Research Capacity and General Community Impact of Five ACIAR-sponsored Projects

A qualititative assessment of five projects completed in 1994*

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* The second stage of a program of assessments of eighteen ACIAR-sponsored projects completed in or about 1994.

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1. Introduction

This small study is a second stage of a program of assessments being undertaken of the research capacity and community impact of bilateral projects sponsored by the Australian Centre for International Agricultural Research (ACIAR) that were completed some five years previously. For the first stage (Mauldon 1999), three projects were selected at random from a total of eighteen projects completed in or about 1994. For this second stage, a further five such projects have been selected from the remaining fifteen.

This program of assessments follows an earlier summary of the external reviews of 111 ACIAR-sponsored bilateral projects completed between 1990 and 1997 (Mauldon 1998). That study provided an overview of the effectiveness of the projects in terms of three criteria:

- their success in meeting project objectives (*technical success*);
- their *impact on research capacity*; and
- their *community impact generally* (on farmers, consumers, regulators, the environment etc.).

All of the external reviews addressed project objectives directly, so *technical success* could be satisfactorily assessed. Assessing *impact on research capacity* was less straightforward, as the reviewers' terms of reference did not relate as directly to this outcome as they did to *technical success*. Assessing *community impact* generally was most problematic of all, since reviewers lacked focus on the implementation of outcomes, and it was usually far too early to evaluate uptake and any impact on the wider community.

As in the first stage of the program, the assessments have been of a 'desktop' nature, drawing on documentation held by ACIAR and information gathered by telephone, fax and email from those involved in the projects in Australia and overseas, supplemented in some cases from other people with experience about project outcomes.

No attempt has been made to assess the quality of the projects themselves—a task which ACIAR undertakes at the conclusion of each project through its external and internal reviews. Nor has any attempt been made to assess how effective the projects have been in achieving ACIAR's wider overall goals such as poverty reduction in collaborating countries. To undertake such an assessment would involve a longer-term and more in-depth analysis than has been attempted in this review.

2. Findings

The projects selected were:

- PHT/1991/004—Occurrence and distribution of *Aspergillus flavus* and aflatoxins in Asian peanuts;
- SWL/1991/003—Environmental impacts of agricultural practices on water resources ofthe Kelantan Plain, Malaysia;
- CS2/1989/018—Biological control of water hyacinth in Thailand;
- AS1/1990/001—Improved management for the production of honey and pollination of tropical forests by bees in Indonesia; and
- FST/1990/044—Increasing productivity of eucalypt plantations in China by inoculation with entomycorrhizas and nutrient application.

Table 1 summarises the findings of the study.

Although broad generalisations should not be drawn from studies of so few projects, five observations were made in the first stage study regarding assessments of research capacity and general community impact. These were:

i. *ex post* impact is not as large as *ex ante* expectations;

ii. an impact on research capacity requires a focus on particular technologies and on an environment that is conducive to research;

iii. it is unreasonable to expect an immediate policy impact from research if there is no institutional structure;

iv. intellectual property could be a source of delaying community impact; and

v. it can take a long time for some aspects of community impact to appear.

Table 1. A summary of the findings of an assessment of the research capacity and general community impacts of five ACIAR-sponsored projects.

Impact on	PHT/1991/004	SWL/1991/003	CS2/1989/018	AS1/1990/001	FST/1990/044
Target country					
Research capacity	n. n.	significant	significant	small	significant
Community					
• commercialisation and farmer/regulator/natural uptake	n. n.	significant	large	modest	modest
• consumers and community/environmental welfare	n. n.	significant	significant	small	small
Australia					
Research capacity	modest	small	large	modest	large
Community					
• commercialisation and farmer/regulator/natural uptake	n. n.	n. n.	large	significant	significant
• consumers and community/environmental welfare	n. n.	n. n.	modest	small	n. n.
Third countries	n. n.	small	large	n. n.	n. n.

[a] Impact is ranked as—not noticeable (n. n.) < small < modest < significant < large.

As none of the projects reviewed in the current study resulted in the ownership of intellectual property, no further insights were obtained about observation iv. However, the projects provide some further insights on observations i, ii, iii. and v. Also, two additional observations are made, namely:

vi. it should not be assumed that outcomes which are widely adopted in commercial practice necessarily have a significant economic impact; and

vii. some aspects of impact flow from a single action, while others require continuing actions.

These issues are discussed below.

i. *Ex post* impact is not as large as *ex ante* expectations

The impact claimed for these five projects at the times they were assessed for ACIAR funding was generally modest. No claim was made that the project on aflatoxins in Asian peanuts (PHT/1991/004) would have any commercial or regulatory impact. Rather, it was seen to be of a fact-finding nature that would lead on to full scale bio-control studies. The project on the environmental impact of agricultural practices on water resources in Kelantan (SWL/1991/003) was designed to provide information for regulatory policy, and this appears to have been used during the last five years.

The claims made for the projects on production of honey and pollination in tropical forests (AS1/1990/001) and mycorrhizal inoculation in China (FST/1990/044) were optimistic from the perspective of impact achieved to date, but for neither of them have all aspects of the impact yet been fully manifest. The external review report of FST/1990/044 anticipated a much larger impact over the following five years than eventuated. But otherwise, no claims were made about time periods over which impact would be achieved.

In the case of the project on biological control of water hyacinth (CS2/1989/018), the researchers expected the introduction of the agent to control the weed effectively in both Australia and Thailand, augmenting another agent previously released. They indicated that economic returns would start to accrue three to five years from the agent's establishment. Though it cannot be claimed that water hyacinth is yet effectively controlled, the agent's release appears to have had a large impact during the last five years.

ii. An impact on research capacity requires a focus on particular technologies and on an environment that is conducive to research

Projects SWL/1991/003, AS1/1990/001 and FST/1990/044 each focused on a single research institution in the principal collaborating country, and had a significant impact on maintaining that country's research capacity over the last five years. Project PHT/1991/004 had no such impact, because the research priorities of the collaborating institutions were different and the collaborating country had no interest in implementing outcomes from the line of research being undertaken. AS1/1990/001 also had only a small impact on the maintenance of research capacity—partly because the research was undertaken on a broad front of topics, some of which were not amenable to highly developed research methodology; and partly due to the pollination research not being located in sites where it was possible for scientists of the collaborating country to work.

iii. It is unreasonable to expect an immediate policy impact from research if there is no institutional structure?

The only project which was clearly oriented to policy-makers was SWL/1991/003, the aim of which was to provide information for environmental regulation. In this regard the outcomes of the project were readily implemented because the collaborating research institution (Malaysian Agricultural Research and Development Institute) had close links with the principal regulatory authority (Pesticide Board of Malaysia) and there were no institutional impediments to the information being used.

The same might be concluded about project CS2/1989/018. Although this was not a policy-oriented project, Thailand's National Biological Control Research Center which directly released the biological control agent has had a close association with the Weed Control and Research Branch of Thailand's Royal Irrigation Department. This Branch has provided an institutional structure which has ensured a large national impact by integrating project outcomes with other weed control measures over the ensuing years.

v. It can take a long time for some aspects of community impact to appear

The commercialisation of outcomes of projects AS1/1990/001 and FST/1990/044 in the collaborating countries has only been modest to date. Yet it was stressed in documentation on both projects that their impact could be much larger over time. A government-based infrastructure to support apiculture in Indonesia is relatively new and it will take some time before small producers gain confidence in improved production techniques. Although areas of commercial eucalypt forests in China inoculated with mycorrhizas are still small, expectations are held for large plantings each year for many years to come. There may also be some large environmental benefits from the rehabilitation of degraded lands as inoculated eucalypt forests are established and mature.

In the case of project PHT/1991/004, from which no commercial technologies were intended, its Australian leader claimed that such technologies are likely to follow from the replacement project due to commence in 2001. He said that it is not unusual for the elapse period between initial studies and final commercialisation of technologies to be thirty years.

vi. It should not be assumed that outcomes which are widely adopted in commercial practice necessarily have a significant economic impact

Following project FST/1990/044, there has been a modest commercial uptake of mycorrhizal inoculation technology in China and a more significant uptake in Australia. However, it should not be assumed that the economic impact of these technologies is as large. The external reviewers of a project replacing FST/1990/044 considered that after three major projects on the subject, the fundamental question of whether inoculation with mycorrhizas is worthwhile in China is still not resolved. The modest growth-rate responses achieved to date are of minor value compared with the large responses being achieved through fertilisers, although the latter are at greater cost. Fertiliser response trials were also the subject of FST/1990/044, but there is no evidence of any usage of fertilisers in commercial plantings of eucalypts in China.

An Australian company which is making extensive use of mycorrhizal inoculation technology in plantation eucalypts have made no particular claim about its economic significance. It believes that inoculation is cheap and does no harm and that, compared with other companies that do not inoculate, its plantations have excellent mycorrhizal populations and are out-performing those of its competitors. But the jury is still out on whether there will be an economic impact. This will only be known many years down the track as the trees approach harvest.

vii. Some aspects of impact flow from a single action, while others require continuing actions

Outcomes of most projects require concerted actions on a continuing basis if they are to have a significant, sustainable impact.For example, to take advantage of the opportunities from supplemental feeding of honey bees in Indonesia, which were demonstrated in project AS1/1990/001, requires an extension infrastructure and assured supplies of supplemental nutrients. If the impact is to be assured after the completion of a project of this type, mechanisms need to be in place by the project's end. These may need to be considered at the project design stage.

On the other hand, in the case of SWL/1991/003, once the biological control agent was released it became sustainable and will have a continuing impact without the necessity for future actions. This does not mean that it has not been worthwhile to make subsequent releases in new sites to accelerate the process and to ensure that the agent is not displaced by a competitive control agent (though one which is complementary for control purposes). Such supplementary releases have occurred following the termination of SWL/1991/003. However, the design of implementation mechanisms was not a critical issue in ensuring that the project has had a sustainable impact.

Project SWL/1991/003 was something of a 'half-way house' in this regard. Its aim was to provide policy information for environmental regulation. Although a continuing agency is necessary to ensure compliance and to monitor regulatory impact, the single action of banning the use of endosulphan has led to a continuing beneficial impact from the project.

3. The projects

All five projects examined here began between January 1991 and January 1992. Each was oriented to practical problems of the participating country(ies). However, expectations about the immediacy of impact differed. At one extreme, an explicit statement was made about project PHT/1991/004 at its commencement that it "will not result in any tangible, possibly commercialisable outputs, but rather will open the way for the development of appropriate control measures, some of which might be commercialisable".

At the other extreme, an objective of project CS2/1989/018 was to establish a biological control agent in the expectation that it would begin to have an impact on the environment upon its release early in the life of the project.

Project PHT/1991/004—Occurrence and distribution of *Aspergillus flavus* and aflatoxins in Asian peanuts

This project was commissioned through the Commonwealth Scientific and Industrial Research Organisation's (CSIRO's) Division of Food Science in Sydney in association with the Department of Agriculture in Thailand. It was designed to monitor peanut crops in Thailand for the fungus *A. flavus* from the time of planting through nut development, harvest and storage, and to assess Australian techniques for reducing fungal invasion under Asian field conditions. For this latter objective, scientists were to evaluate fungicidal treatments with potential to control *A. flavus* and also to develop fungal strains that do not produce aflatoxins and inhibit strains that do.

Field studies in Thailand indicated low levels of infection in developing plants and peanuts, but invasions increased during drying and storage. Virtually all the aflatoxins occurring in the stored peanuts were shown to have come from *A. flavus*.

The assessment of Australian techniques for reducing *A. flavus* invasion under field conditions was subsequently considered by the project leaders to have been a poorly defined objective, since Australian work was not well advanced at the time the project commenced. It was reported that the use of fungicides had been rejected and that promising results had been obtained in Australia from using inoculated millet seeds as a vehicle for delivering non-toxicogenic strains of *A. flavus* at the time of planting. However, details of these results were not documented in the project's termination report since this work was being funded from other sources.

In order to develop some of these outcomes further, and to extend their potential impact to other Southeast Asian countries, a replacement ACIAR-sponsored project (PHT/1997/017) has been approved to commence in mid-2001. This will be cooperatively undertaken in Indonesia and Australia.

Project SWL/1991/003 — Environmental impact of agricultural practices on water resources of the Kelantan Plain, Malaysia

This project was commissioned through CSIRO's Division of Water Resources in Perth in association with the Malaysian Agricultural Research and Development Institute (MARDI). It studied water pollution problems in two agro-ecosystems—tobacco on light-textured soils and rice on heavier soils—in north-eastern Malaysia. Its objectives were to identify and assess important water pollutants in relation to land use; quantify their transport in soils and shallow aquifers; develop and evaluate computer models of water and pollutant transport through landscapes and aquifers; and identify parameters for computer modelling purposes. The project was aimed at providing information for regulatory policy rather than for individual farmer use.

A survey found that a number of inorganics, pesticides and microbial counts in shallow groundwaters exceeded permissible international levels—particularly in light-textured soils of the tobacco areas, and near household septic tanks in those areas with nitrate and bacterial pollution. Parameters for modelling were derived from two experimental sites and the application of relatively simple models was demonstrated for computing

travel times of several pollutants in typical soil profiles and aquifers. A model developed by Cornell University was validated and the possibility of reducing nitrate contamination through management techniques was demonstrated.

On the basis of this work, a replacement project (LWR1/1994/054) commenced in 1996 to study water pollution management in southern Thailand and the Cameron Highlands of Malaysia. No further work was to take place in Kelantan.

Project CS2/1989/018—Biological control of water hyacinth in Thailand

This project was commissioned through CSIRO's Division of Entomology in Brisbane in association with Thailand's National Biological Control Research Center (NBCRC) and subsequently also with a working group on aquatic weeds comprised of various organisations in Malaysia. Its objectives were to increase levels of biological control of water hyacinth in Thailand and Australia by introducing a South American beetle, *Neochetina bruchi*, to complement an existing beetle, *N. eichhorniae*, which had been established in both countries in the 1970s. Interactions between the two species were to be monitored and their respective ecological requirements assessed.

Stocks of *N. bruchi* were released in Australia in 1990 and in Thailand in 1991. By the end of the project the insect was widely established in both countries. Releases were also made in Malaysia in 1992, and establishment was confirmed at some sites by the project's conclusion. Considerable insect damage was observed at all sites, but it was not possible to attribute a specific component to *N. bruchi* since *N. eichhorniae* was also established at all sites. Although the monitoring and ecological objectives in retrospect appeared over-ambitious, the primary objective of establishing *N. bruchi* in Australia and Thailand, and later Malaysia, was clearly achieved.

A replacement project (CS2/1993/020) with cooperating organisations in Vietnam, Indonesia and Australia, commenced in 1995 to extend biological control of water hyacinth to other Southeast Asian countries.

Project AS1/1990/001—Improved management for the production of honey and pollination of tropical forests by bees in Indonesia

This project was commissioned through the University of Queensland, Gatton, in collaboration with CSIRO Forestry and Forest Products (Canberra), the University of Western Sydney (Hawkesbury) and the then New South Wales Department of Agriculture and Fisheries. The collaborating organisations in Indonesia were the National Beekeeping Centre of Parung Panjang and the Indonesian Ministry of Forestry. The project arose from a concern that the common honey bee, *Apis mellifera*, which had been introduced into the tropical areas of Australia and Indonesia, had produced substantially lower yields of honey with higher water content than in temperate areas, and also was more prone to parasites and pathogens. A further concern for Indonesia was that introduced eucalypts and acacias, which had otherwise performed well, had poor yields of seeds.

The broad objectives for project AS1/1990/001, a joint Forestry project, therefore were to increase the quantity and quality of honey produced by *A. mellifera* in tropical areas; evaluate Australian strains of *A. mellifera* in tropical environments; and define the role of *A. mellifera* in seed production in tropical forests.

The forestry objective was reported as having been largely achieved. Following the introduction of hives into eucalypt seed production areas in Indonesia and Australia (both tropical and temperate), quantities of seed increased, and in some instances seed weights also increased. Results with acacias in Indonesia were less successful, but still encouraging.

The study in northern Queensland was reported to have led to the design of management programs which maximise the utilisation of natural resources, increase bee longevity and minimise the build-up of nosema disease. In Indonesia, experiments with mite control followed by feed supplementation demonstrated very large increases in honey production. Australian hive designs were demonstrated to improve hive yields, and improved honey harvesting systems were demonstrated which reduced the moisture content of honey.

An outbreak of chalk disease in Australia necessitated a halt in the export of bees to Indonesia. So the second objective could not fully proceed. However, bee strain evaluation studies suggested that there was as much variation within strains of *A. mellifera* as there was between them, suggesting that genetic improvements are possible from bee selection irrespective of the initial bee stock.

Project FST/1990/044—Increasing productivity of eucalypt plantations in China by inoculation with ectomycorrhizas and nutrient application

This project was commissioned through CSIRO's Division of Forestry and Forest Products, Perth, in association with Murdoch University's School of Biological and Environmental Sciences. The collaborating organisation was the Chinese Academy of Forestry in Long Dong, Guanhzhou, and as an add-on later in the project, the National Institutes of Biotechnology and Microbiology, University of the Philippines, Los Baños. The project built on an earlier ACIAR-sponsored project (FST/1987/036).

The objectives of FST/1990/044 were to identify strains of mycorrhizas that would be effective in enhancing growth of eucalypts in different soil types in two regions of China and develop techniques for their isolation, storage and bulk production for nursery use. Field trials were to be undertaken to demonstrate increases in wood production through inoculation with the effective strains and nutrient deficiency symptoms were to be defined in eucalypt plantations. Scientists were to be trained in microbiological techniques and technology transferred. As an add-on, the performance of selected eucalypt species in the Philippines was to be determined, and the effects of mycorrhizal inoculation and nutrient applications to tree growth examined.

It was concluded that Australian strains of mycorrhizal fungi, when introduced in modified Chinese nursery practices, can colonise roots of eucalypts and persist in the field. They can out-compete the related Chinese fungi, which are not specific to eucalypts. Nutrient deletion trials identified nutrient deficiency symptoms and nutrient concentration standards were set for diagnosis of deficiencies in plant tissues. Significant tree growth responses were reported in trials where inoculations were successful. Experiments were also conducted to test whether the phosphorus status of soils could markedly affect mycorrhizal development and tree growth response. These indicated significant mycorrhizal inoculation and phosphorus responses, but no marked interactions between them.

Work in the Philippines demonstrated rapid establishment of eucalypt species on degraded forest sites. Heavy metal toxicity was shown to be a major limitation on tree establishment in some sites, and mycorrhizal fungi were shown to detoxify heavy metal concentrations in some soils. Trials did not run long enough to demonstrate growth rate responses to mycorrhizal inoculations in the Philippines.

Project FST/1990/044 was replaced by a subsequent project (FST/1994/025) involving the same collaborating organisations in China and Australia, which commenced in 1996 and terminated in 1998.

4. Impact

In accordance with the terms of reference, impact since the termination of each project have been assessed in terms of:

- maintenance and development of research capacity, including access to new techniques in the collaborating countries;
- whether the project's outcomes have been progressed to uptake through (where appropriate) commercialisation, extension or other services to farmers, conservation practices, regulatory arrangements by appropriate authorities etc. in the collaborating countries;
- any flow-ons to consumers and improvement of community welfare generally in the collaborating countries; and
- any impact in third party countries.

Because this was a short, desktop study, not all of these categories of impact could be followed through with confidence. The chief sources of detailed information were the Australian and collaborating country project leaders, although in several cases comment was also received from other researchers involved or from people who were informed about developments in either Australia or the collaborating country/countries.

It was not possible in all cases to attribute some changes which have taken place to outcomes of the projects under review. This was a particular problem where the project replaced a previous project (PHT/1991/004 and FST/1990/044) or where a replacement project was immediately put in place in the same collaborating overseas country and has subsequently been completed (FST/1990/044).

Despite the mixed and sparse information base on some of the impact topics, a picture of the general impact of each project was able to be built up. The assessments are qualitative, but conclusions about each category of impact have been ordered according to whether it is not noticeable or deemed to be small, modest, significant or large.

These rankings should not be used to make comparisons of the size of impact between, say, one participating country and another. Nor should they be taken as indicators of net benefits of the projects. Some outcomes which are widely adopted may be of relatively minor economic or social significance, while others that are more narrowly focused might nevertheless have yielded large benefits relative to costs. At least one of the projects involved in this study (PHT/1991/004) has itself been the subject of a separate in-depth cost–benefit study by ACIAR (Lubulwa and Davis 1996) which is different in nature and longer-term in its assessed flow of benefits than the assessments made here.

Project PHT/1991/004—Occurrence and distribution of *Aspergillus flavus* and aflatoxins in Asian peanuts

Impact during the project

The external reviewer's report was of little value in assessing any community impact during the period when project PHT/1991/004 was being conducted, since it was prepared after only one year of experimentation and well over a year before the project's termination. However, from his comments and those of both the Australian and Thai project leaders it is apparent that the project had minimal impact in Thailand on all fronts. However, the same conclusion could not be drawn about impact in Australia.

Overall assessment of impact

Impact on research capacity. Both the Thai and Australian leaders considered that the project has had no impact on Thai research capacity, though for different reasons. Although the Thai government established a National Committee of Mycotoxin Control in Agricultural Commodities in 1985, its activities and subsequent research do not appear to have extended to monitoring techniques. The Thai project leader reported that there has been an explicit rejection of continuing any work on the control of aflatoxins through non-toxicogenic strains of *A. flavus*. He said that Thailand had developed sufficient research capability from training and research provided through collaboration over 25 years with the United States of America, United Kingdom and Japan. Research on aflatoxin control in

Thailand has been reported since 1994 (Kositcharoenkul 1996; Siriacha 1999) but none of it refers to monitoring or to control through the use of non-toxicogenic fungi. Indeed, no references are made in those studies to work done in Australia or collaboratively with Australians.

The Australian project leader indicated that PHT/1991/004's research orientation was different from that of research being undertaken in Thailand. He said that such research capacity as had been transferred from PHT/1991/004 would have been short-lived, since there has been no opportunity to make use of it in Thailand.

The project was instrumental in continuing CSIRO's involvement in aflatoxin research, which had begun ten years previously. It created a base for work that has continued through projects funded from other sources. Although no commercial techniques have since been developed, the Australian leader reported that there had been developments in techniques hinted at during PHT/1991/004 but unattainable at that time. He claimed that outcomes of PHT/1991/004 will provide a basis for working towards commercialisation through replacement project PHT/1997/017 when it commences in 2001. He also said that PHT/1991/004 had helped to develop field research capacity in Australia by providing a 'second season' for growing peanuts, opposite to that of Queensland. It can be concluded that the project has had a modest impact on research capacity in Australia.

Impact on uptake. At the time PHT/1991/004 was being considered for approval, an external reviewer noted that "the project will not result in any tangible, possibly commercialisable outputs, but rather will open the way for the development of appropriate control measures, some of which might be commercialisable". The Australian project leader confirmed that view. The project was designed to be fact finding and lead on to full scale bio-control studies. Those had not yet taken place; no commercially useable techniques had been developed since the project's termination; so there would not have been any uptake impact.

The Thai project leader also considered that the project has had no impact on Thai aflatoxin control practices. He did not comment on monitoring procedures, but claimed that the Department of Agriculture had rejected the idea of using non-toxicogenic strains of *A. flavus* as an aflatoxin control measure. This was because nuts could become mouldy and not saleable from exposure to such fungi, even if they were not toxicogenic.

The project did not have any orientation to immediate uptake in Australia. Commercially oriented projects funded from other sources may have been facilitated from outcomes of PHT/1991/004. However, no such impact was claimed for PHT/1991/004 by the Australian project leader. Furthermore, a March 1999 workshop on aflatoxin control in Queensland makes reference to future research in bio-controls through the use of non-toxicogenic strains of *A. flavus* in the soil and to postharvest monitoring, but there is no indication that these techniques are in current commercial practice. It can be concluded that thus far the project has had no noticeable impact on uptake in either Thailand or Australia.

Impact on community welfare. Because PHT/1991/004 has had no noticeable impact on uptake by farmers or on regulatory authorities which monitor aflatoxins or protect public health, it can be concluded that thus far it has had no noticeable impact on community welfare in either Thailand or Australia.

Impact on third countries. Neither the Thai nor Australian project leaders considered that any impact of the project had flowed through to third countries, though there should be flow-ons to Indonesia through replacement project PHT/1997/017 when it commences in 2001.

Project SWL/1991/003—Environmental impact of agricultural practices on water resources of the Kelantan Plain, Malaysia

Impact during the project

The external reviewers of this project reported shortly before it was completed that it was at a stage where results could be disseminated by MARDI to agricultural extension officers, policy-makers and environmental regulators in Kelantan. They also reported that Australia's Commonwealth Environment Protection Agency was evaluating models for chemical regulation, and that the project's Australian studies could provide useful input for the validation of those models.

In terms of research capacity, the reviewers considered that the project had provided MARDI with the capacity to maintain field sites and design new ones. MARDI was also reported to have the capacity to undertake simulation modelling of solute transport. In Australia, the project was said to have led to advances in soil measurement technology and to a better understanding of fundamental solute transport processes.

Overall assessment of impact

Impact on research capacity. No claim was made that SWL/1991/003 has been instrumental in maintaining or increasing CSIRO's research capacity in water resources research. However, the Perth group reported having reviewed, subsequent to SWL/1991/003's completion, the applicability of models for the Land and Water Resources Research and Development Corporation. Experience gained through SWL/1991/003 was said to be of some importance in this review. Overall, the impact of SWL/1991/003 on Australian research capacity can be assessed as small.

Considerable post-graduate training of Malaysian scientists was a feature of the project. The Malaysian project leader claimed that research capacity built up in MARDI through the project had continued to be utilised in the replacement project—both within Malaysia and extended to Thailand. Technology had also been transferred to other Malaysian scientific bodies. However, this research capacity had been maintained through Malaysian funding. He also said that no further models/simulations had been developed by researchers at MARDI, and this was the weakest element of its research capability for which there had been insufficient technology transfer. The project can be assessed as having had a significant impact on Malaysia's research capacity.

Impact on uptake. An impact attributed to this project by its Malaysian leader was the withdrawal by the Pest Control Board of Malaysia of endosulphan use by rice farmers. Significant residues of this insecticide, which causes high fish mortality, had been detected in the rice agro-ecosystem. No other specific changes to environmental regulations were reported, although the findings were said to have led to more stringent controls over pesticide use generally and to more widespread use of piped water and water filters nationwide.

It can be concluded that the impact of SWL/1991/003 on farmers and regulators in Malaysia has been significant. No claim was made that the project has had any impact on uptake or regulation in Australia.

Impact on community welfare. The Malaysian project leader reported that public awareness of health risks due to agricultural contamination is increasing in Kelantan. Although the findings from this project were widely published in national and local newspapers, increasing public awareness could not be attributed to this project alone. However, the Malaysian leader claimed that more judicious use of agricultural chemicals and improvements to water quality, particularly following the withdrawal of endosulphan from use in the rice agro-ecosystem, are improving community welfare generally. In particular, greater supplies of pesticide-free fish from flooded rice fields are adding to the nutritional status of poor farmers.

It can be concluded that the project has had a significant impact on community welfare in Malaysia. There is no evidence of any impact on community welfare in Australia.

Impact on third countries. No third-country benefits were claimed for the project in terms of practices used by farmers or regulators, or of community welfare generally. However, the Malaysian project leader reported that research capacity developed by MARDI through SWL/1991/003 had been transferred to Thailand during the replacement project. One student from Nigeria had graduated with a PhD from a Malaysian university, and two were currently undertaking MSc studies using experience developed in the project. On this basis it can be concluded that the project has had a small impact on third countries.

Project CS2/1989/018—Biological control of water hyacinth in Thailand

Impact during the project

Because the monitoring objective had not been entirely successful, by the end of the project it was too early to conclude that there had been any measurable impact from the introduction of *N. bruchi*. However, impressions from a principal research scientist were of an increasing level of control in Australia that was attributed to *N. bruchi*. The principal research scientist in Thailand was more cautious about the impact there. However, regardless of what impact *N. bruchi* had at that time, it can be concluded that the species had been successfully established in Australia, Thailand and Malaysia.

CSIRO's expertise in rearing, distributing and monitoring insects for biological control was appropriately transferred during the project, not only to Thailand and Malaysia but also to Vietnam, Fiji and the Philippines. Thailand itself has provided applied plant protection courses for trainees from a wide range of Asian and African countries. CSIRO had also provided insects to the Philippines for release.

Because of the visibility of the project, it was reported to have received wide popular exposure that would establish with future generations the important principle of the safety of biological control methods.

Overall assessment of impact

Impact on research capacity. Both its Australian leader and the external reviewer reported that project CS2/1989/018 had put water hyacinth on to the research agenda in this country. Without it, Australia would not have had the capacity for the mass-rearing of *N. bruchi* or for monitoring its impact. That technology has subsequently been maintained on a considerably broader scale with CSIRO's involvement with other projects, facilitated through the replacement project CS2/1993/020. It can be concluded that its impact on Australian research capacity has been large.

The project successfully transferred much of the technology to Thailand, with the possible exception of a monitoring capability comparable with that of Australia's. Thailand appears to have been able to maintain the technology transferred to it, and indeed to transfer it on to several other countries, without further support from Australia. However, there is no evidence that there has been an independent capacity in Thailand to develop the technology. It can be concluded that the impact of project CS2/1989/018 on Thailand's research capacity has been significant.

Impact on uptake. There has been a continuing program of field releases of *N. bruchi* (as well as of *N. eichhorniae*) in Thailand since the project was completed. The Thai project leader reported that research results have been disseminated to other authorities concerned with water hyacinth control. The Royal Irrigation Department is said to be the main client of NBCRC in this regard.

As a result of the initial releases and these subsequent actions, *N. bruchi* has clearly been established in Thailand. Although optimal control strategies may involve continuing releases, once a biological agent has been established its uptake normally proceeds naturally as a continuing low-cost form of control. Therefore, and with the ongoing program of releases of *N. bruchi* and *N. eichhorniae*, it can be concluded that the project has had a large impact on uptake in Thailand.

N. bruchi is now also established in Australia and is spreading. Australian monitoring is reported to be showing that *N. bruchi* is a more effective control agent than *N. eichhorniae*, though they complement each other. This is more on a regional basis than at individual sites, since they have been shown to separate out on different plant tissue types. For the same reasons as for Thailand, it can be concluded that the project has had a large impact on uptake in Australia.

Impact on community welfare. It has been reported that since 1979, when *N. eichhorniae* was introduced to Thailand, the incidence of water hyacinth has been significantly reduced in over half the infested areas in the country. Because of the prior and still dominant role of *N. eichhorniae*, it cannot be claimed that *N. bruchi* has contributed to this result. However, whatever the complementarity between the two species, it is likely that its introduction has had a significant impact on environmental and community welfare.

Most of the impact is likely to have been beneficial and include: the easing of waterway transport; improvements in water quality; and the removal of habitats for disease-bearing mosquitos and other insects. The Thai leader reported some negative effects, although these were considered mild compared with the benefits. Some people who use water hyacinth for handicrafts have complained of a deterioration in the quality of remaining plants. Some fishermen have claimed that they are unable to make use of water hyacinth as floats for fish spawning. Also, after ridding waterways of water hyacinth there has been a natural ecological succession of other water weeds, although these have not led to such severe problems.

The successful establishment and subsequent spread of *N. bruchi* as Australia's single most effective biological control agent indicates that it must at least have had a modest beneficial impact on community welfare through environmental improvement.

Impact on third countries. The impact of project CS2/1989/018 on third countries has clearly been large. Even during the period when it was being undertaken, its technology was being extended by Australia to Vietnam, Fiji and the Philippines. Thailand was also providing applied plant protection courses for trainees from a wide range of Asian and African countries. The project led on to a replacement project which involved collaboration, not only between the three original countries involved, but with Vietnam and Indonesia. The technologies developed are reported subsequently to have been applied in Papua New Guinea and Lake Victoria in Africa.

Project AS1/1990/001—Improved management for the production of honey and pollination of tropical forests by bees in Indonesia

Impact during the project

Even before the project ended, its hive design and management component was considered to have had an impact on beekeeping in both northern Queensland and Indonesia. The work in northern Queensland was being undertaken in conjunction with private beekeepers who were using results as they were generated. In Indonesia, informal transfer of information to extension officers and beekeepers was reported, as the experimentation took place near the regional training and extension centre in central Java. The same was said to be taking place in eastern Sumatra.

The impact of the forestry component at the project's completion appears to have been greatest in (temperate) Tasmania where North Forest Products (NFP) was reported to have decided to place hives in their eucalypt seed orchards during future flowerings to encourage seed production. No commercial uptake was reported in Indonesia.

It can be inferred that the status of research capacity at the termination of the project was good in northern Queensland for honey production and excellent elsewhere in Australia for forest seed production. Some aspects of the project were not amenable to highly developed research methodology, while some other aspects that were, such as DNA fingerprinting, were not transferred from Australia to Indonesia. The termination report claimed that, following a reorganisation of control of the project in its final year, training of Indonesian researchers had been excellent.

Overall assessment of impact

Despite efforts to contact the Indonesian project leader and a senior Indonesian officer involved in each of the apicultural and forestry components of the project, no information was obtained from these sources. However, use has been made of a communication about impact received by the Australian project leader from his Indonesian counterpart some two-and-a-half years after the project's completion.

Impact on research capacity. A high level of technology transfer to Indonesia at a basic level appears to have been achieved in the project's latter stages. Although there is no evidence of this having been further developed, the National Beekeeping Centre in Parung Panjang has been able to maintain some research capacity. Two-and-a-half years after the project's end, the Indonesian project leader reported queen breeding research taking place there. There is no indication of any forestry research proceeding as a result of this project. During the project it was reported that Indonesian government forestry researchers were excluded from the private sites on which the forestry research was undertaken, and it was doubted that the research capacity could be maintained.

CSIRO had begun documenting basic phenological and floral patterns for a range of eucalypt and acacia species, together with the development of techniques for controlled pollination and improved seed production, before AS1/1990/001 had commenced. The project allowed this research to be expanded to a wider range of species and sites than would otherwise have been possible. Following the project, a manual of seed production in eucalypts was prepared. This methodology has subsequently been expanded by CSIRO Forestry and Forest Products, which continues to make advisory visits to Indonesia.

There is no evidence of any continuing impact of the project on apicultural research capacity in Australia. However, the Rural Industries Research and Development Corporation (RIRDC) is reported to have taken up some of the issues developed in AS1/1990/001 in projects it has subsequently financed.

It can be concluded that the project has had a small impact on research capacity in Indonesia, principally through apiculture, and a modest impact in Australia, principally through forestry.

Impact on uptake. The Indonesian project leader reported some two-and-a-half years after the project's termination that local honey producers were beginning to use supplementary feeding and it was being extended to colonies utilising a wider range of tropical crops than kapok, on which the nutritional research was undertaken. He indicated that productivity in one region of central Java had tripled to 20 kg per hive, but this was still only about half the 41 kg per hive achieved with supplemental feeding in the nutrition trials. No indication was given of the numbers of producers making these changes or the impact they were having on total honey production or quality.

In Australia, a manual, *Fat/Skinny Bees*, using research results from the project has recently been commissioned by RIRDC. Although results from the research have previously been published in *The Australasian Beekeeper*, this manual will be the

only source of published information about tropical apicultural management in Australia. However, the Australian project leader claims that there has been a major increase in supplemental feeding of bees in tropical Queensland, to which the project has contributed.

A scientist from CSIRO Forestry and Forest Products has reported that as part of advisory visits to Indonesia by divisional staff, recommendations have been made on the use of bees as part of seed orchard management. But there is no evidence that the suggestions are being taken up. Despite requests, no information has been obtained from the company on whose land the forestry component of the project was undertaken.

It was reported during the project that NFP was using bees as a standard management tool in eucalypt seed production in Tasmania. However, an officer of NFP has subsequently reported that although an agreement was entered into with an apiarist to operate in the company's seed orchards, following the retirement of the apiarist there has been no further formal arrangement. Apiarists are permitted to use the company's forest areas, but they do not figure in the company's seed production management plan.

Compared with the large benefits expected for Indonesia when the project was externally reviewed, its impact on honey production thus far appears to have been modest while there has not been any noticeable uptake of project outcomes on commercial forestry seed production. Although honey production in tropical Australia is not large, the project's relative impact on that production appears to have been significant. At this stage, the impact of the project on commercial forest seed production in Australia has been small.

Impact on community welfare. To the extent that there has been a modest impact on honey production in Indonesia, it can be concluded that there has been a small beneficial impact on the nutritional status of consumers there. Any flow-through impact on Australian consumers of increased honey production in north Queensland is considered to be not noticeable.

In north Queensland, environmental benefits from the project were noted from increased seed production in natural eucalypt stands. These presumably would be sustained for as long as *A. mellifera* populations remain. The senior CSIRO forestry scientist also reported that the project's outcomes have supported results emerging from RIRDC-financed studies which suggest that *A. mellifera* increases seed production of some native species where the level of pollination is low, without having an observable impact on others.

It can be concluded that the project has had a small beneficial impact on community welfare in both Indonesia and Australia—in Indonesia coming mainly through improved human nutrition and in Australia from a favourable impact on seed production in native forests.

Impact on third countries. Considerable interest in the project from third countries was reported while the project was under way, and the Second Asian Apicultural Conference held in Yogyakarta soon after its completion was said to have attracted interest in its findings from many delegates. The senior CSIRO forestry scientist also claimed he had disseminated results of the project widely in Thailand and China through contacts made on visits there. However, although the project may have created a research interest in those countries, no evidence was provided of any impact on actual research capacity or commercial uptake of research findings.

Project FST/1990/044—Increasing productivity of eucalypt plantations in China by inoculation with ectomycorrhizas and nutrient application

Because project FST/1990/044 was the second of three successive mycorrhizal projects in China, the third of which has been largely completed during the last five years, it has been difficult to separate its research capacity and general community impact from those of the others. The following assessments therefore cover an impact continuum, part of which is drawn from documentation about the replacement project FST/1994/025. However, to the extent possible, the emphasis remains on FST/1990/044.

Impact during the project

The external reviewers of FST/1990/044 considered that, by its termination, there had been significant sustainable technology transfer from Australia to China. They also considered that Australia's forestry research capacity had benefited greatly, now having a foundation of data on mycorrhizal fungi associated with eucalypts without precedent.

The reviewers also considered that the project was starting to have a dramatic impact through practical commercial application in China and that deforested sites were being rapidly restored to

industrial and protection forests in experimental and demonstration plantations. They considered that it was too early to come to conclusions about impact in the Philippines but noted that there was evidence of rapid reforestation of degraded sites with eucalypts in that country. Although they were enthusiastic about the potential impact on Australian plantation nursery practices, no mention was made of any such impact having occurred.

Overall assessment of impact

Impact on research capacity. FST/1990/044 was responsible for the establishment of a 48 m^2 glasshouse facility for the growth of inoculated seedlings in China. Technologies on fungal culturing, inoculation and applications in afforestation appear to have been successfully transferred. Apart from short-term training of scientists in China during the project, one PhD student has subsequently completed training in mycorrhizal research, two are currently pursuing training and one senior professor and two associate professors are reported to have depended on the succession of projects for their research development. This said, no claims were made that capability had been extended through the project to new areas of mycological or nutritional research.

Comment received from the Philippines indicates that the development of research capacity was a minor orientation of the project in that country, other than PhD training in plant nutrition at Murdoch University. A Filipino PhD graduate from Murdoch University is currently involved in the monitoring trials initiated during FST/1990/044, while a scientist who was involved in the early monitoring of the trials in China is currently undertaking PhD studies at Murdoch University.

The external review report of replacement project FST/1994/025 has documented a considerable body of research techniques, further fungal collections and screenings, and nutrient studies associated with mycorrhizal trialling that has followed from foundations laid in projects FST/1987/036 and FST/1990/044. The succession of funding has undoubtedly contributed to a significant development of the collection and classification of Australian mycorrhizal fungi and to the research facilities in CSIRO and Murdoch University which are able to make use of that material.

It can be concluded that the succession of projects have had a significant impact on research capacity in the principal target country, China, although project FST/1990/044's impact on research capacity in the Philippines has been small. The succession of projects has had a large impact on research capacity in Australia.

Impact on uptake. Although the Chinese project leader claimed a large uptake of inoculation in new forest plantings, the 700 ha of eucalyptus plantations reported to have been established in China using mycorrhizal techniques since 1992 are small compared with 25,000 ha planted by one company in Western Australia since 1994 using these techniques. However, the Chinese leader reported that one local company had commenced a program of commercialisation through the preparation of inoculum products for twelve million eucalypt seedlings. He foreshadowed plantings of some 20,000 ha per year in southern China using mycorrhizal techniques. He also acknowledged that on nutrient-depleted soils, early responses to phosphates would be much greater than those to inoculation, though at greater cost. No comment was received on the extent to which the nutritional trials, which confirmed that conclusion, had resulted in the use of fertilisers in the establishment of eucalypt plantations.

Commercial plantings of eucalypts in the Philippines are reported typically to be inoculated with mycorrhizas, though it is unclear whether this practice is an outcome of FST/1990/044. Inoculations are said typically to be from a variety of mycorrhizas taken from nearby sites rather than from commercially prepared cultures of Australian-origin fungi. Furthermore, these practices appear to have been in use in the Philippines before FST/1990/044 commenced. However, the project was seen to be of significance in the reforestation of degraded grasslands, especially through the introduction of selected eucalypt species for that purpose.

The Western Australian company which had planted 25,000 ha of inoculated eucalypts since 1994 claimed that, based on advice received from the Murdoch University research leader, a cheap and effective method of inoculation had been developed. It plans to plant a further 10,000 ha of inoculated eucalypts in 2000. Since all plantings have been on sites with a long pasture history, the inoculations are made to bolster any natural mycorrhizal populations. Because of long fertiliser histories on these sites, no applications of phosphate have been made, but applications have been made of trace elements. (Australian trials of seedlings grown on old pastures have indicated no response to phosphorus but significant responses to copper and manganese.) The company believes that

it has benefited from trace element applications and inoculations, but it has not tested to see if responses are from either source or from their interaction.

There appears to have been great interest in China regarding mycorrhizal inoculation techniques and there are prospects for a very large commercial impact. However, these have not eventuated to date. It can be concluded that the impact of the succession of projects on commercial uptake in China has been modest. A similar conclusion can be drawn about the Philippines. In Australia, action has been documented for only one commercial company, but to date it has planted over three times more inoculated eucalypts than in China. It can be concluded that the projects' impact on commercial uptake in Australia has been significant.

Impact on community welfare. Apart from any commercial benefits of mycorrhizal inoculation techniques, it has been claimed that deforested sites in China are being rapidly restored to industrial and protection forests in demonstration plantations. There is no indication of the extent to which such plantings have occurred or of their impact on environmental improvement other than through the 700 ha of commercial planting already reported. However, the external reviewers of FST/1994/025 concluded that the succession of projects had increased interest in tree planting on degraded lands in China.

The principal benefits of FST/1990/044 in the Philippines may also have been its impact on the reforestation of degraded grasslands through the introduction of selected eucalypt species for this purpose. Again, no figures are available to indicate the extent of any such environmental improvements that may have been achieved.

No adverse environmental impact of the project(s) was reported, although the external reviewers of FST/1994/025 suggested that because of the exotic origins of Australian mycorrhizas in China, this possibility should be kept in mind.

It can be concluded that, apart from its commercial impact, FST/1990/044 has had a small impact on community welfare generally in China and the Philippines. It has had no noticeable flow-on impact on community welfare generally in Australia.

Impact on third countries. The external reviewers of FST/1990/044 were enthusiastic about the potential for spill-over benefits, not only to other areas in Australia, China and the Philippines, but to degraded sites in many parts of tropical and sub-tropical Asia. But no such spill-overs were claimed to have been achieved by the time the project was terminated. Other than the report of a workshop for scientists from China, Vietnam, the Philippines and Thailand held soon after FST/1990/044's completion, no comment was made about any subsequent impact on countries other than the three participants in FST/1990/044. It can be concluded that there has been no noticeable impact in this regard.

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