Rep 48, ACIAR, Canberra, 2000).

Since the project's final review, further transgenic resistance in the *Gajah* and *Kelinci* cultivars has been demonstrated using the technologies developed during the project.

The difference the project has made

Indonesian research

IPB and RIFCB scientists and postgraduate students have used many of the project outputs, including transgenic plants, diagnostic technologies, equipment, technical information and virus survey results. Interest in peanut transformation is largely confined to the two institutions which were involved in the ACIAR-funded project. IPB has continuously and routinely used *Agrobacterium*-mediated peanut transformation technology since the completion of the project, most recently to improve peanut response to drought stress and fungal pathogens including *Sclerotium rolfsii*.

Of 25 putative PStV-resistant plantlets sent to RIFCB at the end of the project, eight have been successfully acclimatised during the following year and three were grown to seed. These plants were confirmed to be resistant to PStV, but lack of ongoing funding and lower priority ranking of peanuts as a commodity by the Indonesian Government has prevented further work.

IBP scientists and postgraduate students have also been routinely using the procedures for in vitro induction of somatic embryos from peanut tissues. The gained knowledge on somaclonal variation among tissue-culture-derived planting material of peanut has been adopted and exploited to generate new and more desirable peanut germplasm.

Further, the procedures developed for *Agrobacterium*-mediated transformation of peanut have been routinely used at IPB as an alternative strategy to biolistics for introducing genes into peanut tissues and generation of transgenic peanut plants. High costs and difficulties in obtaining supplies needed to use the biolistics apparatus appear to be the reason for not adopting this method for plant transformation at IPB.

Chinese research

Chinese scientists are using the relatively low-tech *Agrobacterium*-mediated peanut transformation instead of the technically more complex biolistic transformation system that was used successfully during the project. As for IPB above, this is due to higher operating costs and difficulties in obtaining supplies.

Work on PStV-resistant transgenic peanut plants has generally not continued, but seeds are being stored. The Indonesian peanut cultivar *Gajah,* which was the main focus of the project, turned out not to be suited to the climatic conditions in Hubei Province and none of the original transformants sent there showed any virus resistance. The resistant trait would need to be introduced into a Chinese commercial cultivar from PstV-resistant *Gajah* by conventional breeding.

However, peanut transformation expertise gained by the Chinese research team has been indirectly used by other scientists in China through locally published papers and reviews. The Chinese project team was the first to establish peanut transformation in China. There are now scientists in three universities and research institutes using this information. Research publications of the Chinese team on this subject are well-cited references.

Project impacts

Community impacts

Community impacts could come from two sources – use of transgenic peanuts and use of diagnostic tests to benefit farmers. No transgenic peanuts have been released as a result of the project. However, the technologies are in place for rapid release of the transgenic lines once national regulations allow. Use of the project-developed diagnostic tests for PStV in seed has also been constrained as outlined below.

The RT-PCR diagnostic assays for seed-borne peanut viruses have not been in regular use in China and are being used only at the institute for testing fewer than 100 samples per year. This is due to the costs involved, which are considerably higher than those of the established serological ELISA diagnostics, especially when testing large numbers of samples. Similarly, in Indonesia these assays have only been adopted at research laboratory level. This lack of adoption may be due to the fact that PStV is endemic in Indonesia, while in Australia, where the PCR test is used, PStV is a quarantine pathogen for which the most sensitive methods of diagnosis are essential to prevent its accidental introduction. Furthermore, peanut seed producers in Indonesia are not required to test their products for the level of virus infection or to provide virus-free seed to growers. It appears that there is little demand for such a diagnostic test under these circumstances and the costs of equipment and consumables are also prohibitively high.

Following further development by research scientists at RIFCB, the simpler dot blot diagnostic technique may be used in the future by quarantine authorities in Indonesia to provide phytosanitary testing for PStV.

Capacity-building and scientific impacts

The project has greatly increased knowledge and skills of participating Indonesian researchers. Several postgraduate students, who participated directly or indirectly in the project, have become faculty members (lecturers and scientists) at universities in different parts of Indonesia. Many of the project participants have excelled as researchers in their institutes, they have attracted external R&D funds and their success can be partly attributed to the training received during the ACIAR-funded project.

During the course of the project, IPB staff and students were trained in Australia and/or Indonesia. The training topics were specifically tailored to suit the research needs towards completion of their higher university degrees and resulted in quick adoption and successful use of project technologies. Training assisted in the successful completion of their postgraduate research and their subsequent R&D activities. On the other hand, only one of three RIFCB staff members trained in Australia during the project is still involved in related R&D in Indonesia. However, the training course held in Indonesia in 1996 appears to have had positive impacts on capacity building: eight of the nine participants from RIFCB are still actively involved in biotechnology research, one of the two participants from Malang is working on sweet potato breeding, and all eight IPB participants continue to work in plant molecular biology.

The project has had a positive effect on the IPB team's capacity to continue related research projects, both in terms of infrastructure and basic equipment. Several new projects in peanut and other crops have been coordinated by the IPB team and financially supported by the Indonesian Government via the National Research Council, the Ministry of Science and Technology, through Integrated Competitive Research Grants (RUT) and the Department of National Education through Graduate Team Research Grants (Hibah Pasca). The success of the IPB team in obtaining international funding (supported by the European Union) is also regarded as in part due to the positive impact of the ACIAR-funded project.

The project has also had positive impacts on various universities in Indonesia that are conducting related research. Former project participants who are now faculty members at those universities are applying their valuable knowledge and skills in current research projects they supervise. Most have been successful in securing external R&D support.

Chinese scientists Professor Xu Zeyong (project leader) and Mr Chen Kunrong received biotechnology training in Australia. This has since led to continued molecular research on peanut and other oil crops (sesame, canola) and their associated viruses. Increased knowledge and molecular skills have resulted in former Chinese project team members attracting Chinese government funding for related new projects. Mr Fang Xiaoping and Mr Chen Kunrong have both been promoted to the rank of Associate Professor. Ms Yan is working towards her PhD degree in a joint project with Wageningen University in the Netherlands, aimed at transgenic resistance to three peanut viruses using RNA silencing technology.

The project training has increased the R&D capacity of the Oil Crops Research Institute in plant transformation and molecular analysis of transgenic plants. This has led to continued research on canola transformation. Furthermore, a new laboratory led by Mr Fang Xiaoping has recently been established to evaluate potential environmental risks posed by transgenic canola. In 2002, the Chinese research team won for the second time a National Award for Scientific and Technological Achievement from the National Council of Central Government. The award was granted for research that included the scientific findings on the molecular biology of peanut stripe and peanut stunt viruses, supported by the ACIAR project.

The ACIAR project has helped to determine and redefine research direction in the IPB team to focus on solving problems associated with peanut production in Indonesia. This has earned IPB positive recognition by the Government and by other scientists. New transgenic peanut lines have been generated to broaden the base for durable PStV resistance. There are also plans to use the confirmed highly resistant peanut lines generated as project outputs as donor germplasm in peanut breeding programs in Indonesia, China, Australia and other countries where the virus already is a problem or may become one.

Permission will be sought from Indonesian authorities to assess the transgenic peanut lines cv. *Gajah* and *Kelinci* for PStV resistance and agronomic performance under field conditions. Once the necessary supporting data have been obtained, these lines will be registered as improved cultivars with the aim of potential commercial release. Achievement of this aim will largely depend on the Indonesian GMO regulations and their operational implementation.

Pyramiding of disease resistance phenotypes by crossing of peanut plants with resistance to either PStV or to fungal pathogens is under way at IPB, Indonesia. Furthermore, peanut transformation technologies are being used to combine natural resistance genes and introduced beneficial transgenes into commercial peanut cultivars to achieve multiple disease resistances and drought tolerance.

Other potential contributions of project outputs in Indonesia include support of pathogen diagnostic technologies, plant tissue culture and transformation technologies and methods to obtain improved germplasm with desirable characteristics using somaclonal variants.

The ACIAR-funded project was the first large multidisciplinary biotechnology project coordinated by Dr Sudarsono's team at IPB. Its successful completion has provided a positive scientific track record, which contributed to the team's competitiveness in attracting continued funding support. The research focus of the IPB team is now widening to attract national and international funding for crop improvement research on soybean and forestry crops such as sago palm and teak. This will include applications of tissue culture and molecular technologies (DNA markers and genetic engineering) to support various breeding programs of tropical crops.

In China, transgenic peanut plants developed at OCRI (not resistant to PStV, but carrying the viral transgene) will be used in a new project to assess their environmental safety, including potential impacts on *Rhizobium* nodule formation and nitrogen fixation or transgene escape to surrounding non-transgenic peanut plants. Work is continuing to use peanut transformation to develop broad-spectrum virus resistance using RNA silencing technology in collaboration with Wageningen University. The Chinese partner institute (Professor Li Yichang) will also be involved in a new ACIAR-funded project with Western Australia for oilseed rape improvement, which is due to commence in 2004.

Control of bacterial wilt by agricultural biotechnology (CS1/1994/052)

Bruce Holloway

Collaborating organisations	Montech Australia (Monash University), Melbourne (Mon); University of Queensland, Brisbane (UQ); University of Adelaide, Adelaide, Australia (AU); Asian Vegetable Research and Development Center, Tainan, Taiwan(AVRDC); Bogor Research Institute for Food Crops Biotechnology, Bogor, Indonesia (BRIFCB); University of the Philippines at Los Baños, Laguna, Philippines (UPLB)
Project leaders	Professor Bruce Holloway (Mon); Professor Asuncion Raymundo (UPLB); Dr Wang Jaw-fen (AVRDC); Dr M Machmud (BRIFCB)
Related projects	CS1/1990/015
Principal researchers	Associate Professor Jeremy Timmis (AU), Associate Professor Chris Hayward, Dr Mark Fegan (UQ), Professor Marina Natural (UPLB), Iryadi Suryadi (BRIFCB), Dr Nenita Opina, Dr Rodel Maghirang (UPLB), Associate Professor Viji Krishnapillai (Mon)
Duration of project	1 July 1996 – 31 March 2000
Total ACIAR funding	$748 226
Project objectives	Integrated disease management (IDM) is a possible solution to bacterial wilt. Controls include the provision of uninfected seed – especially of potatoes, breeding resistant cultivars, systems of crop rotation, and soil amendment. This project contributed to the breeding of resistant cultivars. The use of weakened strains of *Pseudomona solanacearum* to control the bacterium in potatoes and tomatoes was also studied. This project sought to refine the techniques of molecular biology so they can be used to identify *P. solanacearum* in the laboratory and field conditions in Asia. Staff from collaborating institutions were trained in these techniques.
Location of project activities	Philippines, Indonesia, Taiwan and Vietnam

Overview

Bacterial wilt, caused by the bacterium *Ralstonia solanacearum*, is a significant disease of tomatoes and potatoes, with the potential to devastate the sustainable production of these crops in South-East Asia. As a result of the ACIAR-funded project on the control of bacterial wilt (CS1/1994/052), work is well under way in the Philippines and at the Asian Vegetable Research and Development Center (AVRDC) to breed tomato varieties that are resistant to bacterial wilt and to improve potato seed quality, based on pathogen-free seeds. Reducing crop losses due to bacterial wilt will benefit farmers in developing countries both economically and in terms of improved supply.

Project achievements

Professor Bruce Holloway from the Centre for Agricultural Biotechnology at Monash University led a team of researchers in Australia and South-East Asia to create an extensive and comprehensive *R. solanacearum* strain collection from geographically disparate sources, so that genetic variability in the organism could be accurately measured. Understanding the variation in *R. solanacearum* was necessary to better manage bacterial wilt and to develop resistant varieties of tomatoes. The project also developed a test for detecting even very low levels of *R. solanacearum* in seed potatoes, enabling *R. solanacearum*-free seed potatoes to be confidently identified and used, thus reducing the overall incidence of bacterial wilt in potato crops.

International quarantine laws significantly limit the extent to which strains of this organism can be sent between countries. Therefore, an important element of this project was the development of scientific capacity in molecular genetics, the use of genetic diagnostic tools for disease management and the training of personnel in these aspects in-country.

In addition to isolating strains of *R. solanacearum* in tomatoes and potatoes, in-country research on bacterial wilt in eggplants, peppers and bananas has been undertaken in the Philippines. In Indonesia, bacterial wilt research is limited to potatoes.

The knowledge flow from the bacterial wilt project is as follows:

In the countries involved, research findings usually go immediately to a government organisation and from there to a seed company, although more recently seed companies may access the research organisation directly. There is more evidence of this method of transfer in the Philippines than in Indonesia.

The project has contributed to two of the essential linkages in this flow of knowledge. These were the link between the project and government organisations and the link between the government organisations and seed companies.

Seed companies in the Philippines do not have the in-house skills or facilities to develop new molecular techniques. In addition, because of the costs involved, they don't have the resources needed to identify and measure the biological diversity of field strains of *R. solanacearum.* Therefore, the seed companies in the Philippines that have become involved in the control of bacterial wilt since the project finished, as well as the AVRDC, which has offices in a variety of countries, found the development of the molecular techniques, and the identification of the wide genetic diversity in field strains, particularly useful.

Wide genetic diversity indicates that developing bacterial-wilt-resistant cultivars of tomatoes (and other crops) will be an ongoing process as pathogen mutation will create new versions of the pathogen that could infect previously resistant cultivars of the commercial crops. Because of this, the University of Queensland (UQ) established and retained an extensive collection of strains of *R. solanacearum*. The value of this activity is confirmed by the fact that it is now known that Seminis, the largest seed company in the world, has a very large collection of strains of *R. solanacearum* derived from worldwide sources, ready to use should it become involved in breeding resistance to bacterial wilt in vegetable crops. Seminis recognises that to create effective bacterial-wilt-resistant tomato and other crop cultivars, the lines produced by selective breeding need to be tested against a wide range of different isolates of the pathogen to confirm that they will be resistant in the field.

The existence of the project, the collaborative network developed, the new skills acquired, and the demonstrated potential for innovative outcomes were instrumental in AVRDC confirming its decision to continue and expand its support for molecular genetic research facilities and projects.

Biosecurity Australia (a component of the Australian Government Department of Agriculture, Fisheries and Forestry) needs to assess risks associated with the importation of Philippines bananas into Australia. The information is required to minimise the risk of introduction of crop pests into Australia and to enable Australia to meet its international trade obligations under existing treaties. Professor Chris Hayward (UQ) and Professor Cion Raymundo (UPLB), who were both principal researchers involved in the ACIAR-funded bacterial wilt project, have assisted by providing Biosecurity Australia with advice on the potential risk of banana diseases. The most significant of all the diseases, called Moko, is caused by *R. solanacearum*.

Professor Raymundo and her associates have demonstrated that Moko and Bugtok diseases of bananas are caused by the same strain of *R. solanacearum*. This is a new finding for the Philippines and has been published. This agrees with results obtained by other workers using different diagnostic techniques.

The characterisation of a new repetitive DNA insertion element, first described by Professor Raymundo, is the subject of a collaborative project involving Professor Raymundo, Dr Rina Bagsic (UPLB) and Dr Mark Fegan (UQ). The aim of this research is to develop a new diagnostic test. The results of this work will be published in the near future.

Staff at UPLB have been involved in attempts to inform potato seed distributors of the importance of *R. solanacearum*-free potato seed for potato production in mountain provinces where bacterial wilt is rife. The commercial significance of this is that potatoes suitable for French fries can only be grown in the Philippines in mountain provinces; otherwise frozen French fries must be imported. At present, around US$13 million is spent annually on such imports from the USA.

Dr Nenita Opina, who was a project team member from UPLB, is involved with a Japanese company that is growing high quality eggplant in the Philippines for export to Japan. Incidence of bacterial wilt in this crop was 80 per cent, and Dr Opina recommended they change locations to land previously used for lowland rice. With her close personal monitoring of bacterial wilt infection, production has risen greatly and eggplant is shipped regularly to Japan.

The four scientists in the public sector have changed their activities by using the molecular genetic techniques developed in the project and giving attention to natural genetic diversity in *R. solanacearum.* This resulted in a change in their research direction and new practical means of precisely identifying isolates of *R. solanacearum.*

Seed companies, such as East West and Marco Polo, have hired former participants or collaborators of the project, hence acquiring new skills and new approaches to developing bacterial-wilt-resistant cultivars.

Several seed companies have made comments that lowland Indonesia is the region where the highest severity of bacterial wilt in the world is found, which echoes the findings of the project on the important anomalies found in genetic profiling of strains obtained from Indonesia.

As a direct result of the ACIAR-funded project, Dr Rodel Maghirang, a project participant, and Dr Conrad Balatero, Dr Maghirang's graduate student in the Plant Breeding Institute at UPLB, were the first to work on the use of molecular markers in tomato breeding in the Philippines. The experience they gained from the project and from attending the ATSE Crawford Fund Master Classes in Molecular Genetics which were part of the ACIAR-funded project, enabled them to start a tomato breeding program that was based on molecular markers (available from American sources), rather than the traditional, non-molecular breeding techniques. Using molecular markers meant that the time involved in the selection process was reduced. In addition, it was possible to produce tomato varieties which contained quality characteristics that were commercially acceptable and had higher resistance to bacterial wilt. The change in breeding strategy, which has undoubtedly saved time and resources in the search for resistant varieties of tomatoes and increased the success rate of the breeding programs, represents a major financial benefit of the project.

Funding to achieve management of bacterial wilt in affected countries has continued. This includes new groups collaborating with AVRDC on bacterial wilt research, as well as institutions that were not previously involved in this area of research. These institutions include the Taiwan Agriculture Research Institute and Khon Kaen University in Thailand.

There are also new technologies being developed chiefly in genomics and bioinformatics that are critical for the study of diseases of plants caused by infectious microorganisms. While these technologies have developed independently of the ACIAR-funded project, individuals involved in the project in the Philippines, Indonesia and Vietnam are now better equipped to understand the importance of these technologies. This would also apply to individuals who attended the Master Classes in molecular genetics, as genomics and bioinformatics are both strongly dependent upon molecular genetics.

The difference the project has made

As the research undertaken in the bacterial wilt project was pure (rather than applied) science, it will be some five to seven years before the knowledge generated in the project will result in farmers planting bacterial-wilt-resistant varieties of tomatoes and other crops in their fields. However, there is a continuing effort and commitment by AVRDC, and seed companies, to achieve this goal through the development of disease management strategies and the sale of disease-resistant germplasm to minimise the effects of bacterial wilt on crop production.

Through the extension activities of the project, farmers are increasingly aware of the seriousness of bacterial wilt and want solutions.

Cooking bananas are grown inside commercial plantations in the Philippines. These bananas provide income and food for the plantation workers who live on the plantations. However, the cooking bananas are not bagged, and they were found to be a source of infection with *R. solanacearum*, possibly insect-borne, which could result in Moko Disease in the plantation dessert bananas. On advice from Professor Raymundo, which was prompted by Biosecurity Australia's draft Impact Risk Assessment, the plantings of cooking banana were removed. The resulting loss of income and food affected the living standards of the workers, and the banana companies were initially reluctant to take the action.

Project impacts

Community impacts

Community impact has been restricted by the inherently long time lag required between pure research and application of the results, the difficulty of breeding for stable resistance to bacterial wilt, the lack of understanding of the reason for the high genetic variability in natural isolates of *R. solanacearum*, and the need to formulate innovative strategies for integrated pest management of this disease.

Nevertheless, the existence of the ACIAR-funded project has raised and maintained awareness of the importance of using molecular genetic techniques to achieve the aim of reducing bacterial wilt in important food and cash crops. Consequently, in the long term, there is potential for a significant impact on those regions of the world where bacterial wilt inhibits production of high-quality crops that are susceptible to this disease, particularly tomato and potato. For example, the significant research grant provided to AVRDC by a major German funding organisation and the commitment to have German scientific collaborators working with AVRDC shows that there is international recognition of the important role that AVRDC can play in the future solution of this disease problem. The very positive response of the AVRDC Board to the reviewers' comments on bacterial wilt research is a positive policy statement on the high quality of the research group at AVRDC working on this topic.

As AVRDC has a long-term commitment to developing productive, disease-resistant varieties of tomatoes suitable for a range of habitats in tropical countries such as Taiwan, bacterial wilt research has continued to be well supported financially by Taiwanese and other sources at AVRDC. The intense nature of Taiwanese agriculture and the high educational standards of Taiwanese farmers mean that it is easier to apply technology in Taiwan than in other countries, and there is an excellent ongoing relationship between Taiwanese farmers and AVRDC. Jaw-Fen Wang has been personally involved in building that relationship.

Capacity-building and scientific impacts

There have been significant impacts in developing the capacity of scientists and researchers in developing countries in relation to bacterial wilt.

The visits of research personnel in the project from the Philippines and Indonesia to the Australian locations of the project have created an ongoing scientific collaboration on aspects of bacterial wilt research. In addition, the training in molecular genetics has had a positive influence on teaching in agricultural science, on the employment opportunities for junior staff and on career development of senior staff. For example, Joseslito Villa, Loida Moreno and Cherry Relevante were all students of either Professor Raymundo or Professor Marina Natural (both major participants in the ACIAR-funded project from UPLB). These students, partly as a result of the high profile of the use of molecular genetics for plant disease research projects at UPLB, have now obtained significant career opportunities that almost certainly would not have been created without the ACIAR project. Joselito Villa is now working in Japan; Loida Moreno is working in PhilRice as a molecular geneticist; and Cherry Relevante is now working with Conrad Balatero at the East West Seed Company.

There were six Master Classes on molecular genetics during the six years of the two ACIAR-funded projects on the control of bacterial wilt (CS1/1990/015 and CS1/1994/052). In the countries involved, the Master Classes have created a cohort of research workers with increased knowledge of molecular genetics, and this knowledge has had major impacts on their careers in agricultural research.

The experience gained with these classes established a format for mid-career training of agricultural scientists that has been used in 22 subsequent classes on a range of topics relevant to agriculture and with individuals from at least 25 countries other than those in these projects. Hence, the ATSE Crawford Fund Master Class program has had an important impact on capacity building in countries other than those involved in the project, in topics other than molecular genetics, and is a recognisable Australian contribution to international agricultural research.

The profile of molecular genetics and its role in agriculture has been raised at UPLB. As a result, Professor Raymundo and Professor Natural have attracted more undergraduate and graduate students through their increased emphasis on molecular genetics in their courses and research work. Professor Raymundo received the PANTAS award 2001 and two UP International Publication Awards 2003. Professor Natural, who worked at Monash with Professor Holloway on two occasions and made a major contribution to specific molecular genetic research aspects of the project, has been recognised at UPLB and in the Philippines generally as an important national figure in plant pathology. Professor Natural received the 2004 Philippine Phytopathological Society – G O Ocfemia Most Outstanding Plant Pathologist award, a UP International Publication Award 2003, and the MS Swaminanthan Outstanding Research Award 2003.

Even if it is not possible to attribute the ability to attract the grants for further research solely to the ACIAR-funded project, UPLB workers have attracted further research funding since the conclusion of the project. For example, it is apparent that the experience and prominence that Dr Opina gained during the project has enabled her to compete more successfully for a series of national and international research grants. It would be reasonable to suggest that without the experience gained in the project, through the visits to Australia and in a Master Class, she would not have been as competitive in these applications.

Professor Raymundo has also been able to attract a UPLB-PCARRD-PANTAS grant for DNA-based detection methods for banana strains of *R. solanacearum* in soil and banana fruits. Professor Raymundo has also helped introduce both MSc and PhD courses in molecular biology and biotechnology at UPLB, and over $100 000 has been allocated and used for building a Molecular Biology Annexe to the Institute of Biological Sciences at UPLB campus.

Professor Natural collaborates with the International Rice Research Institute using molecular genetic techniques obtained from work in this project. Professor Natural has been Professor (since 2000) and Chairman of the Department of Plant Pathology UPLB (since 1997), a member of the Scientific and Technical Review Panel of the Department of Science and Technology (since 2003).

There continues to be active collaboration of UPLB with UQ on *R. solanacearum* research. For example, Jocelyn Zarate from UPLB was funded by UNESCO to work at UQ from February to May 2004 and Rina Bagsic (UPLB) worked at UQ from November 2000 to January 2001.

There has also been increased knowledge and use of molecular genetic techniques by scientists at RIFCB and RIV, the relevant Indonesian Government Institutes.

In addition to various publications, the techniques developed in the ACIAR-funded project have attracted international funding, researchers and graduate students to AVRDC. For example, the molecular genetic techniques that were developed in the ACIAR-funded project are to be used in a German-funded project at AVRDC. Overall, at AVRDC there has been a firm commitment to continue molecular genetic and other approaches to the management of bacterial wilt. The ACIAR-funded project played a catalytic role in this commitment.

Integrated control of citrus pests in China and South-East Asia (CS2/1996/176)

Andrew Beattie

Collaborating organisations	University of Western Sydney, Hawkesbury, Australia (UWS); Guangdong Entomological Institute, Guangzhou, China (GEI); Department of Agriculture, Bangkok, Thailand (TDoA); National Institute of Plant Protection, Hanoi, Vietnam (NIPP); Southern Fruit Research Institute, Tien Giang, Vietnam (SOFRI); Agricultural Research Centre, Department of Agriculture, Kuching, Malaysia (DoAM)
Project leaders	Professor Andrew Beattie (UWS); Mr Stephen Leong (DoAM); Mrs Pimolporn Nanta, Mr Vitt Namruangsri (TDoA); Professor Huang Mingdu (GEI); Dr Nguyen Van Cam (NIPP)
Related projects	Follow-on project to CS2/1993/005
Principal researchers	Dr Duncan Watson, Dr Debbie J Rae (UWS); Dr Rut Morakote, Mr Vitt Namruangsri, Ms Busabong Manasmankong, Ms Saowanit Maimala (TDoA); Associate Professor Tan Binglin, Mr Du Tongyuan, Ms Xiong Jinjun, Mr Liu Deguang, Ms Cen Yijing, Dr Wang Jinxian, (GEI); Dr Pham Van Lam, (NIPP); Dr Nguyen Minh Chau, Mr Huyen Tri Duc (SOFRI)
Duration of project	1 July 1997 – 30 June 2000
Total ACIAR funding	$979 168
Project objectives	This project aimed to develop sustainable ways of controlling insect pests on citrus trees in South-East Asia. The project used the techniques of integrated pest management (IPM) and concentrated on China, Malaysia, Thailand and Vietnam. The work also sought to refine existing IPM programs for citrus that are used in Australia. The main technology studied was the application of petroleum spray oils.
Location of project activities	Guangdong Province, China; Mekong Delta, Vietnam; Thailand; Sarawak, Malaysia

Overview

An ACIAR-funded project on the integrated control of citrus pests in China and South-East Asia (CS2/1996/172) was undertaken by the Centre for Horticulture and Plant Sciences at the University of Western Sydney in collaboration with Guangdong Entomological Institute, China; the National Institute for Plant Protection and the Southern Fruit Research Institute, both in Vietnam; the Agricultural Research Centre in Malaysia; and the Entomology and Zoology Division of the Department of Agriculture in Thailand.

Citrus growers in China, Vietnam, Thailand and Malaysia can now use a horticultural and agricultural mineral oil in sprays to control citrus pests, as part of natural enemy and mineral-oil-based integrated pest management (IPM) programs. Farmers using this approach can significantly reduce pest management costs and the use of synthetic pesticides. The use of mineral spray oils as an alternative to synthetic pesticides has the potential to dramatically improve the environment as well as the health of citrus growers.

The need for the IPM programs was recognised in the 1970s and 1980s by scientists who collaborated in the project. They were concerned about excessive, widespread and often environmentally unacceptable and hazardous use of synthetic pesticides in citrus cultivation in the region. They were also concerned about limited reliance on biological control and sustainable low-pesticide-based IPM programs, and limited monitoring of pest and natural enemy populations. Consequently, there was little understanding of the use of pest thresholds to determine when pesticides were necessary. There was also limited and poor marketing of mineral spray oils, and generally limited and poor knowledge of the effectiveness of mineral oils as effective and sustainable alternatives to synthetic pesticides.

Project achievements

The project was able to demonstrate that mineral spray oils can be an effective selective pesticide in temperate, subtropical and tropical regions of China and South-East Asia. In particular, integrated pest management programs using oil were equal to or better for control of most major citrus pests than control programs based on broad-spectrum synthetic pesticides. Additionally, natural enemies were better conserved, and thus available to attack pests, in oil-based IPM than in synthetic pesticide programs. In most instances, no phytotoxicity was seen in the experiments, and external fruit quality was enhanced in most locations.

The cost of the mineral-oil-based programs was shown to be less than broad-spectrum pesticide programs in China. While conventional programs proved to be cheaper in the Mekong Delta in Vietnam, oil-based programs were more cost-effective overall because of their higher efficacy levels and the ability of depleted natural enemy populations to recover more quickly than when excessive synthetic pesticides were used.

The project team also developed and tested multiple, 'low concentration', 'adequate coverage' spray programs to control a range of pests and diseases simultaneously, and used this approach successfully in research on other crops, through projects funded by Horticulture Australia Ltd.

The project provided the basis for further, ongoing research which is being undertaken in Australia, China and South-East Asia.

The difference the project has made

To enable farmers to take up this new approach to IPM, it was important that the manufacturers and formulators, wholesalers, and distributors of horticultural and agricultural mineral oils recognised the usefulness and potential of mineral oils for pest management. Caltex/Chevron Texaco, the SK Corporation, TotalFinaElf, Sunoco, ExxonMobil, BP, and several other international oil companies that produce horticultural and agricultural mineral oils, have either registered or sought to register products in China, Thailand, Malaysia and Vietnam, and more widely in the region. For example:

- Ampol Limited became the first oil company to register a horticultural mineral oil called Ampol D-C-Tron NR for use in China. Caltex regional companies subsequently registered D-C-Tron Plus in China, Thailand, Vietnam and Kenya. Initial registrations in Asia were for citrus.
- Caltex regional companies in Vietnam, China, Thailand, and Kenya became the first oil companies to appoint entomologists (one in each country, in early 1997, November 1998, December 1998, and early 1999 respectively) to assist with technology transfer through distributors (e.g. Chia Thai in Thailand, and VIPESCO in Vietnam). Caltex also became active in India in late 1999.
- Sunoco became the second company to register products (SunSpray 7E, 9E and UltraFine) in China. It has also registered its products in Thailand and elsewhere in South-East Asia.
- The SK Corporation (of Korea) became the third international company to register a product, SK EnSpray 99 (an AMO based on a food-grade mineral oil certified by the US FDA) for use on crops in China, Thailand and Vietnam, and is seeking registrations in Taiwan, the Philippines and Malaysia.
- TotalFinaElf markets Citrole in Taiwan and in mainland China. It is also seeking to register the product in Vietnam.

Each oil company usually has one major distributor, with staff numbers related to the size of the country and numbers of farmers. These distributors sell products directly, or through retailers. Most technical and sales staff within companies with links to major international oil producers would be aware of the results of the project, to varying degrees. For example, Sotus International, the distributor of SK EnSpray 99 in Thailand, has 118 staff, including 40 field staff that are technically qualified and actively involved in sales through 250 dealers in 10 sales regions. All of these personnel are familiar with results of the project. Senior staff are also aware of the project results. Sotus has about 70 per cent of the market share for quality mineral oil products in Thailand. Caltex and then Sunoco share the remaining 30 per cent. Sotus currently focuses on the central and northern provinces.

The number of government extension officers actively educating farmers about IPM practices is unknown. However, more than 150 extension staff are involved in technology transfer in Vietnam, mostly through Farmer Field Schools. In China, extension staff promoting this technology may exceed several hundred; and in Thailand the number may be greater than 50.

Communication and extension activities, mostly through registrations and assistance with marketing, has led to estimates of more than 200 000 households in the region that are now familiar with monitoring of pest populations and the use of horticultural and agricultural mineral oils. However, this is a fraction of the potential number and the rate of subsequent adoption is slow and oil use is mostly based on use with other chemicals (synthetic pesticides) rather than on use alone.

Although farmers are more aware of the mineral oils and their use through extension and marketing activities, use of low-quality petroleum-derived oils still exceeds that of high-quality horticultural and agricultural mineral oils that meet international standards for use on plants for the control of pests because the lower grade, less effective products are available at a cheaper price per unit. Also, within some countries there are several manufacturers of the poor-quality products that do not meet international standards for horticultural and agricultural mineral oils. For example, in China there appear to be at least three such companies and it seems that one or more of these companies export products to Thailand and Vietnam. There are currently about 10 unregistered products (most or all poor quality) being marketed in Thailand.

The resources and marketing activities of synthetic pesticide manufacturers and their distributors remain a major constraint on our ability to extend sustainable pest management practices, particularly reliance on natural enemies. Farmers are accustomed to using chemicals to control pests and diseases, and the resources of pesticide manufacturers and their distributors allow them to promote chemical use more effectively than our more limited resources allow us to encourage IPM.

While there is still excessive use of pesticides, conversations with farmers, researchers and extension workers indicate that pesticide use has declined as a result of the project, and through the activities of other research agencies. These changes have been documented. Government policies (e.g. the Green Food program in China and a food safety program in Thailand) have also had an impact. Quantification of these changes was beyond the scope of this adoption study but the rate of change in pesticide use should increase.

In Thailand, the number of advisers and consultants promoting IPM appears to have increased and large farms employ technicians to monitor pests and diseases. According to Dr Morokore and Mr Namruangsri (TDoA), the Thai 'food safety' program requires some 300 000 farmers to register within the next two years. Although only a small number have registered so far, Dr Morokote and Mr Namruangsri believe that mineral oils will play a major role in enabling farmers to enter the program. This may be enhanced as more farmers seek to register as organic.

The rate of adoption of technology developed during the project and its predecessor has been slower than anticipated. The potential use of horticultural and agricultural sprays oils is much larger than current sales volumes indicate. The extent of monitoring of pest populations by farmers and reliance on natural enemies is also less than anticipated, particularly in the inland provinces of China where pest pressures are low and sprays, even of mineral oils, should be rarely required. Concentrations of oil in sprays are less than optimal in some instances, particularly in Thailand and China where farmers need to gain confidence after using poor-quality petroleum-derived spray oils (mostly machine oils) in the late 1980s and early 1990s. Spray volumes for all pesticides are in most instances lower than they should be (this enhances ecosystem disruption and contributes to poor control) and spray application practices still lead to partial coverage of trees.

In China it seems that more than 200 000 households are aware of results of the project. This represents less than 20 per cent of households involved in citrus production over 1.5 million ha. Most of these households probably use poor-quality machine oil rather than high-quality horticultural and agricultural mineral oils. Data from Zhejiang suggest that 10 per cent of farmers in the province have adopted 'oil' technology and that 260 000 L of oil was used in 2003. Data from Guangdong suggests that 60 per cent of pomelo farmers in Miexian County have adopted IPM technologies developed during the project and its predecessor. The total volume of poor-quality machine oil sold for use in citrus in China in 1993 was apparently 1.5 million L. Estimates suggest that some 1.7–2 million L of machine oil (mostly from Guangdong and Jiangxi) is now sold. Sales of high quality products by Caltex (ChevronTexaco), SK Corporation, and Sunoco are currently estimated to be greater than 100 000 L but this may be an underestimate (and should increase through increased competition and awareness). The first of these

products was not available in China until late 1996. Impediments to their use include the sale of cheaper, poorer quality products that should not be used on citrus, and ongoing promotion of synthetic pesticides by the pesticide industry.

In Thailand, where individual farms are larger than those in China and Vietnam, Sotus International estimates that 1000 farmers bought 240 000–300 000 L of horticultural and agricultural mineral oils in 2003–04. The company estimates that these products are used regularly on more than a hundred, mostly large, farms. Poor-quality oils (up to 10 products) are also used by Thai farmers. IPM practices are gaining popularity in Thailand and the average number of pesticide sprays applied by farmers has probably fallen from around 52 to 35–40 applications per year over the past 10 years. Rates of adoption of the results of the project and other IPM projects in Thailand appear to be greater than in China, Vietnam and Malaysia, but most growers are not yet sufficiently confident to use quality mineral oils at rates recommended by UWS and TDoA.

The main impediments to adoption in Thailand are related to plant toxicity caused by earlier poorer quality products 10–20 years ago, and to ongoing promotion of synthetic pesticides by the pesticide industry. The latter impediment also applies in Vietnam. There is also a widespread tendency throughout the region for distributors of petroleum-derived oils to encourage use of oils with other pesticides, as most distributors believe that this leads to better pest control. The project showed this to be false.

There is a sense that distributors also fear the impact of increased oil sales on sales of other pesticides. The relatively lower price of poor-quality (machine) oils discourages use of high-quality horticultural and agricultural mineral oils. This is serious and most evident in Jiangxi where phytotoxicity caused by machine oils has discouraged farmers from using oils, particularly in the warmer months of the year when their use is most effective.

In Vietnam, sales, areas planted to citrus, recommended rates, frequency of use and average land holdings suggest that 12 000 households (about 20 per cent) now use horticultural and agricultural mineral oils. These oils were not available in Vietnam until mid to late 1997. As a result of the project, farmers also use high-quality oils on other fruit trees, vegetables and tea.

No information was available for Malaysia, where marketing of horticultural and agricultural mineral oils is due to start in 2004.

Project impacts

Community impacts

The results of the project and concurrent studies demonstrated that horticultural and agricultural mineral oils can be used to control a range of pests and diseases simultaneously with no threat to human health and the environment. The project and its predecessor led to marketing of high-quality mineral oils in the region for the first time, thus providing farmers with an opportunity to use non-toxic products as biorational alternatives to synthetic pesticides. Availability of these products also reduced the risk of phytotoxicity, which was most commonly linked to the sale of poor-quality products in the region. Several other major oil companies have followed Caltex into the region. This, through competition, should enhance technology transfer and adoption. To date, it seems that some 20 per cent of households involved in citrus production in China and Vietnam have been influenced by the project and subsequent extension activities, and ongoing extension is required to maintain and increase adoption of the technology.

Even though adoption has been slower than anticipated, where farmers are using high-quality horticultural and agricultural mineral spray oils, the following changes have been seen:

- increased monitoring of pest populations by farmers;
- greater use of petroleum-derived spray oils as alternatives to synthetic pesticides;
- marketing and use of high-quality mineral oils for the first time in China, Thailand and Vietnam;
- reduced pesticide use on farms where IPM practices have been adopted;
- lower pest management cost on these farms; and
- higher quality fruit.

These changes have been quantified in Meixian County, Guangdong, where losses of up to 3500 tonnes were avoided in 2003 and where a decline in pesticide use has saved the county 5.6 million yuan/year (about AUD 1 million over 16 670 ha). Brand names have also been enhanced and prices received for fruit have increased.

Elsewhere in China, farmers who have mastered IPM in Zhejiang are saving 400–600 yuan/ha/year. However, adoption rates by the 12 000 farmers trained in Zhejiang are variable. Information was not available from Guangxi and Jiangxi for changes in farmer practices, but information from Sichuan indicates that pest management costs have not changed. This is probably the case through most of China, as oils are still most commonly used with synthetic pesticides despite the fact that this is not necessary in most citrus-producing regions of China.

Thai farmers are applying fewer sprays annually than they did in the late 1980s and early 1990s. The proportion of Thai farmers who are aware of IPM and its benefits is greater than in China and Vietnam. This is related to education and the size of farms (some are 400 to 1000 ha), which is larger than in China and Vietnam; it also comes from the fact that higher proportions of the total area are planted to citrus in Thailand. Therefore, the structure of the Thai industry, government policies, education levels, and the activities of researchers, extension personnel and distributors combine to enhance adoption of technology.

Where the project's natural enemy and oil-based IPM technology have been adopted, it is clear that use of synthetic pesticides can be reduced, thereby leading to lower pest management costs and higher quality fruit with less risk of toxic residues (none if oils are used alone). However, ongoing successful technology transfer will depend on inputs from UWS and other agencies with similar expertise. It will not be possible to maintain this expertise unless we can identify means of doing so at a time when most countries in the region are reducing their support for research and extension.

Some farm-to-farm transfer of technology will occur in the absence of inputs from researchers, extension officers and oil companies. However, this is more likely to be successful and adoption to be more widespread in temperate regions (with a narrower range of pests and lower pest pressure) than in tropical regions (with a broader range of pests and higher pest pressure), and in regions with relatively small numbers of large farms (e.g. Australia and Thailand) than in regions with relatively large numbers of small farms (e.g. China and Vietnam). Rates of adoption are also related to income and education. Poor, less well educated farmers with small holdings are the most difficult group to service. In Australia, the spread of IPM practices from 1970 was more rapid in the southern temperate regions than in Queensland, where the range of pests and diseases is greater and successful programs require more inputs (e.g. monitoring, sprays and releases

of natural enemies). In China, IPM is easier to achieve in inland temperate provinces (e.g. Jiangxi, Hunan and Sichuan) than in coastal subtropical provinces (e.g. Guangxi, Guangdong and Fujian). There are fewer pests in the inland regions and the most serious pests, Asiatic citrus psyllid and citrus leafminer, are generally confined to the coastal provinces.

Farmers with small holdings are often, but not always, the most difficult group to educate about the benefits of IPM, and about the differences between poor and good quality oils. Transfer of technology to farmers with large farms can also be difficult – but once they are convinced, change can be rapid and their costs and use of pesticides can fall dramatically (as has occurred in Queensland on large properties). Extension based on conventional means is best suited to farmers with large holdings and Farmer Field Schools are best suited to farmers with small holdings. Both require inputs from researchers and knowledgable/trained extension personnel.

All farmers are continually exposed to advertising from the manufacturers and distributors of synthetic pesticides who use radio, television and glossy brochures to promote their products. They have the resources to continually promote use of chemicals. Many of their products are not suitable for use in IPM and overuse is rarely discouraged. Distributors in some instances provide finance to farmers, a practice which through debt can lead to distributors having undue influences on the farmers' use of pesticides. It is not uncommon for extension personnel in Asia to be linked in some way to the manufacturers of synthetic pesticides and their distributors.

The oil companies find it difficult to compete with the marketing strategies of the manufacturers of synthetic pesticides. They generally have limited expertise in marketing their products for pest and disease management. In most instances they market their spray oils through distributors who also sell synthetic pesticides and tend to view oils as an effective means of increasing the effectiveness of some synthetic pesticides, not as stand-alone products. Extensive use of horticultural and agricultural minerals and widespread adoption of IPM practices could also reduce their income from sales of synthetic pesticides – income that they might not recoup from the sales of oils. This situation is not helped by the fact that marketing personnel in some oil companies have also marketed synthetic pesticides, and some believe that oils are best suited for mixing with synthetic pesticides because, in their view, farmers believe that the only good insect is a dead insect. This is the easiest way to sell product, as it requires limited inputs. Promoting use of oil alone requires greater effort and possibly narrower profit margins, at least initially, through higher marketing costs and reduced sales to manufactures of synthetic pesticides. These factors have had an impact on successful marketing of horticultural and agricultural mineral oils in Asia. The per litre cost of oil also leads to the perception that pest management based on oils is more costly than programs based on synthetic pesticides, a view easily exploited by manufacturers and distributors of the latter and one that the oil companies alone do not have the resources to counter, particularly in Asia where the technology has only recently been introduced through the two ACIAR-funded projects on the integrated control of citrus pests (CS2/1993/005 and CS2/1996/176).

It is not the responsibility of the oil companies to directly promote reliance on natural enemies, even though successful use of their products is enhanced by increased natural enemy activity in the absence of disruptive synthetic pesticides. However, it would be in their best interests to do so by collaborating with government agencies, university, technical colleges and related institutions to educate farmers about the benefits of natural enemies, as is being done through the Farmer Field Schools (FFS) in Vietnam. This said, there is considerable scope for establishing commercial insectaries for production of natural enemies and commercial pest monitoring services in Asia, but such services are in their infancy and difficult to establish in an environment dominated by synthetic pesticides.

Support for technology transfer activities is required to facilitate further community impacts. At this point, UWS relies on its funds from agencies such as AusAID for the CARD 'Extension of citrus IPM in Vietnam' project, and oil companies for interactions with distributors of horticultural and agricultural spray oils.

The AusAID-funded FFS have been very successful. They are an effective way of transferring technology in countries where farm sizes are small (e.g. China and Vietnam). Further funding of FFS in Vietnam is essential to ensure training of adequate numbers of Vietnamese trainers and farmers.

Funding of FSS would greatly enhance technology transfer in China and help overcome the negative activities of synthetic pesticide manufacturers and distributors, the limitations of working with oil companies, and the inadequate funding of support for technology transfer activities in China since the end of CS2/1996/176. UWS wants to be involved in extension activities in China but does not have the resources, other than through oil companies, to do so. We know that our partners at the Guangdong Entomological Institute (GEI) would like to be actively involved in extension, through demonstration farms and publishing of extension material. Prof Huang Mingdu (GEI) has translated the AusAID-funded 'A guide for using mineral oils in Vietnamese citrus IPDM' by Rae *et al.* (published in 2003) from the original English text, and he is now adding information relevant to China and deleting text that is not. We are seeking funds to complete this task and to publish the book. We have also discussed publication of the book in Thai with our colleagues in Thailand; and have discussed with Stephen Leong the prospects of the book being produced in Malay, Chinese and English for use in Malaysia. The FFS in Vietnam indicate what can be done with the assistance of UWS, with a focus on maintaining a balanced emphasis on pest monitoring, reliance on natural enemies and use of horticultural and agricultural mineral oils where necessary.

The contribution that the oil companies have made to technology transfer is appreciated. It has provided farmers with the opportunity to apply biorational products in the same manner as conventional sprays. The benefit of this strategy, which has been a key component of extension activities to date, means that farmers only have to learn about the benefits of a new product, rather than having to learn about a new product and a new application method. However, uptake of the new product could be limited as UWS can only work effectively with one company at a time, continuity of relationships is not certain, and selling products through distributors whose businesses depend on sales of conventional pesticides can, as mentioned above, be disadvantageous.

The project demonstrated that natural enemy and mineral-oil-based IPM programs can reduce pest management costs and, through reduced use of synthetic pesticides, improve the health of farmers and reduce the impact of pesticides on the environment. Our task in technology transfer would be easier if legislation and government polices more effectively discouraged excessive use of synthetic pesticides and regulated the activities of pesticide manufacturers and distributors.

Capacity-building and scientific impacts

While there has been a demonstrated increase in the knowledge and skills of those involved in the project, the impact has, with the exception of the AusAID CARD project in Vietnam and regular UWS visits to Thailand, gradually diminished since the end of the project. This is in some part due to changes in personnel and retirements and new staff and scientists being appointed who have limited access to support. In addition, some scientists, whose work has contributed greatly to understanding of how mineral oils can benefit horticultural industries, have chosen to pursue careers outside of their home countries. The knowledge base is increasing, yet there are some concerns about the capacity for information to be further communicated to key audiences across the region.

Significant scientific achievements of the project include the demonstration of the behavioural effects of mineral oils on a range of pests, and the recognition that behavioural effects are more important than suffocation (anoxia), which had been the traditionally accepted principal mode of action for more than a century.

Studies on phytotoxicity, and use of 'multiple application' 'adequate even coverage' sprays for simultaneous control of a range of pests and diseases, including Asiatic citrus psyllid and 'huanglongbing', were original and influenced studies on crops other than citrus – for example, the use of oils to suppress oviposition by *Helicoverpa* spp. in cotton and tomatoes and recently completed studies on two polyphagous fruit flies (Queensland fruit fly and Oriental fruit fly). Underexploited avenues for managing pests have been greatly enhanced and new areas for research on arthropod behaviour have been identified.

Other important studies include the work on degree-days and weather station logging intervals as part of the ACIAR-funded project on integrated control of citrus pests in China (CS2/1993/005) and Liang Weiguang's PhD studies comparing the impact of mineral oils and synthetic pesticides on orchard ecosystems.

The 1999 conference proceedings, *Spray oils beyond 2000* (GAC Beattie, DM Watson, ML Stevens, DJ Rae & RN Spooner-Hart eds, University of Western Sydney, 2002), is a landmark publication on spray oils that was edited by UWS project staff, who also presented papers at the conference, along with project personnel from China, Malaysia and Vietnam.

Development of improved mud crab culture systems in the Philippines and Australia (FIS/1992/017)

Colin Shelley

Collaborating organisations	Bribie Island Aquaculture Research Centre, Queensland Department of Primary Industries, Australia(QDPI); Northern Territory Department of Primary Industries and Fisheries, Darwin, Australia (NTDPIF); South-East Asian Fisheries Development Centre, Aquaculture Department, Iloilo City, Philippines (SEAFDEC); Institute of Fisheries Policy and Development Studies, Iloilo City, Philippines (IFPDS)
Project leaders	Dr Clive Keenan (QDPI); Professor R D Fortes (IFPDS); Dr Oseni Millamena (SEAFDEC) Related projects FIS/1994/011
Principal researchers	Dr Colin Shelley (NTDPIF)
Duration of project	1 January 1995 – 31 December 1999
Total ACIAR funding	$799 236
Project objectives	The objectives of this project were to optimise the conditions for the production of mud crabs at all stages of their development in a number of research trials and to have these improved methodologies adopted by mud crab farmers. Few of the procedures used in this project were new. They were primarily modifications or adaptations of existing technologies developed in a manner appropriate to the countries involved.
Location of project activities	Bribie Island Aquaculture Research Centre, the Darwin Aquaculture Centre, Australia; the University of the Philippines in the Visayas, Philippines

Overview

An ACIAR-funded project developed mud crab culture techniques in the Philippines. This project was undertaken by the Northern Territory Department of Primary Industries and Fisheries in collaboration with the Queensland Department of Primary Industries, the South-East Asian Fisheries Development Center and University of the Philippines in the Visayas (UPV). As a result, new information on hatchery production and technical advice on the best techniques to rear crablets and how to grow-out mud crabs is available for farmers in the Philippines.

Traditionally, crabs are collected from the wild for farming, causing significant depletion of wild stocks. The results of the project have revealed that rearing mud crablets, and the farming of mud crabs in mangrove areas, can be a benign, environmentally sustainable activity and can reduce pressure on the wild fishery.

Project achievements

The ACIAR-funded Philippines mud crab culture project developed appropriate technology for hatchery and nursery production of crablets while also investigating increased pond productivity in the grow-out phase. A project extension allowed a training course in mud crab hatchery production to be conducted. The training course led to an increase in human resource capacity in aquaculture.

In collaboration with mangrove researchers at SEAFDEC, in particular Dr Primervera, guidelines for the design of pens for farming crabs have been developed. Building a range of pens in different types of mangrove forests, and using different techniques, resulted in a publication on pen culture for crabs. This work was significant, as it has demonstrated that, if particular guidelines are followed, farming of mud crabs in pens in mangrove areas can be a benign, environmentally sustainable activity. Information on how to culture crabs in mangrove enclosures is detailed in the publication on pen culture of mud crab in mangroves.

Economic models have been developed for both the hatchery/nursery and grow-out components of mud crabs by economists attached to SEAFDEC to complement the technological development.

SEAFDEC and UPV produced their own publications on how to farm mud crabs for the Philippine industry, although SEAFDEC also uses its publications in training courses which included overseas participants.

The Bureau of Fisheries and Aquatic Resources (BFAR) is continuing to support ongoing trails of mud crab culture in the Philippines, using research outcomes from the project, and training courses in mud crab hatchery production have been offered by both UPV and SEAFDEC.

The difference the project has made

There appears to have been limited uptake of the mud crab hatchery technology to date, despite the advice on hatchery production that is now available through a number of publications. The reason for the limited uptake appears to be that there is still a preference to maintain the tradition of catching crablets or crabs from the wild to stock farms.

Before work on grow-out in ponds or in mangrove enclosures undertaken in the ACIAR-funded project, the advice to farmers was based on pond grow-out systems for crabs caught in the wild. The technical advice to crab farmers on best techniques to rear crablets and how to grow-out mud crabs has changed as a result of the ACIAR-funded project. This change is reflected in the handbooks for farmers that were produced as part of the project.

While several mud crab hatcheries have been developed to date, and some farmers have stocked and grown-out hatchery-produced crablets with good results, the vast majority of farmers are still using wild fishery sourced stock. This is because hatchery production has been limited and so wild-caught crablets are transported, even between islands, to farmers. It appears that within the aquaculture industry in the Philippines, farmers are taking a 'wait and see' attitude. That is, the farmers are waiting for someone else to develop a hatchery and grow crabs from hatchery-produced crablets, rather than take the risk themselves.

Nevertheless, as a direct result of the ACIAR-funded research, several non-ACIAR funded projects are underway to prove the viability of different types of mud crab production. In total, these projects may be able to encourage the adoption of the improved mud crab hatchery and grow-out techniques by farmers. The projects are listed below.

- In a European Union (EU)-funded mud crab project, which is being undertaken in both the Philippines and Vietnam, hatchery technology is being used to produce crablets for stock enhancement trials. The EU-funded project is divided into a number of project areas including seed production, mangrove pen grow-out (including silviculture), stock enhancement, diseases and a key to larval crabs.
- Under a German Technical Cooperation (GTZ)-funded project, UPV will be supplying crablets to support various aquaculture trials. Under the GTZ project, some 20 farmers will be given financial assistance to undertake pen culture of crabs, so that the economic potential of the activity can be determined.
- The Land Bank (a Philippines bank) is currently funding a project with UPV to demonstrate mud crab farming techniques to the private sector. The project is to validate the hypothesised economic outcomes of mud crab farming.
- A seafood dealer has also approached UPV staff to discuss a country-wide project to develop the mud crab industry in the Philippines. This is still at a development phase.
- The Asian Development Bank is funding a Fisheries Resources Management Project in the Capiz and Aklan areas, where six crab-farming operations are being given financial support to be part of the project. However, wild crablets are currently being used in the research.

To date, the results from the research undertaken in the ACIAR-funded project have shown that if farmers are provided with small C2-C4 crablets (known as megalopae) and use hapa nets (fine meshed nets used to hold larval or juvenile stages of aquatic organisms) in the ponds as a preferred nursery technique, the growth of the crablets is rapid, there is relative conformity in size and a relatively high survival rate compared to stocking ponds with wild seedstock.

Project impacts

Community impacts

Community impacts from R&D investment in mud crab culture appear to have been limited to date, although a variety of projects are in progress, the results of which may change this situation. Crab farming is perceived as being a significant alternate use of brackish water ponds to shrimp and milkfish, and as such the results of the research to date, and ongoing extension work, could have an effect on the development of mud crab farming.

Economically, some farmers have used hatchery-produced crablets with positive results. As word of these results spread, there is likely to be increased demand, which may lead to further hatchery production.

From an environmental perspective, the development of crab farming appears to be linked to some development of pen culture in mangroves. This environmentally benign activity is also likely to lead to planting of mangroves to enhance the productivity of pens in the mangrove zone, a positive outcome when compared to the mass clearing of mangroves which accompanied a lot of shrimp farm development in the Philippines.

As a 'wait and see' approach is being taken to mud crab farming based on hatchery-produced crablets, establishing or supporting a demonstration hatchery and grow-out operation may be a useful communication device. Such demonstration facilities could then be used to develop real-world economic models for mud crab farming and also be used to provide hands-on experience to potential crab farmers.

The current hatchery at SEAFDEC is not adequately resourced to produce crablets on a commercial scale. Whilst the SEAFDEC mud crab hatchery only has the capacity to produce crablets to support research trials at present, it has supplied excess production to farmers over the last few years. Investing in human resources and infrastructure to establish a commercial hatchery at SEAFDEC could have several advantages. A substantial supply of crablets at commercial prices from the SEAFDEC facility could stimulate more farmers to get involved with crab culture, or at a minimum, trial some ponds of hatchery-reared stock alongside wild-caught stock. The production of commercial quantities of crablets would also generate profits, which could be re-invested into research at SEAFDEC.

Research staff at both SEAFDEC and UPV have been asked for advice and assistance in developing mud crab farming. Whilst there has been significant farmer interest in obtaining crablets for grow-out, neither UPV nor SEAFDEC have been able to supply commercial quantities.

Whilst white spot virus is a major threat to shrimp farming, in the Philippines it has been reported that crabs carrying white spot (as tested by PCR) are little affected by the virus. It was reported that stock tested positive for white spot would still grow normally to harvest, unlike shrimp, which usually experience serious losses.

Several reasons were suggested to explain why mud crab culture is growing faster in Vietnam than in the Philippines. These included high transportation costs between the numerous islands of the Philippines, inefficient bureaucracy, and a lack of financial support from government. In terms of extending the technology to the private sector, it was thought that more consideration should be given as to how best to achieve this. A technical verification and commercialisation division established within SEAFDEC was perceived to be undertaking the same work that has been BFAR's responsibility in the past. The mechanisms and process for technology transfer to industry, in terms of mud crab aquaculture, would appear to be worthy of re-examination.

A looming threat to the expansion of mud crab culture in the Philippines is the availability of trash fish. In many areas supplies are limited and becoming expensive. A significant issue is that trash fish are also being used for human consumption by poor coastal communities. Consequently, the need for a formulated feed for mud crabs to support the expansion of mud crab farming in the Philippines is also seen as a significant issue.

Currently costs for *Scylla serrata* crablets from the wild fishery vary from US$0.12–0.4 depending on their size, with US$ 0.12 being paid for C3/C4 crabs. As such, the operation of mud crab hatcheries should be profitable, providing that production levels of crablets in the Philippines can improve to match those achieved in both Vietnam and Australia.

Capacity-building and scientific impacts

From a human capacity-building perspective, one UPV researcher involved in the ACIAR crab project went on to obtain an MSc at James Cook University on aspects of larval mud crab nutrition. A further two students obtained their Master degrees from UPV on mud crab aquaculture topics: Conrad Rendon on hatchery and nursery work, and Gil Lamaze on digestive morphology and physiology. Gil has subsequently gone to the US on a Fullbright scholarship. Other students are now being trained through a related EU-funded project on mud crab fishery and aquaculture. In addition, international visits to Australia and then to Vietnam and Europe (under the EU-funded project) have enabled SEAFDEC staff to obtain new skills and experience.

Two technical staff trained in mud crab culture techniques in the ACIAR-funded project were hired by the private sector to operate a hatchery to produce blue swimmer crabs, obtaining valuable commercial experience. This also indicated the potential value of crab hatchery training to local staff.

Each year, a network of 14 R&D institutions have a meeting where information on marine fisheries and aquaculture is shared. UPV takes part in this process, providing another way in which information from mud crab work has been disseminated throughout the country, improving national capacity.

From an infrastructure capacity perspective, ACIAR funded a mud crab hatchery/nursery at UPV which is still being used for crab research and teaching.

As a result of the ACIAR-funded mud crab project, staff at SEAFDEC are recognised throughout the region as experts in the field. Their reputation was enhanced by the numerous research papers they presented at conferences and the number of papers they have published in journals. Partly because of their expertise in the field, members of the group were invited to collaborate on the EU-funded mud crab fishery and aquaculture project, which represents a partnership between research and academic organisations in Vietnam, the Philippines and Western Europe.

Involvement in the ACIAR-funded mud crab project was directly responsible for SEAFDEC obtaining further funding through the EU-funded mud crab project, which has a significant wild fishery component to it, in addition to aquaculture. The ACIAR experience similarly assisted UPV with their involvement in the GTZ VisSea project, and Land Bank projects.

Development of leading centres for mud crab culture in Indonesia and Vietnam (FIS/1999/076)

Colin Shelley

Collaborating organisations	Bribie Island Aquaculture Research Centre, Queensland Department of Primary Industries, Australia (QDPI); Research Station for Coastal Fisheries, Jakarta, Indonesia (RSCI); Research Centre for Aquaculture No. 3, Nha Trang, Vietnam (RIA3)
Project leaders	Dr Clive Keenan, Dr Brian Paterson (QDPI); Mr Co Thach Nguyen (RIA3); Dr Ketut Sugama (RSCI)
Related projects	FIS/1992/017; FIS/2000/065
Principal researchers	Mr David Mann, Mr Tom Asakawi (QDPI); Mr Yunus, M Ibnu Rusdi (RSCI)
Duration of project	1 April 2000 – 31 March 2002
Total ACIAR funding	$114 220
Project objectives	The main objective of this small project was to develop leading centres for crab aquaculture at key institutions undertaking nationally funded mud crab research programs in Vietnam and Indonesia.
Location of project activities	Bribie Island Aquaculture Research Centre, Australia; Vietnam and Indonesia

Overview

This ACIAR-funded project followed on from the project conducted in the Philippines (FIS/1992/017). It was undertaken by researchers at the Queensland Department of Primary Industries' Bribie Island Aquaculture Research Centre, in collaboration with Indonesia's Research Station for Coastal Fisheries and Vietnam's Research Institute for Aquaculture No. 3. This report focuses only on adoption of the technologies in Vietnam.

As a result of this project the demand for hatchery-produced crablets is outstripping supply and the area devoted to mud crab aquaculture in Vietnam has increased five-fold.

In addition to economic benefits, further development of mud crab culture will also have environmental advantages. As the industry grows, based on hatchery-produced crablets, it should become economically viable for a formulated feed to be produced for mud crab culture. The development and sale of a formulated feed for crabs could reduce the quantity of trash fish used in farming activities, thus preserving natural fish resources. In addition, because uneaten trash fish can encourage bacterial proliferation, replacing trash fish with a formulated feed could improve water quality, thus reducing the need for, and cost of, aeration and water exchange.

Project achievements

Infrastructure was established at Vietnam's Research Institute for Aquaculture (RIA) No. 3 to support the development of, and training in, mud crab hatchery and nursery production and to undertake larval rearing trials. Extension workshops were carried out and the technology for crablet production has been forwarded to national and provincial governments.

Scientists at RIA No. 3 are successfully using techniques for culturing mud crabs previously developed in the Philippines and Australia. Crablets produced from the project at RIA No. 3 have been sold to the private sector, and the demand far exceeds the potential supply.

Government researchers and hatchery staff, who are able to promote the use of hatchery-produced crablets, were provided with a significant amount of training, including a practical hands-on component, as part of the project. In addition, the project demonstrated to farmers that they could produce two or more crops of crabs per year, with a higher stocking density if they used hatchery-produced crablets, rather than crablets caught in the wild.

The difference the project has made

Industry development

Mr Nguyen Co Thach was the project leader at RIA No. 3. Following the successful production of mud crab crablets by Mr Thach and his team, the Vietnamese Government (at both national and provincial levels) invested in the development of mud crab hatcheries in Hai Phong, Hue and Nghean. Mr Thach oversees all three operations in addition to his work at RIA No. 3.

A percentage of crablets produced from government hatchery production are being used for stock enhancement to help re-build wild stocks, in addition to supporting the growth of the mud crab aquaculture sector.

The Ministry of Fisheries sees mud crabs as a significant alternative export industry to shrimp production, and as such is giving strategic importance to the development of the Vietnamese mud crab industry. The Ministry is looking to divert effort from wild fishing to aquaculture, particularly mud crab culture.

The information on stock enhancement that came out of the ACIAR-funded project differed from the information provided by the European Union (EU)-funded mud crab project, which had involved Vietnam and Indonesia. In the EU-funded project, which was limited to areas near Can Tho in Vietnam, it was found that *Scylla paramamosain* was so abundant in the wild that stock enhancement would not be useful. However, the Vietnamese coast is long and covers a variety of coastal habitats, experiencing varying degrees of fishing pressures. Hence, it is most likely that, although Can Tho may not require stock enhancement in the short term, other crab populations and the fisheries they support may be experiencing significant declines.

Wild populations will benefit from expanded hatchery production, because collection of crablets from the wild should decline, as more hatchery stock – of better quality and lower price – becomes available.

Extension materials are being developed to describe standard procedures for hatchery production of crablets and for the grow-out of crabs, based on the results from the ACIAR project.

Under a new system for land management that has recently come into law, leases of land or mangrove areas can now be approved from 30 to 50 years for activities such as mud crab farming. Planning for aquaculture development is undertaken at a national level and then implemented at the provincial level. It is planned that thousands of hectares of land for mud crab culture will be developed.

Crab culture was traditionally based on the collection of wild crablets, which are limited, and so little industry development occurred. However, now that hatchery-produced stock is becoming available, industry is moving into a growth phase and the government is supporting the intensification of mud crab culture to achieve improved productivity and returns per hectare. The Hai Phong mud crab hatchery (developed with provincial government funds) is now producing crablets and supplying them to farmers within the province. In the first instance, the crablets are being provided to farms under government control. As a result of a high demand for hatchery crablets, the initial hatchery has been enlarged.

However, if the opportunity for the expansion of a hatchery-crablet-based mud crab industry is to be fully realised in the Hai Phong province, a formuated feed industry also needs to be developed for both resource-based and environmental reasons. The quantities of trash fish and bivalves (used as feed for mud crabs) that are currently available would not support a significant expansion of mud crab culture in the province. In addition, because water quality can be affected by trash fish and bivalves when farmed at higher densities, an alternate, relatively environmentally friendly, formulated feed for mud crabs is needed to ensure the long-term sustainability of a viable and expanded mud crab industry.

Now that mud crablets can be produced from hatcheries, provincial fisheries departments, such as in Hai Phong, can set targets for industry growth. Mud crab is now considered as a proven alternate crop to shrimp. In Hai Phong province, the provincial government has a target to increase the area of mud crab ponds from 2000 to 10 000 ha and to increase density to 2 tonnes per ha from current levels of 600–800 kg/ha. If these targets are met, production will increase from 1000 to 20 000 tonnes per year as farmers move out of a system that is based on wild crablets to one that uses hatchery-produced crablets. These new targets are aimed at supporting a rapidly growing domestic as well as export market, particularly to China. The Hai Phong provincial government also plans to develop a new economic model for the farming system, now that the industry is to become more significant to the province. The provincial government sees mud crab farming as a genuine opportunity to diminish poverty.

There are plans to develop mud crab hatcheries in most coastal provinces. RIA No. 3 has received numerous requests to assist with the design and operation of them. The hatchery in Hai Phong is well designed and full of crab larvae and crablets at all stages of development.

Farmer uptake

The average family typically owns or leases a pond that is around 1–1.4 ha in size. Mud crab farming has, until recently, been based on collection of mud crabs from the wild. Farmers are now using crablets supplied from hatcheries, where available. Crablets produced from hatchery production are often cheaper for farmers to buy than wild crablets. For example, hatchery stock are being sold for US$0.10–0.70 compared to juveniles from the wild which are sold for US$0.50. In addition, hatchery crablets have a better growth and survival rate compared to their wild counterparts, so farmers can stock their ponds at higher rates. Hatchery-produced crablets are also considered by farmers to be of higher quality than wild crablets. In general, it takes only 3-4 months for hatchery crablets to reach harvestable size, compared to 6 or more months for wild-caught crablets. This means that farmers can produce two or three crops of crabs per year. Finally, as wild mud crablets are not available all year round, farmers could not stock their farms at certain times of the year. In comparison, hatcheries can supply crablets all year. This feature of hatcheries will overcome the current seasonal limitations on the industry. As a result, the demand for hatchery-produced crablets is extremely high. This has driven the rapid development of provincial mud crab hatcheries to try to meet that demand. For example, the Hai Phong hatchery was designed to produce 1.5 million crablets per year.

As crablets from hatcheries become more available, shrimp farmers are likely to take up mud crab farming, because crab farming is seen as a cheaper enterprise than shrimp farming. Moreover, as crabs appear to have fewer health issues than prawns, the risk of losing a crop of crabs is perceived to be lower than it is for shrimp.

If the expansion plans for Hai Phong province are reflected in other coastal provinces, as would appear to be the case, there could be a five-fold increase in the area of mud crab ponds. In addition, stocking density per hectare could more than double (conservatively), so mud crab production in Vietnam is likely to expand significantly over the next few years. Many of the ponds used will be those previously used for shrimp culture. Mud crabs will either be grown in monoculture, as part of a rotating system (i.e. crop of crabs, followed by crop of shrimp) or in polyculture with shrimps and possibly algae. In the polyculture system, shrimps are added when the crabs are more that halfway through their grow-out period, because if the crablets and post-larvae prawns are stocked simultaneously, the prawns will eat the crablets when they moult.

There is a trend for mud crab farmers (along with shrimp and other aquatic producers) to move to cooperative structures along the lines of cooperatives in Western countries, where marketing and group purchasing are more efficiently done as a larger group. In the cooperative farm visited in Hai Phong, farmers are allowed to keep production of saleable crabs over and above an anticipated yield for their own benefit. With more reliable stocking (using hatchery crablets) the chances of farmers exceeding their targets will be increased, and thus so will the probability of increasing the income of the farmers.

While the total number of farmers who would benefit from new mud crab farming techniques was not estimated as part of the adoption statement, it was apparent that mud crab farming could significantly impact on brackish coastal pond culture in Vietnam. RIA No. 3 is currently investing in mud crab enclosure and pen trials in mangroves. Their opinion on how successful, profitable or significant for Vietnam that approach might be has yet to be formulated.

With intensification of crab farming, some diseases have been encountered. Research into disease (and how to manage it), and into formulated feeds were the two priority areas highlighted by all groups (government, hatcheries and farmers) encountered. Mr Lee, the director of the 300 ha mud crab farm, advised that in the past five years the price of crablets from the wild had increased fourfold, while the cost of trash fish and bivalves had tripled. This highlighted the increasing need to develop a cost-effective formulated diet.

Project impacts

Community impacts

The project has had a surprisingly large community impact. The construction of three mud crab hatcheries in three different provinces to take up the technology that Mr Thach and his team have developed is quite outstanding. According to the Ministry of Fisheries, interest from other coastal communities is extremely high.

As hatchery-reared crablets have received such favourable reviews from farmers, the demand for crablets is apparently very high and will probably drive significant further hatchery development. Mud crabs are now seen as a viable alternate species to shrimp, which is very significant for a country that has invested so heavily in that industry.

The availability of crablets will enable the industry to grow and employ more people. In mid-2004 the 300-ha mud crab farm in Hai Phong employed 160 permanent staff and 200 temporary staff. If these figures are indicative of normal staffing levels then the 10 000 ha industry proposed for the province could employ 12 000 people, which would have considerable socioeconomic benefits.

The model of hatchery development, training and extension of results to farmers that has and is being undertaken in Hai Phong by the provincial government, with the support of the Ministry of Fisheries, seems to be very successful. If that approach is continued throughout the coastal provinces, mud crab farming is likely to boom in coming years. However, this boom will only happen if economically viable formulated feeds can be developed, as trash fish and mollusc resources to support a significant industry expansion are not available. In addition, both provincial and national governments are concerned that if an alternative source of feed is not found, the increased use of these trash fish and molluscs will have detrimental effects on water quality as farming operations expand.

With increased densities of crabs and volumes of crabs being produced, the need to identify and manage diseases will also become increasingly important. Currently, knowledge of mud crab diseases is poor, because the low farming intensity, which has characterised the industry to date, has resulted in low incidence of diseases. Consideration should be given to collaborative research in mud crab health issues if the industry is to grow as anticipated by governments and farmers in Vietnam. Such research would also be of significant value in Australia as its fledgling industry starts to develop, and would build upon the excellent work it has undertaken in prawn farming in recent years with the support of ACIAR.

Capacity-building and scientific impacts

Mr Thach said that Australian scientists through the ACIAR-funded program taught him how to cooperate with overseas collaborators. It also improved his skills in technology transfer, through planning and contributing to workshops. During his five-week visit to Australia he was introduced to a range of new equipment and techniques.

The success of the work by Mr Thach's team led to hatchery and farm development in at least four provinces. Mr Thach was apparently also a key player in the development of shrimp farming in Vietnam. Such a track record will no doubt continue to attract funding for his institute.

As a result of all his work on mud crabs and aquaculture, Mr Thach was awarded a VFORTECH prize for achievement in science. In addition, as a result of the extension of his work in the Hai Phong Province, Mr Thach was awarded a certificate of merit by the leader of the Hai Phong Peoples Committee. Internationally, Mr Thach received a 'best inventor' award from the World Intellectual Property Organisation (WIPO).

The excellent extension of the ACIAR-funded project to the provinces, involving a range of training and mentoring initiatives, has significantly increased human capacity for mud crab production in Vietnam.

Ectomycorrhizal fungi for eucalypt plantations in China (FST/1994/025)

Bernie Dell

Collaborating organisations	CSIRO Forestry and Forest Products, Centre for Mediterranean Agricultural Research, Perth, Australia (CFFP); Murdoch University, Perth, Australia (MU); Chinese Academy of Forestry, Guangzhou (CAF); Xinhui Forest Bureau, Guangdong; Gaoyao Forest Bureau, Guangdong; Chuxiong District Forest Research Institute; Kunming Institute of Botany, Kunming, China.
Project leaders	Dr Nicholas Malajczuk, Dr Mark Brundrett (CFFP); Mr Gong Mingqin (CAF)
Related projects	FST/88/48, FST/90/44, FST/91/15, FST/91/27, FST/92/08, FST/92/27
Principal researchers	Dr Bernard Dell (MU); Dr Xu Daping (CAF)
Duration of project	1 January 1996 – 31 December 1999
Total ACIAR funding	$798 056
Project objectives	Compatible mycorrhizal (root) fungi that improve nutrient uptake and growth performance of eucalypts are often missing in exotic eucalypt plantings. An earlier project (FST/1990/44) showed how introduced Australian fungi improved growth and establishment of eucalypts in China and the Philippines. This project aimed to match the fungi to important plantation eucalypts in a range of climatic and soil situations in China and Australia. In Australia, only about 5 per cent of Australian ectomycorrhizal fungi have been characterised. Individual species and isolates of ectomycorrhizae vary in their abilities to extract nutrients from the soil matrix and otherwise modify soil conditions for the host. During the project scientists evaluated mycorrhizal fungi to find those compatible with key eucalypt species. They also selected and matched the fungi to proposed sites in China and Australia, and identified site criteria for predicting which mycorrhizal–nutrient interactions determine inoculation responses in plantations in the two countries.
Location of project activities	Guangdong and Yunnan Provinces, China

Overview

The ACIAR-funded project on ectomycorrhizal fungi for eucalypt plantations in China (FST/1994/025) brought together the expertise of CSIRO, Murdoch University and the Chinese Academy of Forestry. As a result of this project, timber plantation managers in China recognise the productivity gains from using cloned eucalypts that are inoculated with mycorrhizal fungi. In addition, the benefits of using balanced fertiliser to improve tree growth is acknowledged.

Project achievements

Before plantation managers could start using eucalyptus root stock inoculated with ectomycorrhizal fungi, the project team had to develop cost-effective spore inoculation procedures for ectomycorrhizal fungi and identify site factors determining mycorrhizal responses and nutrient interactions in eucalypt plantations.

Field trials were established at three sites in China (two in Guangdong Province and one in Yunnan) to test Australian mycorrhizal fungi in phosphorus-deficient soils. Molecular techniques were developed for confirming the presence of some introduced fungi on tree roots in the field. Recommendations for macro- and micronutrient fertilisers for eucalypt plantations in China were also developed. Knowledge and skills were transferred through practical training and extension activities including mycorrhizal workshops in China. Chinese-language handouts and ACIAR research notes with recommended procedures for managing mycorrhizal plants in the nursery and in the field were produced and distributed. During the project extension, scientists from CSIRO developed a website containing information on mycorrhizal fungi (see http://www.ffp.csiro.au/research/mycorrhiza/intro.html).

The ACIAR monographs *Nutrient disorders in plantation eucalypts* (first edition by B Dell, N Malajczuk & TS Grove issued as monograph 31 in 1995; revised edition by B Dell, N Malajczuk, D Xu & TS Grove issued as monograph 74 in 2001) are widely used by the industry.

The difference the project has made

This project has resulted in about 25 per cent of total plantings now being inoculated in nurseries. From discussions with private forest company staff, it is predicted that in the next two years, the majority of private forest companies will be inoculating over 50 per cent of their clonal eucalypts. Inoculation with ectomycorrhizal fungi increases the sustainability of plantations by improved nutrient cycling and greater efficiency in the use of fertiliser by trees. In addition, it is estimated that tree productivity will be increased by a further 10 cubic metres/hectare/year MAI (mean annual increment) as a result of the improved fertiliser regime suggested by the project.

All new commercial eucalypt plantations are being supplied with fertiliser manufactured in China containing appropriate macronutrients (nitrogen, phosphorus, potassium and sulfur) and appropriate micronutrients such as boron and/or zinc. At least three companies are producing their own blend of compound fertiliser. Several companies are routinely using foliar analysis to determine limiting nutrients for tree growth.

Scientists in China are now able to provide start-up inoculum to forestry companies and the Forestry Bureaus. They have also extended the applied research from eucalypts to agricultural crops such as banana, litchi, longan, cassava and to ornamental crops such as flowering plants. Forest technicians are providing advice on mycorrhizal technology in the regions to nursery managers.

Project impacts

Community impacts

Overall, the biggest tangible project output has been the realisation that eucalypt productivity can be substantially lifted by inputs of site-limiting nutrients at the time of establishment. This has resulted in tracts of unproductive land, previously considered to be commercially nonviable for eucalypts, being reforested. This is evident in Guangxi and Yunnan and also in parts of Guangdong Provinces. As a consequence, there has been significant investment in commercial eucalypt plantations in the last six years. The expansion of the forest industry in China has had a positive impact on rural communities by providing employment in rural areas, and is likely to continue to do so. Local people prepare the land, plant, fertilise, and do weed control and harvesting. Thus people who were previously subsistence farmers are now able to obtain a cash income. The villagers are also better off because of increased availability of fire wood for cooking fires.

Plantation forest companies also benefit from research undertaken in the ACIAR-funded project. Since the project was conceived there has been a major shift in China, with the Central Government withdrawing from commercial eucalypt plantations. The majority of eucalypt planting (estimated to be 90–95 per cent) is now undertaken by Chinese or foreign companies. Consequently, the uptake of the research results has been largely by these companies rather than by government-owned plantation managers. There are now about ten technicians in forestry companies who specialise in mycorrhizal technology and are responsible for producing inoculum and for inoculating seedlings and clonal eucalypts in the company nurseries.

There is no evidence that the increased planting of eucalypts is displacing other land uses in the lowlands. However, in south-west Yunnan, land traditionally used by minority peoples for agriculture is being turned into industrial tree plantings, and the impact of industrial eucalypt tree plantings on these local communities should be further investigated.

Capacity-building and scientific impacts

The ACIAR-funded project had a significant impact in helping to build a team of Research Institute of Tropical Forestry (RITF) scientists with mycorrhizal and nutrition knowledge and technical expertise. This has resulted in RITF scientists now being the dominant players in mycorrhizal fungus research in South China, and also having links into non-forestry areas.

Since the ACIAR-funded project, RITF scientists have extended the scope of the research and have attracted more than five research projects. These include: a study on semi-man-made simulation culture techniques in matsutake (Chinese Forestry Administration 1998–2001); persistence of mycorrhizal fungus–tree associations (Chinese Natural Scientific Fund 1998–2001); mycorrhizal inoculum development and application (Guangdong Scientific Plan Project from the Guangdong Bureau of Science and Technology 1999–2001); and mycorrhizal fungi applied in regeneration/rebuilt forests (Chinese Ministry of Science and Technology 2003–2005). In addition, RITF has obtained funds from forestry companies to provide research and development on inoculum production, fertiliser prescriptions, eucalypt silviculture and sustainable farming practices.

Overall, the RITF group has produced 38 technical publications and three books since 1996, the majority since the end of the ACIAR-funded project. Since 1998, they have undertaken four nursery trials in Hainan Province and more than 20 field trials in South China.

RITF now provides advice to a much wider portfolio than just commercial forestry. For example, RITF scientists have extended their research to include field crops, horticultural tree crops and ornamentals. The eucalyptus mycorrhiza and nutrition research also promoted the development of research on edible, high-value mycorrhizal fungi, such as matsutake and truffles. Finally, recent research into the silviculture of indigenous Chinese trees for wood production (genera such as *Quercus*, *Betula* and *Populus*) is encompassing mycorrhizal fungi and essential micronutrients.

Tree production technologies for the Philippines and tropical Australia (FST/1996/110)

Peter Dart

Collaborating organisations	University of Queensland, Brisbane, Australia (UQ); Queensland Forest Research Institute, Gympie, Australia (QFRI); Department of Environment and Natural Resources, Region 7, Cebu City, Philippines (DENR7); Department of Environment and Natural Resources, Region 8, Tacloban City; Philippines (DENR8); Visayas State College of Agriculture, Department of Agronomy and Soil Science, Baybay, Leyte, Philippines (ViSCA); Forestry Research Division, Philippine Council for Agriculture, Forestry and Natural Resources Research and Development, Los Baños, Philippines (PCARRD); National Institute of Molecular Biology and Biotechnology, University of the Philippines at Los Baños, Laguna, Philippines (BIOTECH); Bukidnon Forests Incorporated, Mindanao, Philippines (BFI)
Project leaders	Dr John Simpson (QFRI); Dr Segundino U Foronda, Dr Romulo Aggangan (PCARRD)
Related projects	ANRE/92/11, ANRE/94/09, FST/90/44, FST/91/14, FST/91/15, FST/91/26, FST/91/27, FST/92/08, FST/92/27, FST/94/25
Principal researchers	Dr Peter Dart, Dr Sharon Brown (UQ); Ms Juliana Libuit Baggayan (DENR7); Mr Edilberto Nasayao (DENR8); Professor Reynaldo de la Cruz (BIOTECH); Dr Angela Almendras (ViSCA); Mr Edmund Cueras (BFI)
Duration of project	1 July 1996 – 30 June 2000
Total ACIAR funding	$753 200
Project objectives	The current project followed on from the earlier projects and was designed to improve the productivity of planted trees in the Philippines and parts of tropical and sub-tropical Australia. It aimed to evaluate tree and shrub species on different sites to develop a better understanding of the soil and climate requirements of particular species or provenances. The project included research to improve diagnosis of the nutrient status of selected tree species and to devise ways of treating nutrient disorders that retard growth. It was also expected to develop management practices for cost-effective establishment and growth of planted trees and shrubs.
Location of project activities	Various provinces in the Philippines; Queensland, Australia

Overview

The ACIAR-funded project on tree establishment and production technologies in the Philippines and Australia (FST/1996/110) was led by the University of Queensland (UQ) in Australia in collaboration with the Queensland Forestry Research Institute, the Department of Agronomy and Soil Science at Visayas State College of Agriculture (ViSCA), the College of Forestry at the University of the Philippines at Los Baños, the Department of the Environment and Natural Resources, the Forestry Research Division, Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD). The project identified appropriate species and management techniques for a comprehensive and widespread forestry industry in the Philippines. As a result, it was shown that on-farm forestry can be a viable and profitable enterprise there, especially in areas needing reforestation, despite continuing industry and structural impediments.

Project achievements

The project developed cost-effective nursery techniques for a range of tree species suitable for planting in the Philippines. This included new, improved potting mixtures based on locally available and inexpensive materials, identification of species that would perform well in different regions in the Philippines, and silvicultural practices for the planted trees, including fertiliser recommendations, weed control, pruning and thinning regimes.

Land preparation and out-planting techniques were developed for both exotic and native tree species likely to be planted on-farm and in industrial plantations. Methods for assessing nutrient deficiencies and toxicities were developed specifically for *Acacia mangium, A. auriculiformis* and *Eucalyptus tereticornis*, along with methods for assessing fertiliser recommendations for good growth of the planted trees. Nutrient toxicity (nickel and chromium) was identified as being the cause of failure of an Asian Development Bank project in Ilocos Norte.

Pinus caribaea and *Pinus caribaea* x *Pinus hondurensis* hybrids, which were introduced by the project, were shown to perform well on ultramafic soils. These soils contain levels of nickel and chromium that inhibited the growth of the other plantation species tested such as acacias, eucalypts and gmelina.

Provenance trials were established to be developed into seed orchards for *Eucalyptus tereticornis, E. camaldulensis, E. pellita, E. urophylla, E. grandis, A. mangium, A. aulacocarpa* complex (*A. perigrinalis*).

Community-based extension programs demonstrated the viability of the project recommendations for species selection, nursery production and planting at the village and individual farmer level. A further workshop highlighting the project's achievements was delivered to officers of the Department of the Environment and Natural Resources of the Philippines (DENR) who were in charge of Divisions concerned with commercial forestry, industrial forestry, forest management and international collaboration in R&D. They asked for a project concept and indicative budget to support forestry research and development to be undertaken in other regions of the Philippines.

After the completion of the project, a Memorandum of Understanding was developed by the Municipality of Matalom and DENR Region 8 for the co-management of the project tree plantings at Matalom and the development of the area into a City Park both for recreational use and for extension of tree production techniques.

The DENR Community-Based Forest Management (CBFM) program adopted the project's recommendations on using genetically superior and site-adapted seed for forest plantings, for the nursery potting mix composition, and for fertilising in the nursery and at out-planting. This is a major change in operational procedure for the government-sponsored social forestry program. DENR now has a program to establish seed production areas for multiplying genetically superior germplasm. This was not previously part of DENR policy. It is also developing regional clonal nurseries. DENR Region 8 Ecosystem Research and Development Service (ERDS) has also adopted the practices developed by the project research for its tree-planting training programs for farmers and People's Organisations which are run at least twice a year.

People's Organisations in Leyte have selected fast-growing, well-adapted species identified by the project – such as *Acacia mangium* and *Eucalyptus deglupta* – and have adopted the nursery and out-planting and agroforestry techniques recommended by the project.

ViSCA—now Leyte State University—has changed its soil science curriculum to include experiments and information developed during the ACIAR-funded project. This would be the first time that nutrient omission trials (following a protocol developed at UQ) are used in class experiments (and in research) in the Philippines. This is a very powerful means at looking at the effects of soil on tree growth.

The difference the project has made

There are now 80 private timber plantings with tree cutting permits that have been established since the project started in the Matalom Municipality, Leyte. Previously there were none. A major intended use for the trees is furniture manufacture.

Agroforestry continues to be developed with demonstration pilot projects based on the ACIAR-funded project at Matalom Municipality, where a 'best practice model' is followed. Commercial operators are becoming more active in agroforestry.

After visiting the project tree plantings and seeing the excellent tree growth at Mr Pongas' farm at Ormoc (a large provincial town), many of the farmers indicated that they would like to replace sugar cane with trees. Other farmers, with sloping land that had been logged, indicated that they too would like to replant. Given the dwindling supplies of native timbers, furniture makers have also contacted Mr Pongas to see if new sources of timber supplies could be established.

Mr Pongas stated that the lack of a seed source and training in nursery management for these introduced species and information on their uses are all factors inhibiting adoption. Mr Pongas intends to retain the project tree plantings as a demonstration park and sanctuary and a tourist destination as part of a program of public service to the community. This would be co-managed with DENR to help encourage tree planting. This will have a powerful resonance with the Ormoc community as, during the time of the ACIAR-funded project, more than 8000 people died in a flash flood reportedly caused in part by deforestation. Support to bring this vision into being would not be very costly and would have a very large impact.

The last phase of FST/1996/110 showed how training programs to enable technology transfer to farmers and extension agents could be undertaken. DENR Region 8 ERDS have continued these training activities on a regular basis. They have trained more than 300 farmers, NGOs and government technicians since the end of the project, with more than 890 ha planted and nine nurseries established as an outcome. The training conducted by the project (with ATSE Crawford Fund support), at Paraclete in Leyte, led to the training of a further 40 People's Organisations (POs) with about 2000 households involved. Fourteen of these POs are active in planting trees under a Community-Based Forest Management Agreement (CBFMA). This is a relatively small fraction of farmers who could potentially adopt the technologies, although approaches to improve the adoption rate are already being implemented.

There are some major generic problems inhibiting uptake of tree planting technologies in the Philippines. They relate to lack of good quality tree seed, lack of easy credit for undertaking plantings, lack of market opportunities for the trees grown and poor supply chain systems to get the planted tree products to market, even though the Philippines is importing more than A$1 billion worth of wood products. A lesser impediment is the lack of a coordinated effort between Local Government Units (LGUs), DENR, Department of Agriculture and Department of Agrarian Reform in establishing a program of training and provision of technical support for farmers wishing to take up tree planting. This is now changing within Region 8, with two municipalities undertaking a coordinated activity with DENR ERDS to promote uptake of the project technologies for tree planting.

In Region 7, further uptake of the project technologies ceased because the project scientists involved emigrated to Canada at the end of the project and no-one was appointed to follow up. The newly appointed Regional Technical Director, Dr Melana, who was involved in the project when it started in 1993, is now developing plans for a Regional Training Centre for farmers and extension officers which will rely heavily on ACIAR-funded project technologies.

Major problems inhibiting further uptake of the project results by farmers in Region 8 include uncertainties about the future market for off-farm use for specific planted tree species. Apart from household construction use and firewood, there are few organised market possibilities within Leyte, as there is no woodchip, fibre board, veneer or plywood plant and only a small furniture manufacturing industry. Use of timber for house and building construction is a possibility, but there are no estimates of the current or predicted future market size. Supreme Aqua Incorporated is now starting to harvest thinnings from its six year old planting of 800 ha of *A. mangium* established under an Industrial Forest Management Agreement with technical support from the ACIAR-funded project. As there is no existing local market in Leyte or Biliran Islands for a large amount of such small diameter log material, preliminary trials in sawing the thinnings are underway, with use of the products in making crates an option. Flooring, light construction timber and special furniture products are other options being considered. If these eventuate as major markets then timber from farmer plantings could also be used.

The supply chain to the market is also a problem. A major impediment to tree planting by the CBFMA holders is the uncertainty regarding permission to sell harvested trees off-farm. A related aspect is the transaction cost in obtaining a permit and progressing the permit request through the DENR and LGU bureaucracy. At present, it is very difficult to obtain such permission because of the interpretation by DENR of the Agreement conditions and by local government attitudes to tree cutting. If farmers can only harvest trees for their own farm use then this severely limits the area that will be planted.

Once the trees are harvested, transporting them to market can also be a major problem, because of poor feeder roads and, particularly in Mindanao, because of the number of check points and the costs involved in passing through these.

Bukidnon Forests Incorporated (BFI) is now planting pine species introduced by the project in its replanting of sites that it is harvesting around Malaybalay City. The trees being logged are from *Pinus kesya* plantations that are more than 60 years old. These pines from Northern Luzon do not seed and re-establish naturally in Malaybalay. The replacement *P. caribaea* grow faster and are more valuable economically to the company than *P. kesya.* As one pine species is replacing another, Malaybalay's reputation as the City of the Pines is preserved and local protests against the logging of the *P. kesya* plantations are diminished. About 200 ha a year are being planted. Some of the areas where the replanting is being undertaken are on ultramafic soils and the project showed that pines are currently the best commercial option for planting in such soils and obtaining a saleable product.

Superior quality seed that is being produced from the plantings of Australian tree species at BFI, originally from seed sourced from the Australian Tree Seed Centre and undertaken as a component of the ACIAR-funded project, is now being used by BFI in its commercial plantations and is being sold as well. This is a major development, as the superior seed is needed throughout the Philippines. It is an example of collaboration resulting from the networking supported by ACIAR-funded projects. This involved the Regional FAO project on Tree Genetic Improvement which established tree seed orchards on Mindoro with the DENR Forestry Ecosystem Research and Development Bureau, the Australian Tree Seed Centre and CSIRO Division of Forestry and Forest Products, the Queensland Forestry Research Institute, the Philippine commercial plantation companies BFI, PICORP, and UQ. Together with the seed orchards of *Acacia mangium* and *Paraserianthes falcataria* established at the plantation company PTFI (again with support from the ATSC and QFRI in the original collection of provenance material planted), these seed orchards now cover the major species of acacia *(A. mangium, A. crassicarpa, A. auriculiformis, A. peregrina*) and eucalypt (*E. camaldulensis, E. tereticornis, E. grandis, E. deglupta, E. urophylla, E. pellita*) shown to be useful for commercial plantings in the Philippines. The commercial companies will use the superior seed that they produce, but the availability of this superior germplasm is not widely known in the Philippines and some system needs to be developed to advertise and distribute it.

There are some other species that have performed well in the ACIAR trials for which there are presently no seed production and distribution systems organised in the Philippines. Examples are *Eucalyptus robusta* and *Casuarina equisetifolia* in the alkaline, limestone-derived soils in Cebu.

DENR Region 8 wishes to establish seed orchards for some of the species that have been shown by the ACIAR-funded project to grow well in that region. This is a major change in attitude by DENR, which is now recognising the importance of seed quality in successful tree production systems. The importance of good nursery management in producing superior planting stock is also acknowledged, and nursery management in DENR and in community-based nurseries has improved considerably since the start of the ACIAR project as a result of this recognition and the extension of the simple technologies that the project developed.

Project impacts

Community impacts

A major impact has been the uptake of on-farm tree planting in the Paraclete Integrated Agro-Forest Development Association near Tacloban, Leyte. This was based on the technology and farmer training approach generated by the ACIAR funded project. The Association now has 243 households and they have reforested more than 500 ha and have a further 200 ha in agroforestry systems. The community nursery is still operational but individual farmers are also maintaining their own nurseries and selling to others. This Association plays a major part in training the other 40 People's Organisations that are linked through the activity of the NGOs Foundation Center Inc through DISOP, which supports the development of Community-Based Forest Management Agreements, and on-farm and community-based tree plantings. Cross visits are regularly made to Paraclete by farmers from other People's Organisations and these, along with the Paraclete Forestry Officer and the DENR ERDS, play a large part in training the local barangay village supervisors of the other People's Organisations.

In Biliran, the Supreme Aqua Incorporated also encourages on-farm planting adjacent to its 800 ha planting of *A. mangium* by providing seedlings to the farmers from the company nursery which ViSCA helped to establish. BFI in Bukidnon, Mindanao, is doing similar things.

There are very large tracts of Cebu with difficult soils which have been deforested. As a result, forest cover in Cebu is estimated to be only about one per cent of the land area and the water supply for Cebu City has a problem with salt water intrusion into the groundwater, so that there is an urgent need to reforest. Tree planting in the catchments could facilitate recharge of the groundwater used for the city water supply by reducing run-off after rain.

In Alcoy village in Cebu, the Farmers Association for Forest Land Inc (KMYLB) multipurpose cooperative has seen that, in the ACIAR-funded project trial, *Eucalyptus robusta* and *Casuarina equisetifolia* have performed much better than any other species in this very difficult limestone-derived soil with high pH and shallow depth. The KMYLB multipurpose cooperative would like to plant more if seed were available, as they now have the nursery skills and silvicultural knowledge to manage extensive plantings. There is a need to develop a seed orchard for the casuarina, and arrangements need to be made to see if seed of *E. robusta* could be obtained from Lantapan in Mindanao where there is reputed to be a planting. (Lantapan is a unique agroforestry experiment which comprises at least 14 research and development projects.) Planting at the other project site in Tabuelan on similar soil showed that a range of other species could grow well in northern Cebu.

The number of farmers who are planting trees on-farm has increased as a result of this ACIAR-funded project, but the numbers are regrettably small for reasons outlined above. In sum, the Philippines needs a system whereby information on the following is readily available:

(i) optimal ways to grow trees, and how to select species/provenances;

(ii) how to obtain credit for growing trees;

(iii) market locations and requirements;

(iv) likely returns from investment in tree planting; and

(v) market-related policy changes.

The lack of support from industry and government for farm forestry is slowing the uptake of tree planting on farms. This is a structural problem that could be addressed by a forestry systems analysis that is sufficiently broad-ranging to integrate all these issues.

Where industrial plantation companies such as BFI, PTFI and Aqua Industries are encouraging neighbouring farms to plant trees and giving some assurance of support with marketing the trees grown, then uptake of tree planting is greater than in the wider community. As they see the quality of the material that is being sold from the commercial companies' plantations, the word spreads that it is much more profitable for farmers to grow trees 'properly' (as the industrial companies are doing) if they wish to maximise the return on their investment. An organised program of farmer visits to successful plantings either on-farm, which is occurring with the Paraclete community plantings and their linked People's Organisations, or to the industrial plantings, or to the project's experimental plantings, would do much to stimulate interest and knowledge about how to grow trees well on-farm. This is now happening in Region 8 and Region 10 with very recent co-management agreements for managing natural resources between DENR and four municipalities which will include management of the project experimental plantings at Matalom.

The appointment of Municipal Environment and Natural Resources Officers that is now taking place in some municipalities that the project has been involved with means that more attention will be paid by local governments to tree planting to improve environmental services for the municipality. In particular, these improvements include off-site effects from reducing erosion and improving stream flow by a catchment

management approach that includes on-farm tree planting. These co-management agreements will increase community awareness of the benefits of reforestation in sustainable management of natural resources and thus affect how farmers manage their land. The LGUs involved in these groundbreaking agreements are also committed to work through a stakeholder participatory approach to natural resource management that has much more chance of success than many earlier approaches to social forestry.

There was a spillover effect of the ACIAR project to the AusAID South-East Asian Regional Program Project 'Conservation of protected areas in the Philippines and Vietnam' that followed (2001–2003) and was also coordinated by UQ. In this project the experience with establishing trees on farm was transferred to the Barangay Imbayao in Malaybalay Municipality, and model agroforestry-based farming systems were set up with the timber trees obtained from BFI nursery of species that were recommended from the ACIAR-funded project. The model farms have served as the basis for the extension of the farming systems to other farmers within the barangay and to other barangays and municipalities within the buffer zone of Mt Kitanglad Range Natural Park, in Bukidnon Province, Region 10. The process was replicated in Vietnam at Tam Dao National Park and will be in a new project funded by Tropenbos in the buffer zone of Bach Ma National Park that UQ is also coordinating.

Further community impacts would happen if on-farm plantings of trees using the project-generated knowledge were to be established through a co-management approach between DENR, LGUs and NGOs. Cross-visits between farms and hands-on, targeted training would then have a powerful impact on farmers' attitudes to, and knowledge of, successful on-farm tree-planting. The results of a systems analysis (recommended earlier) should be made transparent and the information made available to farmers in a form that can help them to make appropriate decisions about sustainable resource management on their farms. This paradigm shift in the way that government agencies interact with local farming communities will lead to better methods of paying farmers for environmental services and this will most likely include support in some way for increased tree planting on-farm. This is already happening in the four municipalities where there is an LGU DENR co-management agreement in place for forested land and inalienable upland forest land.

Improved access by farmers to quality planting stock at a reasonable price from nurseries (based on seed production systems whose establishment was supported by the ACIAR-funded project and nursery techniques developed by the project) would increase community impact. Training programs would then facilitate the technology transfer for nursery production of tree seedlings from superior quality seed to be taken up by some farmers for their own use and for sale of planting stock. This is already happening at Paraclete in Region 8.

Improved capacity of timber merchants to handle smaller diameter stems would also help with the cash flow for trees grown on-farm. This could include approaches such as finger jointing, or use of fibres or small wood pieces to reconstitute as an industrial board that is economically attractive to the grower, merchant and consumer. Adaptive research to establish such systems in the Philippines as well as a capital investment program is likely to be needed. Such new technologies are being developed in Australia, for example.

The DENR Training Centre for Upland Management proposed by Region 7 needs to have a feasibility study and business plan developed to see whether it will be a cost-effective way for technology transfer to the large number of municipalities in Region 7. The Centre would cater for LGUs to help train their staff in land use planning and sustainable environmental management, as well as train farmers in such issues and in on-farm tree planting. This Centre would make use of the nursery-developed trees planted near the proposed site as part of the ACIAR project experiments.

CBFMAs now cover more than 5 million ha in the Philippines and there is a major opportunity for the ACIAR-funded project to have a very large impact on forestry in the Philippines through dissemination of the project technical recommendations to holders of CBFMAs. A collaboration between ACIAR and AusAID would be a good vehicle to support this development phase through targeted workshops extending project findings, pilot demonstration plantings, and establishment of farmer and People's Organisation networks to undertake on-farm, participatory adaptive research (action research leading to development).

Capacity-building and scientific impacts

A major outcome of this ACIAR-funded project has been the capacity building aspect. This was acknowledged by all the agencies involved in the project that were visited in the Philippines to undertake research for this adoption statement. The project showed the benefits that could accrue from collaboration between agencies such as DENR, PCARRD, universities, NGOs and private companies. The project improved the profile of the universities with the DENR and commercial companies. This involved a major change in attitude. While this has continued to some extent after the end of the project, the same level of coordination and collaboration is not occurring in the development phase. UPLB College of Forestry and BIOTECH are disseminating project outcomes through presentations at National and ASEAN level. The mycorrhiza inoculum developed through project research has been sold to DENR in seven Regions, to the Department of Agriculture and the Department of Agarian Reform. In the case of UPLB, the human resource development that occurred through ACIAR-funded project activities was a major achievement, with PhD students trained in Australia as well as training of different duration in the Philippines.

For ViSCA, now Leyte State University (LSU), human resource development was also a major outcome. Dr Angela Almendras, the project leader, is now the Director of Research at LSU and she attributes her capacity to undertake this job to the training in research management that she received as a result of the ACIAR-funded project. She stated that "it was the holistic systems approach and integrated view of problem-solving, and the ability to conduct meetings and workshops that the project gave me, that has been a major project output for me". Dr Almendras has since conducted train-the-trainer programs, farmer field days, and has been a lecturer for the International Centre for Research on Agroforestry (ICRAF) based at Lantapan in Mindanao. She is also a collaborator in the Cornell University (USA) Soil Health Indicators Project. Professor Paciencia Milan, LSU President, also acknowledged that human resource development was a major outcome from the project, improving LSU research capacity and personal capital of the researchers, especially their confidence and technical skills. This has enabled LSU staff to take a leading role in the internationally funded, Leyte Island Program. LSU is developing a proposal to establish a Native Tree Germplasm Storage Centre based on the National Centre for Root Crops Research located at LSU and the Australian Tree Seed Centre, with development of seed orchards, training in nursery propagation techniques including vegetative propagation for trees with seeds having short viability periods and irregular production, a tree seed storage system and a biodiversity evaluation program based in part on molecular markers. This has helped LSU along with UPLB to be the leading agencies for forestry research in the Philippines.

DENR staff, particularly in Regions 7 and 8, also benefited from experience working with the project by learning how to establish and manage field experiments. Mr Edilberto Nasayao, Region 8 project leader, is now the Regional Technical Director and the Program Coordinator of the Leyte Island Program for environmental management, and leader of the project on Rehabilitation of Abandoned Mined-out Areas in Samar Island. Mr Nasayao has submitted a report on the ACIAR-funded project activity in Region 8 to a national DENR competition. One staff member in Region 8 became the forestry officer for the Paraclete Integrated Agro-Forest Development Association and then the Environment Management Specialist for

Tacloban Municipality. In this position, he has established a municipal nursery and is involved in planning an Environmental Rehabilitation Project for 2400 ha with reforestation as a major activity. There is an MOU developed between the municipality and DENR for co-development of the 3330 ha of timberland in the municipality. This relationship has links back to the collaborations developed during the ACIAR-funded project.

The communities most directly linked to the project at Alcoy in Cebu and Paraclete in Leyte learnt about forestry silviculture through the project activities.

Mr Celso Diaz, Director of the DENR Ecosystems Research and Development Bureau at Los Banos, Mr Gualberto Tortosa, Director of the DENR Foresty Sector Project and Mr Domingo Bacalla, Director of the DENR CBFM Division, acknowledged that the ACIAR-funded project had done much to change the attitude towards research within the forestry-related management structure of DENR. Their visits to the project experimental plantings showed senior management just how well trees could grow if they were adapted to the site and managed with appropriate silvicultural inputs. Mr Tortosa said that the "demonstrations were very convincing and effective, a very good approach that has influenced others and the project species introductions were also very good for the Philippines, as well as the fertiliser recommendations and potting mixes". The realisation for DENR that soil constraints were a major factor in planted tree performance and that the quality of the planting stock had a large influence were important outcomes of the ACIAR-funded project. "The project plantings in Region 8 were among the best in the country", said Mr Tortosa. As a result, in the last five years, tree seedling quality and growth after out-planting from DENR projects had improved. A recommendation that comes from this is that consideration should be given in planning ACIAR forestry projects to the establishment of easily accessible field plantings of the project experiments, as this has a large flow-on effect to managers, policy-makers and to the community.

The project also had a major effect on the research capacity of the five industrial plantation companies it interacted with. These companies looked to the project for advice on planning research trials and to obtaining tree seed germplasm for those trials. Regular site visits by project staff and the involvement of company researchers in the planning and review meetings and visits to three of the companies' field trials during these meetings provided the company researchers with feedback. It also increased the researchers' confidence because of the benchmarking inherent in the cross-visit approach. Before the ACIAR-funded project, visits by outsiders to company field sites (by personnel from DENR or other companies) had not been encouraged. This has changed as a result of the ACIAR-funded project and company staff have benefited from this broader experience. It has also meant that goodwill towards ACIAR and the project staff has remained intact. In the case of BFI, the excellent relationships between the New Zealand-funded forestry consultants advising on the plantation development and the ACIAR-funded project staff contributed to the capacity development of BFI staff.

The project established the fast-growing species and their provenances that grow well in the Philippines, both in industrial plantations and on-farm. A large impact on industrial and farm forestry in the Philippines is occurring through these provenance trials established by the project at BFI which are being converted to tree seed orchards. These seed orchards will provide the Philippines with quality seed, at an affordable price, from most of the fast-growing species likely to be grown for income. The project established the benefit of synthesising knowledge of the various facets of tree planting and production into an integrated approach to tree production. Previous research in the Philippines had been rather piece-meal and in the main directed to specific aspects of the system (and was not very successful in developing outcomes) – such as choosing plus trees, response to mycorrhizal inoculation and silvicultural aspects

such as planting hole size. The project supported the development of the nascent research programs at BFI, Alcantara and Sons, PTFI and Supreme Aqua, and this led to changes in nursery practice, fertilisation after out-plant, and selection of adapted germplasm for Regions 8, 10, 12 and 13, the major plantation regions in the Philippines.

The finding through project intervention that *Pinus caribaea* grows well on the ultramafic soils in Mindanao has large implications not only for the BFI site near Malaybalay but also for other parts of the Philippines with similar soils – such as in Nueva Ecija in Northern Luzon. In this case, an earlier US$24.5 million, Asian Development Bank-supported reforestation project which planted 13 374 ha, was shown by the ACIAR project to have failed because of the ultramafic soils.

The ACIAR-funded project demonstrated that trees could grow well in the Philippines if appropriate silvicultural practices are adopted. Previous plantings sponsored by DENR through a range of externally funded development projects had led to very poor achievements in terms of plantation forests established. Poor choice of species for the site, lack of good quality seed and planting stock, poor weed control and lack of fertilising, inadequate thinning regimes leading to trees being too close to develop into saw logs or even to develop biomass, lack of fire control and use of fire-susceptible species all contributed to this poor outcome from an estimated $1.5 billion investment over 20 years in reforestation. The ACIAR-funded project showed that, if proper attention was paid to each aspect of tree growing in a systematic fashion, then economically valuable trees would grow very well indeed in the Philippines, both in industrial plantations and on-farm.

In Australia the major scientific outcome was that mycorrhizal inoculation in the nursery could establish the inoculum strain but that this did not feed through to an effect on tree growth in the soils tested. The research also showed that soils which had been deforested many years before contained very few ectomycorrhiza propagules and that this could limit planted tree growth. The production of inoculants with good shelf life also proved to be very difficult and this would limit the widespread use of inoculants developed through axenic culture. The response to the use of spores of *Pisolithus tinctorius* as an inoculum proved too variable to be of use in commercial nurseries, notwithstanding the difficulty of obtaining fruiting bodies on a regular and reliable basis. The research on nutrient concentrations in leaves and symptoms of nutrient deficiencies or toxicities for *Acacia mangium* and *Eucalyptus tereticornis*, when grown in deficient, adequate or toxic quantities of different elements, provided a basis for determining soil fertility management in plantations.

Phosphine resistance in insect pests of stored grain (PHT/1994/015)

Greg Daglish

Collaborating organisations	Queensland Department of Primary Industries, Brisbane, Australia (QDPI); Department of Storage, State Administration of Grain Reserves, Beijing, China (SAGR); State Internal Trade Bureau, Dept of International Co-Operation, Beijing, China (SITB); Central Food Technological Research Institute, Infestation Control and Protectants Department, Mysore, India (CFTRI)
Project leaders	Dr Merv Bengston, Dr Greg Daglish (QDPI); Li FuJun, Deputy Director (SAGR); Mr Chuan Bin Xue (SITB); Dr N G K Karanth (CFTRI)
Related projects	PHT/90/35, PHT/93/21
Principal researchers	Dr P J Collins (QDPI); Dr S Rajendran (CRTFI); Cao Yang, Zeng Ling, Liang Yongsheng (SAGR)
Duration of project	1 January 1995 – 31 December 1999
Total ACIAR funding	$981 829
Project objectives	Insecticides and fumigants were the most effective and flexible means of controlling pest activity in grain storage and handling, with phosphine being used as the main fumigant of grain in Australia, China and India. However, resistance to phosphine fumigation emerged among many major pest species in Australia, China, India and many other countries. The aim of this project was to develop and implement management practices that would limit the current problem of phosphine-resistant pest species and delay the further development of phosphine resistance.
Location of project activities	China, India and Australia

Overview

An ACIAR-funded project on phosphine resistance in insect pests in stored grain (PHT/1994/015) was undertaken by the then Queensland Department of Primary Industries in collaboration with the Central Food Technological Research Institute in Mysore, India, and the State Administration of Grain Reserves in China. New practices recommended by the project were to increase the fumigation period and to use sand rather than moist soil or mud to seal the plastic cover sheet of grain stacks. As a result of implementing these, losses and deterioration of stored grain caused by insect pests such as beetles and weevils that display phosphine fumigant resistance have been reduced in India.

This study of adoption of project outputs was undertaken only in India.

Project achievements

The aims of the project were to develop strategies and procedures that would reduce losses and deterioration of stored grain in India caused by phosphine-resistant insects, and to determine how best to control resistant insects and minimise or prevent further resistance development. To achieve this, researchers set out to determine and characterise the levels of phosphine resistance with particular regard to prolonged exposures, and to determine phosphine concentrations over time in storages fumigated according to current and modified fumigation protocols. They also studied the cross-resistance to other grain protectants, such as hydrogen cyanide, carbon dioxide, low oxygen, methyl bromide and the candidate fumigant carbonyl sulfide.

Laboratory research in India was able to quantify the effects of concentration and exposure period on key weak and strong resistant strains of major insect pests of stored grain from Australia and India and, importantly, confirm the threat to effective fumigation from stronger resistances. These species included two of the most important species: the lesser grain borer, *Rhyzopertha dominica* (F.), and the rice weevil, *Sitophilus oryzae* (L.).

Fumigation monitoring in India helped develop effective fumigation requirements for resistant insects and established that cross-resistance does not occur to methyl bromide, the major alternative fumigant to phosphine.

The difference the project has made

Grain after harvest is prone to attack from a suite of insect pests. If left unchecked, insects can cause considerable direct losses by eating grain, and heavy infestations can increase grain temperature and moisture to favour the growth of spoilage fungi. Qualitative losses include the lower prices received because of the presence of insects or the higher percentages of damaged seeds.

The project has demonstrated the effectiveness of increasing the fumigation period from five days to a minimum of seven days, and raised awareness amongst key grain storage managers of the resistance problem and the need to take appropriate action.

After disseminating the results through papers and workshops, the Central Warehousing Corporation (CWC) and the Uttar Pradesh State Warehousing Corporation have adopted the research results. The CWC is a major grain storage agency in India and Uttar Pradesh is the most populous state in India. These two organisations store about 9.6 million and 3.9 million tonnes of grain respectively. The adoption of fumigation recommendations has resulted in fewer phosphine fumigations being needed.

Project impacts

Community impacts

The total grain storage capacity in the public sector in India is approximately 60 million tonnes. The foodgrain storage capacity of Central Warehousing Corporation is 9.6 million tonnes (17 per cent of the public sector's total storage) and that of the Uttar Pradesh State Warehousing Corporation is 3.9 million tonnes (6.5 per cent of total storage). Both these Corporations adopted the research results because of the expected economic benefits to be gained through reduced grain losses due to pest problems, improved quality of stored grain, and reduced labour and fumigation costs. Even though uptake of the project outputs has been limited to just two grain storage warehouses, given the considerable amount of grain stored by the two adopting corporations, the economic returns for the project are still likely to be significant.

Capacity-building and scientific impacts

The project enhanced the research capability of the CFTRI research team by providing appropriate equipment and through exchanges with scientists in India and Australia. Delegates from the Central Warehousing Corporation and the Uttar Pradesh State Warehousing Corporation, who participated in the phosphine resistance management workshop, learnt about the resistance problem and possible solutions.

The results from the ACIAR-funded project have appeared in 13 published papers or reviews. Also, project results were presented orally at a major international scientific conference, and this paper appears in the conference proceedings. These papers may not have an immediate impact, but they will serve as important sources of information, within India and internationally, on phosphine resistance and its management.

As a result of the experience gained through the ACIAR-funded project, the CFTRI received funding from the Central Warehousing Corporation and the Uttar Pradesh State Warehousing Corporation to undertake further research on managing stored grain insects in their warehouses. Central Warehousing Corporation funded a project on protocols for effective management of insect pests in stored food grains in Central Warehousing Corporation. This project was undertaken from August 2002 to 30 June 2003 and cost A$728 000. The Uttar Pradesh State Warehousing Corporation funded a project that focused on fumigation protocols for effective treatment of wheat and milled rice with phosphine from June 2001 to September 2003. The cost of this project was A$717 000.

Computer-assisted learning as a tool to improve grain storage pest management in key ASEAN countries (PHT/1997/131)

Barry Longstaff

Collaborating organisations	CSIRO Entomology, Canberra, Australia (CE); University of New South Wales, Sydney, Australia; University of Queensland, Brisbane, Australia; National Postharvest Institute for Research and Extension, Manila, Philippines (NAPHIRE); Postharvest Technology Institute , Ho Chi Minh City, Vietnam (PHTI); Badan Urusan Logistik, Indonesia (BULOG)
Project leaders	Dr Barry Longstaff (CE); Dr Mulyo Sidik (BUL); Professor Le Van To (PHTI); Dr Sylvestre Andales (NAPHIRE)
Related projects	PHT/1993/021
Principal researchers	Jan E van Someren Graver, R H Driscoll (CE); J Tumambing (NAPHIRE); H Halid (BULOG)
Duration of project	1 January 1998 – 31 December 1999
Total ACIAR funding	$149 072 ($1 176 867 including related project)
Project objectives	The major objectives of this small project were to document institutional arrangements for grain storage and marketing and infrastructure for training within the collaborating organisations, to refine and extend the existing computer-assisted learning (CAL) system, to develop and conduct three international training courses in regional centres and to undertake development of training plans for the participating organisations. Location of project activities Indonesia; Philippines; Vietnam

Overview

A suite of computer-aided learning tools has the potential to greatly improve the management of stored grain in South-East Asia, and thus reduce losses and improve profits. This ACIAR-funded project on computer-aided learning as a tool to improve training standards in grain storage management in key ASEAN countries (PHT/1997/013) was undertaken by CSIRO Entomology, the University of New South Wales, the University of Queensland, the National Postharvest Institute for Research and Extension, Philippines (NAPHIRE), Postharvest Technology Institute, Vietnam (PHTI), and Badan Urusan Logistik, Indonesia (BULOG).

This project followed an earlier project on the development of decision support tools for managing pests in grain storage (PHT/1993/021). The tools developed in the collaborative projects have proven a valuable adjunct to training.

Project achievements

The project developed a suite of Computer-Aided Learning (CAL) tools integrated within a framework called 'Pest Management Workbench'. The suite includes a tutorial system, dealing with concepts and techniques of pest management and the logical processes used by experts in diagnosing pest management problems, together with a tutorial builder, an interactive pest identification component for training field staff in pest identification, and a simulated grain storage complex.

While the initial project proposal set out to develop decision support tools to facilitate the rational and sustainable management of pests in grain storages in Indonesia (presented in a CD-ROM called *Grain Storage Tutor*), it soon became clear that a better option would be to develop a system that would provide the managers with a better understanding of the issues involved in making pest management decisions and thus enable them to make better decisions.

Although not part of the original proposal, it was decided that it would be valuable to include Thailand as another member of the project. The CAL system was rewritten and expanded to encompass new tutorials on grain-drying, moulds and mycotoxins as well as Integrated Commodity Management (ICM). A new reference section was also included.

Training materials were developed for courses given in Indonesia, the Philippines, Thailand and Vietnam.

In total, about 700 people have participated in training courses in the four countries during and since the project, about 500 of these being in Vietnam.

The difference the project has made

Indonesia

BULOG used the CAL tools to implement a more intelligent pest management program that treated the grain when necessary, rather than on a calendar basis, as previously. This was aided by an enhanced capacity to identify pest species, resulting from use of 'Pest Management Workbench'.

In 2001, BULOG also used 'Grain Storage Tutor' in two training courses on the use of alternatives to methyl bromide fumigation, funded by UNIDO and attended by about 45 participants.

Philippines

There has been only limited post-project activity, largely as a result of budgetary reductions and changes of priorities within NAPHIRE, and the lack of follow-up actions from Australia. The departure from NAPHIRE of key partner Justin Tumambing, to Australia, where he was subsequently employed by a fumigant supply company, Cytec, may also have affected opportunities.

Vietnam

PHTI capitalised on the training to establish a fumigation company which undertakes fumigation of grain store pests. In 2000, PHTI also hosted for 6 months an Australian Youth Ambassador, Mr Romolo Tassone, on secondment from Agriculture Western Australia's phosphine resistance monitoring program. Mr Tassone provided some logistical backup in planning AusAID-funded CARD training activities and also helped PHTI to develop a phosphine resistance laboratory which supplemented the activities of the 'commercial' grain fumigation team established by PHTI.

In 2000, a new ACIAR project, Enhancing the efficacy of phosphine fumigation, began in Vietnam with the Department of Plant Protection and PHTI Hanoi as well as QDPI and Chinese institutions as partners.

Region

Mr Justin Tumambing, a key Filipino collaborator, emigrated to Australia and now works for CYTEC Australia, who market ECO2FUME (a phosphine–carbon dioxide formulation) in Asia/Pacific. Justin continues to draw on the CD-ROM in developing training material for the bulk handlers that he works with (Australia, New Zealand, Thailand) and considered that the training materials could be more widely utilised in this sector.

Project impacts

Community impacts

By focusing primarily on 'training-the-trainers' we believe that the greatest degree of amplification of benefit for the investment by ACIAR will be achieved. However, this focus also makes it very difficult to assess the impact of the project on the community at this stage. In principle, the resulting increase in technical skills of people involved in postharvest technology will, in turn, lead to reductions in commodity losses and treatment costs and will facilitate domestic and international trade, thereby contributing to economic growth, and thus to poverty alleviation, social welfare and food security. More efficient use of chemical control measures will also reduce the environmental impact of such measures.

The rate of uptake in the four countries reflects the levels of investment and interaction, with Vietnam being by far the highest. There was no follow-up activity budgeted for in the Philippines, and Thailand was not actually an official partner in the projects and received only minimal support during the project and none afterwards. The fact that there have been several expressions of further interest from both countries is encouraging, indicating an appreciation of the system's potential, and we are seeking ways to foster this interest. Both countries will receive updated versions of the CAL system early next year and the conduct of one or more training courses in each of these countries would greatly facilitate uptake of the system.

Capacity-building and scientific impacts

These projects were overtly capacity building and, as such, have had a particularly significant impact in Vietnam, where about 500 people have been involved in training courses conducted within and outside the project. Whilst most of the courses were general in nature, with participants being mostly trainers or lower-level managers with responsibilities for pest management, two specialised courses were run, one for practising fumigators and another for prospective mycotoxin experts. Personnel in both PHTI and PPD have become sufficiently skilled to run many courses of their own. This is now a routine activity for them. They are also now in a position to look critically at the content and make constructive suggestions for improving and expanding the CAL system and refining its use as a training tool.

The capacity-building impact has also been significant in Indonesia, where about 120 people have so far participated in training courses. The number of people trained outside the project in the Philippines and Thailand has been marginal to date, with only about 50 and 20 people respectively being involved in training courses.

The potential exists to use this training approach to harmonise training in the management of postharvest quality of durable commodities across the ASEAN region and enhance the ability of participating countries to address current issues and meet new challenges in this sector in the future. To this end, funding is being sought from AusAID's AADCP Regional Partnerships Scheme to:

- establish a regional training infrastructure under the SEAMEO-BIOTROP umbrella;
- review and extend the CAL system to include important new technologies and additional languages;
- conduct general and specialised regional training courses on postharvest topics in Indonesia and Vietnam;
- provide capacity-building support to the emerging economies of Cambodia and Laos.

Although not the primary focus of these projects, there is no doubt that the projects have had and will continue to have an impact on R&D for pest management of stored grains in both Indonesia and Vietnam. By promoting the philosophy of ICM, the project has highlighted the need for a more holistic approach to research on postharvest problems. As pest management options become more constrained – for example through the imminent loss of methyl bromide as a grain fumigant or market intolerance of chemical residues – solutions require a greater understanding of the interaction between system components and potential managerial actions. Hopefully, this will stimulate greater interaction between scientists involved in pest management issues, mycology and engineering.