ADOPTION OF ACIAR PROJECT OUTPUTS

STUDIES OF PROJECTS COMPLETED IN 2000–2001

Editors: Viv McWaters, Simon Hearn and Robin Taylor

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Australian Government
Australian Centre for International Agricultural Research

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 to 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.

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

The Research Program Manager
Policy Linkages and Impact Assessment Program
ACIAR
GPO Box 1571
Canberra ACT 2601
Australia

Phone +61 2 6217 0500
Email aciar@aciar.gov.au

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V. McWaters, S. Hearn and R. Taylor (eds) Adoption of ACIAR Project Outputs: studies of projects completed in 2000–2001

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Foreword

The Australian Centre for International Agricultural Research (ACIAR) has an annual funding base of about A$50 million and invests in agricultural research projects with a focus on poverty alleviation. About 200 projects are funded at any one time, with 40–50 projects completed each year.

The Australian Government provides these 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 used wisely and have delivered against the corporate mission to achieve more productive and sustainable agricultural systems for the benefit of developing countries and Australia.

One of the challenges for ACIAR 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. 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, and expanding the range of, project 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. These studies are designed to highlight the level of uptake of project results. This publication, the second compilation of reports for assessing the adoption of ACIAR projects, refers to projects completed in 2000-2001. From the lessons learnt in these studies, we hope to improve our future efforts and to provide direction for subsequent economic impact assessments undertaken when project results have been taken up by end users.

Adoption studies also help to provide insight into research selection and management practices, and contribute to decisions about ACIAR's future research directions and priorities.

I would like to thank each of the Australian project participants who undertook the task of revisiting partner countries to gather and collate data and write the adoption statements that form the basis of this publication. I also want to thank the many project participants in our partner countries who hosted visits, 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
Australian Centre for International Agricultural Research

Contents

Planning for agricultural development and sustainable land management in Papua New Guinea (ASEM/1996/044)

Bryant Allen

Collaborating organisations	Australian National University (ANU), Canberra; Macquarie University (MU), Sydney; WA Department of Agriculture (WADA), Perth; University of Queensland (UQ), Brisbane, Australia; Department of Agriculture and Livestock (DAL), Konedobu; National Agricultural Research Institute (NARI), Port Moresby, Papua New Guinea
Project leaders	Mr Bryant Allen (ANU); Mr Balthazar Wayi (DAL)
Related projects	ANRE/1996/043
Principal researchers	Dr R D Ghodake, Director General, National Agricultural Research Institute
Duration of project	1 July 1997 – 31 December 2000
Total ACIAR funding	A$908,013
Project objectives	This project aimed to have existing natural resource databases used more widely for scientific research and policy planning.
Location of project activities	Papua New Guinea

Overview

Decision makers in Papua New Guinea (including MPs, district planners, provincial planners, government departments, NGOs, international agencies and consultants) are using census data and information on natural resources and agriculture in a new way. They are thinking about the inter-relationships between population, resources and agriculture and the future, in many cases, for the first time thanks to this ACIAR database development project.

Within the National Agricultural Research Institute, many research proposals now incorporate information about agricultural systems and environmental conditions that were formerly unable to be taken into account.

Project achievements

Agro-ecological zones (AEZ) were identified for PNG. These are based on reliable and relevant environmental parameters from the Papua New Guinea Natural Resource Information System (PNGRIS) and include landform, lithology, relief, slope, altitude, annual rainfall and soil conditions). The AEZs identified were based on the capability of land to grow sweet potato, the most important subsistence food crop produced in PNG and a staple food to around 65% of the population. The AEZs were determined by an iterative combination of computer assisted searches and the detailed knowledge of project researchers.

Farming systems and their locations within AEZs were identified by adding cash cropping, other cash earning activities and a measure of accessibility to the existing agricultural systems contained in the Mapping Agricultural Systems Project (MASP). The population increase from 1980 was estimated. A report was written on the intercensal changes in PNG between 1980 and 1990 and on the problems of measuring changes from census data. This work was carried out by Dr Gael Keig and Mr John McAlpine, who were involved in the development of PNGRIS by CSIRO.

'Vulnerable' or 'disadvantaged' farming systems were identified, and were based on a disjuncture, or a potential future disjuncture, between agricultural practices, population change, social and economic conditions and natural resource conditions, such that degradation was occurring or could be expected to occur.

Areas that have potential for development were identified. These are areas of good quality land that are presently not used for agriculture, or are used for agriculture below the level of intensity that natural resource potential suggests they could be. A number of these areas were found to be within the area of destruction of prehistoric cataclysmic volcanic eruptions.

Since the end of the project, the PNG Rural Development Handbook has been published. It contains the major findings from the project simplified for ease of interpretation. The information is presented by province and district. The handbook includes 110 full colour maps as well as graphs and text that describes the agricultural and natural resource conditions of each province, together with information on roads, access to markets and population distribution. Districts are ranked by 'disadvantage'.

Bryant Allen

Mark Tine and Jimmy Maro in the NARI GIS Section; both trained during the extension of the ACIAR project. The project has had the greatest impact in the area of capacity building. The GIS capacity of NARI was increased from almost nil to near the best in the country.

The difference the project has made

The project offered a radically different way of viewing data and of turning numerical data into spatial patterns. All of the participants who continued to use the methods learned made significant changes in their professional practice. For example, NARI developed its own AEZ maps and developed policies and research programs for each of its research stations, depending on its AEZ location.

An example of the way in which the project benefited NARI staff is related by one of the two original NARI trainees:

> *"Now all scientist at NARI use the database to make sure that they are working within a specified agro-ecological zone and the databases really help. In the provinces, people now appreciate that they truly have different agro-ecological zones and not all should be made to follow or adapt a technology. For example, with the introduction of vanilla and its lucrative market (at that time), even small-holders had to be told the altitudinal limit of the crop. And the provincial staff and NARI had to explain why crops were not performing well and it was because of certain limitations such as altitude. Although we had not been to the farmer's area physically, we had the database to guide us. The farmers wondered how we knew things about their places, even though we had not been there." (Sharyl Ivahupa)*

The Department of Agriculture and Livestock developed district profiles using outputs from the project.

MASP (and PNGRIS) data were used in assessing the droughts in the 1990s. Some of the data from MASP (eg, dominant crops and fallow periods) were used in the district profiles by the Land Use Officers. These district profiles have become very useful in the DAL Provincial and Industry Branch (P&ISS) in doing district agricultural activities and planning. (Regina Kiele)

Other uses of the project's outputs include:

- mapping the impacts of the 1997 drought
- developing a method of estimating the cost of delivering services within districts
- district maps of land quality, staple crops, estimated incomes and accessibility
- research on global climate change and agriculture in PNG
- mapping oil palm settler blocks, and recording production and spatial patterns of production
- a new GIS of smallholder blocks on oil palm schemes
- identifying places where particular interventions have potential to bring about improved agricultural production and examining the environmental and agricultural background of community groups that are being brought within the NARI technology linkage program.

The 2000 National Census that was conducted during the project's life geo-located all census units and made available digital maps and population counts. The project participants were able to immediately begin using this data for research (eg land use intensity measures, population density, numbers of people using a staple crop, etc).

During the adoption study visit to NARI in November 2004 the Director-General observed that the project outputs are now "essential, a basic part of research", within NARI. He said, "The project outputs provide visual, spatial and contextual perspectives that NARI did not previously have". NARI is now interested in learning how to update data and expand the use of the databases, eg, to use them in transferring technology to new areas, and to search for areas suitable for new crop species, such as the white yam.

Project impacts

Community impacts

Community impacts will be indirect and difficult to observe in the short term. Community impacts from the project will occur in the long term in the form of better-directed research and improved planning and policies. The benefits of improvements such as these will not be seen at the village level in the short term. However, potential benefits are many.

NARI's research program can be better prioritised and thus benefit a larger number of communities, through the ability to know where particular agricultural systems are located, which crops are most important and where particular techniques are employed. The project has also located areas where development potential is highest and where development is most constrained by poor natural resources, and poor access. This knowledge can also be used to guide research policy and planning.

Poor communities in PNG can be assisted through being identified by the World Bank's poverty mapping project, which used results from the project to compare villages in PNG against a poverty line. The poverty study took into account, natural resources, accessibility and food production.

The National Economic and Fiscal Commission is responsible for determining grants from the national government to the provinces. The Commission is using project outputs to estimate the costs of delivering services to rural areas.

The National Statistical Office has incorporated production estimates calculated using the databases into PNG's national accounts. This has increased the relative importance of the contribution of smallholder agriculture to the PNG economy. The Department of National Planning and Rural Development is aware of this change and is arguing at the highest decision making levels for more resources to be directed towards smallholder agriculture and for macroeconomic decisions to take into account their potential impact on village agricultural producers.

Capacity building and scientific impacts

The project has had the greatest impacts in this area. The capacity to use the databases and to use information generated from them has increased significantly in a number of PNG organisations.

The GIS capacity of NARI was increased from almost nil, to near the best in the country.

The full adoption of the methods used by the project requires access to reasonably high-powered computers; expensive software; specialist training in how to use the software; and access to the data. Project participants were provided with computers or had their computers upgraded and were provided with the software. They were trained in its use. Others were not so lucky, even though the project provided them with access to the data. This has been a major constraint to the ongoing use of these methods.

A primary objective of the project was to raise the adoption rate from only one organisation in PNG (DAL), to at least six organisations, by teaching participants from these organisations how to use the GIS software, providing them with copies of the software and the databases, and by showing them how the analysis of the data was relevant to their professional lives. Although it was not part of the original project, ACIAR provided funds to buy new computers and printers, which are still in use.

In the 2000 extension of the project, 10 Papua New Guineans were trained in GIS methods and how the project outputs had been produced. They came from organisations other than NARI:

- Department of Agriculture and Livestock (DAL);
- Department of National Planning and Rural Development (DNP&RD);
- National Forests Authority (NFA);
- National Weather Service (NWO);
- Forest Research Institute (FRI);
- Oil Palm Research Association (OPRA);
- National Economic and Fiscal Commission (NE&FC).

The spread and adoption of the project's outputs to organisations beyond those that participated in the project has come about mostly from the personal movement of project participants to other organisations.

When NARI was informed its two original trainees were resigning, it immediately employed two graduates trained in GIS at the University of Technology. They understudied the two initial trainees and NARI also arranged through the Australian Contribution to a National Agricultural Research System (ACNARS) project, to bring them to Canberra where Luke Hanson familiarised them with the methods and outputs of the project. They were also taken on a field trip around NSW to examine the relationships between environment, and agricultural land use. These two employees have now taken over the GIS and Database Management Unit in NARI and are offering training and awareness raising at province and district level. The original NARI trainees had no GIS background but were agricultural science graduates. They were trained in GIS and the use of databases. They are now both competent GIS practitioners. Their replacements in NARI were GIS graduates and they report that while they have been easily able to use the databases and the project outputs, they have had difficulty understanding how the outputs can be applied to agricultural science research. This suggests that it is easier to teach the principles and use of GIS in a short time, than it is to teach the principles of agricultural science and research methods.

There is no doubt that access to the methods and outputs from the project have caused people to change scientific practices. Even where individuals have changed organisations, they have still changed scientific practices. At New Britain Palm Oil Ltd (NBPOL) a project participant writes:

> *"… the skills learned [from the project] have been valuable as the company is going through a major research restructure to gain more information on its palm oil holdings. Furthermore, the need to protect the environment means we have been required to collect baseline data from all areas where the company operates. As such agronomic and environmental data are vital, an understanding of how to interpret this data is important. We have now used these data to build up our own database system linked to a GIS which allows us to do various analyses such as to look at yield trends, soil nutrients, foliar nutrients and so on. We can now produce yield maps and tables. With the skills gained from the project, I have been able to help set this up and advise our operators what sort of data was required, so that we can monitor our production. It has been very useful for us at NBPOL." (Tom Betitis)*

A former NARI participant has recently taken up a position as agronomist working on drought resistant sweet potato varieties. She has copies of the databases and software in her possession and uses them in the following way on this new project;

> *"The World Vision project I am currently involved in is actually a drought response project in collaboration with NARI. Although NARI has provided information about which areas we should target for our trials, I am checking these places after doing a ground-truthing survey. I have been out in the field confirming the sites for trials and using my knowledge of the database, I can cross-confirm that the areas in a larger scale actually are as described because usually, the baseline databases are extrapolated and must be confirmed by a field visit." (Sharyl Ivahupa).*

A project participant from the National Weather Office spoke of how his participation in the project allowed him to engage in collaborative research with an agriculturalist to look at potential global change impact on PNG agriculture.

Increasing the effectiveness of research on agricultural resource management in the semi-arid tropics by combining cropping systems simulation with farming systems research (LWR2/1996/049)

Peter Carberry

Collaborating organisations	Agricultural Production Systems Research Unit (APSRU), Australia; National Agricultural Research and Extension System (NARES), India, Zimbabwe, Malawi and Kenya; Tropical Soil Biology and Fertility Programme (TSBF), Uganda, Kenya and Zimbabwe
Project leaders	RJK Myers, ICRISAT, Zimbabwe; RL McCown and subsequently BA Keating, CSIRO/APSRU, Australia
Related projects	CS1/94/968, CS1/95/122, EFS/83/26, LW/87/35, LW/94/35
Principal researchers	P Carberry (APSRU), J Dimes and G O'Leary (ICRISAT)
Duration of project	1 January 1996 – 30 April 2001
Total ACIAR funding	$1,550,000
Project objectives	The project's goal was to develop a farming systems research capability in ICRISAT that combines simulation of crop production systems with agronomic experimentation and socioeconomic research and to use this capability to enhance ICRISAT's research on improved management of crops and production resources in the semi-arid tropics of Asia and Africa. In order to achieve its ultimate goal, the project aimed: (i) to train ICRISAT staff and collaborators in using simulation modelling in agricultural systems R&D (ii) to enhance APSIM to better enable simulation of the important cropping systems in the semi-arid tropics

	(iii) to develop a system for storage and retrieval of experimental data which efficiently serves simulation objectives (iv) to systematically compare APSIM simulations against field experiments to test model performance (v) in conjunction with experimentalists, to use APSIM to extrapolate experimental results in time and space (vi) in conjunction with NARS and NGOs, to apply APSIM in evaluating farmers' management options
Location of project activities	The project was originally based at ICRISAT Headquarters, Patancheru, Andhra Pradesh, India but was relocated to ICRISAT-Bulawayo, Zimbabwe in August 1999.

Overview

The ACIAR-funded collaboration on agricultural / resource modelling and applications in the semi-arid tropics (CARMASAT) project aimed at developing a farming systems research capability based on systems simulation. The resulting agricultural production systems simulator (APSIM) has proved its effectiveness in enhancing research on improved management of crops and production resources in the semi-arid tropics of Asia and Africa. While adoption by researchers is disappointing, the potential for APSIM remains high.

Project achievements

Over 160,000 smallholder farmers in Zimbabwe achieved 30–50% yield increases in their maize crops due to the aid-sponsored distribution of seed and fertiliser in the 2003–04 season. Key architects of this aid program readily attribute systems modelling within ICRISAT as being one source which supported the proposition of small doses of inorganic fertiliser applied in the lower potential regions of Zimbabwe. This outcome, and subsequent efforts, which focused on developing supply networks for small fertiliser packets in Zimbabwe and South Africa, represent a significant consequence attributable, in part, to the CARMASAT project.

In early 2005, a farming systems research capability based on systems simulation is well adopted within ICRISAT's research efforts in Zimbabwe and South Africa. However, such capacity is not employed more extensively — adoption within ICRISAT-India, other international agricultural research centres (IARCs)and collaborating NARES has been disappointing to date. Reasons for poor adoption vary from poor underlying skills, low credibility of models, to lack of institutional support.

The legacy of CARMASAT persists today within a range of current and planned research, development and extension projects being undertaken by ICRISAT and its collaborators. As commented by a funder of research in Africa: *"the seeds of past investment remain and returns will be gained in the longer term".*

ICRISAT and its NARES partners made significant progress in applying simulation models to agricultural systems R&D. Key achievements from the development of APSIM include:

- trained, active users who had applications of APSIM in their work plans, both in ICRISAT and NARES
- Following the enhancements made to APSIM, it was more widely used in the semi-arid tropics in India and Africa to help small-scale farmers
- Use of APSIM was enhanced through the use of experimental data sets applicable to India and Africa.
- Documentation of new APSIM modules and the results of research using APSIM were becoming available to other scientists through formal publications
- A web-based 'help desk' was established to support APSIM usage
- Linking of participatory methods to simulation improved on-farm participatory research methodology which increased the knowledge of the researchers, benefiting the NARES colleagues who have been trained in the improved methods, and helped the small-scale farmers in the study villages
- more than 30 papers were either published or were at an advanced stage of preparation for publication

The project succeeded in developing a new attitude to the use of modelling in research and extension in ICRISAT in India. This had started but needed to be developed further at African locations. A conclusion was that APSIM had become a valuable tool for research and extension in the semi-arid tropics. In the future, modelling applications will increase and diversify, and ICRISAT and APSRU could play a leading role in this. However, in a research environment with diminishing resources and on-going structural change, it took longer than expected to achieve these outcomes, and further efforts are required. ACIAR's investments in this and associated projects will undoubtedly be fully rewarded in the future.

The difference the project has made

During the course of CARMASAT, and subsequent to its termination, there were a number of examples where the project made a difference. Most of these examples relate to changes in research practice whereby a research question is addressed now by using participatory on-farm research and systems simulation. The big change is acknowledging the role of simulation in identifying research opportunities and in analysing the data from on-farm trials.

Example 1: On-farm monitoring and modelling of peanut sowing date and cultivar choice effects in the Pollachi region of Tamil Nadu, India.

Madhiyazhagan Ramadoss (Tamil Nadu Agricultural University, Aliyarnagar, India)

Researchers and extension officers collaborated with farmers to address peanut cropping and sowing decisions using on-farm experiments and cropping systems simulation in the Pollachi region of Tamil Nadu, India. The most influential variable affecting the peanut productivity in this irrigated region regards sowing date. During the 1998–1999 rabi (post rainy) season, three farmers' fields in villages in Pollachi region were selected and monitored. The APSIM model was used to simulate the effect of sowing date. The APSIM-peanut module simulation demonstrated close correspondence with the field observation in predicting yield. The model predicted that December sowing resulted in higher yield than January sowing due to a longer pod filling period, and this was confirmed by farmer experience. The farmers and extension officers became comfortable with their role as owners of the collaborative experiments and custodians of the learning environment.

In 2004, Mr Madhiyazhagan Ramadoss submitted a PhD thesis at University of Queensland on the topic of using the APSIM systems model to explore dryland maize within Australian farming systems. He recently returned to India as Assistant Professor (Agronomy) with the TNAU, Coimbatore, where he intends to establish a research program utilising systems simulation.

Example 2: Systems modelling and farmers' participatory evaluation of cropping options to diversify peanut systems in Anantapur region, India

V. Nageswara Rao, Piara Singh, Y. Padmalatha, and T. J. Rego (ICRISAT, Patancheru, India; Agricultural Research Station (ARS) of Acharya N G Ranga Agricultural University (ANGRAU), Anantapur, India)

Through systems simulation, peanut/short-duration pigeonpea intercrop systems were identified as the most suitable system for the rainfed Anantapur region. Farmer field trials were conducted during the 2000–2002 seasons to determine the adoptability of this system for the region. During these seasons, peanut yields were higher with sole peanut although system productivity was consistently higher with peanut/ short-duration pigeonpea systems. Short duration pigeonpea yields were higher compared to medium duration pigeonpea in the intercrop systems. Adoption of a peanut/short duration pigeonpea system by farmers in the neighbouring villages during the third cropping season


Bruce Pengelly

Following the enhancements made to APSIM, it was more widely used in the semi-arid tropics to help small-scale farms. After a workshop involving researchers and smallholder farmers in Zimbabwe, the farmers implemented and managed trials investigating manure and inorganic nitrogen interactions, legumes and their responses to phosphorus.

(2002), and better productivity in a severe drought year (2003) benefited farmers. Tools and methodologies employed in this study may well be utilised for similar situations in the semi-arid tropics. The use of simulation has potentially shortened the period of research prior to adoption by farmers.

Mr V. Nageswara Rao remains at ICRISAT, Patancheru, within a small crop modelling unit led by Dr Piara Singh. While this unit now concentrates largely on desk-top studies (eg yield gap analyses), Mr Rao has maintained his interest in combining systems simulation with on-farm research, with more recent efforts concentrated on exploring, with farmers and local NARES researchers in the Anantapur region, the potential application of seasonal climate forecasting. Through interviews with farmers and researchers who have collaborated with Mr Rao, it is clear he has achieved significant results from this effort. Without doubt, Mr Rao represents a strong advocate for the research approach and impacts which can be achieved from participatory research and systems simulation.

Example 3: Response of maize to low doses of manure and nitrogen in smallholder farms under semi-arid conditions

B. Ncube, S. Twomlow (ICRISAT, Bulawayo, Zimbabwe)

In 2001, a farmer group in the Tsholotsho district of Zimbabwe participated in the Linking Logics II activity where participative simulation generated farmer interest in on-farm experiments on the use of manure and inorganic fertiliser. Consequently, three seasons of experimentation have been conducted with about 35 farmers, which have demonstrated large maize yield gains from low doses of fertiliser (as little as 10kg N/ha).

The on-going activity at Tsholotsho currently forms the basis of a PhD thesis (University of Wageningen) being conducted by Ms Ncube. Her intention is to analyse the experimental results using APSIM.

Example 4: Workshops on harmonisation of farm operations with climatic information and crop models

K.P.C. Rao (ICRISAT, Nairobi) and G. Okwach (KARI, Katumani)

A two-day workshop was held with 26 smallholder farmers from Mwala Location, Machakos District, Kenya in July 2004. The participating farmers were exposed to systems information based on seasonal climate forecasts and systems simulation. This workshop was followed by two subsequent workshops attended by 50 farmers. The outcome of these workshops is a joint research proposal to ASARECA between ICRISAT and KARI to explore the further application of these systems tools in semi-arid Kenya.

> *"Farmers were excited and started asking for their own scenarios … we stopped at 6pm but the farmers still wanted to go on … it was the most exciting day of my scientific life"*
>
> **NARES scientist**

However, as at February 2005, 24 research/extension staff associated with the CARMASAT project (8 ICRISAT, 10 NARES, 3 IARC, 2 other) could be identified as having been trained in the application of APSIM and now were competent in its use. Of these probably only nine researchers would see APSIM as a key component of their current activities.

Given the first project objective of training ICRISAT staff and collaborators in using simulation modelling in agricultural systems R&D, roughly a 6% adoption rate (9 users out of around 140 trainees) can be regarded as low for close to 10 years effort. However, low adoption of simulation within agricultural RDE has been characteristic of these type of projects. Similar results were reported for the SARP and IBSNAT projects sponsored by the Dutch and US agencies in the 1980 and 1990s. Similarly, more recent efforts by ICAR in India to establish a crop modelling unit ended with few serious users of their INFOCROP model despite training of more than 150 scientists.

The question, “Why is there low adoption of APSIM (or other models) in agricultural RDE?” was posed to interviewees in this study. A number of reasons were proposed:

- NARES researchers/extension staff don’t possess underlying skills in computer literacy, mathematics and university-based modelling courses to readily adopt modelling. Therefore, selecting collaborators for modelling activities needs to account for their affinity for modelling rather than accepting any comer (as most other projects do). In addition, the few who do become proficient, thus demonstrating talent, are poached into other jobs and careers.
- Learning to become proficient in modelling takes significant time, commitment and resources. Input data requirements for models are not readily available for new users and are costly to collect. In addition, one requires a reason to invest in becoming proficient in modelling and most trainees have not approached their training with specific reasons in mind.
- The perception amongst non-modellers is that models are not good enough to capture systems performance nor have modelling efforts to date demonstrated much benefit in either the research or smallholder farming domains. This perception is shared by donors.

> *“I don’t believe the models”*
>
> **IARC researcher**

In addition to these more common issues, there were reasons proposed specific to the CARMASAT project:

- The initial APSIM licence arrangement, whereby APSIM distribution was controlled by APSRU and not made freely available to anyone, was seen as a significant barrier early in the project. This access policy differed from most other models and was seen as restrictive to the free transfer of scientific knowledge between researchers. Now that this policy has changed in order to make APSIM available to anyone who seeks a licence, the cost of the licence ($A2000pa) is seen as a barrier to most NARES.
- Modellers maintain loyalty to the ‘camp’ where they first trained and to the associated model. ICRISAT had a long association with the IBSNAT project and the DSSAT models and rivalry developed between this existing camp and the new CARMASAT project, especially in India.

> *“it takes a long time on a model to become proficient and so you need to stick with it. It is understandable that people will want to stick with a familiar model”*
>
> **ICRISAT scientist**

- Establishing new skills and technologies within an institution such as ICRISAT required management support. While CARMASAT initially received such support, the project was implemented at a time when ICRISAT was undergoing management and institutional change driven by declining resources. Consequently, the CARMASAT project within ICRISAT had high turnover of collaborating staff.

> *"we could have done more but needed institutional support"*
>
> **ICRISAT-India**

- CARMASAT spent too long early in the project concentrating on model development and therefore took too long to focus on applications. Most effort of the project in India concentrated on developing new modules (pigeonpea, millet, manure, soil P). While these themselves are significant achievements, relevant applications could have proceeded alongside development of these new modules.

Despite relatively few active users of APSIM within ICRISAT and collaborating NARES, the project succeeded in creating awareness of and appreciation for the contribution of modelling to RDE efforts. Senior management within ICRISAT universally were highly supportive of simulation modelling. In fact, concerns expressed by managers included the current over-commitment of their few modellers and the current demand for simulation analyses which remain unfulfilled.

There is a strong contrast between ICRISAT sites in India and Zimbabwe on how simulation is employed. ICRISAT-India appears to have reverted to using simulation in policy research projects (eg yield gap analyses) which were the stable application of modelling at ICRISAT prior to the CARMASAT project. Adoption of CARMASAT tools and approaches is therefore low — probably only 5% of activities run from the site. In contrast, ICRISAT-Zimbabwe has actively adopted the use of simulation within a farming systems research context. The impression is that most projects run from ICRISAT-Zimbabwe seek input from simulation and so adoption here is very high, approaching 80% of activities. The difference between sites can be explained by the shifting of the CARMASAT team from India to Zimbabwe in 1999.

> *"to be frank, when I started I was advised to be sceptical of models. Why take notice of them? Now I am convinced they work and are useful"*
>
> **ICRISAT-Africa scientist**

> *"absolutely, the small fertiliser dose effort was a key outgrowth of the modelling ... it indicated the highest returns and productivity gains were from low doses and this was confirmed in field trials"*
>
> **ICRISAT-Africa researcher**

> *"modelling has become an integral part of ICRISAT capacity in Africa ... modelling output has been an important part of many funding bids"*
>
> **ICRISAT-Africa researcher**

Little evidence could be found for active adoption of simulation analyses stemming from the CARMASAT project within the NARES in India, Zimbabwe or Kenya. While trained APSIM users exist in each of these countries, simulation effort concentrated around few users who have maintained strong linkages to ICRISAT or APSRU.

Project impacts

Community impacts

Few farmers in semi-arid areas of Africa use fertiliser and virtually none use recommended levels of application. Essentially, the formal fertiliser recommendations of national research and extension systems have been ignored by smallholder farmers in Africa's extensive semi-arid regions. Because of this, productivity gains from fertiliser use remain grossly under-exploited.

Over 160,000 smallholder farmers in Zimbabwe achieved 30–50% yield increases in their maize crops due to the aid-sponsored distribution of seed and fertiliser in the 2003–04 season. Most of these farmers were in the drier regions of Zimbabwe, where previous efforts had not included fertiliser. This initiative resulted in a short-term economic benefit for this large group of smallholder farmers in that particular season. This effort was to continue in the 2004–05 season but has been hampered by Government intervention. It is reasonable to predict a proportion of participating farmers would realise the benefits of applied N fertiliser and adopt this practice without subsidy. If so, the result would lead to economic, social and environmental benefits within these communities. Unfortunately this proposition could not be tested due to the current circumstances in Zimbabwe.

Key architects of the 2003 aid program readily attribute systems modelling within ICRISAT as being one source which supported the proposition of small doses of inorganic fertiliser applied in the lower potential regions of Zimbabwe. And modelling has become a core component within several follow-on projects within ICRISAT. Continued work on low fertiliser rates and engagement with agribusiness companies in southern Africa (Zimbabwe, RSA, Malawi, Mozambique) forms the basis of such effort. Already there are indicators of continued and widespread impacts with several agribusiness companies demonstrating interest in supporting fertiliser use by smallholder farmers.

A key recommendation from this review is to continue to support ICRISAT in its efforts to utilise its in-house systems modelling expertise to work with the private and public sectors in seeking greater adoption of fertiliser use in semi-arid Africa.

Brad Collis

The project succeeded in creating awareness and appreciation of the contribution modelling could make to agricultural research. The level of adoption has been disappointing but the potential remains high.

Capacity building and scientific impacts

The first aim of the CARMASAT project was to train ICRISAT staff and collaborators in using simulation modelling in agricultural systems R&D. Nine years hence, the outcome of this objective is a mix of success and disappointment. Success in that systems simulation remains an active tool and approach employed within ICRISAT centres in both India and Africa and the main legacy of CARMASAT, the use of the APSIM model, persists at most sites. Disappointment, because modelling remains a tool used only by a few devoted practitioners despite efforts at broad-scale training of staff from ICRISAT, other IARCs and NARES. Only within ICRISAT-Zimbabwe can systems modelling claim to be institutionalised through acknowledged key contributions to many projects run from this site. This outcome has been achieved due to the efforts of Dr John Dimes in providing simulation support and because his local managers, Drs Steve Twomlow and David Rohrbach, are strong advocates for systems modelling.

> *"we have not been able to impress and convince colleagues on modelling ... while all say it is a useful tool, modelling has not contributed much ... we are yet to make a dent in on-farm applications"*
>
> **ICRISAT-India scientist**

> *"in IARC, there is no institutionalisation of modelling ... never a whole-hearted endorsement but rather a cautious acknowledgement of value"*
>
> **APSRU researcher**

> *"it's a management decision ... when there is competition for funds between field research and modelling, then modelling will fall out"*
>
> **IARC Manager**

Reasons for the low adoption of systems models in agricultural research, development and extension was discussed earlier. However, it is sobering to reflect on the lack of capacity building impacts achieved from the significant effort represented by CARMASAT and related projects. This is especially so when combined with past investments in trying to build capacity in systems thinking and simulation. The Kenyan Agricultural Research Institute has invested in training researchers in modelling since at least 1986 (funded by an ACIAR project) and yet in 2005 there are fewer than 10 modelling practitioners left in KARI despite continued funding support (from the Rockefeller Foundation). Likewise, crop modelling units established within the Indian Council of Agricultural Research and Zimbabwean Department of Research and Special Services both lasted less than five years. These efforts add to those documented in other large scale efforts to train researchers in systems modelling which have also largely failed to generate and sustain capacity in the area of systems modelling – (i) the Simulation and Systems Analysis for Rice Production (SARP) project[1], funded by the Dutch government, provided modelling training for rice-based farming systems in Asia, (ii) the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) Project[2], funded by the US Agency for International Development, developed and provided training in the DSSAT model, and (iii) the International Consortium for Agricultural Systems Applications (ICASA)[3] supports training in decision support tools and models.

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1 ten Berge, H.F.M., 1993. Building capacity for systems research at national agricultural research centres: SARP's experience. In: Penning de Vries F.W.T., Teng, P.S. and Metselaar, K. (eds.) Systems approaches for agricultural development. Kluwer, Dordrecht, pp. 515-538.

2 Uehara, G. and Tsuji, G.Y. 1991. Progress in crop modelling in the IBSNAT Project. In: R.C. Muchow and J.A. Bellamy (Eds.). Climatic risk in crop production: Models and management in the semi-arid tropics and subtropics. CAB International, Wallingford. p. 143-156.

3 www.icasa.net

The lack of widespread and sustained capacity in systems modelling stemming from the CARMASAT project is a disappointment felt by many associated with the project. However, some believe that this investment can still repay into the future.

> *"CARMASAT has been a net success and I'm glad we had it …but it is still an unfulfilled promise "*
>
> **ICRISAT scientist**

> *"the seeds of past investment remain and returns will be gained in the longer term"*
>
> **funder**

The scientific impacts of the CARMASAT project are impressive, manifest mainly through the development of added capacity to the APSIM model and associated publications. The CARMASAT project was responsible for initiating the development of four new APSIM modules:

- APSIM-SoilP – Probert, M. E., 2004. A capability in APSIM to model phosphorus responses in crops. ACIAR Proceedings no. 114, 92–100.
- APSIM-Manure –Probert, M.E. Delve, R.J. Kimani S.K. and Dimes J.P., 2004. The APSIM Manure Module: Improvements in Predictability and Application to Laboratory Studies. ACIAR Proceedings no. 114, 76–84.
- APSIM-Pigeonpea – Robertson, M.J., Carberry, P.S., Chauhan, Y.S., Ranganathan, R. and O'Leary, G.J., 2001. Predicting Growth and Development of Pigeonpea: A simulation model. Field Crop Res 71, 195–210
- APSIM-Millet – van Oosterom, E.J., Carberry, P.S. and O'Leary, G.J., 2001. Simulating growth, development, and yield of tillering pearl millet. I. Leaf area profiles on main shoots and tillers. Field Crop Res, 72, 51–66

All of these modules are available in the current release of APSIM (version 4.0) and are used in many research activities worldwide. These modules, and the science they capture, represent a significant contribution of the CARMASAT project beyond its own project timescale.

The CARMASAT and follow-on projects have generated more than 50 publications. This large publication output, as well as the continued use of APSIM, will likely influence future research investment worldwide.

Mixed shrimp farming-mangrove forestry models in the Mekong Delta (FIS/1994/012)

Barry Clough

Collaborating organisations	Australian Institute of Marine Sciences (AIMS), Townsville; University of Tasmania, Launceston, Australia; Network of Aquaculture Centres in Asia Pacific (NACA), Bangkok, Thailand; Research Institute for Aquaculture No. 2 (RIA2), Ho Chi Minh City, Vietnam.
Project leaders	Dr Barry Clough; Mr. Tran Thanh Xuan; Mr. Thieu Lu
Related projects	FIS/1994/011, FIS/1994/019
Principal researchers	Mr Tran Thanh Xuan, Research Institute for Aquaculture No. 2, Vietnam (RIA2); Dr Michael Phillips, Network for Aquaculture Centers in Asia Pacific, Thailand (NACA); Mr Thieu Luu, Sub-Institute for Fisheries Research, Ca Mau, Vietnam (SIFR); Dr. Barry Clough, Australian Institute of Marine Science, Australia (AIMS)
Duration of project	1 July 1995 – 30 June 2001
Total ACIAR funding	$966,236
Project objectives	To develop improved farm designs and management strategies for mixed shrimp culture and mangrove forestry farming systems that will increase farm incomes and thereby reduce rural poverty in the southern Mekong Delta of Vietnam.
Location of project activities	Mekong Delta, Vietnam

Overview

Improvements in shrimp farm design and management are paying handsome dividends for farmers in the Mekong Delta who have adopted this project's recommendations. Farmers are reaping the benefits of higher yields, better quality and higher prices. Mangrove forestry will similarly benefit, but in the longer term. There is much potential for further expansion and adoption.

Project achievements

The project has developed improved farm designs and management strategies to increase shrimp survival and pond yields. Farm trials carried out in the second phase of the project demonstrated that an increase in survival from about 1% (at the beginning of the project) to at least 30% were possible using the recommended pond designs and management strategies.

In relation to mangrove forestry, the project developed an improved planting and thinning strategy that could potentially increase wood yields by about 20%. These wood yields are yet to be realised, however, due to the long-term nature of forest rotations.

Extension workshops were held for extension workers, enterprise leaders and farmers in 1998, including regular (usually weekly) technical advice on farm management given to farmers by project staff during the on-farm trials carried out between 1999 and 2001.

An extension booklet for farmers and extension workers was developed, printed and distributed in 2002. However, the distribution of extension manuals to farmers has not been effective, with only four farmers claiming to have seen the manual. The few copies of the farmer extension manual seen during farm visits were in very bad condition as a result of water damage or inappropriate storage.

Scientists at RIA2 and SIFR are successfully using project techniques, notably those for water quality and fauna, in a variety of other projects, including several Mekong River Commission projects.

The difference the project has made

Aquaculture practices are changing rapidly in Ca Mau and neighbouring provinces from many influences. The rapid increase in intensification and the development of large-scale commercial shrimp farms seen in the neighbouring provinces of Soc Trang and Bac Lieu is also evident to a lesser degree in Ca Mau province. In addition, Ca Mau Fisheries Extension Service produces its own extension material based on a wide variety of sources, including the ACIAR project. It is evident that the Provincial People's Committee sees a continuing role for project outputs in areas designated for mixed shrimp-mangrove culture. In response to demand from European and Japanese markets there has been a shift to so-called 'organic' shrimp farming in SFFE 184 Enterprise. This involves the

Farmers in the Mekong Delta are reaping the benefits of higher yields, better quality and higher prices due to improvements in shrimp farm design and management developed in this project.

culture of shrimp without any chemicals or feed during the growout phase. The market price per kg for 'organic' shrimp is nominally about 15% higher than for non-organically grown shrimp. However, the demand and actual price paid for 'organic' shrimp is rather variable, so farmers often don't receive the full benefit from producing 'organic' shrimp.

Ca Mau Department of Agriculture and Rural Development has changed mangrove forest replanting densities to 10,000 per ha, in line with project recommendations. In addition, rotation length and thinning plans have been made more flexible to allow for market demand for end products and optimising the economic returns from mangrove silviculture.

Notwithstanding the ineffective distribution of extension manuals to farmers, nearly all of the 47 farmers surveyed appear to have adopted some of the project recommendations. For example, all but one of the farmers surveyed now use techniques for selecting shrimp seed that were recommended by the project. Similarly, most farmers have improved their pond designs and water management strategies at least in part along the lines recommended by the project. Nevertheless, lack of access to project extension materials is likely to have reduced the adoption rate.

Specifically, farmers are now constructing better ponds by widening them, removing internal dikes and levees, and deepening them to 0.8–1.0 m in depth. More than 80% of farmers now use a settlement pond to improve water quality (compared to less than 10% at the beginning of the project). In addition, most farmers now use a nursery pond or nursery area to tend the post larvae for the first 30 days after stocking.

Most farmers now understand how to check and select healthy post larvae and use techniques suggested by the project for post larvae selection. They regularly check the condition of shrimp in the pond, and take appropriate action, such as harvesting or changing water, when there is evidence of a health problem. More than half of farmers feed the post larvae for the first 30 days after stocking, but feeding after 30 days is still uncommon.

There is a trend towards increasing the diversity of farm products. Crab production now accounts, on average, for about 10% of farm income. Some farmers have also diversified into fish, snails, cockles and/or pig production.

The failure of most farmers to fully implement the recommendations of the project may be associated with limited access to extension materials in the first instance, but also limited access to investment funds — even though farm incomes are now significantly higher compared with the beginning of the project and farmers have more capital to invest back into their farming activities.

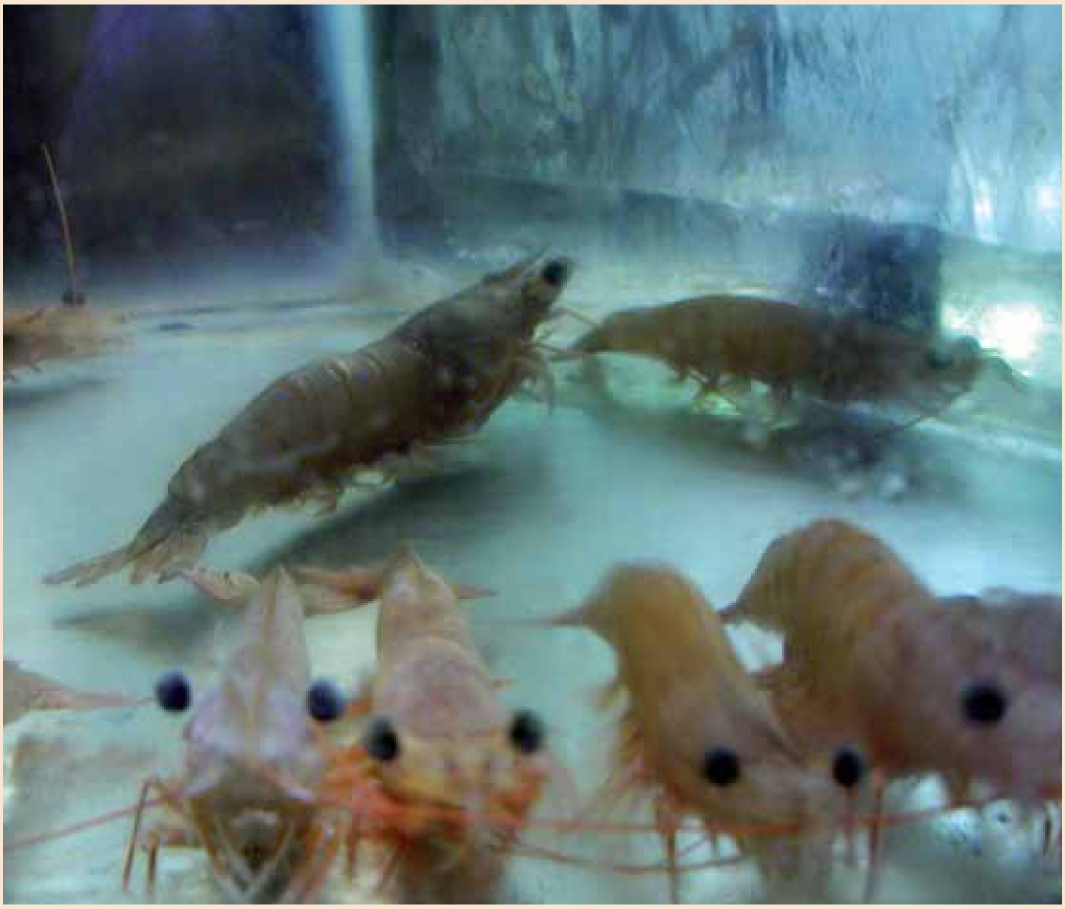
A significant characteristic common amongst farmers in Ca Mau Province is that they are satisfied with their way of life if they can provide for the day-to-day livelihood of their families, and therefore see no point in working harder than is necessary. Most farmers in the project area are poorly educated and do not think in the long term.

Project impacts

Community impacts

Average incomes for extensive/semi-intensive farms in shrimp-mangrove areas of Ca Mau Province are now more than three times greater than at the beginning of the project. For example, the average gross income (not including income from mangrove forestry) of the 47 farms sampled in November 2004 was about VND 55 million (US$3500), with some farms grossing more than US$6000. Shrimp culture accounted for about 85% of gross farm income and crab culture for about 10%. Though shrimp production is still the main source of income, the trend towards increasing diversification means that farmers are spreading their production base, and becoming less dependent on a single crop (shrimp).

Income from forest products is not included in these figures because only a few farms derived income from forest harvesting or thinning in 2004. The average profit margin is 65% of gross income (excluding income from mangrove wood products).



Geoff Allan

Most farmers now understand how to check and select healthy post larvae and use techniques suggested by the project for post larvae selection.

A consequence of the higher economic returns is that farmers now have more capital for investment in pond improvements. This is reflected in greater investment in pond improvements, with some farms investing up to USD 1,000 in pond improvements in 2004.

A higher rate of adoption of project outputs would lead to greater community impact. Apart from their poor distribution, the farmer extension booklets tend to be mistreated or hidden away, and are often not easily found or very visible. All farmers decorate the walls of their houses with calendars and posters. It would therefore make more sense to produce farmer extension materials in the form of posters, laminated with plastic to protect them from moisture that can be used to decorate the walls of farmers' houses. This would make the extension materials easy to find and highly visible, not only to farmers but also to their visitors. This could stimulate discussion amongst farmers and improve the adoption rate significantly, and lead to a greater community impact. Laminated posters can be produced very cheaply in Vietnam.

Capacity building and scientific impacts

A number of staff at RIA2 say they have used the techniques learned and experience gained in this project to improve their contribution to MRC and other projects. A number of staff have also advised that the experience gained in this project has created opportunities for them to be selected to participate in other donor-sponsored projects. One staff member from SIFR, Mr. Tuan, was accepted by ACIAR as a candidate for PhD study in Australia.

Limited though it is, the water quality and environmental data generated by this project is still the most comprehensive available for Ca Mau Province. Consequently it has been used in the formulation of the environmental monitoring component of the CWPDP.

Project results have also made a scientific contribution to several DANIDA sponsored projects that have been carried out in Ca Mau.

Acknowledgments

Dr Danielle Johnston (Australian Institute of Marine Science) and Mr Vu Anh Tuan both worked full time on the project and both made a huge contribution to its successes.

Overcoming production constraints to sorghum in rain-fed environments in India and Australia (CS1/94/968)

Ian Godwin

Collaborating organisations	Queensland Department of Primary Industries (QDPI); Indian Council for Agricultural Research – National Research Centre for Sorghum (NRCS); The University of Queensland (UQ); CSIRO Tropical Agriculture; National Research centre for Plant Biotechnology, New Delhi, India (NRCPB); International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India (ICRISAT)
Project leaders	Dr Graeme Hammer (QDPI); Dr B S Rana (NRCS)
Related projects	CS1/1995/122
Principal researchers	Dr Ian Godwin, Dr Mark Cooper, Dr I DeLacy (UQ); Dr Russell Muchow, Dr S Chapman (CSIRO); Dr S V Rao, Dr S L Kaul, Dr S Ravi Kumar, Dr B U Singh (NRCS); Dr P Ananda Kumar (NRCPB), Dr N Seetharama, Dr H C Sharma (ICRISAT).
Duration of project	1 July 1996 – 31 December 2000
Total ACIAR funding	$926,000
Project objectives	To develop technologies for optimal development of sorghum genotype and crop management combinations that best match major biotic and abiotic production constraints in rabi sorghum in India and dryland sorghum in Australia.
Location of project activities	Hyderabad, India and Townsville, Australia

Overview

In parts of Australia and India sorghum productivity has not increased over the past 20 years, largely because water and nitrogen are in short supply and insect damage high. This project sought to overcome these constraints by deploying an integrated approach comprising genetic engineering, plant breeding and crop modelling. The scientists used genetic transformation techniques to develop varieties resistant to sorghum stem borer. They have improved plant breeding and selection methods to develop sorghum types better suited to the rabi (post-rainy) crop in India and the summer dryland crop in Australia. A model developed by incorporating data from climate x water x nitrogen interactions was used to construct and test for the best crop management combinations under Indian and Australian conditions.

Project achievements

This purely research project to develop improved strains of sorghum that are disease resistant has contributed to the growth and development of biotechnology capacity and research in India.

Sub-project 1: Genetic engineering for insect resistance

Two tissue culture and regeneration systems based on organogenesis and somatic embryogenesis were developed to be used for genetic transformation of the sorghum. The organogenic system overcomes many of the problems associated with genotype specificity, allowing for a wider range of genotypes to be used for transformation. A sorghum transformation system has been developed using the microprojectile system known as a Particle Inflow Gun (PIG) made at The University of Queensland.

From research at the National Research Centre for Plant Biotechnology (NRCPB) in Delhi, a meristem-specific promoter was isolated from sorghum. This will be useful to achieve expression of insecticidal genes in the meristem to overcome shootfly damage. An artificial diet for *in vitro* rearing of shootfly was developed but insect growth and survival was not of sufficient level to allow for screening of insecticidal proteins.

Transgenic sorghum plants have been produced with Bt genes designed to confer resistance to stem borer. These plants had not been analysed at the time of project completion. At the time of project completion, no transgenic sorghum plants had been produced in India, but the capacity had been built up, particularly at the National Research Centre for Sorghum (NRCS) in Hyderabad where a new biotechnology building was completed in 1999.

A sorghum biotechnology workshop was held at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in 1999, with two days of presentations given by scientists involved in the project, plus others working on biotechnological approaches.


Ian Godwin

Research students in some Australian sorghum hybrids growing near Warwick, Queensland. As a result of the project a number of Indian scientists have been trained in skills of plant genetic engineering, retrospective analysis of breeding trial data and the development and application of crop simulation models.

Research at UQ beyond the end of the project allowed for further analysis of transgenic plants. Transgenic sorghum progenies have been tested for presence and expression of the cry1Ab transgene. The gene was demonstrated to segregate in the progenies of eight independent transgenic lines of M35-1 (*rabi*) and 296B (hybrid parent for *rabi* and *kharif*), both Indian sorghum inbreds. Protein expression analysis with ELISA demonstrated that protein expression was not at a high enough level to confer resistance to stem borer. Highest expression levels were in the order of 450–500 ng/g whereas it has been estimated that ideally resistant plants would have a minimum of 1 µg/g of cry 1Ab protein in young leaves and stems.

Sub-project 2: Improved breeding methods

A database of advanced yield trials for *rabi* sorghum conducted by the All India Coordinated Sorghum Improvement Program (AICSIP) was constructed, with data from 10 years and 31 locations. Analysis of variance on the AICSIP revealed that G x E (Genotype x Environment) interaction accounted for 77% of total genetic variance for grain yield. Regional adaptation patterns were identified and five near homogenous groups were found.

As a result, an optimal multi-environment trial program was recommended. This recommendation would reduce the number of years for variety trials from three to two and the number of locations could be reduced to 20 or fewer, while still retaining most of the G x E interaction variance. In India, scientists and farmers differentiate between 'varieties' (inbred lines) and 'hybrids'.

Training workshops were conducted in India to introduce AICSIP scientists to the methodology of analysis of adaptation, including the use of ASREML (a statistical analysis program) and pattern analysis software. It was believed that there was limited capacity however beyond Drs Kaul and Rana in the use of these techniques.

Sub-project 3: Improved management strategies

Data from past sorghum experiments were collated in an electronic database of soils and climate. Soil, climate and crop growth data from relevant sorghum experiments (from this and past projects) were assembled into the CROPBAG electronic database.

An experimental protocol was produced in booklet form for both Australian and Indian scientists involved in field experiments to ensure standardisation of data collection. The physiological basis of the response of key Indian and Australian sorghum genotypes to climate x water x nitrogen interactions was quantified by measurement and modelling. The sorghum crop growth simulation model APSIM-SORG was modified to take into account differences in Indian genotypes, and then tested against independent data. Higher radiation use efficiency (RUE) was found in the Indian hybrid CSH13R, which was quite unexpected and created wider interest among Australian sorghum research groups and breeders. The resultant model of sorghum growth and yield was therefore more appropriate for application to sorghum in India.

Simulation of the environmental yield potential for *rabi* sorghum was undertaken assuming standard sowing date and density for the major inbred line M35-1. Productivity on deeper soils was found to be substantially higher than that achieved on the shallow soils typical of the major *rabi* sorghum areas around Solapur in Maharashtra. Using the model and assuming that shootfly was not an issue, an analysis of the effects of soil depth, N content, sowing date and maturity was completed, leading to a much better understanding of sorghum response to these management practices.

The difference the project has made

Following the project, both NRCS and ICRISAT have developed transgenic sorghum plants with a variety of genes, including Bt genes. Much of this research has continued with funding from the Andhra Pradesh Netherlands (APNL) Biotechnology Program. These plants are currently being evaluated as third generation progenies. All this work has been aimed at developing stem borer resistant lines, with no effort at controlling shootfly, because of a lack of ability to rear shootfly larvae in vitro.

Research scientists in India and the United States are using the sorghum transformation system which they learnt after visits, conference presentations, training and other communications.

A sorghum landrace. A major scientific impact of the project has been the growth in interest in sorghum genetic engineering research in India, which was non-existent at the start of the project. Both NRCS and ICRISAT have now developed transgenic sorghum plants with a variety of genes.

The development and use of in vitro feeding techniques for rearing Lepidopteran pests such as *Chilo partellus* (stem borer) were transferred from ICRISAT and NRCS to NRCPB in Delhi. NRCPB is now using the system to test other Bt toxins and vegetative insecticidal proteins (developed at NRCPB and ICGEB) on this and other insect pests.

NRCS and, to a lesser extent, ICRISAT, have changed the way in which they have been involved in the use of sorghum genetic engineering. Before 1996, there was no research underway at either institution in transgenic approaches to sorghum improvement. Now there are many projects at these and other institutions using the very techniques developed through this ACIAR-funded project. It must be noted that in the past five years, there has been a great deal of interest in biotechnological approaches to improving sorghum productivity in India, and funding for this has come from the APNL project which commenced in 1998 and terminates in 2006.

Transgenic sorghum plants in the glasshouse at The University of Queensland. Plants have been produced with Bt genes, designed to confer resistance to stem borer.

A number of collaborative projects are in progress involving NRCS, NRCPB, Osmania University, Central Research Institute for Dryland Agriculture (CRIDA), Acharya NG Ranga Agricultural University (ANGRAU), and two private seed companies (BioSeeds India and J.K. Agrigenetics Ltd India). These include the further testing of Bt toxin-expressing sorghum lines for stem borer resistance. T3 lines are currently being evaluated in the glasshouse at NRCS. Field testing will be required to determine whether there is an acceptable level of stem borer resistance.

An additional, and unexpected user of the technology is a small Hyderabad-based company, Endeavour Enterprises. Endeavour Enterprises is effectively a technical engineering company which provides services such as controlled environment facilities, research greenhouses and animal facilities, and the development of technical machinery and apparatus. This company became involved in making a particle inflow gun (PIG) for ICRISAT in 1999. After the workshops in 1999, the company identified great demand for such apparatus and began to manufacture and market the PIG. They have refined it to a version known as the Gene Pro 2000He (website www.GenePro2000He.org) and have sold models of this gun to ICRISAT, Osmania University, Hyderabad University, Jaharwalal Nehru University, University of Delhi, Central Research Institute for Dryland Agriculture (CRIDA) and a number of state agricultural universities.

Major users of the breeding G x E information are predominantly NRCS plant breeding programs and the associated institutions at state agriculture departments and agricultural universities involved in the AICSIP. As there are now more than 20 private seed companies in India (both national and trans-national companies) involved in producing and selling hybrid and inbred sorghum cultivars, this information will be used by some of them in designing and applying their variety trials.

Breeding programs have changed some of their breeding and selection practices. For the AICSIP, rationalisation of testing locations is not easy but three separate zones for *rabi* sorghum are now recognised (a rationalisation of the five target environments identified by this project). The predominant factor in differentiating these zones is soil depth, with shallow, intermediate and deep soils characterising the three zones. Overall, the breeding focus is on these three zones, with the recognition that in all cases there is a need to shorten the duration of the crop. This is most marked for shallow soils, such as those in Maharashtra, where the stated aim for breeding programs is to select for lines of 100–105 days to flowering, which is 10–20 days earlier than the most commonly grown varieties and hybrids.

Major users of the APSIM-SORG model include the research institutions at QDPI, CSIRO and UQ in Australia, and scientists at NRCS and ICRISAT in India. Information gained from the r*abi* seasonal conditions have extended the utility of the model for a wider range of soils and environments.

Project impacts

Community impacts

Major community impacts will only be possible with the delivery of mechanisms of shootfly resistance in *rabi* sorghum. This will require further research and there are great opportunities to develop new initiatives to continue this collaboration.

The greatest community impact from the delivery of shootfly resistance will be economic. It would confer the ability to plant earlier, which will enable farmers to improve the use of the available soil moisture and result in higher productivity and security of production. Earlier plantings would mean that farmers would also be more likely to benefit from the application of N fertilisers, and hence would see the benefits of investment in better crop management. An additional impact of shootfly resistance will be that sorghum will become more attractive as an alternative for *rabi* sowings and it would be highly likely that the area sown to sorghum in India would increase.

Capacity building and scientific impacts

Indian scientists now have the capacity to genetically engineer sorghum. This has been instrumental in allowing progress to be made under the APNL biotechnology program. The biotechnology building at NRCS has benefited from equipment gained from the ACIAR-funded project. The Indian researchers are in the process of developing molecular markers and genome analysis which will greatly enhance their capacity for sorghum genetic improvement.

The capacity building has involved scientific visits between Australia and India and a number of Indian scientists have been trained in skills of plant genetic engineering, retrospective analysis of breeding trial data, genotype x environment analysis, and the development and application of crop simulation models.

The breeding programs overseen by the AICSIP umbrella are being updated with the knowledge gained from this project. There are however some obstacles to progress, but there is resolve within NRCS and ICAR to make the necessary changes to improve the breeding efficiency of *rabi*, *kharif* and forage sorghum breeding programs.

Seed companies are now heavily involved in the production of hybrid sorghums in India. More than 20 companies are involved in sorghum seed production, many in direct cooperation with ICRISAT and the AICSIP. These companies are benefiting from the research findings of this project.

A major scientific impact of the project has been the growth in interest in sorghum genetic engineering research in India, which was non-existent at the beginning of the project. In addition to the continued work on stem borer resistant lines with Bt genes (funded by APNL), NRCS has formed new linkages with other groups. These include the linkages with CRIDA (aimed at improving drought resistance traits), GB Pant University (improving *rabi* sorghum roti-making quality and shelf-life) and Osmania University (drought resistance traits and grain mould resistance). There are also projects at Tamil Nadu Agricultural University and ANGRAU developing sorghum transformation techniques. Finally, two seed companies are collaborating on sorghum transformation.

The APNL project has been focussed on the use of genes such as chitinase to overcome stalk rots and grain mould, and the use of Bt for stem borer. The stem borer work is well advanced, and much of the success for this project has come from the ACIAR-funded research. The ACIAR-funded project has enabled infrastructure and expertise to build up, and the Indian national system has taken up the technology with gusto. There is evidence that the transfer of Dr Seetharama from ICRISAT to NRCS has helped this to happen. Conversely, it also appears that this has been a loss to ICRISAT and currently almost all the transgenesis research at ICRISAT is focused on pigeonpea and groundnut under the guidance of Dr KK Sharma.

Scientists at NRCS, NRCPB and ICGEB are very interested in developing a new proposal with UQ to develop shootfly resistant sorghums. We have had discussions on the potential use of small peptides aimed at Dipteran proteases to prevent shootfly larvae from completing their life cycle. ICGEB has been involved in developing this technique to control malaria mosquitoes. We will also explore the potential to down-regulate the sorghum volatiles which attract female shootflies to the young seedlings. This would also involve collaboration with entomologists at DPI&F.

Genetic improvement of cultured tilapia and redclaw in Fiji and Australia (FIS/1996/165)

Peter Mather

Collaborating organisations	Queensland University of Technology, (QUT), Brisbane; Queensland Department of Primary Industries (QDPI) Fisheries Division, Walkamin, Queensland, Australia; Ministry of Agriculture, Fisheries and Forests (MAFF), Suva, Fiji
Project leaders	Dr Peter Mather (QUT); Mr Maciu Lagibalavu (MAFF)
Related projects	FIS/92/006
Principal researchers	Mr Satya Nandlal (MAFF); Dr C Jones (QDPI); Dr C McPhee (QDPI)
Duration of project	1 July 1997 – 30 June 2001
Total ACIAR funding	$696,000
Project objectives	To assist Fiji with a tilapia stock improvement program; to document the extent of genetic resources in wild redclaw stocks in northern Australia; and to develop a collaborative research program with QDPI and CSIRO on improving productivity of farmed redclaw crayfish (Cherax quadricarinatus) stocks in Australia
Location of project activities	Viti Levu, Fiji; Atherton and Brisbane, Queensland, Australia

Overview

This ACIAR project has resulted in an increased interest in, and use of, aquaculture in Fiji by poor subsistence farmers who can now diversify into growing the sought-after, genetically-improved culture strain of Nile tilapia (GIFT Fish) that has been introduced from the Philippines. The demand by consumers for tilapia and the subsequent increased income for farmers has led to further diversification and, in some cases, commercial or semi-commercial production. During the project, the introduced stock was evaluated in culture in Fiji and later fry produced at government hatcheries were disseminated to local farmers. The capacity of MAFF Fisheries staff to manage improved aquatic culture strains was significantly improved.

In Australia, the patterns of genetic diversity in wild redclaw stocks from across the natural range of the species were determined using molecular markers. The study showed that there is extensive genetic diversity present in wild stocks of the species that are still healthy across much of their natural distribution in northern Australia. In addition, an improved redclaw culture stock ('Walkamin strain') was developed and evaluated in a breeding program.

Project achievements

Fiji

At the beginning of the project, tilapia farming had been developed in Fiji by the MAFF Fisheries Division but the relative productivity of the tilapia strain available in the country ('Chitralada') provided to farmers had not been evaluated. There was a general belief that the productivity of the strain may have declined since it was introduced in the 1980s as a result of past poor stock management leading to increasing levels of inbreeding. At this time, a genetically improved strain of Nile tilapia had been developed by WorldFish centre in the Philippines, referred to as the GIFT fish. GIFT had shown superior performance to all other cultured tilapia lines there and also showed superior performance when it was later disseminated in the region. Farming of GIFT had led to a significant expansion of the industry and improvement in poor farmer income in the Philippines and elsewhere in Southeast Asia. The GIFT strain was introduced from the Philippines under quarantine conditions to Fiji and evaluated in quantitative trials in two different culture environments (integrated and non-integrated) against the best performing strain ('Chitralada') of the three local strains held by the Fiji Fisheries Division. In parallel, MAFF staff received training in the Philippines and Australia in the concepts and practice of managing improved aquaculture stocks.

Results of the evaluation trials in Fiji showed that GIFT provided a minimum of 19% growth advantage over the local strain in both culture environments (integrated and non-integrated). This advantage can allow up to four crops per year (three-month production cycle from stocking to harvest) to be achieved from a single pond while a maximum of only three cycles had been possible under the best conditions with the 'Chitralada' strain. Local farmers are now supplied with GIFT fingerlings (at no cost) from the

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The ACIAR project has resulted in an increased interest in, and use of, aquaculture in Fiji by poor subsistence farmers. The genetically improved Nile tilapia (GIFT fish).

MAFF hatcheries and provided with training and extension services to maintain GIFT stock quality over time. Dissemination of the GIFT strain to farmers led to a significant expansion of the tilapia culture industry on the main islands of Fiji (Viti Levu and Vanua Levu) with many local farmers seeking opportunities to diversify from agriculture (largely vegetable production) into aquaculture as a result of higher income they can obtain culturing the GIFT fish. The tilapia stock improvement project in Fiji also later led to diversification by some farmers into freshwater prawn culture, because additional income received from tilapia was used to develop their farms to culture *M. rosenbergii* post-larvae (also supplied by MAFF) that can provide higher returns compared with tilapia production.

Australia

The Australian component of the project was divided into two subprograms. The first, based at QUT, documented genetic diversity in wild stocks of the redclaw crayfish from across the natural range of the species in northern Australia. The second subprogram, based at QDPI Walkamin Research Station, undertook a breeding program using redclaw juveniles sourced from two wild stocks (Flinders and Gilbert Rivers in Qld.) to improve the growth performance of stock used in culture. As part of the study of wild redclaw genetic resources, two types of genetic markers were developed at QUT (mtDNA and microsatellites) and variation screened in more than 20 populations collected from discrete major natural drainages from the Northern Territory to the eastern side of Cape York.

Genetic diversity was extensive among populations from discrete drainages with a major divergence evident between the Northern Territory and Queensland stocks. The data suggest that the two lineages (NT and Qld) have been evolving independently for a long period of evolutionary time and may represent sibling species. Limited experimental laboratory crossing studies suggest that 'hybrids' between the two major wild stocks may show reduced viability. For management purposes therefore, they represent discrete units and probably should not be mixed. Extensive variation (while evident at a much reduced level), was also present among populations within each divergent lineage (NT vs Qld). Genetic marker studies showed that unique genes characterised populations from discrete major freshwater drainage in northern Australia where redclaw occur naturally. This result suggests that dispersal among major drainages is limited or absent in modern times such that sufficient time has elapsed for new allelic forms of genes to evolve *in situ* within each large river system across the north. Thus, overall genetic diversity is high in wild redclaw stocks and structured at a river basin level. Little of this genetic diversity has yet to be exploited in culture and most existing culture stocks are derived from a limited sub-sample of the natural diversity present in only two major Queensland southern Gulf drainage basins (Mitchell River and Flinders River).

The redclaw subprogram at QDPI Walkamin Research Station undertook a breeding trial using 'among' and 'within' family selection to improve the growth rates of wild redclaw stock sourced directly from the Flinders and Gilbert rivers in the southern Gulf region of Queensland. New wild stock was acquired for the study because past management of commercial culture stocks was likely to have led to high levels of inbreeding. To achieve a positive response from artificial selection, levels of genetic diversity need to be high in the broodstock. After two generations, the selected line showed a 39% improvement in growth rate compared with the controls. The improved strain is currently undergoing on-farm trials in real culture situations to determine if the gains achieved in the experimental trial will translate into an economic advantage to commercial redclaw farmers. If so, the Walkamin strain will be the first improved native crayfish species to be farmed in Australia.

Taken together, the outcomes of the two facets of the redclaw stock improvement program that comprised the Australian component of the project have demonstrated the potential for improving redclaw culture lines for Australian farmers and showed that considerable natural genetic diversity is present in wild redclaw stocks, providing a resource for use in future breeding programs.

The difference the project has made

Fiji

The tilapia stock improvement project has made a significant difference to development of the tilapia aquaculture industry in Fiji because local farmers recognise that the GIFT fish is a high performing culture strain that is appealing to consumers.

MAFF Fisheries staff conduct regular surveys of consumers and report that people actively seek the fish in preference to alternatives (eg reef fish) when stocks are available at local markets, both for flavour and for appearance. As this information has spread, many farmers, previously unaware of


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A new aquaculture sector plan being developed in Fiji will reactivate hatcheries in outlying regions on Viti Levu and Vanua Levu and establish demonstration farms.

aquaculture, have become interested in it. MAFF staff observe that many poor farmers who have taken up farming GIFT have significantly improved their economic position. Some tilapia farmers have been so successful that they have been able to diversify into other species (eg freshwater prawns, ducks and integrated vegetable farming) that can offer higher economic returns from their land. This has led to development of a freshwater aquaculture farmers' association on the main island of Viti Levu that meets regularly to promote the development of the industry. The association has developed a strong relationship with the Fisheries Division of MAFF. Together they have improved the marketing facilities for tilapia and now tilapia is sold live in some larger markets where previously live fish sales were not available or reef fish were too expensive for many consumers.

During a recent visit to Fiji by the project leader, the Tilapia Farmers' Association received tanks and equipment donated by aid agencies to expand facilities for sale of live tilapia at local markets. Availability of live fish for sale has resulted in an increase in the unit price in many markets so that tilapia can now demand similar prices to fresh reef fish. At the peak of tilapia production in Fiji in 2000 there were 300 tilapia farms producing fish for personal consumption and sale, where 220 metric tonnes of tilapia and 82 tonnes of freshwater prawns were produced with a total market value of F$880,000 and F$82,000 respectively. Unfortunately this level has declined significantly in recent times as a result of political events.

While there is strong evidence that tilapia culture has promoted development of aquaculture in Fiji, the civil and political problems associated with two unsuccessful coups during the course of the current project have meant that the rate of tilapia culture expansion has declined in recent times. This is because production of GIFT fingerlings and prawn post-larvae at government hatcheries was disrupted by political events and has only been re-established at a few major hatcheries. Farm numbers declined from a peak of more than 300 farms across Fiji in 2000 to around 140 in 2004 because farms away from the major hatchery at Naduruloulou were unable to obtain fry to stock their ponds and many ponds lay idle.

MAFF is now tackling this problem and last year a new Aquaculture Sector Plan was developed for 2005–2010 that will reactivate hatcheries in outlying regions on Viti Levu and Vanua Levu and establish demonstration farms to encourage farmers disillusioned by the impact of recent political problems. The plan seeks to grow the tilapia industry from the current 26 ha of ponds to around 6000 hectares by 2010 and to increase the value of the industry from F$125,000 in 2004 to F$42 million. Parallel increases are expected in freshwater prawn production and those of other cultured freshwater species (ie carp) to produce a total industry value of about F$62 million by 2010. Regardless of whether this target can be reached, it is widely recognised by both farmers and fisheries staff that introduction and dissemination of the GIFT fish as part of the ACIAR project has made a large impact in Fiji. It awakened interest in fish farming and helped poor subsistence farmers to diversify and become commercial or semi-commercial producers. The capacity for staff of the Fisheries Division to undertake future projects of this type on tilapia and other aquatic species has also been significantly enhanced.

Australia

The impact of the project is more difficult to gauge for the redclaw industry in Australia. The focus of the redclaw component of the ACIAR project was essentially experimental: to determine the extent of exploitable genetic diversity that may exist in wild stocks of the species; to initiate a collaboration between Australian research partners (QUT, QDPI and CSIRO); and to complete an existing breeding program at QDPI designed to determine if application of family selection could improve redclaw growth rate in culture. So the outcomes could not be measured in terms of direct practical outcomes for farmers at this stage but rather in demonstrating the potential for a breeding program to deliver positive outcomes for farmers in the future. In this respect the project was very successful, because the outcomes of the diversity study showed that there is extensive genetic diversity present in wild stocks of the species that are still healthy across much of their natural distribution in northern Australia. Secondly, the work by QDPI at Walkamin Research Station demonstrated clearly that a breeding program employing family selection can produce a faster growing redclaw culture strain. The improved strain is being tested in real farm situations to determine if the faster growth rates achieved under experimental conditions can also be achieved when stock are produced on real farms using commercial diets and feeding regimes. The complexities of genotype-environment interactions mean that this may not always be the case, but as little of the natural genetic diversity present in wild redclaw stocks has yet to be exploited in culture, the opportunities to develop improved lines via artificial selection approaches in the future are very favourable.


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Local farmers recognise that the GIFT tilapia is a high performing culture strain that is appealing to consumers.

Project impacts

Community impacts

The major community impact of the project has been the awakening of the farming community in Fiji to the opportunities that fish farming can provide, something that many were largely unaware of before the advent of the GIFT fish as part of the ACIAR project. The social structure of traditional indigenous Fijian villages is well suited to small-scale communal fish farms growing tilapia because of collective ownership of the land and sharing of tasks, resources and rewards. Thus there are a number of examples of indigenous groups achieving substantial returns for their villages after introducing tilapia and freshwater prawn farming. If the supply of fry from government hatcheries can return to the pre-2001 levels, be normalised and expanded across the islands, then tilapia farming will expand. This development will open up the opportunity for commercial production and the associated financial incentives to many poor indigenous farmers who have been limited in the past to subsistence production from their land.

Capacity-building and scientific impacts

The project has greatly increased the knowledge and capacity of Fijian MAFF staff in the development, maintenance and production of improved strains of aquatic species. As part of the project, MAFF staff (Mr Satya Nandlal and Ms Cherrie Whippy) travelled to the Philippines to receive training in handling, tagging, maintenance and breeding of the GIFT fish by experts at the WorldFish Centre. In addition Satya Nandlal (Aquaculture Manager at Naduruloulou Research Station) enrolled in a Masters of Applied Science degree at QUT where he completed a project that trialed mass selection to improve the colour attributes ('redness') of hybrid tilapia stock held at Naduruloulou Research Station. Thus, the technical capacity of the staff who have the responsibility for maintaining the quality and breeding of GIFT fry for dissemination to farmers was greatly enhanced. Equally, the staff now have the training, necessary conceptual background and experience to undertake rigorous breeding programs on new aquatic species in the future. Satya Nandlal has since taken up a secondment to the Secretariat of the Pacific Community (SPC) as Aquaculture Development Officer for the Pacific region and has received many requests to apply his new skills to developing freshwater aquaculture in Samoa, Vanuatu and Papua New Guinea. He is also contributing in an advisory role in a new ACIAR project promoting sustainable aquaculture in the Pacific and is currently helping fisheries staff in Vanuatu and Wallis and Fortuna to trial juvenile growout of an indigenous freshwater prawn species (*Macrobrachium lar*) in taro ponds.

Suggested actions to facilitate community uptake:

A major impediment to future expansion of fish farming in Fiji is the lack of a tradition of aquaculture amongst indigenous people. Many people in regional areas are totally unaware of its potential. The Fiji Fisheries Department has considered either developing some small existing farms in the regions as demonstration farms or establishing new government farms to showcase tilapia and prawn farming to poor farmers. This development in parallel with promotion and expansion of existing extension offered to farmers would significantly enhance development of aquaculture in Fiji. In addition, help with developing satellite hatcheries in regional areas (both infrastructure and training for hatchery staff) would greatly enhance uptake of the technologies as the few existing hatcheries have difficulty meeting local demand and very limited capacity to supply farms far removed from their physical location. This has lead to some small farms closing in regional areas — especially in Viti Levu — and the ponds remaining idle simply because of a lack of availability of fingerlings.

Minimising disease impacts on Eucalypts in Southeast Asia (FST/1994/041)

Kenneth Old

Collaborating organisations	CSIRO Forestry and Forest Products (CFFP), Canberra, Queensland Forestry Research Institute (QFRI), Brisbane, Australia; Forest Science Institute of Vietnam (FSIV), Hanoi, Vietnam; Royal Forest Department (RFD), Bangkok, Thailand
Project leaders	Dr Kenneth M. Old (CFFP); Dr Nguyen Hoang Nghia (FSIV); Mrs Krisna Pongpanich (RFD)
Related projects	FST/1991/015
Principal researchers	Dr Mike Ivory, (QFRI)
Duration of project	1 January 1996 – 31 December 2000
Total ACIAR funding	$787,648
Project objectives	The project's objectives were to determine the causes and etiology of foliar and stem diseases of eucalypts in SE Asia and Queensland; develop methods for screening for disease resistance of seedlings or clonal plants in the greenhouse and controlled environment chambers; and to incorporate selection for resistance to tree diseases into tree improvement programs in the field. In addition, the project aimed to develop the capacity to map regions of high hazard for important eucalypt diseases in SE Asia and Australia, using bio-climatic modelling.
Location of project activities	Australia, Vietnam, Thailand

Overview

Managing eucalypt plantation diseases in Vietnam and Thailand is now more effective thanks to this ACIAR-funded project. There is an increased awareness and understanding of diseases and their impacts on tree health and productivity, which has led to selecting disease-resistant clones for release to farmers.

Farmers and communities in Thailand and Vietnam benefit from these more robust trees which can be sold as cash crops for processing as pulp and paper or used for housing and other building projects. They are now less likely to have to bear the cost of losses caused by major disease outbreaks.

Project achievements

Pathogens causing moderate to severe foliar disease in both Thailand and Vietnam were identified, including *Cryptosporiopsis eucalypti, Cylindrocladium reteaudii,* an un-named species of *Pseudocercospora*, and the newly-introduced pathogen, *Phaeophleospora destructans.* The relative importance of these pathogens varied, with *C.reteaudii* being of major importance in Vietnam, but causing damage only in very wet years in Thailand. This difference in severity closely corresponded to predictions of bio-climatic modelling of this pathogen for Southeast Asia. The regular monitoring of leaf pathogens in trials in south-eastern Thailand detected a new incursion of *P. destructans* into mainland Southeast Asia.

Several important eucalypt stem diseases were found in Thailand and Vietnam for the first time, including cryphonectria canker, coniothyrium canker and (in Vietnam), bacterial wilt (*Ralstonia solanacearum*). Other records were made for Queensland and the occurrence of these diseases in trials was used as a resource for training overseas staff on attachment to CSIRO FFP, Canberra.

Rapid screening methods suitable for greenhouse or controlled environment chambers (CE) were developed for *Cylindrocladium* and *Cryptosporiopsis.* However, these methods were not used in Thailand or Vietnam for determining provenance resistance to pathogens because of the high level of between-tree variation, and the shortage of suitable facilities.

The establishment of 3.5 ha of *E. camaldulensis* as a provenance-progeny trial at Chon Thanh, Binh Phuoc Province provided the opportunity to select trees for growth, form and disease resistance. Following discussions at the 1999 workshop in Ho Chi Minh City a stratified sample of 72 trees was relocated to Song May, Dong Nai Province, a highly disease-prone environment, to allow further evaluation as clonal mother stock for future plantations. A 50-clone replicated trial at Song May established from plus trees (ie trees with superior performance) selected in the south-east region of Vietnam was evaluated during the last year of the project.

In Thailand, close relations were established with the Siam Pulp and Paper Co. (SPPC) and its subsidiary the Siam Forestry Co. The company established a series of large replicated trials of more than 200 selected clones at 30 locations in western Thailand. Three of these were monitored for resistance or susceptibility to leaf blight and canker diseases, by Mrs Pongpanich, who also trained company staff in recognising pathogens, scoring disease impacts and selecting disease resistant clones. The selection of superior clones in Thailand has resulted in the identification of 30 clones of *E. camaldulensis* for release to farmers for planting in the SPPC resource area. This is an on-going program with some clones being changed every year to reduce risks from damage by pests and diseases.

In Vietnam, five replicated trials of selected clones from the 50-clone and 72-clone trials at Song May have been set up in southern, central and northern Vietnam. These trials are testing the performance of clones selected for growth, form and disease resistance across a range of climatic and edaphic conditions. The trials are also being used to assess performance of trees against pests and pathogens which were undetected in Vietnam at the outset of the research program, eg *P. destructans*, *Coniothyrium zuluense*, and a severe gall forming insect yet to be identified. This unknown pest resembles *Leptocybe invasa,* which causes severe damage to eucalypt plantations, especially *E. camaldulensis*, in Africa and the Middle East (Mendel et al. 2004).

The project has generated a range of extension/resource materials including a manual of diseases of eucalypts in South East Asia, supported by ACIAR and published in 2003 by the Center for International Forestry (CIFOR) (Old et al 2003). In Vietnam, Dr Nghia published a book on tree improvement and selection for disease resistance.

The difference the project has made

There has been a major change in participating countries in Southeast Asia, in the approach to managing eucalyptus plantation diseases as a result of the activities and outputs of this project.

There has been an increase in the awareness of diseases and their impacts on tree health and productivity by scientists, tree improvement technicians, plantation managers, forestry enterprises and commercial forestry companies. This has led to changes in selection criteria to include resistance to specific pathogens rather than reliance on gross crown health classes, and to the establishment of a series of replicated clonal trials across climate and geographical gradients to assess impacts on growth and tree health. These trials have included selected clones of differing resistance to known pathogens. Without such clones, impacts of pathogens cannot be assessed and reliable selection of superior resistant clones cannot be made.

In Vietnam, provincial forestry enterprises now regularly refer observed disease problems to FSIV staff trained in forest pathology and entomology, and headed by Dr Pham Quang Thu. Before 1995 there was little R&D capacity in forest health. Examples of such referrals to Dr Thu's team have included pine wilt in the Central Highlands, incursion by *P. destructans* throughout Vietnam during 2001–2003 and recent major outbreaks of canker diseases in hybrid acacia plantations in central and northern Vietnam.

Ken Old

Dr Pham Quang Thu and staff of the Forest Sciences Institute of Vietnam in a 50-clone *Eucalyptus camaldulensis* trial at Song May, Vietnam. They are examining a clone which is showing susceptibility to a canker disease caused by the fungus, *Coniothyrium zuluense*.

In Vietnam, clonal lines, certified for resistance to the major pathogens which have affected eucalypt health, will be released to growers in 2005 and the adoption rate is expected to be high. These changes in awareness of the importance of plantation health in Vietnam have occurred against a background of a decade-long shift from plantation forestry based on seedlings to clonal forestry. The ability to recognise and manage disease and pest outbreaks will be critical to the sustainability of current and future forests.

In Thailand, the Siam Tree Development Co will provide planting stock selected for resistance to the serious leaf blight pathogen, *P. destructans*, during 2005. This should avoid costly crop failure and economic hardship to farmers in the event of a wet season comparable to that experienced in 2000.

Improved record keeping about which clones are planted where and which pathogens are present and cause impacts is needed. There is also the need to remove the secrecy attending pest and disease outbreaks, especially in Thailand. There is often little willingness at the highest levels in companies to accept that pests and diseases are always present at some level in tree plantations.

Whether the concern is about impacts on shareholders and investment prospects is not clear. Some companies, eg Siam Forestry Co Ltd, have been very open in this regard, and have given a high level of cooperation to researchers, but other companies have been less receptive. As a result, this company has been one of the main collaborators in and beneficiaries from the outputs of the project.

In Thailand, virtually all companies have now included resistance to disease as a major selection trait for clones to be released to farmers. Adoption has been strongest by those companies which actively cooperated with RFD and CSIRO during the term of the project. For example, the Siam Forestry Co Ltd provided major research sites where their field staff developed a high level of skill in recognising the main pathogens. K. Old visited Suwan Kitti, a subsidiary of Advance Agro, following the 2000 Bangkok workshop and advised on a strategy to minimise the impact which the incursion of *P.destructans* was having on the feedstock supply for the company's recently commissioned pulp mill. Immediately after the workshop, three major companies secured large supplies of seed of well-adapted species from the Australian Tree Seed Centre to broaden the genetic base of their tree improvement programs.

In Thailand, farmers are planting clones less likely to be subjected to severe damage by leaf blight and stem pathogens in the event of seasons highly conducive to fungal diseases. This is due to the selections which have been carried out in large replicated clonal trials in several parts of the country during and since the completion of the project. Also, the number of clones available is much greater and they have been selected from a broader genetic base than previously. Rapid adoption has been made possible through concurrent and rapid advances in propagation methods including tissue culture. Replicated clonal trials are also providing information on tree performance (including disease impacts) on contrasting site conditions — waterlogged or calcareous sites.

Companies are hiring dedicated tree health professionals to capitalise on the benefits of these trials and to monitor plantation health across feedstock catchment zones.

In Vietnam, clonal forestry is now standard for all provincial forestry enterprises. This will facilitate rapid deployment of disease resistant material from the FSIV eucalypt improvement program. Provision of suitable planting material more broadly will come from state and private nurseries and the Vietnam Tree Improvement Co. Vegetative propagation from cuttings rather than seedlings would have proceeded in any case, however clonal forestry offers considerable benefits in optimising gains from selection of resistant plants, which can be rapidly multiplied and distributed for planting in disease-prone regions.

Project impacts

Community impacts

Thailand. In Thailand, where the companies typically provide eucalyptus planting stock to the farmers and contract to buy the logs after short, 5–7-year rotations, the community benefits are potentially large. Farmers have been encouraged to put a proportion of their land into tree production rather than cassava, legumes or other crops, to diversify and provide alternative sources of income.

In 2000, however, when climatic conditions were very favourable for disease and significant areas of eucalypt plantation were killed outright or rendered unusable by incursion of the new pathogen — *P.destructans*, the initial losses in income fell on the farmers.

The companies in Thailand are now much more aware of the potential vulnerability of clonal plantations to disease. Their willingness to move rapidly to broaden the genetic base and actively select resistant clonal lines should greatly mitigate disease epidemics in the event of another unusually wet season or further incursions by exotic pathogens. This will reduce the risk of economic hardship to farmers and potential shortfalls in supply to the pulp mills which have sprung up in the region.

Vietnam. The less sophisticated economy of Vietnam will derive similar benefits in the longer term. In the short term, in many parts of the country, eucalypts are being replaced by acacias as the main plantation species, due to their rapid growth rates — and, so far, their relative disease-free status. Eucalypts, however, have special properties that ensure a secure future. For example, companies usually mix a proportion of short, higher-quality eucalypt fibre with acacia material. Also, eucalypt poles, especially of *E.camaldulensis* with its excellent self-pruning characteristics, smooth straight stems and high density can be used for many purposes, housing, sheds, fences etc. Thus, the retention of eucalypts in village economies is of significant benefit.

Capacity building and scientific impacts

The project has undoubtedly had major impacts on the level of knowledge, skills and acceptance of forest pathology as an integral part of plantation management and tree improvement in Thailand and Vietnam.

Thailand. On a short, pre-project visit to Thailand in 1993, the level of available skills in forest pathology appeared to be very low. Ms Pongpanich of the Royal Forests Department, Bangkok was identified as the main hope for the future. This project has given her an opportunity to develop her career and when the head of laboratory retired she succeeded to the position. She has built up a small group of enthusiastic staff, mostly female, who have worked closely with company staff to provide the expertise for scoring field trials and monitoring existing and new disease problems. Mrs Pongpanich now has a significant publication record as co-author of papers on fungal pathogens with internationally renowned scientists. As a result of her detailed surveys of disease in eucalypt-growing areas of Thailand she was able to recognise a new incursion of a very serious pathogen — *P. destructans*, in 2000 and this was conveyed to the Thai Forestry Industry at the Bangkok workshop. Very rapid identification of an incursion is a rare event for forest pathogens which often go unnoticed for years. Mrs Pongpanich occasionally gives lectures at Kasetsart University and assisted with the ACIAR eucalyptus rust workshop in Bangkok in October 2004.

Vietnam. In 1994 when the author first visited Vietnam, forest pathology skills were either absent or invisible. There was no formal, disciplinary expertise in the south of the country, and in Hanoi two or three staff worked in very poor facilities on activities peripheral to forest health. The massive problem of eucalyptus leaf blight in central and southern Vietnam, and lack of local expertise, prompted the request for ACIAR funding for this project. Dr Nghia, an extremely able and dedicated expert in tree improvement, headed up the Vietnamese team, and put Dr Thu in charge of pathology, disease surveys and made him our main collaborator. Dr Thu rose to the challenge. He received very good support from FSIV, secured extra funds from the Vietnam Government to equip the Hanoi lab and has become the outstanding forest pathologist in Vietnam.

Dr Thu now heads a team of 10 forest health staff including four entomologists and six pathologists. He presented a paper on his research on pine wilt nematode at the prestigious International Plant Pathology Congress in Christchurch in February 2003, and co-authored a poster on the spread of *P. destructans* through Southeast Asia. Dr Thu first recorded this pathogen and documented its spread throughout Vietnam. He is the focal point for the FAO Asia Pacific Invasive Species Network and collaborates with international scientists. He recently spent three months in South Korea working on endophytes, and is seeking placement of his staff overseas for tertiary studies. He is in great demand by provincial forestry departments and provincial forest enterprises, and has been asked to look at a major problem in hybrid acacias which are being planted throughout Vietnam on a large scale.

The experience gained in Vietnam by Dr Thu in his work with eucalypt diseases has given him the capacity and confidence to apply his skills to other tree /disease combinations. The best example is his work on pine wilt nematode in the southern highlands of Vietnam. Having been called in to advise on widespread death of pines in the Da Lat area, he was able to show that although a *Bursaphelenchus* sp was involved, and that it was vectored by the pine sawyer beetle *Monochamus alternatus*, the nematode was not *B. xylophilus*, but a hitherto unnamed species. By monitoring tree deaths and nematode presence over several years Dr Thu has shown that the problem is not severe and the outbreak has been contained by removal of dead trees and disposal of felled stems and branches following harvesting which act as breeding grounds for the vectors. His paper on this was well received in Christchurch and was of particular interest to Australian pathologists who have experience a somewhat similar syndrome in suburban Melbourne.

Reference

Mendel, Z., Protasov, A., Fisher, N., and la Salle, J. 2004. Taxonomy and biology of *Leptocybe invasa* gen. @ sp. N. (Hymenoptera: euclophidae), an invasive gall inducer on *Eucalyptus*. Aust Journal of Entomology 43, 101–113.

Old K.M., Wingfield, M. J. and Yuan Zi Q. 2003. A manual of diseases of eucalypts in South East Asia. Center for International Forestry Research , Jakarta Indonesia 98p.

Increasing crop production through biological control of soil-borne root diseases (LWR2/9680)

Maarten Ryder

Collaborating organisations	CSIRO Land and Water (CLW), Adelaide, Australian Cotton Research Institute (ACRI), Myall Vale, Australia; China Agricultural University (CAU), Beijing, Chinese Academy of Agricultural Sciences (CAAS), Beijing, Zhejiang Agricultural University (ZAU), Zhejiang, China
Project leaders	Dr Maarten Ryder (CLW); Associate Professor Peng Yufa (CAAS)
Related projects	LWR2/1992/009
Principal researchers	Prof Zhang BingXin (ZAU); Prof Tang Wenhua (CAU); Dr V S Putcha (ACRI)
Duration of project	1 July 1997 – 30 June 2001
Total ACIAR funding	$866,549
Project objectives	The aim of the project was to evaluate soil-borne bacteria and fungi, isolated in Australia and in China, for their ability to control target root diseases of wheat, cotton and vegetable crops; and to elucidate the mechanisms by which selected bacterial and fungal treatments control disease and enhance plant growth and yield.
Location of project activities	

Overview

To make biological control agents available to farmers, a commercialisation step is involved. The scientific and technical cooperation between China and Australia has enabled this step to occur in this project. It was especially good to have the funding from DEST / MOST after the main ACIAR project was completed, to assist the commercial development phase.

This project was successful because so many of the team members in both countries were committed to the goal of developing practical biological control treatments, and there was genuine two-way traffic of ideas and exchange visits. This meant that all team members could appreciate and gain from the variety of approaches brought by the different participants. The project was based on joining together previously existing research projects in the two countries — in other words, there were pre-existing expertise and collections of likely candidate biocontrol organisms that had been screened for activity in one or more crop/disease systems. The road to commercialisation was made easier by the project having the expertise of Dr Yang Hetong in formulating microorganisms. Formulation is a vital step in preparing microbes for practical use and sharing of this knowledge enabled several groups to make much more rapid progress.

Project achievements

The final aim of this project was to enable the development of a commercial product for farmers to use, though this commercial development was not expected to occur within the life of this project. The fact that this stage was reached in 1999 in China demonstrates a positive future for biological control, and also the strength of the cooperation and the high level of skills available to the project.

A biological fungicide based on the beneficial soil-borne fungus *Trichoderma* Tk7a (from CSIRO) was produced under licence and preliminary registration in China by the MinFeng company (1999 and 2000). Factory procedures for producing the product were developed. Although the MinFeng company no longer produces biological control products, possibilities for new sub-licensed production in China have progressed involving CAU, SDAS, CSIRO and the Qinhuangdao Leading Science and Technology Development Company (QLST). This recent advance forms the basis of a DEST/MOST-funded commercial development project between CAU and CSIRO with commercial partners in China and Australia.

Biocontrol treatments for wheat were field-tested in Australia in 1999–2002 using *Trichoderma* product formulated according to Chinese-developed methods. This illustrates the excellent two-way cooperation that has occurred in the ACIAR project. Potential for further commercial development of this treatment in Australia is also part of the DEST/MOST commercial development project. The partner commercial organisation in Australia is Becker Underwood Pty Ltd.

As a result of the ACIAR project, CAU scientists developed a new bacterial biocontrol treatment which was based on a study of soils in Shandong province that are suppressive to wheat disease. The bacterium, a *Pseudomonas* strain (CPF10), is now patented by CAU and is registered in China for the control of bacterial wilt of ginger. It is produced commercially by the Qinhuangdao Leading Science and Technology Development Company.

A great deal of useful information was generated during the project, much of it in the original aims but also from some additional work that arose out of mutual interest between the scientists (eg ZU and CSIRO).

Research scale biocontrol of vegetable damping-off diseases was achieved in commercial greenhouse conditions in China. This work has not yet led to commercial products, however several microbial strains show promise and could be developed if there is sufficient commercial interest.

Research scale biocontrol of cotton diseases (Verticillium wilt, damping-off) was achieved in the field in China. Several microbial strains of both Chinese and Australian origin show good ability to increase cotton yields and could be developed commercially.

Seedling pathogens resistant to a common chemical fungicide were found in vegetable-growing soils in both China and Australia. The work indicated that (a) there is a risk that chemical disease control of damping-off diseases can fail and this may become more common in the future and (b) that biocontrol treatments can assist in achieving good crop stands where chemical control is no longer effective.

Understanding of the mechanisms operating in disease control was improved as a result of the project. This was probably only the second study anywhere in the world of the mechanisms by which *Bacillus* strains control disease, and therefore made a considerable contribution to biocontrol research (there are numerous *Bacillus* products commercially available for biocontrol but very little work has been done on their mechanisms of action).

The difference the project has made

New inoculant products: QLST produces *Rhizobium* in China and plans to expand its range to include biocontrol agents such as *Trichoderma* Tk7a. *Pseudomonas* CPF 10 has already been registered and is produced commercially in China by QLST. Field demonstration trials with commercial product have been carried out in at least six provinces in China. An improved formulation is being developed by CAU. The government is also trialling CPF10 in the field trial as an alternative to methyl bromide, which is being phased out globally as a plant protection treatment.

Becker Underwood Australia is considering the commercial feasibility of a *Trichoderma* product for Australia. The target markets being considered are wheat and sugar cane.

When commercial products are available, the company producing the inoculants can inform the network of extension workers who are able to pass on information on new treatment options to farmers.

Several other potential microbial products could be developed from the project in future. For example, binucleate *Rhizoctonia* from CSIRO could be developed for control of cotton diseases in both China and Australia. Commercial partners have been briefed about these new possibilities, which now require commercial decisions on the desirability of developing new products. In some cases, suitable formulations of the microbes must also be developed commercially before release will be possible.

The DEST/MOST-funded bilateral project has greatly assisted the commercial development process by bringing together scientists and commercial partners within and between the two countries.

The practice change for farmers is practical use of the biological control treatment which is an environmentally-friendly alternative to chemical fungicides and to the harmful chemical pesticide methyl bromide. This occurred in 1999–2000 in China when the Min Feng company produced and sold *Trichoderma* Tk7a. The preliminary registration lapsed in 2000 but the Qinhuangdao Leading Science and Technology Development Co is currently re-registering *Trichoderma* in China. A transfer of the CSIRO–CAU licence agreement to QLST is being negotiated.

As extension staff become aware of new treatments for controlling diseases, they can either organise demonstration tests or recommend trying a biological disease control treatment. The biological control can be promoted as an alternative to chemical fungicides or a disease control treatment where none was previously available.

Project impacts

Community impacts

Community impacts at this stage are small because the commercial production of biocontrol agents from this project is still in the early stages of development. Community impact requires adoption by farmers and in this case a commercial development step is necessary. There is a potential for community impact to grow as biocontrol treatments are developed commercially and deployed over greater areas. This is likely through the renewed commercial development of a biocontrol treatment based on CSIRO's *Trichoderma* Tk7a.

The recent demonstration trials of CAU's *Pseudomonas* CPF10 in at least six provinces in China could increase demand for this new biological treatment. Importantly, this biocontrol agent is being trialled as an alternative to methyl bromide soil fumigation treatment for control of soilborne diseases. Methyl bromide is being phased out and so new treatments are needed to enable maintenance of current levels of crop production. If the biological method is successful, the government will support its use. Replacing chemical disease control and reducing chemical use is beneficial both for operators and for the environment. Factory production of chemical pesticides also results in negative environmental impacts (generation of toxic by-products and use of toxic raw materials), so the increased use of biocontrol products will have a second potential environmental benefit.

People in China generally are paying much more attention to the quality of food (lower levels of pesticide residues, called 'green food'). Everyone is affected by food quality, so reduced chemical pesticide loading in the environment and on food products is very desirable.

Since women are very much involved in the everyday activities of agricultural production in China, benefits to farmers will clearly be beneficial to women. Most women peasants are engaged in agricultural activities throughout the year and women commonly carry out activities such as chemical spraying, with associated risks to their health. Women could expect the following benefits from using chemical fungicides in a more targeted manner (with reduced doses and using seed application instead of foliar spraying): reduced costs, less risk, time and energy of chemical spraying, lower intensity of farm labour, reduced risk of allergic reactions and other physical illnesses caused by the use of chemicals.

Controlling diseases using biological treatments can lead to increased production and income benefits. As an example, a cost–benefit analysis for the use of *Trichoderma* 'Tk7a' biocontrol agent gave a 10% yield increase (this is less than the average yield increases obtained in more than 12 field trials in China from 1994 to 1997); 100 g of product will treat 1 mu (1/15 ha); cost of product = 3.5 Chinese Yuan; the yield range is 300–400 kg/mu; and an extra 10% gives 30–40 kg extra yield /mu. At a price of 1 yuan per kg of wheat, this is an extra 30–40 yuan per mu, giving a benefit–cost ratio approximately 10:1.

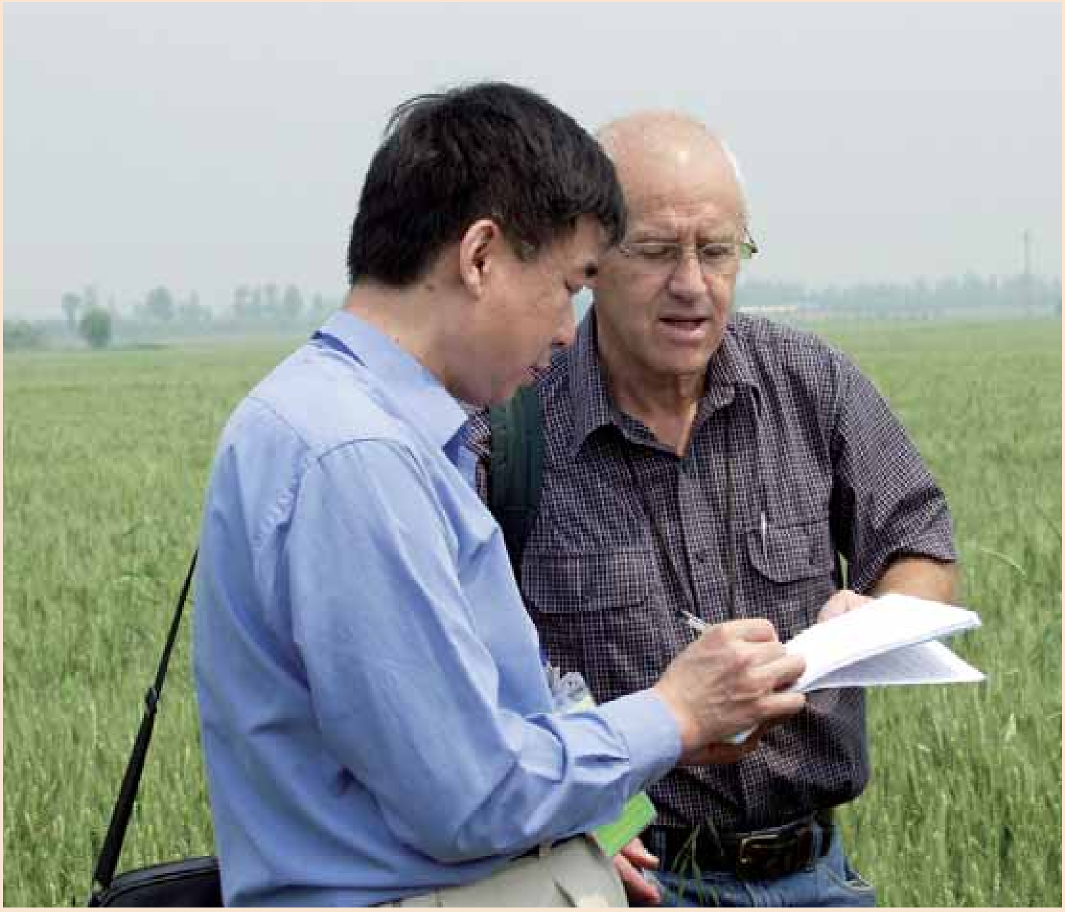
Other, wider economic benefits:

- More efficient use of agricultural by-products which are used to grow biocontrol agents (eg wheat straw, bran, rice hulls).
- Establishment of new industries (factories), resulting in increased local employment. Both men and women will be working in these factories.
- In the cooperation project there were many female scientists, including scientists working at all levels, from research leaders to students and technical staff.

Capacity building and scientific impacts

Several postgraduate degrees have been awarded in China through this project. Aside from the scientific and technical advances in the work, the students have clearly benefited from the personal knowledge they have gained which is now being applied in other projects — several former students are actively expanding their work in biocontrol research; scientific networks in China and international links with Australia have been increased and strengthened resulting in many potential collaborations for future research.

During the project a great deal of emphasis was placed on exchange visits between China and Australia, which benefited all of the staff involved. It was a genuine two-way collaboration with the focus on the final aim of producing biological control agents and gaining information about when and where the biological treatments can be expected to work. As well as the laboratory work, three visitors to Australia were able to increase their knowledge and networks considerably by attending the first Australasian Soilborne Disease Symposium in 1999.



An important capacity-building activity which resulted from the project was the ATSE Crawford Fund Master Class on 'Soilborne pathogens of wheat'. Dr Maarten Ryder and student in the field at the master class.

One postdoctoral fellow is now Institute Director at the Shandong Academy of Sciences. This appointment is leading to a large amount of continuing and related biocontrol work, much of which is very innovative. Some of this research has been published in the Chinese scientific journal Shandong Science as a series of papers based on the November 2004 biocontrol workshop in Jinan. Another visitor to Australia on the Crawford Fund program is now a full Professor at Henan Agricultural University.

The collaborations are continuing and extending to other institutes. For example, CSIRO is discussing future scientific collaboration with China Agricultural University, Shandong Academy of Sciences, Hebei Academy of Agricultural and Forest Sciences, Shanghai Academy of Agricultural Sciences, and Henan Agricultural University.

A very important capacity-building activity which has resulted from the project was the Crawford Masterclass on 'Soilborne pathogens of wheat' held in Zhengzhou (Henan Agricultural University) in May 2005. Many of the staff of this class (three Australian and four Chinese scientists) have had a long and active involvement in the ACIAR project.

This project generated some significant scientific impacts.

Biocontrol research has expanded in China as a result of this project, and an associated international conference held in Beijing in 1996, which was chaired by Prof Tang Wenhua of China Agricultural University.

During the project, the researchers increased the level of awareness about the importance of plant pathogen diversity in biocontrol research and its application in the field. The attention to design of replicated field trials and statistical analysis of the data in the early stages of the project may have had an impact on the conduct of other trials.

Many of the researchers involved took their work much closer to practical application. This was greatly assisted by the expertise of Dr Yang Hetong in formulating microbes for practical application in the field. This drive to take the research through to adoption by formulating the micro-organisms and by making close linkages with the inoculant companies in Australia and China was facilitated during the last two years by the MOST/DEST-funded project.

Molecular genetic techniques were introduced to students and staff, which greatly strengthened the ability of the whole project group to study pathogen diversity, to track biocontrol agents in the environment using inserted marker genes and to study the mechanisms of action of 'yield increasing bacteria'.

This was probably only the second study worldwide to study mechanisms in the action of *Bacillus* biocontrol agents and 'yield-increasing bacteria' and therefore made a considerable contribution to biocontrol research.

The team from this project visited a controlled traffic tillage field site in China (ACIAR project LWR 1996/143) and identified common root rot as a serious problem in the area (previously unrecognised). This finding again highlighted the need to pay attention to soilborne diseases in crops, especially when changing farm management systems. The experience also formed part of the rationale for holding the Crawford Fund masterclass on soilborne pathogens of wheat in China in 2005.

The scope of inoculant work was broadened to include other inoculants that increase yield. For example, collaborators in both Australia and China have recently completed projects on *Penicillium* isolates that increase yield.

Examples of further research on increasing the effectiveness of inoculants that builds effectively on project outputs in both countries are:

- CAU's patented *Pseudomonas* strain CPF10 (2001) for control of soilborne disease of tomato. Genes for antibiotic production from CPF10 have been cloned, sequenced and transferred to a non-antibiotic-producing *Pseudomonas* biocontrol agent (strain P32 which is a registered commercial product in China).

- Work at SDAS, Jinan, on cloning chitinase and glucanase genes from *Bacillus* strains, that came from disease-suppressive soil at Avon in South Australia.
- Further collaboration between CSIRO and SDAS (MoU 2002) and between SARDI Adelaide and SDAS on disease-suppressive microorganisms.
- Microbial ecology research at ZU through an NNSF project (microbial ecology in the rhizosphere). Prof Zhang at ZU also received NNSF funding for cooperative research on rhizosphere ecology and biological control of soilborne diseases of vegetables and pathogens (2003–2006).

New Leucaenas for Southeast Asian, Pacific and Australian Agriculture (FST/94/33)

Max Shelton

Commissioned organisation	The University of Queensland (UQ), Brisbane, Queensland Department of Primary Industries (QDPI), Brisbane, CSIRO Tropical Agriculture (CSIROTA), Aitkenvale, Agriculture Western Australia (AWA), Perth, Australia; Rural Development Bank (RDB), Lae, Papua New Guinea University of Technology (Unitech), Morabe Province, Papua New Guinea; Bureau of Animal Industry (BAI), Manila, International Centre for Tropical Agriculture (ICTA), Manila, Philippines; Hanoi University of Science (HUS), Hanoi, Vietnam
Project leaders	Assoc. Prof. Max Shelton (UQ); Dr Werner Stur (ICTA); Prof Le Van Khoa (HUS); Mr Alex Castillo (BAI); Mr Keith Galgal (RDB); Dr Mick Komolong (Unitech)
Related projects	FST/1998/036, FST/1991/013, FST/1992/011, FST/1992/020, FST/1993/018
Principal researchers	Dr Raymond Jones (CSIROTA), Mr Steven Petty (AWA), Mr Colin Middleton (QDPI)
Duration of project	1 July 1995 – 31 December 2000
Total ACIAR funding	$1,279,050

Project objectives	To identify new cool and frost-tolerant, acid soil tolerant and psyllid resistant provenances and hybrids of leucaena; evaluate and select superior provenances and hybrids of leucaena for high forage quality; select and distribute elite germplasm, disseminate information on leucaena production and use to producers; develop techniques for the propagation of elite germplasm identified in the first phase of the project, and in particular the L. pallida x L. leucocephala KX2 F1 hybrid; train collaborators in Vietnam and the Philippines in techniques of vegetative propagation of KX2 F1 hybrids and to evaluate the material on farm; ensure that the KX2 F1 hybrid is palatable to ruminants; publicise the work of the group to all those interested in Leucaena research and development through LEUCNET News.
Location of project activities	Australia, Philippines, Papua New Guinea, Vietnam, Kenya

Overview

Smallholders in Papua New Guinea, the Philippines and Vietnam have benefited from this project's research into new leucaena varieties for grazing stock, particularly cattle and goats, with increased productivity and robustness. In the Philippines, where there has been a significant problem with the psyllid insect that severely affects growth in the dry season when leucaena is most needed, a new introduced leucaena hybrid is proving to be far more productive and, importantly, psyllid-resistant providing much needed forage and fuelwood in the dry season. In all countries, these new leucaena varieties have great potential, mostly unrealised.

Project achievements

Germplasm evaluation and adaptation to growth-limiting environments

The key outcome of the germplasm evaluation programs was identifying the high yield potential and broad adaptation of several *L. leucocephala* x *L. pallida* F1 hybrid accessions (designated KX2). These hybrids were the highest yielding accessions in all environments of the multi-site evaluation. Accessions of *L. trichandra* and *L. diversifolia* were adapted to low temperatures, with this adaptation most apparent in highland-tropical environments. No accessions were specifically adapted to strongly acid-infertile soils. Accessions of *L. leucocephala* were highly productive in environments where psyllid pressure was low, but their relative productivity declined rapidly as psyllid pressure increased.

Leucaena growing on contours. Leucaena-based grazing systems first demonstrated by the project have been extraordinarily productive and robust under grazing.

There were large differences in psyllid tolerance among accessions of the collection and four major groupings were identified viz. highly resistant, moderately resistant, moderately susceptible and highly susceptible. Considerable variation in psyllid resistance was evident among accessions within species of *L. trichandra, L. diversifolia, L. pallida* and *L. collinsii*. All *L. leucocephala* lines were classed as highly susceptible. *L. collinsii* subsp. *collinsii* was highly psyllid resistant, had very low condensed tannin content and very high in vitro digestibility. This species was thus of considerable interest and was tested for palatability and animal production potential in the animal trials.

Seed production orchards were established for several elite accessions including *L. leucocephala* K636 X K584 hybrid, *L. diversifolia* CPI 46568, *L. pallida* K748, *L. collinsii* subsp. collinsii 52/88 and *L. trichandra* 53/88. Small quantities of seed were harvested from these blocks for distribution or use in subsequent research. Commercial seed production of *L. leucocephala* cv. Tarramba began on the property of Mr Peter Larsen in Central Queensland and seed has been sold commercially since 1997.

A reasonably robust method of vegetative propagation of the KX2 F1 hybrid, the most vigorous accession identified in phase 1, was developed at The University of Queensland and 6000 rooted cuttings were produced and planted in the field. Cutting propagation techniques were further refined by the Forest Science Institute in Vietnam where more than 50,000 cuttings were propagated. Grafting techniques that enable the KX2 F1 hybrid to be propagated on both *L. pallida* and *L. leucocephala* rootstocks were also identified.

Assessment of forage quality

It was important to assess the best accessions agronomically for forage quality and suitability for feeding ruminant livestock.

Palatability. Initial trials assessed the acceptability/palatability and chemical composition of promising accessions within the genus. Acceptability was determined by monitoring the grazing behaviour of cattle given access to a broad range of *Leucaena* accessions in short-term 'cafeteria trials' in Australia and the Philippines. In these trials, cattle graze in a field containing representative plants of all of the promising accessions arranged in a random fashion. The researchers observe which plants the cattle eat and how much to determine palatability.

The relative acceptability to grazing cattle of 21 *Leucaena* accessions was found to be high in comparison with three non-*Leucaena* genera (*Sesbania, Calliandra* and *Gliricidia*). The most preferred *Leucaena* species included the *L. leucocephala* commercial cultivars Tarramba and Cunningham, while the least acceptable species were *L. macrophylla* and *L. trichandra.*

The long-term palatability/acceptability of three of the most promising *Leucaena* accessions, the KX2 F1 hybrid and its two parents *L. leucocephala* K636 and *L. pallida* K748 was evaluated with cattle in Australia and with goats in Vietnam. *L. leucocephala* was the most palatable species, closely followed by the KX2. *L. pallida* was of considerably lower palatability and this was later reflected in lower milk yields and liveweight gains.

Condensed tannins (CT). Chemical composition as determined by *in vitro* digestibility, and proximate cell wall and condensed tannin analyses, provided a broad overview of forage quality.

Methodologies for the accurate measure of extractable/free CT were developed and published. The accuracy of the measurement of bound CT was greatly improved by the integration of computer software and spectrophotometer technologies.

There was large variation in in vitro digestibility across the genus ranging from 42 to 69%. Most of the species with high digestibility had low neutral detergent fibre of <25%. Condensed tannin concentration varied widely across the genus and there was a strong negative correlation between digestibility and CT content. Condensed tannins in the leucaena were found to reduce the digestibility of dry matter and of protein but all tannins did not behave equally. There were large differences in the capacity to bind protein among the tannins, and gains to bypass protein from the presence of tannins were often offset by higher losses of endogenous nitrogen. In laboratory studies, tannins in the *Leucaena* genus were found to vary greatly in molecular size, and the proportions of the different sized tannins varied between species. There were also greater than two-fold differences in the protein binding capacity of the tannins from different species. These results indicated that the higher tannin leucaenas will be less effectively utilised as ruminant feeds.

A study of seasonal variation in CT content of *Leucaena* spp. revealed significant differences (x5) in CT over a 12-month period. Interactions with growth rate data and climatic parameters were examined. Seasonal variation in CT has ramifications for interpreting published CT data. Cutting the trees (for ease of management) also affected CT status, indicating that defoliation management may be effective in manipulating forage quality. This aspect requires further evaluation.

Experiments investigating the effect of environmental parameters on CT found that tannin concentrations increased at low temperature, were lower at intermediate temperatures and then increased at high temperatures; CT levels decreased under water stress compared to well watered plants; P deficiency reduced CT concentration; and N deficiency increased CT concentration. The results of these experiments conflict with many published results from environmental studies on other plant species and plant defence/carbon allocation theories. The data indicated a positive relationship between total non-structural carbohydrates (TNC) and CT status of leucaena plants.

Animal production. The best accessions of *Leucaena* were evaluated both as supplements and as sole feeds for ruminants. This involved feeding cut herbage to sheep to determine in vivo digestibility and intake at various proportions of the diet with low quality roughage as the other component. These pen-feeding trials were conducted at Unitech in PNG and showed that *Leucaena* feeds with low to moderate levels of condensed tannins could be used as protein supplements.

Finally, the animal production potential of key accessions was assessed in large grazing trials as this was the ultimate indicator of forage quality. These trials were undertaken in the Markham Valley of PNG in collaboration with RAMU Sugar Pty Ltd. and on the island of Masbate in the Philippines on a research station operated by the Bureau of Animal Industries. Four accessions of *Leucaena* were established at each site. *L. leucocephala* K636, *L. pallida* CSIRO composite and *L. collinsii* subsp. *collinsii* 52/88 were common to both sites while *L. diversifolia* CPI46568 was used in PNG and *L. trichandra* 53/88 was used in the Philippines. A grass control treatment was included at both sites. The grazing trials showed that all treatments containing *Leucaena* improved animal production over grass-only pastures. Productivity from *L. leucocephala* cv. Tarramba and *L. collinsii* was excellent but was limited by the poor overall growth at Masbate. The long-term acceptability of *L. pallida, L. trichandra* and *L. diversifolia* declined with time and this had a negative effect on animal production.

Future outcomes

The long-term value of the KX2 F1 hybrid was undertaken by comparing its palatability and live-weight grain potential in relation to its parental accessions, *L. leucocephala* K636 and *L. pallida* K748. This occurred in Australia with grazing cattle, and in Vietnam with stall-fed goats. Data showed that it was a quality high-protein feed.

All of our collaborators have continued their work and further developed the programs initiated during the project, but to varying extents.

Several key factors need to be in place before significant adoption of tropical forages (>10,000 farmers or >50,000 ha planted) can occur (Shelton *et al.* 2005, invited IGC paper). When promoting new technology, project staff must:

- Meet the needs of farmers,
- Be compatible with the socio-economic context of farmers,
- Establish relevant partnerships eg with related government and non-government agencies, seed companies and other aid donors,
- Involve all stakeholders in a genuinely participatory way so that feedback and evolution of the technology can occur, and

- Have long-term support (10–20 years) and the involvement of champions, or a progression of champions over time.

Forage development based on promotion of stylo varieties was successfully completed in Thailand as the criteria for adoption were met. In Papua New Guinea, the Philippines and Vietnam, the technology has met farmers' needs and been compatible with their socio-economic context. However, partnerships that can collectively progress the development opportunity do not yet exist and there has been insufficient time for them to develop. Without further injection of resources, the development process will move slowly and may even stall.

The difference the project has made

Papua New Guinea

The leucaena-based grazing systems first demonstrated by the project, have been extraordinarily productive and robust under grazing. The success of cultivar Tarramba has dramatically lifted the potential for ruminant production in the Markham Valley; company-owned cattle properties there are very interested in it, especially since the start of the live cattle export market out of Lae to the Philippines and Indonesia. However, development of the technology into the indigenous smallholder sector is crucial for the future expansion of the industry. Five hundred hectares has been planted with the cultivar Tarramba.

Philippines

Leucaena (called ipil-ipil locally) has long been an important feed source for cattle and goat production by more than 50,000 smallholder farmers, especially in the dry season. It is now limited by the psyllid insect which severely affects growth in the dry season when the leucaena is most needed. The use of KX2 leucaena overcomes this problem; indeed its high productivity increases the availability of both forage and fuelwood. There is now a need to scale up the adoption of KX2. The current work has demonstrated that the KX2 option is successful with the limited number of villagers involved; however, there is much unrealised potential.

Scale-up also requires partnerships with government, non-government extension agencies and credit agencies. Scale-up requires a greatly increased output of KX2 planting material either from grafted trees or rooted cuttings. The officials charged with promoting KX2 need to link with experienced forestry nurseries to improve their rooted cutting success rate. Relationships could be developed with private companies or with farmer groups to speed up supply of grafted or rooted cuttings.

BAI will need to remain the central organisation to train the trainers in a scaled-up program and to troubleshoot problems as they arise. Villages where successful adoption has occurred should be used as key demonstration areas in training courses. Cattle and goat weighing competitions create healthy competition and promote farmer interest in improved feeding strategies based on the use of KX2 leucaena.

Leucaena fodder gathered for tethered cattle; leucaena has long been an important feed source for cattle and goats in parts of Southeast Asia.

Vietnam

Professor Khoa's group at the Hanoi University of Science has demonstrated that KX2 leucaena can be successfully integrated into Vietnamese smallholder farming systems, and can improve the productivity, economic viability and environmental sustainability of smallholder livestock producers. He now has about 1000 farmers who have received training or are feeding KX2 or Tarramba to their livestock.

As with PNG and the Philippines, there now needs to be scale-up to a much larger number of farmers to achieve significant and measurable economic impact, and to ensure that the development process does not stall.

Research and development issues

The single most important factor limiting the adoption of the KX2 F1 *Leucaena* hybrid is the moderate difficulty that some groups have experienced in producing planting materials. Propagation is best performed by specialist nurseries that belong to agencies with forest seedling experience. For instance, the Forest Research Centre at Ba Vi has been very successful at producing rooted cuttings and large-scale production of cuttings (>100,000 per year) was feasible. In the Philippines, collaborators in the Department of Agriculture have attempted to produce rooted cuttings and have been less successful. Consequently, they have relied on propagation by grafting performed by trained farmer groups. This requirement has limited the widespread adoption of the KX2 F1 hybrid; more specific support for this activity will overcome this obstacle.

In Australia with MLA support, a long-term breeding program began recently at the University of Queensland. Commercial seed of the KX2 hybrid is expected to be available in 2010. This material will be productive in Southeast Asian environments and demand from the region is expected to be strong.

Project impacts

Community impacts

Papua New Guinea

Availability of this technology has injected great confidence and enthusiasm into the local large-scale expatriate managed cattle industry. With the advent of a live cattle export market out of Lae to the Philippines and Indonesia, there is now new market opportunity for increased cattle production in PNG, further adding to local confidence in the industry.

With little development of the technology in the indigenous smallholder sector, however, community impacts are yet to be realised. Nevertheless, the future for expansion of the industry lies with development of smallholder cattle enterprises and not with the company properties which are constrained by land shortage. A prosperous smallholder sector will bring much needed income to indigenous communities and provide the crucial impetus for expansion of the cattle industry. Both indigenous operators and the large-scale operators in the Markham desire this.

Philippines

As with PNG, there is a need to scale-up the adoption of KX2. The work has demonstrated that the KX2 option is successful in the limited number of villages involved; however, there is much unrealised potential.

Farmers in the regions targeted by the project have had a long history of feeding *L. leucocephala* to ruminants. Leucaena was introduced in 1977 as part of a Philippine-wide program to upgrade rural communities. Many smallholder farmers routinely buy animals at the local auction market, and fatten them with leucaena for a period of 4–6 months before resale for slaughter. The returns to farmers for sales of fattened cattle are about 8000–10,000 pesos per animal, providing much needed income for smallholder families and rural communities. These smallholders who continue to use ipil-ipil would benefit from a change to KX2 leucaena which overcomes the problem of damage by psyllid insects, and consequently, greater returns.

The President of the Malimartoc Farmers Association village, Mr Mariano Bautista, is enthusiastic about the value of KX2 leucaena, noting that it was more resistant to the leucaena psyllid and more than twice as productive as traditional ipil-ipil; it also had the same feed value and palatability (triplets were relatively common due to good nutrition), supplied fuelwood throughout the year, and did not cause the diarrhoea that psyllid infested ipil-ipil often caused in their goats.

Vietnam

There is less of a history of leucaena use in ruminant feeding systems. However, smallholders dependent on sale of livestock products for income, were immediately interested. For instance, the smallholder dairy farmers at the Moc Chau Milk Company in the highland limestone environment of Moc Chau Province, found that KX2 leucaena offered a cost-effective supply of protein. They said that cattle find it very palatable, there is no problem with the taste or smell of the milk, and there is an increase of 1–3 L/day of milk yield, an increase in butterfat percentage with more dense milk if cows are fed 5 kg of fresh KX2 per day (10–12% of diet). They also said that KX2 produced forage year round and did not frost as the grasses did.

In Bac Ninh Province, Mr Nguyen Xuan Vieng, vice chairman of the farmers' association, said that KX2 had been very successful with their farmers as: (a) it was very vigorous all year round, producing a lot of forage; (b) its use reduced the need for concentrate (mixture of rice bran, maize, soybean) from 5kg to 3kg per day, saving about 14,000 Dong per day per cow; (c) milk yields increased by 1–3 kg/day; (d) lactation length increased from 10.5 to 11 months; and (e) the taste and smell of the milk were very good. The Farmers Association nursery has produced 10,000–15,000 seedlings per year and a total of 25,000 seedlings for distribution to around 800 farmers over the past two years (250–300 trees each).

Mr Nguyen Xuan Vieng is now looking for extra funds to support expansion of the project. He wants to construct a new nursery to produce 35,000 cuttings a year. The farmers' association plans to promote the use of KX2 leucaena through the annual folk song festival (Bac Ninh is nationally famous for its farmer folk songs). The song will tell story of planting, growing and feeding KX2. This will be a very popular activity for the province.

Now that the KX2 technology has been successfully demonstrated as readily adopted by livestock farmers, it is strongly recommended that there needs to be scale-up to a much larger number of farmers to achieve significant and measurable economic impact.

Capacity building and scientific impacts

Project collaborators in Australia, Vietnam and the Philippines have developed considerable knowledge on the following topics:

- Genetic variation in the *Leucaena* genus,
- Psyllid resistance and tannin content among *Leucaena* accessions,
- Vegetative propagation of KX2 F1 hybrid from cuttings and grafting,
- Forage quality in *Leucaena*, including relative palatability of *Leucaena* accessions, significance of condensed tannins on the nutrition of ruminant livestock, and the animal production potential of the different *Leucaena* species,
- Practical skills in vegetative propagation, tree planting and management, protocols for assessing the palatability of forages,
- Methodology for working with farmers interested in adopting the technology for animal production.

These results and experiences have been passed on in the training courses held in all countries that have enhanced the capacity of those who attended, and the capacity of those giving the courses.

The scientific impact of the work has been significant. There were 21 published papers during the life of the project, 29 papers in the ACIAR Proceedings No 86, and 24 publications since Project completion in 2000. There were 8 poster papers published at 18th IGC in Canada in June 1997.

Reference

Shelton H.M., Franzel S. and Peters M. 2005. Adoption of tropical legume technology around the world: analysis of success. In 'Grassland: a global resource', ed. McGilloway, D.A., Wageningen Academic Publishers, The Netherlands, pp. 149–166.

Measurement and prediction of agrochemical movement in tropical sugar production (LWR1/1994/046)

Bruce Simpson

Collaborating organisations	Queensland Department of Natural Resources (QDNR), Brisbane, Australia; Mauritius Sugar Industry Research Institute (MSIRI), Reduit, Mauritius
Project leaders	Mr Bruce Simpson (QDNR); Dr Rene Ng Kwee Kwong (MSIRI)
Related projects	LWR1/1992/001. LWR1/1994/054
Principal researchers	Dr Heather Hunter, Mark Sallaway, Cyril Ciesiolka, Dr Mark Silburn, Dr Richard Walton, Grant Fraser and Dr John Armour, Australia; Gunshiam Umrit, Assenjee Bholah, Daniel Ah Koon, Ronald Ng Cheong and Maryse Chung, Mauritius
Duration of project	1 January 1997 – 30 June 2001
Total ACIAR funding	$1,124,923
Project objectives	• To determine the effects of soil, climate (rainfall) and cropping management practices on the persistence, transport and fate of applied agrochemicals (fertilisers and pesticides) in tropical sugar production. • To quantify the impact of the hydrology (surface and ground-water) of catchments on the downstream dilution of off-site 'contaminants'.

	• To use data from different sites to modify and validate existing models for cropping systems and chemical transport at plot and field scale and to apply modelling at a catchment scale to evaluate the impact of pesticide and fertiliser inputs (and management practices) on downstream 'contamination'. • To provide an improved understanding of the processes of agrochemical fate and transport to the sugar industry to enable it to develop improved management practices for minimising environmental impacts. • To identify key risk factors determining the environmental impacts of agrochemical use to allow for effective decision making. • To provide information on the current position and on key strategies for minimising off-site movement of agrochemicals for technology transfer networks in the Australian and Mauritian sugar industry.
Location of project activities	Valetta (main site) and selected river systems, Mauritius; Bundaberg (main site), Atherton Tableland and South Johnstone (Australia)

Overview

Sugar production is a major industry in Mauritius, which contributes greatly to employment and the economy. There were concerns, however, that this benefit was at the cost of the environment. With tourism an equally important industry, both the government and the sugar industry itself were keen to assess the environmental impact of current management practices in the sugar industry, and make any necessary changes.

As a result of this ACIAR project, Mauritius can now be confident that current management practices in its sugar industry do not contribute to unacceptable levels of pollution to surface and groundwaters.

In addition, the project has provided valuable data and expertise within the country to ensure that other agricultural activities do not adversely affect water quality.

As a tropical sugar producing state with a large tourist industry, Queensland has a number of similar economic and environmental characteristics in common with Mauritius. In this context a number of spin-off benefits for Australia have been identified.

Project achievements

The overall aim of the project was to identify and understand key processes involved in the off-site movement of agrochemicals in tropical sugar production and to assess the environmental impact in terms of both surface and groundwater quality. These findings together with an improved understanding of cultural practices would be used to develop:

- Recommendations on land management options for minimising off-site transport of agrochemicals
- Identification of key risk periods and conditions for agrochemical movement to surface and groundwaters
- Decision support tools for growers and the industry
- Relevant information for technology transfer networks for the Australian and Mauritian sugar industries

In addition to many publications and workshops, the project also generated the 'Brolga' time-series database, specifically developed by the Australian project team to handle all the Australian and Mauritian project data that was available during the project phase. This remains a valuable tool.

An additional key output, particularly of importance for Mauritius, was to establish whether current management practices were contributing (or not) to unacceptable levels of surface or groundwater pollution. This was driven by the public perception that use of fertilisers and pesticides by the local sugar industry was contaminating drinking water as well as polluting the environment. This perception was considered potentially damaging to the sugar industry itself, but also to the rapidly developing tourist industry — promoting a tropical 'paradise'.

The difference the project has made

The results of the project have been used to promote the message in Mauritius that current practices are not resulting in unacceptable levels of pollution and that should issues be identified, the sugar industry is now in a strong position to use improved scientific understanding to immediately address them. It is now judged that the public perception has been changed to a point where any non-point pollution by the sugar industry is considered minor and low on the list requiring priority remedial action. Discharge from mills is a separate issue and not one addressed by the project.

Within MSIRI, technical staff are directly (or indirectly) using either the results of the research or new knowledge or awareness that they have gained from the project in new projects (new applications) or in the continued refinement of management guidelines.

Bruce Simpson

As a result of the ACIAR project, Mauritius can be confident that current management practices in its sugar industry do not contribute to unacceptable levels of pollution to surface and groundwaters.

At the time of this adoption study, there are more than 29,000 planters in the Mauritian sugar industry. Because of the close and on-going relationship between the extension staff of MSIRI and the sugar-growing community, MSIRI staff strongly believe that growers generally follow its recommendations. This confidence is helped by the fact that the mechanisms in place throughout Mauritius result in a high grower contact with extension messages.

A recent survey conducted by MSIRI indicated that approximately 85% of all large/medium planters (covering about 50,000 ha and representing 68% of the production area) fully adopted MSIRI recommendations. The overall industry adoption rate (for following management guidelines) was considered to be above 60%.

When asked whether grower practices had actually changed as a result of the project, the general response by MSIRI staff (research and extension), was 'no'. This is because the recommendations given before and since the project have evolved, taking into consideration both the agronomic and environmental aspects of farm management. As such, the recommendations (combined with the pressures of economic drivers) have seen changes in fertiliser and pesticide applications which optimise (and often reduce) their use. For example, previous recommendations to apply split fertiliser applications have been changed to recommendations for single applications (perhaps the same total amount) but all applied earlier (prior to the onset of the higher rainfall (high-risk) period. This, combined with increased adoption of minimal tillage and increased green-cane harvesting (and associated mulching) has helped to reduce some requirements for herbicide use and will help to minimise soil (and sediment) losses.

The project confirmed and reinforced the industry's understanding of the need for responsible management practices (which they had been recommending or implementing anyway), so no change was necessary as a direct result of the project. However, while no significant management-practice changes were linked to the project itself, some fine-tuning has occurred as a result of the project findings (such as the recommendations for single, earlier fertiliser applications).

Because the project results confirmed that recommendations being made by MSIRI were in the right direction, the overwhelming opinion is that MSIRI (and the sugar industry) is comforted by the fact that they now have sound scientific evidence to support such advice and are well positioned to address changed requirements, ie they are not being complacent.

Whilst there have been no formal significant changes to management recommendations, it was stressed that management advice incorporates the environmental considerations, including such practices as applying pesticides and fertilisers away from known risk periods and only when needed (rather than simply scheduled).

More growers are taking advantage of the free soil-testing service (offered by MSIRI), which provides useful information for customising fertiliser requirements.

Before the project it was generally thought by those advising fertiliser recommendations (MSIRI) that excess application of phosphate fertiliser would do no harm and in fact could act as a store for subsequent use by the crop if needed (and would stay where applied). As a result of the knowledge gained from the project on off-site movement of nutrients, thinking has been modified and recommendations for phosphate applications now reflect lower rates and improved sediment management.

This change of thinking has identified the need (suggested by MSIRI) for a new project to identify high-risk areas where sediment transport and associated loss of phosphate is a potential issue. The outcome of such a study would result in more targeted management guidelines for such locations. This will be of additional value if (when) such lands are used for other purposes.

The project clearly showed the benefit of strategic spatial sampling (for water quality) and the argument for a higher resolution temporal sampling, particularly during runoff events. It appears that no change has yet been made to modify the existing water quality sampling program (by the agencies), which relies on infrequent sampling intervals, eg, four times a year.

It must be recognised that it was not a direct role of this project to advise government agencies on their water-quality monitoring program. Nor is it the role of MSIRI to undertake ongoing water quality monitoring of the rivers or groundwater systems. However, it would be fair to say that as a result of the project, there is now expertise within MSIRI which is more advanced than that within the government agencies in terms of the design and interpretation of water quality monitoring. Certainly the ability to understand spatial and temporal data in context, is a key prerequisite for designing and interpreting meaningful monitoring programs.

Not only is existing government-agency, water-quality data somewhat limited, but its usefulness is further constrained by the lack of an effective database or visualisation system. In summary, there is room for improvement, particularly in establishing meaningful position statements on existing water quality and on long-term trends.

Perhaps where similar projects are conducted in future, in addition to packaging information for the scientific and extension personnel, eg the extension workshops, conferences etc., consideration should be given for a separate forum where the findings, information and recommendations are targeted at 'national agency personnel' not just the technical representatives, but particularly the policy makers. The intention would be to inform as well as influence those who have the formal responsibilities for activities outside the boundaries of the project teams' host agencies. The packaging of the information would need to be modified (from existing material) to optimise the effectiveness in delivering key messages to the target audience.

The above suggestion is less relevant where the participating (project team) agency is also the State or national agency with wider (state or national responsibilities) at community level (rather than industry or research level only).

Project impacts

Community impacts

As a result of the publicity given during and following the project, it is generally believed that the previous community perception that fertilisers and pesticides used by the sugar industry were polluting surface and groundwater resources has now changed. It appears that those previously concerned have been placated by the project findings and believe that MSIRI now has the appropriate skills and understanding to provide sound guidance on the need for any changed practices or the need to address any developing issues.

Given that Mauritius is still a developing country, the project findings and key community messages need to put into context, particularly with respect to the current concern over point-source pollution from factories (including sugar mills), industry and urban sources.

The 'change' in community perception regarding 'off-farm' pollution is seen as a major 'plus' for the industry, which is facing increasing financial pressures, particularly with the planned reduction in the sugar price (now maintained by EEC). The sugar industry is a vital component of the Mauritian economy at MUR 9 billion (A$450 million) per annum representing 20% of the foreign exchange.

More than 18,000 people are directly employed in the industry and a further 40,000 indirectly. Clearly, any publicity which paints the industry as 'a polluter' would threaten exports and thus jobs.

In addition to the sugar industry itself, the rapidly growing tourist industry is promoting the natural beauty of the island and any negative publicity regarding polluted water (for drinking, washing or in the reef lagoon) would certainly have a negative impact on the economy. The tourist industry employs about 18,000 people and has an annual value of MUR 18 billion (A$900 million).

Bruce Simpson

During the project, Mauritian scientists undertook training in Australia. As areas of sugarcane production are progressively replaced by other land uses, the new scientific skills and understanding gained could be of considerable value in establishing sound science-based management practices for minimising environmental damage.

Had the previous public perception been shown to be correct, resulting in negative publicity, there is no doubt that at least the sugar and tourism industries would have felt the impact. The actual level and duration of such impact would obviously depend on many factors but if it resulted in a downturn of only 10% in the sugar and tourism markets alone, the annual loss could be in the order of MUR 2.7 billion (A$135 million) per annum.

The fact that 'pollution by the sugar industry' is not listed as a priority environmental issue for the Mauritian government, is seen as a positive outcome from the project. It is believed that this is more than just a good news story for the immediate industries (particularly sugar and tourism) but has helped to place the impact of sugar production on water pollution in context with all other inputs. Such information is of key interest to others such as the health authorities, as well as those with environmental responsibilities.

While there may be a higher level of 'comfort' that the sugar industry (sugar production component) is not a 'significant polluter' of the water resources, this needs to be placed in perspective. For example, a recent travel feature on Mauritius by David May in the Brisbane Sunday Mail (Sunday 7 November 2004), stated "…. The air was thick with the syrupy scent of burnt sugar and clouds of acrid diesel smoke billowing from a van in front with a sign on the driver's door that read 'Ministry of Health and Quality of Life'".

As other environmental issues are progressively addressed, it can be only hoped that there will not be complacency (at the government level) regarding the need for enhanced monitoring and assessment of surface and groundwater quality. It is not MSIRI's role to undertake such monitoring but the institute now has the expertise to provide professional guidance on monitoring design, data management and interpretation as a direct result of the project.

Certainly it is felt that the project has empowered MSIRI with credible data and new knowledge to protect the community by ensuring that sugar production in Mauritius is following 'best practice'.

In the case of Australia, the study has delivered an enhanced and more wide ranging comprehension by landholders, scientific and extension personnel of the environmental behaviour of pesticides and nutrients (particularly under sugar production) and the effects of management options.

There is also a greater awareness level and multidisciplinary approach to addressing the threats and options related to agrochemical usage in tropical sugar production amongst sugar growing researchers and policy makers in New South Wales and Queensland. This has been implemented by active communication of the project's findings to relevant industry and government stakeholders at a time when environmental pressures have been increasing.

Capacity building and scientific impacts

Before the beginning of the project, MSIRI had a range of skills in nutrient and pesticide analyses. While most of the previous nutrient analytical work was directed at agronomic aspects, some leaching studies (using lysimeters) had been completed. Most of the previous pesticide analytical studies were looking at sources of drinking water to ascertain whether pesticide levels were acceptable (below guideline values).

The project not only helped to expand on these existing analytical skills but, perhaps more importantly, provided the opportunity to link these with new skills in hydrological measurement, thus providing the ability to quantify off-site movement of the chemicals of interest (as well as measuring sediment and soil losses).

There is no doubt that the scale of this exercise (infrastructure, training, facilitation etc) was most demanding for all involved. However, it deliberately covered both surface and subsurface hydrology from plot to large-catchment scales and demonstrated the ability and importance of covering both inputs and outputs over a continuous timeframe. This was a very ambitious but highly effective project component because, in addition to adding technical skills and knowledge, it introduced a true multidisciplinary team approach and a more holistic thinking.

It terms of assessing the degree of capacity building that is being utilised after the project, there are a number of clear examples of how the new skills and knowledge are being used. Some new projects are being undertaken that use the skills/capacity developed in the ACIAR project, including 'The measurement of soil erosion and validation of the revised Universal Soil Loss Equation', and 'The determination of water requirement of potato'.

As well as the above examples, MSIRI is using a rainfall simulator (purchased by MSIRI) that was designed and built towards the end of the ACIAR project on advice from the Australian project team. Whilst this equipment was not used for the project itself, its purchase was a direct result of the new skills and knowledge acquired by the MSIRI scientists. This new capacity in the use of such approaches will have on-going application.

Although there was not a continuation of the main ACIAR project (by ACIAR or by MSIRI itself), it is clear that the scientific thinking by MSIRI team members has changed; the nature and level of the change being influenced by the individuals' past expertise and their current interests.

The newly acquired knowledge on hydrology, the increased understanding of chemical transport processes and the links between the various scales (plot to river) has helped to increase the conceptual understanding to a point where the enhanced scientific understanding has influenced and prioritised new investigations. Also, proposed projects such as identifying areas of higher vulnerability to sediment and phosphorus are a result of rethinking the scientific hypotheses that were previously in place.

As some areas of current sugarcane production are progressively replaced by other land uses (eg, current expansion in edible palm plantings) the new scientific skills and understanding could be of considerable value in establishing sound science-based management practices for minimising environmental damage. This will be of particular importance in the high rainfall/high slope areas which are most vulnerable and are likely to be the areas where sugarcane is first replaced.

The actual extent to which the new scientific skills and understanding are applied by MSIRI personnel will, of course, depend on MSIRI policy, research priorities and funding.

There is clear evidence that the multidisciplinary approach, combined with enhanced scientific understanding, is already being applied to new projects within MSIRI and will no doubt be of continued value for other such MSIRI projects. However, the level to which this will be used in any multi-agency context will depend on MSIRI and government policy.

Scientists within MSIRI indicate that as a direct result of the project, they have either directly or indirectly (eg advising work colleagues) utilised the findings, new knowledge or new skills to undertake new investigations.

For example:

- The head of weed agronomy now considers the environmental fate and persistence data for new (and existing) herbicides when making decisions or recommendations for herbicide use in sugar cane (and other cropping systems). He also now stresses the need to have local data if possible — not just literature values. This has resulted from both exposure to the project results and also to a higher multidisciplinary or more holistic approach. The same officer stated that this new information had also been most helpful on external advisory committees where there is need to consider pesticide use applications.

- Greater knowledge about the methodology for quantifying hydrological processes has been applied in soil erosion studies on multiple sites and in quantifying the leaching of nutrients and heavy metals from mill mud and effluent applications on cane lands. Both examples also include automatic measurement of rainfall (total and intensity) to derive far more understanding of the dynamics of the system — a vital issue under tropical situations.
- Modelling activities at both small and catchment-scale have been initiated since the completion of the project. Such activities demonstrate that the project has helped to create a climate of increased knowledge and confidence to undertake such innovative work. There is also clear evidence that the knowledge and skills have continued to develop, as those undertaking the studies explore new techniques or build on existing ones.

At MSIRI, there is clear evidence of a more holistic, multidisciplinary approach to a number of activities and a greater level of comfort in working across disciplines, including the extension areas. It appears that the ACIAR project has helped to create this positive climate, not only with those directly involved but also with those who have had a keen interest in the project outcomes. Some staff members who were not directly involved in the project indicated that as they became progressively aware of its nature and value, they wished they had been part of it from the beginning. This was not said as a criticism but simply to express the fact that the project had multiple benefits across many different disciplines, in addition to those immediately involved.

A number of spin-off benefits for Australia were also identified under this heading, including:

- Improved information and technical expertise which has informed new environmental research programs and priorities, including the design of new water quality research and monitoring projects.
- An enhanced software information system on environmental issues drawing on the findings from both the ACIAR project and related studies by other Australian institutions.
- An extended and more efficient data management system with added data analysis and interpretation capacities.
- Environmental (water quality) risk management and land-use modelling capacity improvements contributing to greater security for both the sugar and tourism industries.

Tools and indicators for planning sustainable soil management on semi-arid farms and watersheds (LWR2/94/35)

George Smith

Collaborating organisations	Queensland Department of Natural Resources and Mines (QNRM), Brisbane and Toowoomba, Australia; Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad, India
Project leaders	Dr George Smith (QNRM); Dr J.C. Katyal (July 1996 - March 1997); Dr. Y.S. Ramakrishna (March 1997 - November 1997); Dr H.P. Singh (from November 1997), CRIDA
Related projects	LWR2/1992/020; SWL/1992/01; SWL/1992/009
Principal researchers	G. Subba Reddy (CRIDA), T. Yellamanda Reddy (Anantapur), M.V. Guled (Bijapur). Australia: A.L. Cogle (QNRM), D.M. Freebairn (QNRM), P. Harris (QNRM), J. Gaffney (QDPI)
Duration of project	1 July 1996 – 30 June 2001
Total ACIAR funding	$1,071,839
Project objectives	The project aimed to improve long-term sustainability and productivity of rainfed lands in the semi-arid tropics of India by providing tools to increase adoption of practices that improve decision making, maintain production, improve water use efficiency, reduce runoff and soil erosion, and maintain soil organic matter. It had three sub-projects: 1. Social assessment of sustainable resource management options;

	2. Assessment of land management options and application of existing models; and 3. economic evaluation as support for sustainable resource management decisions.
Location of project activities	Hyderabad, Kothapally watershed, Anantapur, Bijipur in the States of Andhra Pradesh and Karnataka, India

Overview

The project has identified some land management practices that offer potential to improve the sustainability of farming in India. But more importantly, the project, which focused strongly on using action learning processes and tools with participatory involvement of farmers in on-station and on-farm experiments, has had significant capacity building impacts. The participatory co-learning approach used in the project has increased farmers' awareness of the factors that influence the performance of their systems, ie, water in the short term and soil quality in the long term, and the practices they can use to influence them. The farmers who have been involved now appear better able to make decisions and to change their practices if circumstances change or they can see a better option.

The positive experiences of scientists involved in the integrated multidisciplinary approach and in the participatory on-farm activities have changed the general approach used in later research projects and programs. The action learning approach and the use of action learning tools and processes as a way of increasing understanding of complex biophysical processes has been widely accepted. The portable rainfall simulator has been a particularly successful tool and other tools have been developed. Similarly, equipment for monitoring runoff and soil loss has been adapted and is being used in other projects with indigenous maintenance.

Watershed management training now has strong emphasis on participatory approaches and the use of action learning tools. Through a fortunate circumstance the project was able to influence the training provided to the Rajiv Gandhi Mission for Watershed Management under IATCBP (India-Australia Training and Capacity Building Project) SP (Sub Project) 28. It has indirectly influenced subsequent training and watershed development activities in Madhya Pradesh.

Project achievements

The benefits of the project included quantitative data on the impact of innovative land management practices on both field and catchment-scale, participation by farmers in the design and evaluation of the innovations being tested, new and improved action-learning

George Smith

The participatory co-learning approach used in the project has increased farmers' awareness of the factors that influence the performance of their systems. The farmers involved now seem better able to make decisions and to change their practices if circumstances change.

tools for use in extension activities to increase rate of adoption of improved management practices, confidence in the wider application of simulation tools, an evaluation of the economic worth of the innovations, a better understanding of interactions between socio-economic and environmental factors and management practices, and improved capabilities in Indian national organisations to develop and apply new methods. Overall there is a platform of enhanced knowledge for land management decision support leading to management systems that are more productive and more sustainable.

The difference the project has made

The project has led to changes in the way research, development and extension are carried out by CRIDA and ICRISAT. There is now more focus on farmer participation and more direct involvement through on-farm experiments that are used as action learning tools. Programs and projects are now designed in a systems-thinking multidisciplinary mode. There is also increased use (and more confidence in the use of) of an action learning approach in developing projects and project teams. Action learning tools are now designed and applied to encourage participation and more focus on capacity building of farmers.

Knowledge, skills and techniques acquired in the project are being applied in training courses for technicians and farmers.

Farmers who were involved in on-farm experiments appear to have better insights into the factors that affect their crops and are more confident in accessing information and making decisions. They do not rely solely on innovative practices introduced through the project but adapt and modify or select new practices if appropriate.

There appears to be a higher general awareness of the importance of water in driving rural economies and of the importance of stopping soil erosion and building soil organic matter to maintain soil quality.

There have also been some changes at the policy level with increased adoption of the farmer-participatory mode as a policy and greater recognition of the role that modern sustainable agricultural practices (such as conservation agriculture, reduced tillage, organic farming and precision farming) can play in agriculture in India.

Project impacts

Community impacts

Farmers and the local communities have a greater appreciation of the role of water in their watershed and livelihoods and the processes that they can influence through their land management and cropping decisions. They have more confidence and an improved capacity to understand and analyse their problems and to work with scientists to solve them.

The increased awareness of NRM issues and the use of the participatory approach have increased the level of involvement in community-based activities. This has played a part in more effective representation for other improvements, eg watershed works, health programs, roads, self help groups and water users' associations, education facilities, milk chilling centres, and piped water supplies.

Improved problem solving could lead to improved and more sustainable agricultural systems and more secure livelihoods. Adopting an improved farming system with better in situ water conservation will increase returns in drought years (increased returns potentially as high as 500–600 Rs/ha were cited for the Hyderabad area) and in good years will increase yield and profitability (increased returns potentially as high as 1500–2500 Rs/ha). Soil depth and rainfall distribution are key factors determining treatment impacts; in the shallower soils and more marginal environment of Anantapur the treatments tested did not give worthwhile responses, nor was there any realistic alternative to groundnut as the preferred crop. This highlights the need for further research to reduce risk in this area.

At Bijapur, it was felt that adoption of more intensive cropping systems that increased returns and reduced risk not only benefited farmers but also increased the stability of employment in the area and would reduce seasonal migration of workers to other areas.

Longer-term economics provides another perspective on the benefits of the adoption of sustainable practices. Even if returns in the short term are not attractive, if farm management maintains the quality of the soil resource it will provide long-term benefits by stopping land from going out of cultivation due to degradation and will reduce the need for more expensive inputs at some time in the future. Wiser management and investments can underpin sustainability.

The options tested in this project can be employed to improve water entry and reduce runoff and evaporation, reduce soil loss and improve the quality of water downstream. There should be less degradation of soils by nutrient removal and less siltation of streams and reservoirs.

The emphasis placed on monitoring physical processes has reinforced the need for improved understanding of processes that can adversely affect the environment. Watershed projects now are more likely to have equipment to measure runoff volume and also to take samples for water quality assessment.

Some watershed works appear to be over-designed in that they are seldom handling runoff that meets their capacity or they act as recharge rather than storage structures. This suggests costs could be reduced and effectiveness could be increased if computer-based design systems were used to integrate knowledge of climate, soil and crop attributes. This could allow the value of stored groundwater vis-à-vis stored surface water (and the number and the size of ponds) to be evaluated to show those districts where one or the other is a better investment.

Increased awareness of the importance of returning organic matter to the soil and initiatives to provide sources, such as growing Gliricidia on field bunds, may over time help to reduce the decline in soil organic carbon. However, there is still strong competition for sources of organic matter by a range of users and the amounts available for adding to soils as mulch or tree-leaf green manure are likely to remain relatively small.

Capacity building and scientific impacts

In the final review report to ACIAR it is observed that the project has made good progress *'through strong capacity building — there appears to be a strong possibility that this project will have a lasting impact on dryland agriculture in the SAT of India'.* The project has had substantial capacity building impacts. The scientists who were involved experienced personal growth and development as well as increasing their knowledge and skills, including increased ability and confidence to analyse situations and problem solve, plan, self-manage and to evaluate performance through the learning cycle approach. This has strengthened performance in leadership and communication roles.

Awareness and knowledge of tools, models and 'instruments' for analysing and understanding systems have enabled scientists to become more analytical and more effective in their approach.

The increased knowledge of adult learning and participatory processes for use with groups has enabled scientists to change the way they operate so that they more effectively engage and communicate (two-way) with farmers and other clients. This stronger ability to use action learning tools in a participatory mode — ranging from use of the portable rainfall simulator to models to on-farm experiments to economic analyses — has given better insights into farming systems and profitability of soil management practices and led researchers towards technologies that are more acceptable to farmers.

The improved performance of scientists and the increased relevance of their research have meant that they can take on and deliver more responsibilities, they can access more resources and that they have better career prospects.

Finally, farmers exposed to the participatory processes now have a greater awareness of biophysical factors affecting their production systems, for example they know more about the importance of soil cover in improving infiltration and of organic matter in maintaining soil fertility. They appear to be better able to obtain information and use it in decision making and are therefore more likely to change their cropping system and soil management practices.

The main scientific impacts have been the adoption of new approaches in strategies for carrying out research, development and extension programs and projects, including:

- An action learning and multidisciplinary systems approach to identifying problems, project planning, implementation and review;
- More focus on monitoring key biophysical processes to help explain results and develop scientific understanding of processes and watershed systems;
- Watershed projects designed and implemented in farmer-participatory mode so that they identify problems, take some responsibility for site and treatment selection and management and have ownership of the findings and outcomes;
- Preference for use of on-farm, rather than on-station, experiments that might be less complex and sacrifice some rigor and control but the results of which are highly relevant to farmers; and
- More reliance on the use of simple but effective action learning tools as an entry point in farmer-participatory watershed activities and in training modules for farmers and technical officers to improve understanding of complex concepts.

Scientists reported that working within the project has given them new insights and afforded co-learning opportunities. In part this was due to exposure to other cultures and environments and opportunities to see how scientists and farmers handled problems similar to their own. It was also due to increased experience in working more closely with colleagues in other disciplines and to working directly with farmers. They now have more confidence to adapt and apply new approaches in a range of situations. They have more respect for indigenous technical knowledge and farmers' wisdom and are more likely to involve farmers as a first choice approach, they are also more inclined to work in partnership with an NGO to have synergistic impacts.

Scientists appreciate that through these approaches they can be involved in projects that give higher levels of job satisfaction and have better impacts within the community. Their better appreciation of the value of on-farm research and skills in applying the approach has enabled some scientists to access additional research resources by putting forward better project proposals. The scientists feel that these impacts can potentially be upscaled and extended for wider adoption across research, development and extension programs and even into education and policy areas.

Control of Pasteurellosis in pigs and poultry (AS2/1995/006)

Ian Wilkie

Collaborating organisations	University of Queensland (UQ), Department of Veterinary Pathology, Brisbane, Monash University (MU), Melbourne, Australia; Veterinary Research Institute (VRI), Peradeniya, Sri Lanka; National Institute of Veterinary Research (NIVR), Hanoi, National Veterinary Company (NAVETCO), Ho Chi Minh City, Vietnam
Project leaders	Prof. Alan Frost (UQ); Dr Ben Adler (MU); Dr M.C.L. de Alwis; Mrs T.F. Wijewardene (VRI); Prof Phan Dich Lan (NIVR); Dr Nguyen Tien Trung (NAVETCO)
Related projects	AS2/1996/016
Principal researchers	Dr Ian Wilkie, Profesor Peter Spradbrow, Dr Ranald Cameron UQ)
Duration of project	1 July 1996 – 31 December 2000
Total ACIAR funding	$1,267,993
Project objectives	To develop live vaccines against all forms of virulent pasteurellosis and to improve on the available bacterins made from dead or attenuated bacteria.
Location of project activities	Australia, Vietnam, Sri Lanka

Overview

This collaborative research project between Australian, Sri Lankan and Vietnamese scientists has resulted in improvements to the safety, effectiveness and duration of vaccines to prevent two serious diseases which occur in poultry (fowl cholera of chickens and ducks), and ungulates (haemorrhagic septicaemia of cattle, buffalo and pigs), throughout Vietnam and Sri Lanka. Fowl cholera was considered the second-most important disease of both chickens and ducks in Vietnam, (avian influenza had not assumed its present status at that time). It is a lesser, but important disease of particular classes of poultry in Australia.

There are few reliable statistics on the incidence of haemorrhagic septicaemia in any Southeast Asian country, due to limited diagnostic and recording facilities, but anecdotal evidence, backed up by (small) serological surveys, indicates it is responsible for sporadic heavy losses which can be devastating at the village level due to the highly infectious nature of the disease and very high case fatality rate if not treated effectively.

The incidence of fowl cholera is also not reliably known, but anecdotal evidence and personal experience suggest it is very common throughout Southeast Asia. The veterinary authorities in Vietnam consider it as one of the major serious diseases of chickens and ducks throughout the country.

Having reliable, cost-effective vaccines to prevent both diseases is of enormous financial and psychological benefit to smallholder farmers throughout Vietnam and much of Sri Lanka. There is also a greater capacity to accurately diagnose the diseases.

In addition, the capacity of Vietnamese and Sri Lankan scientists to research these and other diseases has improved considerably because of their involvement in the project. Further collaborative work continues, as a direct result of alliances formed during the Pasteurella project.

Project achievements

Over 300 isolates of *Pasteurella multocida* from cases of haemorrhagic septicaemia in pigs and fowl cholera in poultry and ducks were serotyped, confirming that bacteria from particular serogroups are responsible for specific disease syndromes, and that there is a fowl cholera causing subset of serotype A1 in Vietnam which is extremely virulent. In particular, it was shown for the first time that isolates from concurrent outbreaks of haemorrhagic septicaemia in pigs and cattle/buffalo were identical. This had been suspected, but never confirmed. The information obtained allowed the principal vaccine manufacturer in Vietnam to rationalise vaccine production and to choose from (local) strains of bacteria with the best potential to make protective vaccines.

Existing and new bacterins (vaccines made from killed bacteria or non-living products of bacteria) were evaluated. All had shortcomings in the degree of immunity they conferred and in the persistence of even minimal immunity. An aluminium-hydroxide-based adjuvant was shown to be as effective as the traditional aluminium sulfate adjuvant, as well as making a more easily administered product, which causes fewer post-vaccinal tissue reactions. However, because of the cost, the improved adjuvants have not yet been widely adopted.

An Australian isolate of *P. multocida* with a very low virulence for chickens, was selected as a live vaccine candidate. It was subjected to *in vitro* metabolic stress which produced a genetic drift mutant with an RNA polymerase defect. This was shown to be less tissue-invasive but still able to invoke very solid immunity to challenge with highly virulent strains isolated from disease outbreaks in Vietnam. The live vaccine candidate was tested in the laboratory and in preliminary field tests where it performed very well. It was confirmed that live vaccines elicited an antibody response in chickens that was more protective than that elicited by bacterins, but the actual antigens inducing the protection could not be identified by the available techniques. Molecular studies at Monash University identified several proteins expressed by the bacteria *in vivo* and *in vitro*, which had theoretical potential as vaccines. Small quantities of these proteins were expressed in vectors, and showed some protective effect when used as vaccines in mice. (Research subsequent to the project, however, has not confirmed any protective effects in chickens).

As a direct consequence of the project, the Vietnamese institutes have a greatly improved ability to diagnose *Pasteurella multocida*-related diseases, to isolate the causative bacteria, and to classify them more thoroughly than previously.

Research was continued after the end of the project at all the institutes involved. At UQ, several postgraduate students researched aspects of the pathogenesis of *Pasteurella*-induced diseases, particularly the two John Allwright Fellows, Ms Gnana Gunawardana from Sri Lanka, and Mr Tran Xuan Hanh from Vietnam. Ms Gunarwardana investigated the antibody responses of chickens to live and killed bacteria, and methods for classifying isolates which are more indicative of biological behaviour than the present serotyping systems. Mr Hanh's studies demonstrated conclusively that haemorrhagic septicaemia spreads from cattle and buffalo to pigs in field outbreaks, and showed the pig is a potential carrier of the disease, although perhaps not as likely to transmit it to in-contact animals as cattle. Both students successfully completed their studies and were awarded their doctorates in 2003 and 2004 respectively. Dr. Gunarwardana has continued her interest in Pasteurella-related research, among other duties, and recently presented two papers on the topic at a conference in Britain.

Both NIVR and NAVETCO have undertaken a considerable amount of further research with the mutant live strain. A strong relationship between all institutes involved in the Pasteurella project persists to the present. At least three other separate projects in Vietnam were initiated through partnerships formed during the Pasteurella project, in response to specific animal health problems encountered during field trips and contact with the farming community. A particularly strong research partnership between members of the veterinary school at UQ and the Molecular Pathogenesis section of Medical Microbiology, Monash, has developed. Collaborative research on the molecular pathogenesis of *Pasteurella* infection has been particularly productive, and has resulted in many scientific papers, multiple PhD theses, a book chapter, and joint presentations at several international conferences, since the end of the ACIAR project. This activity has established a significant national and international profile for these institutes in this area of research.

The difference the project has made

Knowledge of the epidemiology gained during the project, although incomplete in several ways, is useful to government agencies in planning animal management and vaccination strategies.

Improved diagnostic capabilities have enabled field veterinary staff to diagnose and confirm disease outbreaks more confidently, quickly and accurately. This will lead to more accurate and more comprehensive tracking of disease outbreaks, and more comprehensive knowledge of the epidemiology of both diseases.

NAVETCO has modified both its haemorrhagic septicaemia and fowl cholera vaccines as a result of information derived during the project (2004 production: 6.6 million doses FC vaccine; 21 million doses HS vaccine).

NAVETCO and NIVR scientists are continuing research on both diseases and are still evaluating the live vaccine for potential limited use. Investigation of alternatives to existing vaccine adjuvants continues. In general, this work is better informed and directed as a result of information obtained, and scientific expertise gained, during the Pasteurella project.

The government vaccine producer in Myanmar has begun evaluation of the modified live vaccine strain for fowl cholera, and is re-examining both its haemorrhagic septicaemia and fowl cholera vaccines in the light of the Vietnamese experiences. Because their existing laboratory strains were unreliable, they have been supplied with a challenge strain of Vietnamese origin to use in vaccine trials.

Field veterinary workers in Vietnam are collecting and submitting more appropriate samples and receiving more timely advice as a result of the diagnostic improvements and better understanding of the epidemiology of haemorrhagic septicaemia.

There are no reliable figures for the number of animals fully vaccinated against Pasteurella-related diseases in Vietnam. The only reliable figures are for vaccine production, and since NAVETCO is the only significant producer of vaccines of this type for Vietnam, there has been virtually 100% adoption rate for the modified vaccines. Vaccination programs tend to be centrally planned, and implemented by provincial veterinary authorities. Limited resources mean many animals are vaccinated only once instead of the two vaccinations at a set interval and annual boost, which is recommended (personal observation).

Current production figures for the vaccines related to the Pasteurella project are 21 million doses produced annually of the haemorrhagic vaccines for cattle, buffalo and pigs. This is not enough to vaccinate all animals annually (recently, MARD estimated total population for cattle, buffalo and pigs at around 28 million head), but meets the demand, which is partially market-driven and partially driven by MARD initiatives. A small amount of vaccine is exported, and the company is presently negotiating to sell haemorrhagic septicaemia vaccine to Thailand and the Philippines (December 2004).

Fowl cholera vaccines for chicken and duck are produced at the rate of 6.6 million doses annually. This is well short of covering the poultry population, which was around 250 million (mostly chickens and ducks) before the avian influenza epidemic in 2004, but again represents close to 100% of current demand.

Farmers now have access to a better quality vaccine to prevent haemorrhagic septicaemia, more appropriate to local conditions, than was previously available.

Farmers have access to a better quality product, more appropriate to local conditions, than was previously available. Cattle and pig production has been increasing steadily for the last 12 years and this has required improvements in all aspects of husbandry. Vaccination against preventable diseases is one aspect of good animal management, and planned vaccination programs are often used as a basis for introducing other improvements to management practices. Although the potential returns from stock saved are many times greater than the small cost of vaccines, the actual monetary value is impossible to calculate because there are no reliable figures for disease incidence. As veterinary diagnosis is improved, more reliable and comprehensive statistics will become available, but by then other husbandry modifications will have had an equal effect on disease incidence. What is very important at this stage of development of animal production in Vietnam and similar countries is that adequate and reliable disease control through a combination of better vaccines, better nutrition and improved hygiene gives farmers the confidence to make the increased investment of time and other resources necessary to increase productivity.

Researchers from all the institutes used the information and field material obtained through the project, as it was fundamental to continued research. As well as post-doctoral staff and PhD students specifically assigned to the Pasteurella project, other postgraduate students at UQ and Monash University were able to take advantage of the activities and information related to the ACIAR project to help with their own research. Soon after completion of the project, some 15 scientific papers were published in a special edition of *Veterinary Microbiology*. These were either from personnel employed in the project itself, or by graduate students and research staff working closely with project personnel. This is a commendable effort by any standards, and must rank amongst the most scientifically productive of ACIAR projects to date.

Current research at UQ and MU continues, building on results and material obtained during the project's lifetime, including a collection of virulent organisms obtained in Vietnam during the project, which has been invaluable in ongoing research into the pathogenesis of fowl cholera and haemorrhagic septicaemia. Further collaborative partnerships have been formed with scientists from other institutes, (eg AAHL, Geelong) and a broadening of the approach and methods to study infectious diseases in chickens has evolved. The core collaboration between UQ and MU groups remains very active, and has extended to include the pathogenesis of other bacterial diseases, capitalising on the techniques and experience gained with *Pasteurella*.

Project impacts

Community impacts

As a direct result of this project, the farming community of Vietnam has access to more effective and safer vaccines against two prevalent and costly diseases of their livestock.

One of the perennial problems with estimating impacts/potential impacts of programs in which disease prevention is the prime objective is the difficulty of ascribing the correct proportion of increased productivity to disease prevention alone. This is not only due to the absence or unreliability of disease-incidence figures; farmers adopting regular vaccination of their livestock often do so as part of an overall upgrade of their management practices through contact with agricultural/veterinary workers carrying out government initiatives, or responding to requests for advice and intervention from the farmers themselves. Being able to administer efficacious vaccines can be an important part of establishing an advisor's credentials with the farmers and villagers. Demonstrable success in preventing specified diseases gains a better degree of compliance with other recommended changes in management practices. Farmers who feel more confident that their livestock are going to survive to fulfil their roles are inclined to pay more attention to the nutrition and general well-being of their animals. As a result of the Pasteurella project and a sister project, (the Newcastle Disease vaccine project) field veterinary and animal husbandry personnel have several new vaccines in their armament, the efficacy and safety of which have been tested, and which they can confidently recommend.

Further community impacts could be made by encouraging and supporting integrated programs of improved livestock management. Vaccination is only one aspect of disease control and management, and sustained increased productivity depends on improved husbandry generally. Unless corresponding improvements in hygiene and nutrition are instigated, potential gains may not be fully realised or totally lost through the confluence of those factors which accompany intensification of animal production. Encouraging improved husbandry has the potential to greatly amplify the impact of any successful vaccine development project.

Improved diagnosis and recording will also help to identify problems more accurately, and allow the relevant regulatory authorities to make rational decisions about how to allocate limited resources most effectively. There is still much room for improvement in the capability and capacity of animal disease diagnostic services in Vietnam, as has been acknowledged since the avian influenza outbreak.

Capacity building and scientific impacts

At VRI, NIVR, and NAVETCO, techniques learnt or refined during the project such as PCR and ELISA, as well as more general laboratory practices have been applied in subsequent research procedures as appropriate. There is now more willingness to commit resources to more sophisticated research methods, evident in the scope of the work proposed in recent grant applications. For example, a new CARD project with NIVR to reduce neonatal piglet loss, beginning in 2005, proposes to use a combination of advanced technology to derive novel information about a newly recognised strain of diarrhoea-causing *E. coli*, as well as proven technology to improve an existing vaccine.

Research capacity building has accrued from several sources apart from the new technologies acquired specifically as part of the Pasteurella project. In interviews with project participants, there was a general consensus that they had acquired a more methodical approach to good laboratory practice and problem-solving as a result of their participation in the project and exposure to a wider scientific community than they had previously experienced. Participants were also asked if they found training in Australia or Vietnam more beneficial. The general answer was that both were highly valued because training in-country means more people could attend the training sessions, which not only increases the efficiency, but also increases the collective retention rate; and training in their own environment using their own equipment gave them more confidence. Applying the techniques to a specific (local) problem also illustrated the relevance more clearly. However, training in Australia enables participants to see well-organised, high-functioning laboratories and good work practices being applied in a daily routine. Library facilities were a revelation and allowed visiting personnel to greatly expand their horizons.

The two John Allwright Fellows associated with the project, Ms. Gnana Gunawardana from Sri Lanka and Mr. Tran Xuan Hanh from Vietnam have successfully completed PhDs at the University of Queensland and have both returned to their original institutions. Dr Tran Xuan Hanh has been promoted since his return to the position of a Vice Director of the institute and Director of Research at NAVETCO. He has been further funded by ACIAR for a small research project furthering work begun for his Ph.D. thesis.

I interviewed Professor Tu, the former Director of Research at NAVETCO. He was very definite in his opinion that the ACIAR projects in which they had been involved for the last 10 years have had a profound effect on the research and application capability of the institute. In particular, he credits this association with the establishment of a quality assurance culture and programs to monitor quality and efficacy of products. This is not only important for their own national agenda, but has been essential in their bid to enter the export market.

The Pasteurella project did not include a very big budget for laboratory equipment as most of the equipment needed was present at the institutes. (In fact, part of the initial project ethos was to encourage good basic research which would be achievable with the equipment currently available, or likely to be available in the near future). Two motor vehicles were the major adjunct equipment items provided by ACIAR during the Pasteurella project. These were intended to support future projects as well as the Newcastle/Pasteurella projects currently underway. Both institutes have been unfailing in providing transport for visiting Australian personnel during subsequent ACIAR and related projects, and this contributed very much to their capacity to participate in projects. The benefits to project field workers in having mechanically sound and reliable vehicles at their disposal when working in-country would be hard to overstate (personal experience!).

The Pasteurella project has been well represented in peer-reviewed journals. Its effects continue to the present, with personnel at UQ and MU still actively and jointly engaged in Pasteurella research. The scientific collaboration has continued, with a further 12 publications on the topics, and more in preparation. Again, it is difficult to ascribe precise values to the project contribution, but it would be a fair and accurate assessment to say that collaborating on the project was largely responsible for establishing UQ and MU as leading centres for Pasteurella research and expertise in several Pasteurella-related diseases, and has enhanced the standing of the leading researchers as evidenced by the invitation to contribute to a respected text-book on bacterial pathogenesis.

Co-authorship of scientific papers and attendance at international meetings has also introduced personnel from the Sri Lankan and Vietnamese institutes to the international scientific community.

All Vietnamese scientists interviewed said they had increased their scientific knowledge, their knowledge of English and their confidence in dealing with the broader scientific community through meetings and correspondence.

Professor Tu, former director of research at NAVETCO said that the association with personnel from the three principal Australian institutes involved in ACIAR projects since 1994 has had a major impact on the scientific capability of NAVETCO personnel, not just because of new methodologies and equipment, but through an improved scientific culture. Staff visits to Australian institutes were an important part of personal and institute development, not only for training in specific technologies but for giving staff the opportunity to experience working laboratory setups and work practices of an international standard.

Both NIVR and NAVETCO have undertaken a considerable amount of further research with the mutant live strain. A strong relationship between all institutes involved in the Pasteurella project persists to the present. At least three other separate projects in Vietnam were initiated through partnerships formed during the Pasteurella project, in response to specific animal health problems encountered during field trips and contact with the farming community. A particularly strong research partnership between members of the veterinary school at UQ and the Molecular Pathogenesis section of Medical Microbiology, Monash, has developed. Collaborative research on the molecular pathogenesis of *Pasteurella* infection has been particularly productive, and has resulted in many scientific papers, multiple PhD theses, a book chapter, and joint presentations at several international conferences, since the end of the ACIAR project. This activity has established a significant national and international profile for these institutes in this area of research.

Overview

Viv McWaters[1] and Simon Hearn[2]

Introduction

This is the second time ACIAR has implemented a process for assessing the adoption of its projects. Australian project leaders assess the effectiveness of large projects three years after their completion – adequate time for an agricultural R & D project to start bearing fruit. This assessment process analyses the degree of uptake of the project's results, and also examines those factors that affect the uptake and why, and whether the project has made any difference to the social, economic and environmental wellbeing of a community. Adoption of research results is an essential component of achieving the wider changes and impacts that beneficial research delivers for producers, scientists and the community.

During 2004-05, ACIAR completed adoption studies for 11 of its projects. While the projects covered a range of scientific disciplines and geographic 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.

1 Beyond the Edge Pty Ltd
2 Senior Adviser, ACIAR

Broad project categories and adoption levels: a qualitative assessment

The 11 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)
3. Knowledge, models and frameworks to aid policy- and decision-making.

The classification of each of the projects and the 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 directly using the research findings that result from the research project activities to change some aspect of the way they operate. They can be divided into two broad groups: next users (eg government agencies responsible for providing advice to landholders, extension officers etc) and final users (eg smallholders, suppliers, policy makers).

All projects have demonstrated some uptake of their results. Four projects in Category 1 (new technology/practical approaches) have demonstrated and considerable use of the results by the next and final users (scored as NF in Table 1). All of the Category 2 projects demonstrated varying degrees of uptake of their results by next users, and due to the nature of these projects, little or limited uptake by final users. These types of research projects often require additional resourcing or the involvement of a third party (such as a commercialization body) before the full impact of the research can be realized. This may take much longer than three years after the completion of the project. All projects in Category 3 were able to demonstrate uptake by their next users.

There is little differentiation in the impact statements between (next and final) users, collaborators, and those who might be interested in the results of the project. Users (next and final) are the specific audience or stakeholder that the project is targeting to bring about a change in the way they operate. While there might be many users of the project's findings, those targeted for change are usually a very distinct group. Without a clear differentiation between the various stakeholders in a project, it is difficult to assess adopted changes and subsequent impacts.

Factors affecting uptake: lessons learnt

It is expected that projects designed to research and develop new technologies and practical approaches (Category 1) will have a high level of take-up, either within the life of the project or shortly thereafter. Those projects that are more pure scientific research (Category 2) may in turn contribute to the scientific understanding required to develop practical approaches. Thus, they may not even target final users, and may have difficulty demonstrating any level of take up beyond the specific next users that the research is aimed at. Projects in Category 3 tend to develop models

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

Project categorized by type	Level of uptake*
1. New technology, practical approaches	
Genetic improvement of cultured tilapia and redclaw in Fiji and Australia	NF
Mixed shrimp farming – mangrove forestry models in the Mekong Delta	Nf
Minimising disease impacts on eucalypts in South East Asia	NF
New leucaenas for Southeast Asian, Pacific and Australian agriculture	NF
Measurement and prediction of agrochemical movement in tropical sugar production	NF
2. Scientific knowledge/understanding (pure science)	
Increasing crop production through biological control of soil-borne root diseases	Nf
Control of Pasteurellosis in pigs and poultry	N
Overcoming production constraints to sorghum in rainfed environments in India and Australia	N
3. Knowledge, models and frameworks to aid policy- and decision-making	
Planning for agricultural development and sustainable land management in Papua New Guinea	Nf
Increasing the effectiveness of research on agricultural resource management in the semi-arid tropics by combining cropping systems simulations with farming systems research	N
Tools and indicators for planning sustainable soil management on semi-arid farms and watersheds	Nf

* Level of uptake is summarized 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 minimal uptake by the final user
N: Some use of the results by the next users but no uptake by the final users
O: No uptake by either next or final users

and frameworks to aid decision-making. The take-up of these projects may depend on access to specialist equipment, specific training, and relies heavily on local capacity to continue to use, and spread the use, of these models and frameworks. When assessing take up of a project's results, it is important to distinguish between factors that specifically affect take up rather than factors that may have inhibited the project' findings. While these are important considerations, this report is focusing on the factors that affect uptake after the project is completed.

According to the adoption studies, there are a number of factors that contribute to, or inhibit, uptake. These are summarized in Table 2 and discussed in more detail below.

Factors contributing to uptake

Relationships

Formal and informal relationships built during the life of the project – and especially those that continue after the project is finished – remain one of the single most important factors that contributes to uptake. For example, the uptake of new eucalypts in Vietnam to minimize the impacts of diseases was strongest by those companies which actively cooperated with the project; and the uptake of new Leucaenas in partner countries benefited from project 'champions' able to keep the project and its findings prominent, well after the project had been completed.

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

Factors contributing to uptake	Factors inhibiting uptake
New technology, practical approaches	
• Demand by consumers for the final product • Targeted workshops and communication activities • Active involvement with the project from the beginning • Long term involvement of project 'champions' • Compatability with the socio-economic context of farmers • The development of market infrastructure including public investment in transport and communications	• Disruption by political events • Complex policy and administration environments • Ineffective distribution of information to farmers/lack of access to information • Government/agency secrecy about disease outbreaks – need to 'save face' • Poor record keeping at industry level • Insufficient time • Lack of appropriate partnerships • Scientist discomfort in simplifying messages and delivering these in an educational/ learning framework • Limited access by farmers to investment funds • Lack of funds to 'scale up' adoption beyond those originally involved in the project • Farmer satisfaction with their way of life and seeing no need to change • Changes in personnel during the life of the project • Inadequate land tenure and reward systems
Scientific knowledge/understanding (pure science)	
• Genuine two-way exchange of ideas and visits between collaborating institutions/ groups • Where the research (eg vaccines) is sold as part of an overall approach to management	• When a commercialization step is required the time frame for adoption becomes much longer and additional funding is necessary
Knowledge, models and frameworks to aid policy- and decision-making	
• Trained project participants taking knowledge gained to new organizations and advocate for its use • Involvement of policy practitioners to ensure results have meaning for policy makers • Opportunities for short-term projects • Regular reviews and policy settings in key countries • Relationships with other agencies	• Access to suitable specialist equipment and materials • Lack of 'modelling' literacy and the understanding of how models can be applied • Suspicion of new approaches • Reverting to old, comfortable models/ approaches • Poaching of trained staff into other jobs and careers • Cost of licences to use models and/or electronic information • Inadequate resources and time – especially where a cultural change is required and/or high levels of farmer participation • Inadequate policy settings and governance practices at local or national levels

In addition to the specific outcomes from projects, many were able to identify unexpected or unintended spin-offs. For example, many staff at Mauritius Sugar Industry Research Institute not involved with the project expressed a wish that they had been from the beginning when they progressively became aware of the nature and the value of the project.

Transfer of knowledge and skills

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.

Many of the projects that reported significant uptake incorporated specific and targeted training activities. The scientific project to increase crop production through biological control of soil-borne root diseases in China credits much of its success in uptake by both next and final users to 'genuine two-way traffic of ideas and exchange visits…allowing pre-existing expertise to come together.' The wide-ranging Papua New Guinea project for agricultural development and sustainable land management benefited from the movement of project staff into other organizations, taking with them their new-found knowledge and skills and capacity to advocate for their use.

Holistic approaches

Uptake of new vaccines developed for the control of pasteurellosis in pigs and poultry were accepted more readily by those in a position to influence their use when they were 'sold' as a part of an overall approach to animal management. It was found that farmers are more likely to care for their stock (feeding and management) when they are confident they will survive.

Responding to real needs

The high-performing, genetically-improved farmed tilapia (GIFT) fish introduced to Fiji not only gained great acceptance by farmers because of their demand to diversify and its profitability, but also by consumers who actively sought the fish in preference to alternatives for both flavour and appearance. The acceptance of new strains of Leucaenas for grazing were accepted in Southeast Asian, Pacific and Australian industries because of their compatability in all cases with the socio-economic context of the targeted farmers. The project to measure and predict agrochemical movement in tropical sugar production in Mauritius confirmed, with sound scientific evidence, that the current practices were justified. This provided local scientists, technicians and extension officers in the sugar industry with the confidence to continue to promote responsible management and notably debunked the environmentally-unsound practice of applying excess fertilizer in the belief that it would act as a store for subsequent use by the crop if needed. Another indicator of uptake is changes in practice in line with project recommendations. For example, Ca Mau DARD (in Vietnam) has now changed mangrove forest replanting densities in line with project recommendations.

Factors inhibiting uptake

Inadequate resourcing, timeframes and equipment

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 appears to be one of the most frustrating factors inhibiting uptake – probably because it is generally the easiest to resolve. In particular, the lack of specialist laboratory equipment, computers and software inhibit uptake of procedures and models beyond the participating organizations, and in some cases, even within those organizations where access is only through exchange visits to Australia.

Some projects, especially those that may require a commercialization step such as the biological control of soil-borne root diseases in China, are unlikely to demonstrate any uptake of the results by final users. However, these projects can usually demonstrate significant interest and uptake by the next users. Further resourcing may be required to facilitate the commercialization step. Other projects report a lack of resources for extension of the findings, or scaling-up adoption beyond those originally involved in the project, indicating that more effort should be put into incorporating and costing an extension component in original project proposals. However, in some cases, the need and suitability for scaling-up may not be evident until well into the project, therefore access to additional funding for these activities should be flexible, and based on demonstrated need and likelihood of success.

Comfort/satisfaction with the way things are

In Vietnam researchers found that many smallholders were satisfied with their way of life and able to provide for the day-to-day needs of their families. Consequently, they saw no need to change their practices, even when more profitability could be demonstrated. This could be attributed to their level of education, a cultural attitude, or both.

While next and final users might exhibit some reluctance to take up new approaches, this is also true of some project scientists. The project that used an action learning model to improve soil management in India identified a reluctance by some scientists to embrace action learning and to revert to a more comfortable, lecture-style approach to training participants.

Personnel changes

Given the complexity, multiple agency nature and length of ACIAR projects, it is not surprising that personnel changes can disrupt projects. While there can be advantages in personnel taking new-found skills and knowledge with them, the departure of key personnel during or shortly after the completion of projects can severely disrupt take up by next and final users.

Communication failure

Inappropriate communication techniques and processes can affect uptake. The action learning (soil management) project in India found that some scientists are uncomfortable when simplifying messages and delivering these in an educational/learning framework. The project to develop a cropping systems simulation encountered a lack of modeling 'literacy' and a suspicion by non-modellers of the effectiveness and benefits of models as a major inhibitor to uptake.

In some cases, targeted farmers may simply not receive the information generated from the project. There may be ineffective distribution and lack of access as was encountered by the mixed shrimp farming-mangrove forestry project in Vietnam. The humid climate of the Mekong Delta significantly affects the deterioration of paper-based manuals.

Political factors

Complex policy and administration environments in foreign countries can affect the progress of a project itself, but more significantly, the scaling up of adoption of new approaches once the project is completed.

Assessing uptake can be made even more difficult in situations where industry-level record keeping is poor, such as was encountered by the project to explore diseases of eucalypts in Vietnam. In Thailand, the same project found government and agency secrecy about the extent of disease outbreaks.

Communication and dissemination activities

Table 3 summarises the approaches used for communication and dissemination to next and final users – and to collaborators and other interested parties – by projects in each of the three categories.

There can be a world of difference between reach (the number of people reached through communication and dissemination activities) and adoption (demonstrated change of behaviour). Communication and dissemination activities could be better targeted if there was a clearer understanding of who was going to use the project's results and recommendations (next and final users) compared with targeting everyone who simply wanted to be informed about the project.

In general, those projects that had the greatest success in uptake by next and final users used a larger range of targeted communication and dissemination activities. There was also evidence that research information (scientific and conceptual understanding) was presented in a useful, user-friendly format (rather than the traditional technical charts, facts and figures). While most of these approaches are fairly standard, there are only a few instances demonstrated in the adoption studies that are specifically targeted to meet the cultural needs of the farmers in a particular country.

For example, it was noted that farmer manuals in the Mekong Delta disintegrated in the humid environment, and consequently were not used. Farmers in this region, however, routinely decorate the walls of their houses with posters and calendars, and it was suggested that a laminated poster might be a better option.

In Vietnam, in addition to constructing a new nursery to produce 35,000 cuttings per year of KX2 leucaena (for grazing), they plan to promote its use at the annual folk song festival in Bac Ninh which is nationally famous for its farmer folk songs. The song will tell the story of planting, growing and feeding KX2 – this will be a very popular activity for the province.

Table 3: Summary of approaches used for communication and dissemination (by project category – see below)

Approaches used for communication and dissemination	1	2	3
Project coordination activities • Coordination meetings throughout the life of the project • Final review workshops • Commercial negotiations		■	
Information published (print or electronically) and targeted at project stakeholders • Handbooks/manuals • Self-assessment tools, including interactive software • Project newsletters • Departmental reports and papers	■		■
Hands-on training • Specific skills training • Short courses • Participatory workshops • Farmer-to-farmer approaches • Inter-country visits/laboratory training • Workshops • Crawford International Masterclass • Instructional video	■	■	■
Demonstrations • Demonstration projects/farms/sites • Field days • Stock weighing competitions	■		
Information targeted at a broader scientific/technical audience • Conference presentations/posters • Specialist journal papers and articles • Seminars • Powerpoint presentations on CD • Book publishing	■	■	■
Informal approaches • Networking by key individuals • Institute visits • Project meetings	■	■	■
Mass media • Electronic: television and radio • Print: newspapers and general magazines	■		■
Tertiary Study • Undergraduate and post-graduate studies including PhDs	■	■	■
Other • Annual folk song festival where the story is told through song	■		

1. New technology, practical approaches
2. Scientific knowledge or understanding (pure or basic science)
3. Knowledge, models and frameworks to aid policy- and decision-making.

Impacts and lessons learnt

Impacts describe the legacy of a project. At ACIAR, an impact is defined as a *change* that has occurred at the community and/or scientific level, and 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 project results 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 4. In general, evidence of community impacts is limited. Projects in Category 1 – new technology, practical approaches – are more likely to be able to demonstrate community impacts due to the nature of the projects and the direct applicability of the outcomes to farmers. All projects were able to identify *potential* community impacts.

There was significant evidence of community impacts in both aquaculture projects (tilapia in Fiji and mixed shrimp-mangrove farming in the Mekong Delta) that were designed to deliver new technologies and practical approaches. The Mauritius sugar project delivered a quite different community impact – confidence in the industry that it is not polluting water resources.

Two of the three Category 2 projects (pure science) require input from others before the full impact can be realized. Three years is probably too short a time for this process to have been completed. The development of a vaccine to control of Pasteurellosis in pigs and poultry in Vietnam has shown significant community impacts and underlines the importance of ensuring that sound scientific research is commercialized and made available to farmers to fully realize its potential.

Category 3 projects face their own unique challenges when demonstrating community impact. By their nature – knowledge, models and frameworks to aid policy- and decision-making – they are usually well-removed from farmers and the community that may benefit from improved policies and decision-making. An exception is the project that used an action learning model to develop tools and indicators for planning sustainable soil management, whereby those involved in developing the tools were the people who would ultimately be using those tools, ie farmers.

Table 4: 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	
Genetic improvement of cultured tilapia and redclaw in Fiji and Australia	Awakening of the farming community in Fiji to the opportunities that fish farming can provide; helping poor subsistence farmers to diversify following success with tilapia (into freshwater prawns, ducks and integrated vegetable farming) to become commercial, or semi-commercial, producers; substantial returns for villages after introducing tilapia and freshwater prawn farming
Mixed shrimp farming – mangrove forestry models in the Mekong Delta	Average incomes for extensive/semi-intensive farms in shrimp-mangrove areas Ca Mau Province in Vietnam are now more than threefold greater than at the beginning of the project. Farmers are also diversifying, becoming less dependent on a single crop (shrimp).
Minimising disease impacts on eucalypts in South East Asia	In Vietnam, none yet identified. In Thailand, there is a greater awareness by forestry companies of the need to produce disease-resistant stock. The use of this stock has great potential as alternative crop for smallholders in both Vietnam and the Thailand.
New leucaenas for Southeast Asian, Pacific and Australian agriculture	Despite demonstrated productivity and robustness under grazing in PNG, there has been little use of leacaenas by indigenous smallholders. In the Philippines, there is much unrealized potential in using the disease-resistant KX2 hybrid for fattening cattle and goats and realizing higher returns; in Vietnam, dairy cows fed leucaena returned a higher milk yield and % butterfat
Measurement and prediction of agrochemical movement in tropical sugar production	In Mauritius, there is a change in community perception regarding off-farm pollution caused by sugar growing. Concern that sugar production was causing pollution has been alleviated thus ensuring the future of the industry and the burgeoning tourist industry that promotes the natural beauty of the island. In Australia, there is a greater understanding of the importance of on-farm management and broader environmental impacts.
Scientific knowledge/understanding (pure science)	
Increasing crop production through biological control of soil-borne root diseases	Community impacts at this stage are small because the commercial production of biocontrol agents from this project is still in the early stages of development. There are many potential benefits including reduced use of, and exposure to, chemicals which will have health benefits for the farmers and wide-spread environmental benefits; and lower input costs and higher production and returns.
Control of Pasteurellosis in pigs and poultry	Vietnamese farmers have access to more effective and safer vaccines against two prevalent and costly diseases of their livestock. In addition, when farmers are confident their stock will survive (diseases) they are more likely to implement other management practices that are good for the stock, such as appropriate and adequate feeding, leading to a healthier and more productive industry overall.
Overcoming production constraints to sorghum in rainfed environments in India and Australia	Major community impacts, especially economic, will be possible with the delivery of mechanisms of shootfly resistance in rabi sorghum. However, this requires further research and development.

Table 4: (continued)

Project	Social, economic and/or environmental impacts
Knowledge, models and frameworks to aid policy- and decision-making	
Planning for agricultural development and sustainable land management in Papua New Guinea	Community impacts from this project will occur in the long term as better-directed research and improved planning and policies.
Increasing the effectiveness of research on agricultural resource management in the semi-arid tropics by combining cropping systems simulations with farming systems research	While there is potential for information from these models to be used to advise farmers on fertilizer application in semi-arid Africa, this is yet to be realized.
Tools and indicators for planning sustainable soil management on semi-arid farms and watersheds	Through their active involvement in the project, farmers are now more knowledgeable and confident, and therefore more likely to apply the project's findings on their farms; become involved in community-based activities; respect the opinions of scientists; and be more aware of the off-farm impacts of their activities.

Capacity-building and scientific impacts

Building capacity at all levels is a central feature of ACIAR funded activities. Moreover capacity building is invariably a pre-requisite to efficient adoption and follow-up activities in partner countries.

Products and activities, such as scientific papers, publications, seminars, training courses, exchange visits, conference presentations, posters and book chapters are commonly cited to indicate capacity-building and scientific impacts. However, it may be unreliable to attribute scientific impact to the number of these only, as publication alone is not a good indicator of scientific impact. A citation index, where the frequency with which the work is cited by other researchers, may provide additional evidence of scientific impact. There is no doubt, however, that the increased scientific knowledge gained by being involved in the project and publishing the results contributes to partner country scientists having a better understanding of their field and therefore able to make more informed scientific decisions.

In general, ACIAR projects contribute significantly to increasing the scientific capacity of the partner country scientists involved directly with the project. Trained, expert local staff continue to apply their new knowledge and skills in their on-going work. This has multiple benefits for partner country scientists, such as:

- More likely to be selected to be involved in other projects
- Being awarded PhD candidatures and places for other post-graduate study
- Ability to secure more funding
- Building local multi-disciplinary teams and encouraging holistic thinking
- Improved laboratory equipment and processes that are used in subsequent projects
- More methodological approach to good laboratory practice and problem solving

- Improved and enhanced, formal and informal, scientific networks and contacts
- New knowledge and skills transferred more broadly as scientists and others move to new positions/organizations/regions
- Building understanding between scientists and farmers, especially where participatory approaches are used.

As a result of the ACIAR project investigating soil-borne root diseases in China, bio-control research has increased in China and has the methodology has provided a model for other trials/research to be taken through to adoption, which has led to more research.

In India there has been significant growth in interest in sorghum genetic engineering research, which was non-existent when the project began.

Where specialist laboratory training is required, there are benefits in both in-country training and training in Australia. Vietnamese scientists involved in the project to control Pasteurellosis in pigs and poultry described the benefits of both:

Training in-country

- More people could attend the training sessions, which increases the efficiency and the retention rate
- Training in their own environment using their own equipment gave them more confidence
- Applying the techniques to a specific, local problem illustrated the relevance more clearly

Training in Australia

- Got to see well organised, high functioning labs
- Were able to see good work practices applied in a daily routine
- Library facilities were a revelation and allowed to greatly expand horizons

There is considerable evidence contained within the adoption studies which indicates that the projects in general left a capacity-building and/or scientific legacy.