# Impact of improved management of white grubs in peanut-cropping systems in India

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International Agricultural Research

# Impact of improved management of white grubs in peanut-cropping systems in India

**Michael Monck and David Pearce**
Centre for International Economics, Canberra and Sydney

2008

**Australian Government**
**Australian Centre for International Agricultural Research**

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# Foreword

This impact assessment study is the second this year that focuses on our research program in India.

The project was chosen using a 'quasi-random, top-down stratified sampling' process; that is, after a quick review of all ACIAR Indian projects, two were selected, one from the animal research area (Impact Assessment Series Report No. 52) and the other from crops (this project). They were not chosen with any prior expectation of large benefits, just that they had been finished long enough for impacts, if generated, to be seen and measured.

This project, which looked at the problems caused by various species of white-grub pests in peanut production in India and Australia, was an interesting combination of some initial research to provide a better understanding of the pests, and development of a package of grub control and other technology options that together improved peanut crop productivity. The project was specifically designed to link with a non-government organisation (NGO), the Agricultural Man Ecology Foundation, to ensure adoption of the technology package in a target region (Raichur) in India.

This impact assessment study shows that the project has generated important benefits for a crop that is largely grown by the poorer farmers in this part of India. The present value of the net benefits was estimated at A$6.1 million, with a benefit:cost ratio of 5.7:1 and an internal rate of return of 29%. All these benefits accrued to India, but the results of the research have also helped to improve understanding of the impact of white grubs on Australian peanut crops and facilitate the application of improvements to production already introduced here.

The results highlight that adoption of integrated packages of technologies that are often relatively complex for poor farmers can be dependent on location-specific promotion efforts, which often do not result in further spread of the technology without similar intensive efforts in each new area. The technology packages were found to have been adopted only in the specific regions targeted by the NGO. While the project has yielded healthy returns to the research and development funds invested, these are not spread over as extensive an area as some other types of research activity supported by ACIAR.

Peter Core

**Peter Core**
Chief Executive Officer
ACIAR

# Contents

**Tables**

# Acknowledgments

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The Agricultural Man Ecology Foundation helped by making its staff available and assisting in field visits. Mr B.C. Kolhar was especially helpful in organising visits to villages in the Raichur region and by providing local knowledge that made our stay in the area enjoyable and enlightening. We are grateful to Dr A. Balamatti and Mr K.V.S. Prasad, also of the Agricultural Man Ecology Foundation, for their hospitality and for organising a meeting with those involved in the project and programs to extend its results.

Mr M.A. Qayum, previously a Joint Director of Agriculture, Mr N. K. Sanghi of the Watershed Support Services and Activities Network, Dr M.S. Chari from the Centre for Sustainable Agriculture and Mr J. Jacob from INGRID also offered their time and expertise during our field visits. Rama Devi Kolli (Society for Transformation Agriculture and Alternatives in Development) welcomed us into her home and provided insights into the research that we would not have otherwise gained.

Lastly, we also extend our thanks to Dr C. Bantilan of the International Crops Research Institute for the Semi-Arid Tropics for organising a meeting with the researchers from that institute. Information obtained at this meeting provided valuable input into the report and we are grateful to have had the opportunity to speak with these experts.

# Summary

This report presents the findings of an economic impact assessment of ACIAR project CS2/1994/050 on *Management of white grubs in peanut-cropping systems in Asia and Australia*.

ACIAR has conducted a number of projects in India over the years, but they have not been well represented in the impact assessments used to estimate the benefits and costs of research. This project was chosen using a quasi-random, top-down process, with the simple constraint that it had been completed long enough for benefits to be seen. No preconceived ideas about the existence or magnitude of benefits influenced its selection for assessment.

The benefits quantified here rely partly on factors outside the research objectives of the project. The researchers involved in the project collaborated with local organisations to promote both the white-grub control measures coming from the research and sustainable farming practices. Together, these two aspects combined to yield benefits that outweighed the costs of the research.

Because they are so closely related, it is difficult to break down the benefits into those that come directly from the research versus those that come from the other practices adopted at the same time. Furthermore, the project acted as a catalyst for the widespread communication of innovative ideas not directly related to the project, so it can be argued that had the research not been undertaken then this additional knowledge would also not have been disseminated.

The benefits to Australia are limited. Aside from establishing strong links with partner organisations in India and gaining extra knowledge from the research, there has been little impact. White grubs do not present a major risk to Australian peanut crops and several existing measures, including pesticide treatments and the use of new peanut cultivars, are effective in controlling what little threat there is.

Countries such as Vietnam and some African nations could stand to gain from the findings but there is no evidence to suggest that this has happened yet, so the potential benefits from these spillovers were not estimated.

The benefits estimated in this assessment apply to the Raichur region of Karnataka state in southern India and amount to $6.1 million over and above the costs. This gives the project a benefit:cost ratio of 5.7:1 and an internal rate of return of 29%. Should the project findings be extended beyond Raichur, these benefits could be much larger. There is no evidence, however, that the findings have been more broadly adopted.

Follow-up studies or extension programs would no doubt see increases in the benefits quantified in this study. The partnerships with local non-government organisations (NGOs) in the Raichur area have played a critical role in realising the benefits from the research

**Table 1.** Summary of benefits and costs of ACIAR Project CS2/1994/050

| | | |
|---|---|---|
| Benefits to India | *$m* | 7.4 |
| Benefits to Australia | *$m* | 0.0 |
| Total benefits | *$m* | 7.4 |
| Total costs | *$m* | 1.3 |
| Net benefits | *$m* | 6.1 |
| Benefit:cost ratio | *Ratio* | 5.7 |
| Internal rate of return | *%* | 29 |

Source: Centre for International Economics' estimates

undertaken in CS2/1994/050. Establishing similar partnerships elsewhere could potentially see the benefits replicated in other locations throughout India. Indeed, the key lessons from this project are:

- the importance of on-the-ground extension activities to achieve real benefits from research, on the one hand, and
- the difficulty in achieving such extension work on the other.

The project most likely would not have generated benefits in the absence of the solid and long-term efforts of the extension agency (in this case an NGO) involved. Practical extension is particularly important in the marginal areas of India where many farmers are illiterate and where there are no other means of transmitting research findings.

The extension work must be committed and ongoing, and should not be viewed as being an automatic or inevitable consequence of producing sound scientific research.

# 1 Introduction

ACIAR project CS2/1994/050, *Management of white grubs in peanut-cropping systems in Asia and Australia*, was designed to help overcome constraints to peanut cropping in India and Australia caused by white grubs. White grubs are soil-dwelling larvae of scarab beetles. They feed on the roots of the peanut plant, killing seedlings and sometimes older plants, reducing drought tolerance and thereby affecting final yields. The research focused on growing the existing body of knowledge about white-grub biology and ecology, and developing means of applying the research findings. It also catalysed the spread of improved farming practices in the villages around the Raichur region in Karnataka state, southern India.

The project benefits accrue mostly to India, those to Australia being largely qualitative. Those benefits that are quantified in India are limited to the area surrounding Raichur, as that is where the research was carried out. There are potential benefits for Vietnam and some African countries, but at present there is no evidence that the project findings have been adopted outside India. Further work in extending the research programs into other areas may lead to benefits greater than those documented here.

The Australian benefits are limited to those coming from establishing new international research networks. No change in farming practices has taken place as a direct result of the project.

The project brought together researchers from the Queensland Department of Primary Industries (QDPI), the University of Queensland (UQ), the Indian Council for Agricultural Research (ICAR) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Total project funding amounted to around $1.1 million in nominal terms.

Chapter 2 of this report gives a brief overview of peanut cropping in India, and discusses the project and the problems it was designed to solve. Also covered are the outputs from, and impacts of, the project. Chapter 3 details the methodology for assessing the benefits from the project, and outlines the data and sources of information used in the analysis. Chapter 4 presents the results of the analysis and, using sensitivity analysis, tests the robustness of findings. Chapter 5 makes some final remarks on the project.

# 2 The project

## Growing peanuts in India

Peanuts (also known as groundnuts) are a major crop in India: around 7 million hectares planted produce 8 million tonnes per year. Most (slightly over 80%) of the crop is grown under rainfed conditions, and some 90% of production is from arid or semi-arid areas. Rainfall patterns mean that there are significant differences in yield between regions and agroecological zones. This is illustrated in Figure 1, which shows yields for 27 locations across all relevant zones of India.

Yields vary significantly, ranging from 1,870 kilograms per hectare in the Junagadh region to as low as 500 kilograms per hectare in Bijapur. Raichur, the region that forms the focus of the analysis in this study, has the second-lowest yields of all the regions considered, producing only 640 kilograms per hectare.

ICRISAT has recently undertaken research into the potential yields achievable in each region. It should be noted, however, that the potential gains are based on experimental data and may not be achievable under actual farming conditions. Furthermore, the theoretical maximums derived from these experiments may not be economically optimal, insofar as the cost of achieving an extra unit at the upper end of production might be greater than the value of the benefit gained. Nonetheless, this research shows that, despite the low rainfall in some areas, substantial gains could be made in most regions. This productivity gap is in the order of 140% for India as a whole and as high as 430% in the region of Dhar. Three regions—Anantapur, Coimbatore and Palaturai—are all producing near their potential maximums. Figure 2 shows the semi-arid region of Raichur could achieve yields approximately 278% higher than those at present.

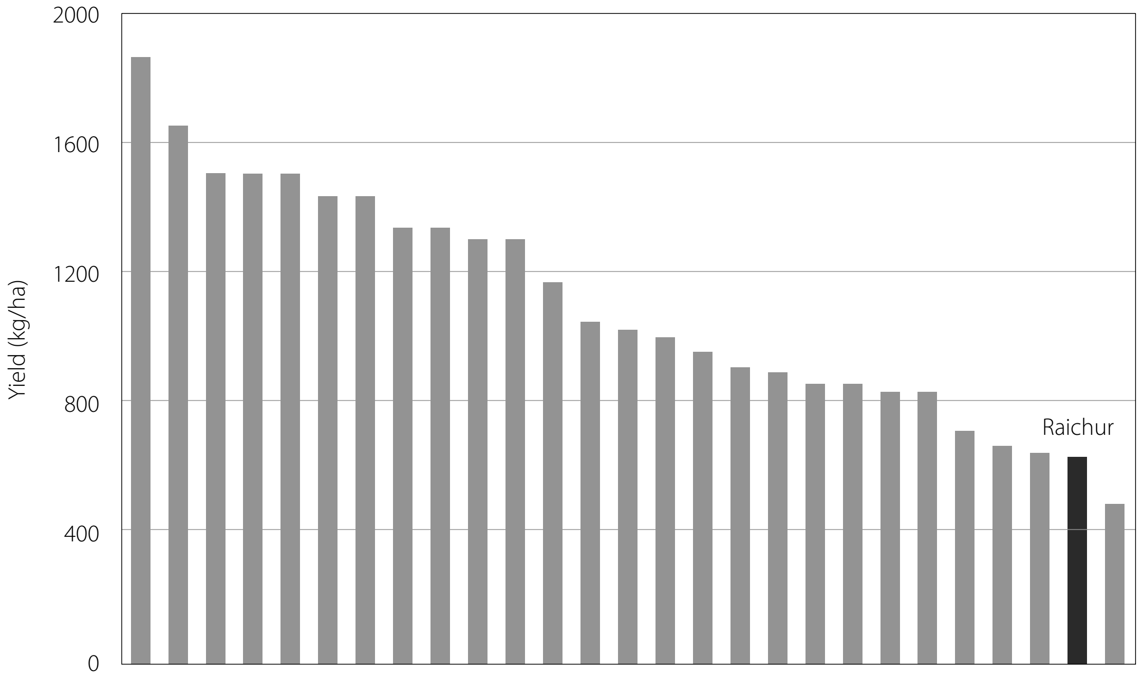
Figure 3 combines the foregoing information to establish a relationship between current yields and the potential percentage gains in yields. Not surprisingly, there is an inverse relationship between current yields and the percentage gains that could be achieved. That is, those areas with low current yields tend to have a larger gap between current production and potential production. Current production in Raichur is at the lower end of the scale and the potential gain in production is therefore relatively large.

There are several reasons for the gap between current and potential yields, an important one being the presence of a variety of pests and diseases. Among the significant pests are the white grubs that are the focus of this report.

## The Australian peanut industry

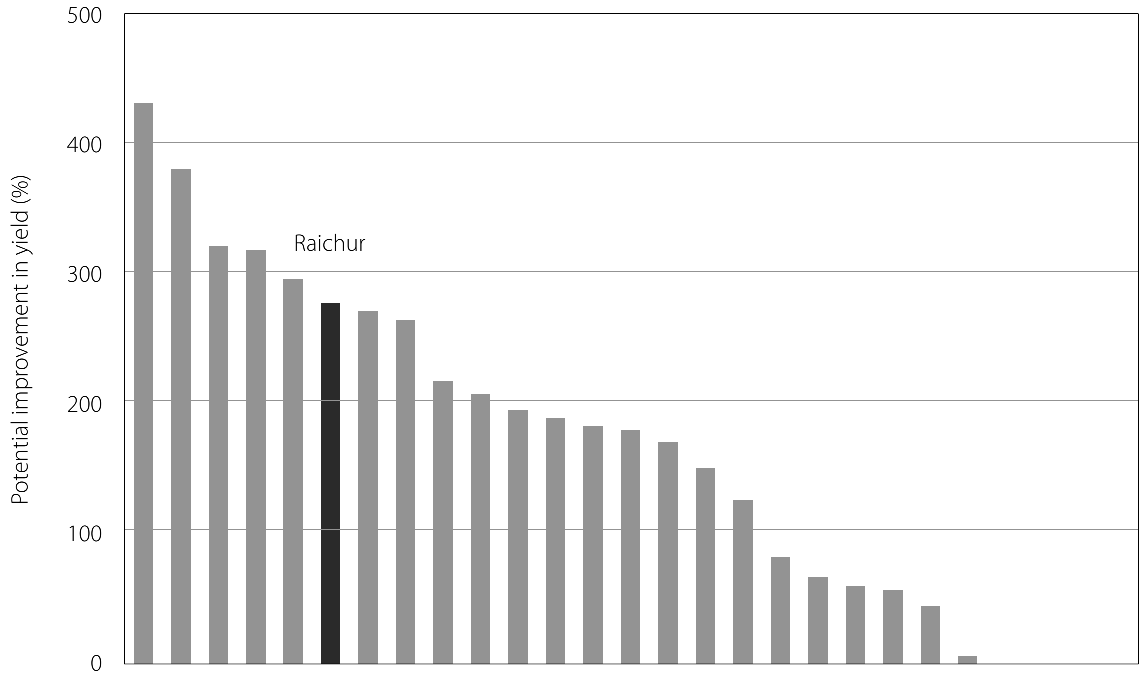
The Australian peanut industry is centred mainly around the South Burnett region in Queensland. The past 20 years have seen a steady decline in the area planted and production. Production in 1987 was almost 48,000 tonnes, falling to around 30,000 tonnes in 2005. The bulk of the produce is processed in Kingaroy where shelling, grading, blanching, roasting and packaging take place.

Most of the output is consumed domestically, but exports are increasing and attract a higher price due to the high quality of Australian produce. Local production does not satisfy domestic demand, and the shortfall is made up by imports.




| Region | Yield | Region | Yield |
|---|---|---|---|
| | *kg/ha* | | *kg/ha* |
| Akola | 660 | Kurnool (Alfisols) | 870 |
| Anantapur | 910 | Kurnool (Vertisol) | 870 |
| Bijapur | 500 | Patancheru | 1060 |
| Coimbatore (Coimbatore) | 1350 | Pune (Nimone) | 1440 |
| Coimbatore (Palaturai) | 1350 | Pune (Otur) | 1440 |
| Dhar | 730 | Raichur | 640 |
| Dharwad (Achmatti) | 850 | Rajkot (Bhola) | 1310 |
| Dharwad (Hogaluru) | 850 | Rajkot (Semla) | 1310 |
| Jaipur | 1180 | Surat (Haldar) | 1510 |
| Jalgaon | 1040 | Surat (Kabilpura) | 1510 |
| Jhabua | 680 | Surat (Sisodia) | 1510 |
| Jhansi | 1010 | Thanjavur | 1650 |
| Junagadh | 1870 | Warangal | 920 |
| Kota | 960 | | |

**Figure 1.** Peanut crop yields in different regions of India. Source: Centre for International Economics' estimates based on data in Bhatia et al. (2006).




| Region | Yield | Region | Yield |
|---|---|---|---|
| *Potential improvement (%)* | | *Potential improvement (%)* | |
| Akola | 380 | Kurnool (Alfisols) | 210 |
| Anantapur | 0 | Kurnool (Vertisol) | 153 |
| Bijapur | 184 | Patancheru | 321 |
| Coimbatore (Coimbatore) | 0 | Pune (Nimone) | 129 |
| Coimbatore (Palaturai) | 0 | Pune (Otur) | 190 |
| Dhar | 430 | Raichur | 278 |
| Dharwad (Achmatti) | 180 | Rajkot (Bhola) | 86 |
| Dharwad (Hogaluru) | 266 | Rajkot (Semla) | 46 |
| Jaipur | 196 | Surat (Haldar) | 7 |
| Jalgaon | 220 | Surat (Kabilpura) | 69 |
| Jhabua | 319 | Surat (Sisodia) | 60 |
| Jhansi | 296 | Thanjavur | 8 |
| Junagadh | 61 | Warangal | 272 |
| Kota | 171 | | |

**Figure 2.** Potential increases in peanut crop yields in different regions of India. Source: Centre for International Economics' estimates based on data in Bhatia et al. (2006).

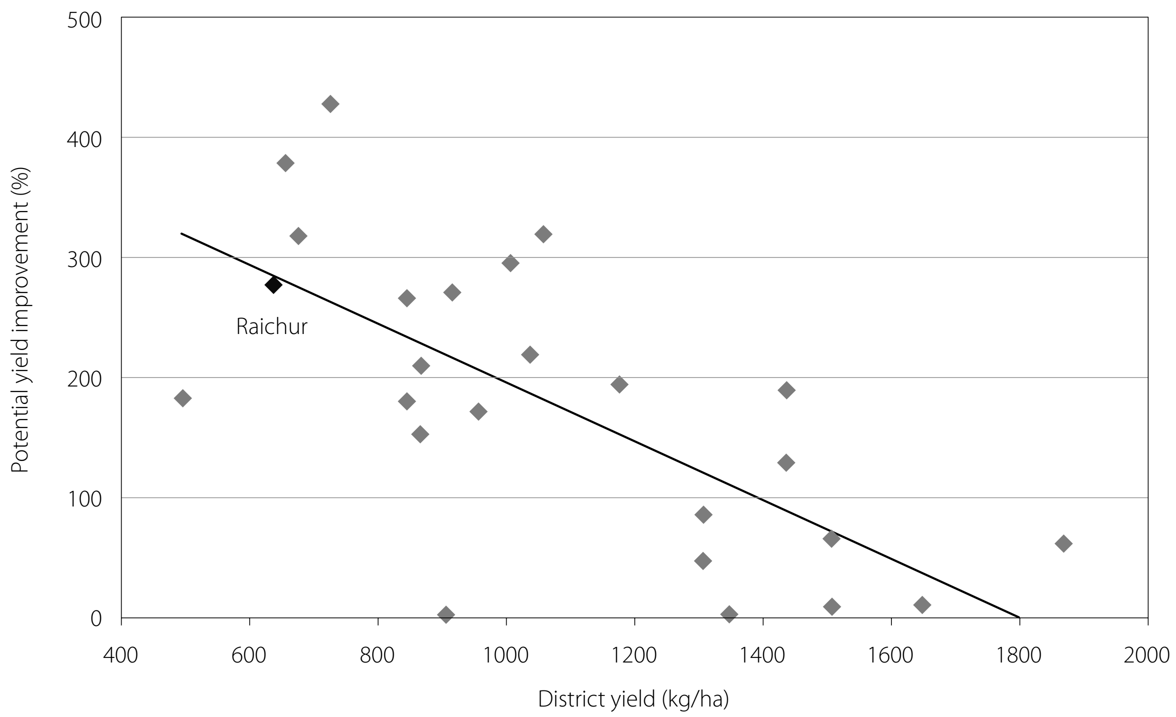



**Figure 3.** Correlation between peanut crop yields and potential yield increases in different regions of India (each point indicates a different location). Source: Centre for International Economics' estimates based on data in Bhatia et al. (2006).

## The project

As noted in the introduction, white grubs are the soil-dwelling larvae of scarab beetles. During this stage of their life cycle they feed on the roots and pods of the peanut plant, killing seedlings and, sometimes, mature plants. Those plants that do not die display reduced drought tolerance and lower yields.

Knowledge of the existence of the white-grub problem is not new. In the 1960s, community action focused on using light traps to capture and kill adult beetles (H. Kolli, pers. comm., Feb. 2008) but this method has not always been effective. The efficacy of light traps varies between species of white grubs and in general the traps attract only around 2% of the population (Yadava 1998). Despite this they remain in use throughout India.

Other methods of control include killing the adult beetles when they congregate in trees that they are attracted to. Yadava (1998) describes two approaches:

> After dark, hit the host trees with bamboo poles to make the beetles fall off the trees. Then pick them up and drown them in water with a little kerosene in it. This procedure should continue for a minimum of 1 week after a rain. This should be done on the preferred host trees, on about 5 trees per hectare, and should take place across the whole study area. If the top branches are too high, they can be cut off.
>
> Spray with insecticide: Five trees per hectare can be sprayed during the day at a cost of about Rs25 per spray per hectare. One or two sprays per year are needed, because each spray is effective for about 5 days. This must be done for 3 years. Two people can spray 150 trees a day. Inputs, including a sprayer, and labour should be organised in advance. This will result in reduction in the population of beetles, and an overall yield increase.

The Indian Government subsidised the use of chlorpyrifos insecticide in the early 1990s. The University of Agricultural Science in Bangalore did research into the treatment methods at that time and established that a chlorpyrifos spray concentration of 6 millilitres per kilogram (mL/kg) was as effective as the then recommended 12 mL/kg (Dr Kumar, pers. comm., Feb. 2008).

Despite this knowledge not many farmers were using the methods or, if they were, they did not understand how to maximise their effectiveness. This was in part due to the sporadic nature of the white-grub problem.

White grub is most problematic in those areas with dry, sandy soils. These areas tend to exist in pockets throughout the country and this limits the free flow of information between farmers. Adjoining regions do not necessarily have the same soil type and therefore do not necessarily share a white-grub problem. The result is that some areas face significant white-grub problems while in others where appropriate methods are applied the grub is well controlled.

The project sought to help overcome these problems by:

- clarifying the distribution and identity of white-grub species damaging peanuts in southern India and Australia
- studying the behaviour, ecology and population dynamics of larvae and adults to provide the biological information necessary for developing improved management processes
- determining the relationship between white-grub population density and crop yield loss for key white-grub species in India and Australia
- extending, testing and modifying control strategies developed in India to Australian conditions
- isolating and identifying semiochemicals (e.g. sex-attractant pheromones) and developing technology for using semiochemicals for the management of white-grub adults in India
- developing appropriate techniques and technology for the production and use of the insect pathogen *Metarhizium anisopliae* for white-grub control in India, by identifying key factors that maximise the infection of larvae and by optimising strain-selection, formulation and field-placement strategies.

The researchers hoped, furthermore, to strengthen linkages with and between appropriate extension agencies to enhance the transfer of technology.

Work on this project contributed to the progress of long-standing research to understand the distribution and impact of white grubs in many crops around the world. Among the findings of research in the projects, four are particularly relevant:

- White grubs are spread across peninsular India.
- White grub feeding damages the plants.
- The damage caused by white grubs leads to a potential yield loss.
- The causes of yield loss may not be immediately evident.

The remainder of this report focuses on the benefits that have arisen from the known adoption identified by those involved in the project (Rogers 2007) and during follow-up field visits conducted as part of this assessment.

Figure 4 illustrates the main pathways for the realisation of benefits from the project, while Table 2 summarises total potential project benefits, setting out those that have been quantified as part of this report.

## Impacts in India

Working with the Agricultural Man Ecology Foundation (AMEF) in Bangalore and Hyderabad, the research team developed a set of control measures. The researchers, together with AMEF, then communicated these measures to farmers.

The main method of control encouraged by the researchers was the use of an integrated farm management system. This consisted of using chlorpyrifos to treat peanut seed to prevent yield losses from white grubs, in combination with other practices that further enhanced yields.

There was also an increased use of organic matter in farming, a movement away from monoculture farming towards a more diversified set of crops, and use of channels and composting to improve water

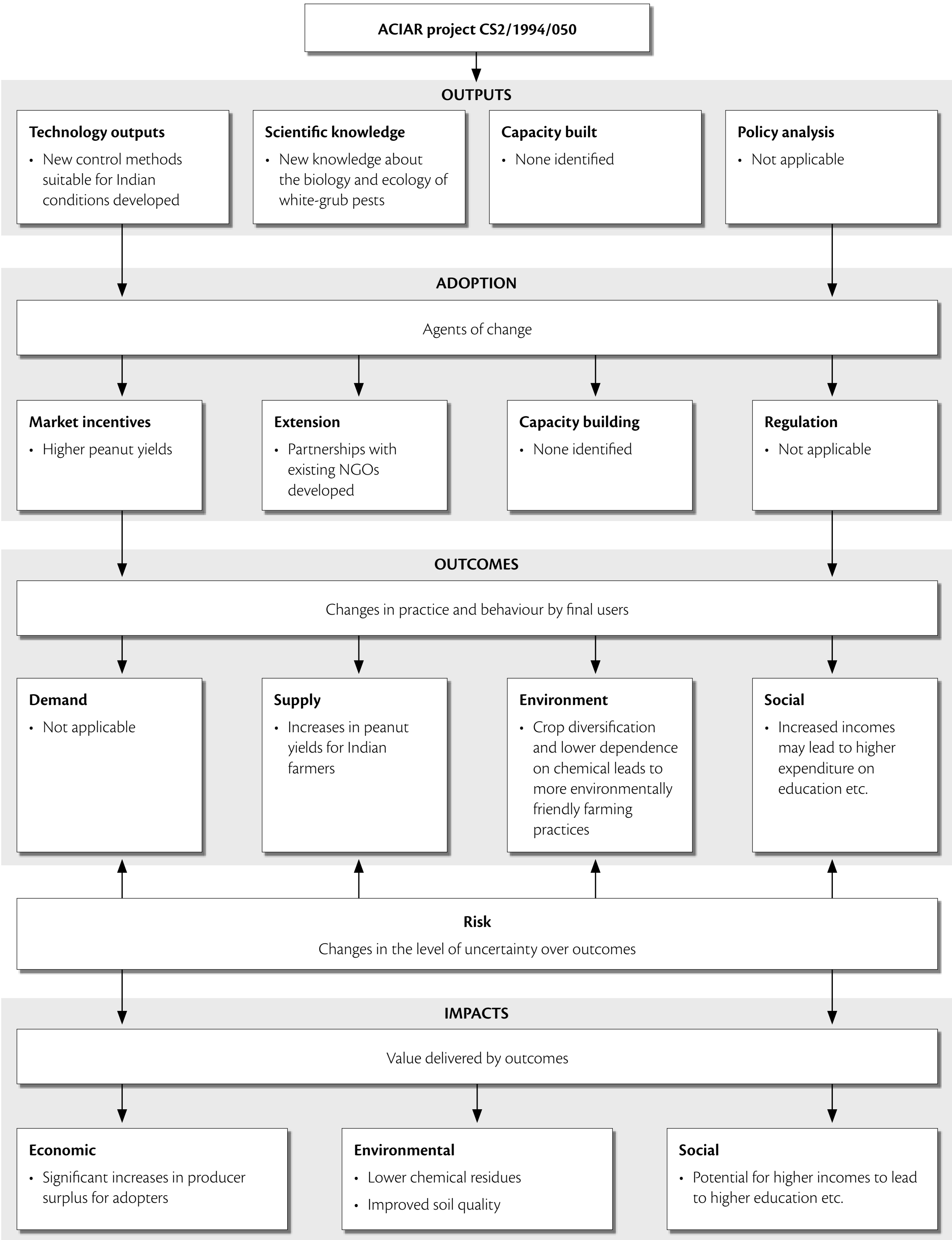



**Figure 4.** Pathways to benefits from ACIAR Project CS2/1994/050

management. While these measures did not arise directly from work in Project CS2/1994/050, it is clear that the project provided significant motivation for the partner NGOs to promote these practices in conjunction with the white-grub control measures. Had the researchers not encouraged the dissemination of the project findings these new farm practices would not have been adopted either.

A large part of the communication effort involved direct farmer contact and demonstration of the control measures but there were also several printed products and DVDs designed to support the effort. 'Why are my peanut plants dying?', an informational booklet designed to help farmers better understand the white-grub problem, was printed in English, Tamil, Kannada and Telugu. The booklet was distributed to farmers via training programs and seminars held in farmer field schools and local villages.

In addition, posters and a DVD were produced to disseminate information to illiterate and marginally literate farmers. The DVD contained farmer accounts of their experiences with the various control measures.

The most significant outcome of the project has been an observable increase in yields in villages around Raichur, as depicted in Figure 5.

The Raichur pre-control bar in Figure 5 represents the yields that were obtained before the research—an average of 680 kilograms per hectare. The second bar, Raichur theoretical control, shows the gains that could be achieved from implementing the control measures for just white grubs. This shows gains of 81 kilograms per hectare (Rogers et al. 2005). What has actually been observed in Raichur is shown in the third bar. This is clearly much higher than the theoretical gains from just controlling white grubs, which suggests that something else is influencing the benefits. Given the additional farm management practices that have been implemented, improving soil quality and further increasing yields, this further gain of 228 kilograms per hectare is not unexpected. The final bar illustrates the potential yield that could be achieved in Raichur. This is based on research undertaken by ICRISAT and is the theoretical maximum production given the conditions present in the region.

**Table 2.** Potential areas of benefit from ACIAR Project CS2/1994/050

| Region or country | Economic benefits | Social benefits | Environmental benefits |
|---|---|---|---|
| Raichur region in India | Clearly demonstrated benefits in this region. These are quantified here using data from field visits to estimate the total welfare change. (Note that improvements in soil quality are part of the productivity improvement measured here.) | Higher real incomes from higher peanut yields will lead to social benefits including educational outcomes. Lack of base data prevents quantification here. | The adoption of the research has involved environmentally sustainable practices. Not all of this can be attributed to the ACIAR-funded research. Lack of base data prevents quantification here. |
| Other Indian regions | There are, in theory, benefits to other regions, but there is no evidence of adoption of results from this project in other regions, so these benefits are considered to be zero here. | Zero benefits attributed | Zero benefits attributed |
| Other countries | There are, in theory, benefits for other countries, but there is no evidence of adoption of results from this project in other countries, so these benefits are considered to be zero here. | Zero benefits attributed | Zero benefits attributed |

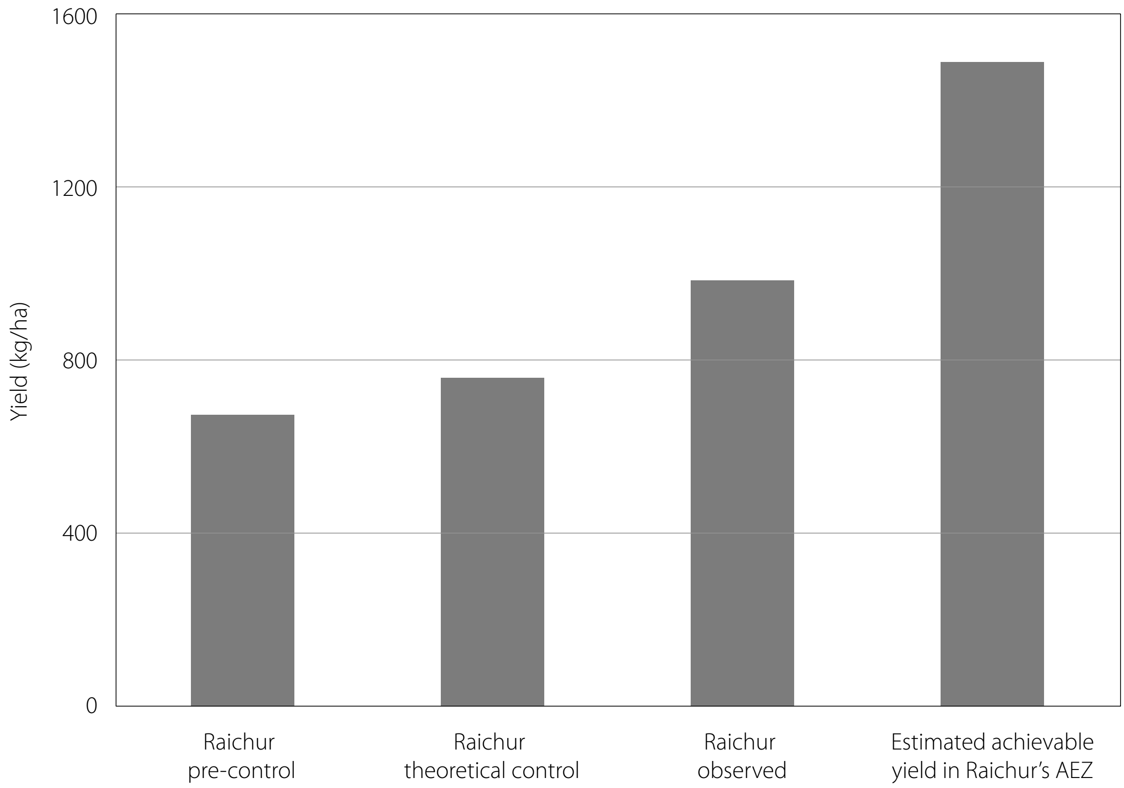



**Figure 5.** Pre- and post-project peanut yields in Raichur. Source: field visits, calculations based on Rogers et al. (2005) and Bhatia et al. (2006).

Before the research in this project the yields obtained in Raichur were 46% of their potential. It can be seen that solving just the white-grub problem would have improved these yields to the extent that they are now 66% of the potential level. In conjunction with the other practices that have been adopted, the gains from the project mean that the gap between potential yields and actual yields has been closed by 38%.

## Impacts in Australia

While Australia will benefit from the increase in knowledge and the development of international research networks, yield increases will be minimal.

The costs of white-grub damage are much lower in Australia than in India, due partly to the smaller size of the industry here, but also because of differences between the two countries in the biology of the pest. The researchers involved in the project acknowledged this and concluded that, in Australia, 'white grub does not pose a major threat to the peanut industry' (Thyer 2006). In addition, the extent to which white grubs have had an impact has been reduced by means independent of this project, including the introduction of a new peanut cultivar that matures before the pest develops into its most destructive stage.

The increase in knowledge does offer a better understanding of how new developments, notably the new peanut cultivars, have resulted in higher yields, but there have been no changes to farming practices in Australia as a direct result of the research findings.

# 3 Data and methodology

This chapter discusses the data sources and methodology used for this study. The project impacted mainly on an area around Raichur, which is approximately 180 kilometres south-west of Hyderabad in the state of Karnataka. The researchers focused their attention on this area, so this study follows suit.

The data for the study came from field visits to Indian peanut farms (Table 3). These farms were the same farms used for the research and have since continued with the control measures arising from the project. The villages visited had around 526 hectares under peanuts and a total population of around 4,000 people. The total reach of the AMEF programs in the Raichur region goes beyond this, however, and is estimated to cover around 2,100 hectares.

The area under peanuts has been declining in India in recent years in favour of other, more lucrative crops. This decline has not been seen in the Raichur region due to the inability to grow many of these alternative cash crops on a large scale in the dry, sandy soils present in the area. In addition, farmers revealed that the increase in the number of males leaving the area to work in cities has not affected production as they return during the peanut season to harvest their crops. With this in mind, the analysis holds the area under peanut in the Raichur region at a constant level throughout the period under consideration.

## Costs and yields

Farmers in the Raichur region estimate their yields to be between 618 and 741 kilograms per hectare. The yield increases due to the practices adopted as part of the project range from 247 to 371 kilograms per hectare.

Data gathered during field visits showed the current production costs to be around Rs15,790 per hectare. Using the aforementioned yields this gives unit costs in the range Rs25.56–21.30 per kilogram.

**Table 3.** Details of project villages in the Raichur area

| Village | Peanut area | Village population | Farmer groups | Scaled-up area |
|---|---|---|---|---|
| | *ha* | *no.* | *no.* | *ha* |
| Jambaladinni | 121 | 900 | 20 | |
| Murakidoddi | 81 | 700 | 20 | |
| Kanyadoddi | 81 | 500 | 20 | |
| Puchaladinni | 162 | 1,000 | 20 | |
| Midagaladinni | 81 | 800 | 20 | |
| Total | 526 | 3,900 | 100 | 2,100 |

Source: Centre for International Economics field visits

The yield increases from controlling white grub cannot be accurately separated from those coming from the other practices implemented at the same time. The control costs presented here therefore incorporate all aspects of the integrated control measures.

The additional measures include summer ploughing, seed treatment, intercropping, planting of border crops, trap cropping, strip cropping, use of organic materials and increased seeding rates. All up, these costs amount to Rs3,286 per hectare.

The effects of the white-grub control measures on costs are shown in Table 4. Where yields are high and the improvement is also high, the savings amount to Rs8.40 per kilogram. With costs at Rs3,286 per hectare the potential savings could be negative in the low-yield/low-yield-increase scenario. A farmer will not carry out pest control measures if they result in a net loss, so a lower end cost of control is estimated by calculating the control costs that would result in zero savings in this case.

## Adoption

Adoption of the new methods will not happen immediately, rather the level of adoption will increase over time. The researchers focused their efforts on the Raichur area, allowing them to communicate with most farmers in the region. Together with the local NGOs almost half of the farmers in the area learned about the control measures and other techniques in the first year or so of the project. In subsequent years this knowledge spread quite rapidly to the remaining farmers in the region. Discussions with AMEF showed the number of farmers in Raichur not using these new practices was insignificant and has been for some time. In the analysis the adoption profile sees rapid uptake in the first few years before reaching almost 100% in 2001. This is representative of the time it took to perform the research and the dissemination period that followed. The profile used is shown in Figure 6.

## Demand, supply and the change in welfare

Much of the demand for peanuts comes from the growers themselves. Farmers generally form groups to maintain land, and they share the crops. Excess supply is sold at market but this tends to be a small proportion of the overall output and an even smaller proportion of the overall market for peanuts.

The area using the research outputs is also small so their adoption is not likely to have a marked impact on peanut prices. Demand is therefore treated as being completely elastic; that is, the bulk of the extra output will be consumed by the farmers and surplus production will be sent to market at current prices.

The Food and Agricultural Policy Research Institute elasticity database[1] shows the elasticity of supply for peanuts in India to be 0.4. This forms the basis of estimates presented here.

Using the supply and demand curves and the vertical shift in supply resulting from the cost savings, a new equilibrium quantity is calculated. A measure of the benefits of the project can be estimated from this by working out the change in producer surplus (consumer surplus remains unchanged due to the high elasticity of demand).

Figure 7 illustrates the effects of the cost reduction. The supply curve shifts down by the amount $k$ and the equilibrium quantity increases from $Q_1$ to $Q_2$. The producer surplus is increased by the area *abcd*, which can be calculated using the formula:

$$0.5 \cdot k \cdot (Q_1 + Q_2)$$

Table 5 reports the values of $k$, $Q_1$ and $Q_2$ from 1997 through 2015. The value of $Q_1$ reflects the production of peanuts from the area adopting the new measures and varies over time. Similarly, $Q_2$ is the production from these adopters after they obtain the yield increase. After 2015 the adoption rate is close to 1, so the values remain constant from that point forward.

1 Available at <http://www.fapri.iastate.edu/tools/elasticity.aspx>

**Table 4.** Yield and cost information before and after white-grub control

| | Unit | Lower-yield scenario | Upper-yield scenario |
|---|---|---|---|
| Yield information | | | |
| Current yields | *kg/ha* | 618 | 741 |
| Yield increase | *kg/ha* | 247 | 371 |
| Production costs | | | |
| Per hectare | *Rs/ha* | 15,789 | |
| Per kilogram | *Rs/kg* | 21.30 | 25.56 |
| White-grub control costs | | | |
| Per hectare | *Rs/ha* | 2,632 | 3,286 |
| Post-research costs | | | |
| Per kilogram | *Rs/kg* | 17.16 | 21.30 |
| Saving | *Rs/kg* | 0.00 | 8.40 |

Source: Centre for International Economics' estimates

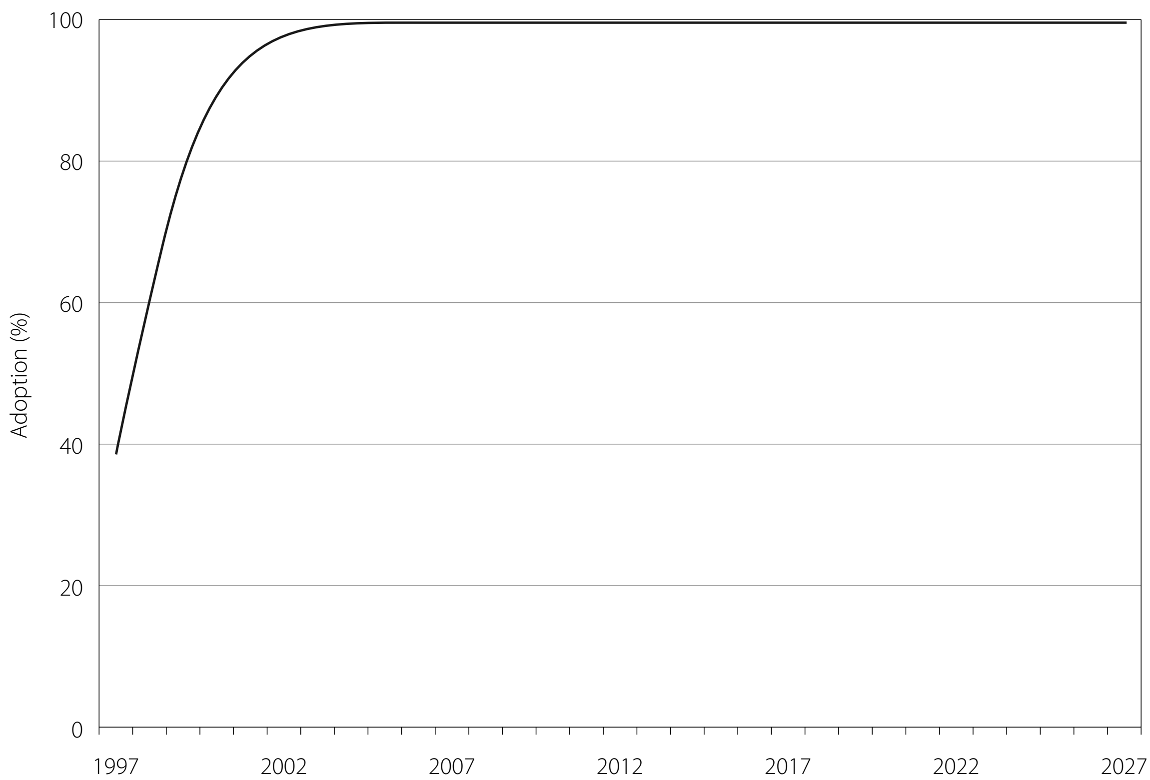



**Figure 6.** Adoption profile for new methods of white-grub control and associated practices. Source: Centre for International Economics' estimates based on field visits and Rogers (2007).

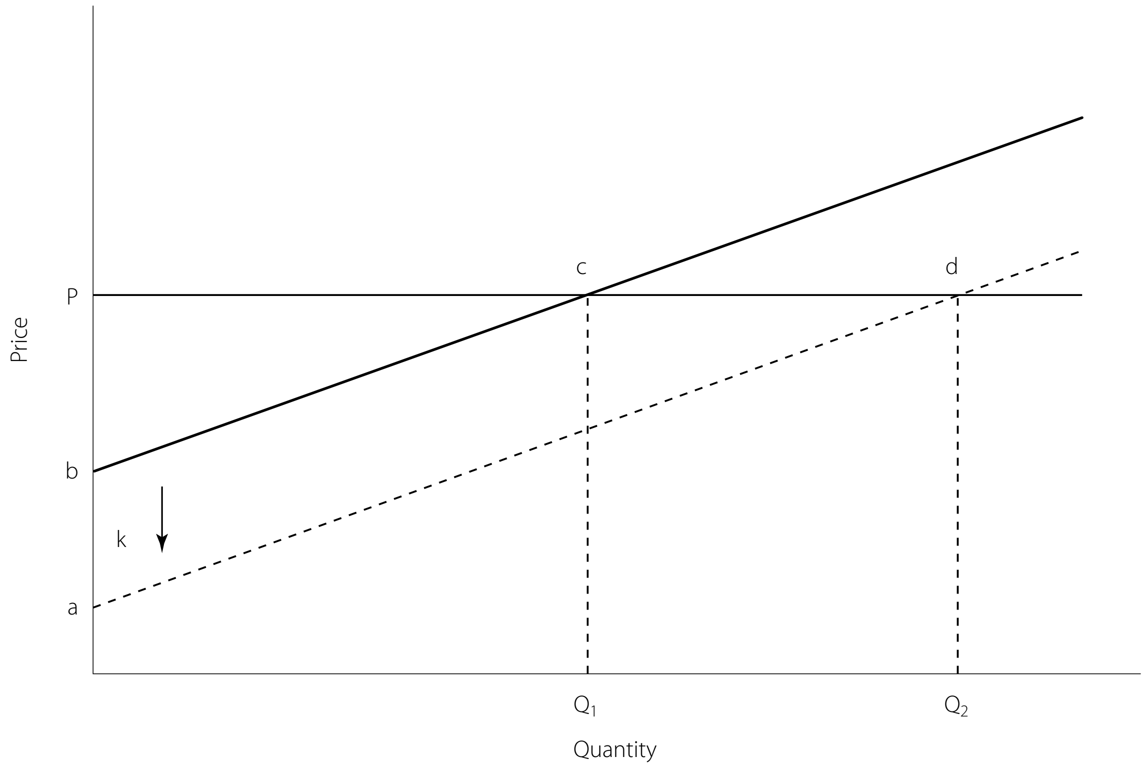



**Figure 7.** Effects of a shift in supply. Source: Centre for International Economics

A surplus for each year is calculated using this method, then discounted, converted to Australian dollars and deflated to constant 2007 dollars. The discount rate applied is 5% per annum while the exchange rates and deflator series (Table 6) are from Gordon and Davis (2007). The exchange rates for pre-1999 years are set to 1999 rates, while post-2006 years are set to 2006.

Table 7 shows the surplus estimates for each year. The nature of the project means that the benefits are constant for each period. After 2027 the values reported are the present value of an annuity for the year 2027 onwards.

The research was funded by the Queensland Department of Primary Industries, the University of Queensland and ACIAR. The costs to AMEF are not included here as we judged that its programs would have proceeded in any case, regardless of the presence or absence of the ACIAR-funded research. Over the 4 years from 1997 to 2000 the initial budget allowed for \$1.04 million expenditure. Due to cost overruns and extensions this budget was increased by \$37,597, or 3.6% of the original budget. No breakdown of additional costs by year is available so the increase is applied evenly across all years according to the original budget. Table 8 shows the budget breakdown, together with the additional costs, deflation and discounting.

Table 9 combines Tables 7 and 8 to arrive at a net benefit value of the project.

**Table 5.** Supply shift and output changes

| Year | k | $Q_1$ | $Q_2$ |
|---|---|---|---|
| | *Rs* | *tonnes* | *tonnes* |
| 1997 | 4.46 | 556,669 | 609,039 |
| 1998 | 4.46 | 873,032 | 955,163 |
| 1999 | 4.46 | 1,135,368 | 1,242,179 |
| 2000 | 4.46 | 1,293,380 | 1,415,056 |
| 2001 | 4.46 | 1,370,953 | 1,499,926 |
| 2002 | 4.46 | 1,405,219 | 1,537,416 |
| 2003 | 4.46 | 1,419,645 | 1,553,199 |
| 2004 | 4.46 | 1,425,595 | 1,559,709 |
| 2005 | 4.46 | 1,428,029 | 1,562,372 |
| 2006 | 4.46 | 1,429,021 | 1,563,457 |
| 2007 | 4.46 | 1,429,424 | 1,563,899 |
| 2008 | 4.46 | 1,429,589 | 1,564,078 |
| 2009 | 4.46 | 1,429,655 | 1,564,151 |
| 2010 | 4.46 | 1,429,682 | 1,564,181 |
| 2011 | 4.46 | 1,429,693 | 1,564,193 |
| 2012 | 4.46 | 1,429,698 | 1,564,198 |
| 2013 | 4.46 | 1,429,700 | 1,564,200 |
| 2014 | 4.46 | 1,429,701 | 1,564,201 |
| 2015 onwards | 4.46 | 1,429,701 | 1,564,201 |

Source: Centre for International Economics' estimates based on data from field visits

**Table 6.** Deflator series and exchange rates

| Year | Deflator | Exchange rate (Rs/A$) |
|---|---|---|
| 1997 | 75.12 | 26.99 |
| 1998 | 75.52 | 25.93 |
| 1999 | 75.91 | 27.79 |
| 2000 | 79.06 | 26.13 |
| 2001 | 82.19 | 24.42 |
| 2002 | 84.29 | 26.44 |
| 2003 | 86.96 | 30.33 |
| 2004 | 89.88 | 33.37 |
| 2005 | 93.94 | 33.68 |
| 2006 | 97.53 | 34.13 |
| 2007 | 100.00 | 34.13 |

Source: International Monetary Fund data in Gordon and Davis (2007)

**Table 7.** Producer surplus estimates

| Year | Producer surplus | Producer surplus | Deflated surplus | Discounted surplus |
|---|---|---|---|---|
| | *Rs ($m)* | *$m* | *$m* | *$m* |
| 1997 | 2.60 | 0.10 | 0.13 | 0.13 |
| 1998 | 4.08 | 0.16 | 0.21 | 0.20 |
| 1999 | 5.30 | 0.19 | 0.25 | 0.23 |
| 2000 | 6.04 | 0.23 | 0.29 | 0.25 |
| 2001 | 6.40 | 0.26 | 0.32 | 0.26 |
| 2002 | 6.56 | 0.25 | 0.29 | 0.23 |
| 2003 | 6.63 | 0.22 | 0.25 | 0.19 |
| 2004 | 6.66 | 0.20 | 0.22 | 0.16 |
| 2005 | 6.67 | 0.20 | 0.21 | 0.14 |
| 2006 | 6.68 | 0.20 | 0.20 | 0.13 |
| 2007 | 6.68 | 0.20 | 0.20 | 0.12 |
| 2008 | 6.68 | 0.20 | 0.20 | 0.11 |
| 2009 | 6.68 | 0.20 | 0.20 | 0.11 |
| 2010 | 6.68 | 0.20 | 0.20 | 0.10 |
| 2011 | 6.68 | 0.20 | 0.20 | 0.10 |
| 2012 | 6.68 | 0.20 | 0.20 | 0.09 |
| 2013 | 6.68 | 0.20 | 0.20 | 0.09 |
| 2014 | 6.68 | 0.20 | 0.20 | 0.09 |
| 2015 | 6.68 | 0.20 | 0.20 | 0.08 |
| 2016 | 6.68 | 0.20 | 0.20 | 0.08 |
| 2017 | 6.68 | 0.20 | 0.20 | 0.07 |
| 2018 | 6.68 | 0.20 | 0.20 | 0.07 |
| 2019 | 6.68 | 0.20 | 0.20 | 0.07 |
| 2020 | 6.68 | 0.20 | 0.20 | 0.06 |
| 2021 | 6.68 | 0.20 | 0.20 | 0.06 |
| 2022 | 6.68 | 0.20 | 0.20 | 0.06 |
| 2023 | 6.68 | 0.20 | 0.20 | 0.06 |
| 2024 | 6.68 | 0.20 | 0.20 | 0.05 |
| 2025 | 6.68 | 0.20 | 0.20 | 0.05 |
| 2026 | 6.68 | 0.20 | 0.20 | 0.05 |
| 2027[a] | 6.68 | 0.20 | 0.20 | 3.91 |

[a] The discounted surplus value shown in 2027 is the present value of an annuity for the benefits arising from 2027 onwards.

Note: Deflated values are in 2007 dollars.

Source: Centre for International Economics' estimates

**Table 8.** ACIAR Project CS2/1994/050 budget

| Year | Original budget | Additional funds | Total | Deflated | Discounted |
|---|---|---|---|---|---|
| | $ | $ | $ | $ | $ |
| 1997 | 210,840 | 7,624 | 218,464 | 290,819 | 290,819 |
| 1998 | 305,195 | 11,035 | 316,230 | 418,737 | 398,797 |
| 1999 | 250,220 | 9,047 | 259,267 | 341,546 | 309,792 |
| 2000 | 273,541 | 9,891 | 283,432 | 358,502 | 309,688 |
| Total | 1,039,796 | 37,597 | 1,077,393 | 1,409,604 | 1,309,096 |

Note: Deflated values are in 2007 dollars.

Source: ACIAR project documentation

**Table 9.** Total net benefit flows from ACIAR Project CS2/1994/050

| Year | Discounted benefits | Costs | Net benefits | Cumulative net benefits |
|---|---|---|---|---|
| | $ | $ | $ | $ |
| 1997 | 0.13 | 290,819 | –0.16 | –0.16 |
| 1998 | 0.20 | 398 797 | –0.20 | –0.36 |
| 1999 | 0.23 | 309,792 | –0.08 | –0.44 |
| 2000 | 0.25 | 309,688 | –0.06 | –0.50 |
| 2001 | 0.26 | | 0.26 | –0.24 |
| 2002 | 0.23 | | 0.23 | –0.01 |
| 2003 | 0.19 | | 0.19 | 0.18 |
| 2004 | 0.16 | | 0.16 | 0.34 |
| 2005 | 0.14 | | 0.14 | 0.48 |
| 2006 | 0.13 | | 0.13 | 0.61 |
| 2007 | 0.12 | | 0.12 | 0.73 |
| 2008 | 0.11 | | 0.11 | 0.84 |
| 2009 | 0.11 | | 0.11 | 0.95 |
| 2010 | 0.10 | | 0.10 | 1.06 |
| 2011 | 0.10 | | 0.10 | 1.15 |
| 2012 | 0.09 | | 0.09 | 1.25 |
| 2013 | 0.09 | | 0.09 | 1.34 |
| 2014 | 0.09 | | 0.09 | 1.42 |
| 2015 | 0.08 | | 0.08 | 1.51 |
| 2016 | 0.08 | | 0.08 | 1.58 |
| 2017 | 0.07 | | 0.07 | 1.66 |
| 2018 | 0.07 | | 0.07 | 1.73 |
| 2019 | 0.07 | | 0.07 | 1.79 |
| 2020 | 0.06 | | 0.06 | 1.86 |
| 2021 | 0.06 | | 0.06 | 1.92 |
| 2022 | 0.06 | | 0.06 | 1.98 |
| 2023 | 0.06 | | 0.06 | 2.03 |
| 2024 | 0.05 | | 0.05 | 2.08 |
| 2025 | 0.05 | | 0.05 | 2.13 |
| 2026 | 0.05 | | 0.05 | 2.18 |
| 2027[a] | 3.91 | | 3.91 | 6.09 |

[a] The value shown in 2027 is the present value of an annuity for the benefits arising from 2027 onwards.

Source: Centre for International Economics' estimates

# 4 Results

Not all of the benefits can be attributed to the research but they can be attributed to the project. Figure 5 shows that actual yield increases exceeded the gains that were expected from control of white grubs. The additional gains arose due to the researchers collaborating with local NGOs to promote the control measures that provided a catalyst for the adoption of other yield-enhancing, farm management practices. Had the research not been undertaken it is unlikely these additional gains would have been realised.

The benefits to Australia are qualitative. The research has not changed farming practices, nor has it led to changes in white-grub management. What it has done, however, is enhance the existing body of knowledge on white-grub biology and ecology and offer insights into why other farming practices have resulted in yield changes. In the South Burnett region of Queensland, for example, planting of new peanut cultivars that mature in around 15 weeks has started. These plants mature before the white grub enters the most damaging stages of its life cycle, thus giving higher yields. Before the research it was not known when the white grub caused the greatest damage, so the better understanding brought by the research has enabled an improvement in production.

In the adoption study report commissioned by ACIAR (Rogers 2007) it is noted that it is possible, for the first time, to estimate the losses to the Australian industry caused by white-grub infestations. The estimates of yield reductions per white grub, combined with survey data from the region, gave estimates of losses of between $567,000 and $823,000 per year, depending on the season. It should be noted that the research did no more than allow this figure to be calculated; it played no role in reducing the damage. The perceived impacts of this are insignificant in that no change in behaviour has occurred, so no benefits have been attributed.

The expected impacts from the project have been quantified and are detailed in Table 10. Some $1.3 million was invested in the research for the project and this yielded $7.4 million in benefits. The benefit:cost ratio for the project is thus 5.7:1. The internal rate of return is 29%.

## Sensitivity analysis

The benefits outlined in Table 10 depend on the inputs to the model. As recommended by Gordon and Davis (2007), the robustness of the results is tested at different discount rates. The starting yields, yield improvements and white-grub control costs are also varied.

Table 11 shows the sensitivity of the results to changes in the discount rate. Using a discount rate of 1%, the benefits and costs increase to $25.1 million and $1.4 million, respectively, giving $23.7 million in net benefits and a benefit:cost ratio of 18.1:1. Increasing the discount rate to 10% reduces the net benefits to $3 million and gives a benefit:cost ratio of 3.5:1.

**Table 10.** Benefits and costs of ACIAR Project CS2/1994/050

| | | |
|---|---|---|
| Benefits to India | *$m* | 7.4 |
| Benefits to Australia | *$m* | 0.0 |
| Total benefits | *$m* | 7.4 |
| Total costs | *$m* | 1.3 |
| Net benefits | *$m* | 6.1 |
| Benefit:cost ratio | *Ratio* | 5.7 |
| Internal rate of return | *%* | 29 |

Source: Centre for International Economics' estimates

**Table 11.** Sensitivity of ACIAR Project CS2/1994/050 benefits and costs to the discount rate applied

| | | 1% | 5% | 10% |
|---|---|---|---|---|
| Benefits | *$m* | 25.1 | 7.4 | 4.2 |
| Costs | *$m* | 1.4 | 1.3 | 1.2 |
| Net benefits | *$m* | 23.7 | 6.1 | 3.0 |
| BCR | *Ratio* | 18.1 | 5.7 | 3.5 |

Source: Centre for International Economics' estimates

Current yields are estimated to be between 618 and 741 kilograms per hectare, and the yield increase consequent on the application of the control method may vary between 247 and 371 kilograms per hectare. Clearly, this will impact on the range of benefits from the research. Furthermore, the cost of the control measure, estimated at Rs3,286 per hectare, may lead to losses for some farmers. In the low-yield, low-improvement scenario, the most a farmer would be willing to pay would be Rs2,632 per hectare, so the results are tested for sensitivity to changes in this variable as well.

Applying these ranges in a triangular distribution gives a 95% confidence interval for the net benefits of $0.8 million through to $10.0 million. The probability distribution is roughly normal, as shown in Figure 8.

Using the same input ranges sees the benefit:cost ratio vary between 1.6:1 and 10.2:1. Certain combinations of the input parameters mean the internal rate of return cannot be defined so it is not tested for sensitivity.

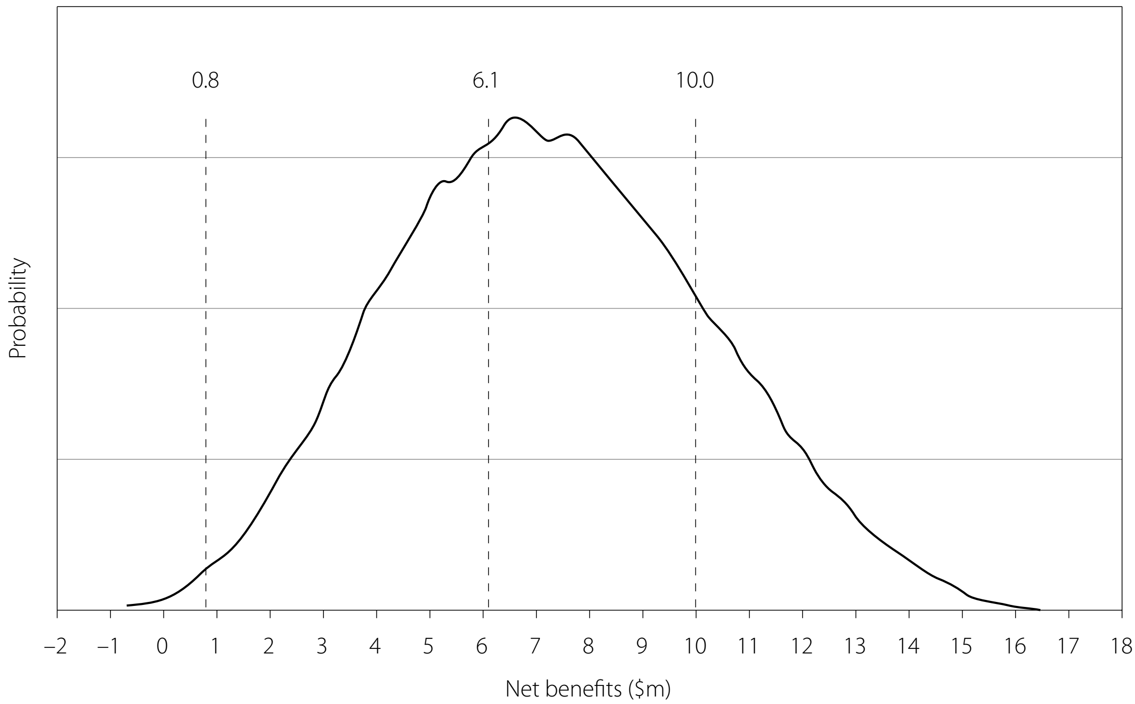



**Figure 8.** Distribution of ACIAR Project CS2/1994/050 net benefits. Source: Centre for International Economics' estimates.

## Estimating benefits beyond Raichur

White grubs present problems throughout arid and semi-arid areas of peninsular India. It is highly likely that the benefits seen in the Raichur region could be extended to other parts of India if these areas adopted the control measures. The NGOs actively promoting the control measures and other practices in the Raichur region do not have the resources to extend their work beyond the areas they currently work in. Nevertheless, their opinion is that many other areas could benefit in similar ways. Despite this they have no knowledge of other organisations working to promote the research findings elsewhere and we were unable during field visits to find any evidence of such adoption. It is therefore inappropriate to extrapolate the results presented here to other parts of India.

Aside from the lack of adoption evidence, assuming the same sorts of yield gains in other regions would be inappropriate, as the gains found in Raichur depend on local conditions there—including rainfall levels, soil types and other environmental variables.

In principle, the finding that there is an economically significant benefit from controlling white grubs may also be applicable in other parts of the world. Vietnam and some parts of Africa stand out as being the most likely locations for benefits to arise. However, there is no evidence of such benefits accruing as a direct result of this project.

# 5 Conclusions

ACIAR project CS2/1994/050, *Management of white grubs in peanut-cropping systems in Asia and Australia*, is unique in a number of ways. Rather than being a purely research-based project it aimed to integrate various results of existing research, and develop practical applications using these findings. It also acted as a catalyst in terms of promoting more sustainable farm management practices. The benefits captured in this report include some that have not arisen directly from the research but were born of a partnership with other organisations. This partnership enabled ideas from the research to be communicated to farmers together with improved farming practices, effectively leveraging the return to the project.

The benefits are fairly localised but offer a good example of how an extension program can add value to a research project. Although the project added to the body of knowledge surrounding white-grub biology and ecology it appears the main source of success is the way the researchers worked with local organisations to promote the spread of ideas and techniques.

The local NGOs that have continued to disseminate the project findings in the region largely do so because this complements their existing work. The white-grub control measures sit well with the set of improved farm management practices already being communicated to the farmers.

Indeed, the key lessons from this project are:

- the importance of on-the-ground extension activities to achieve real benefits from research on the one hand, and
- the difficulty in achieving such extension work on the other.

The project most likely would not have generated benefits without the solid and long-term efforts of the extension agency (in this case an NGO) involved. Hands-on extension is particularly important in the marginal areas of India where many farmers are illiterate and there are no other means of transmitting research findings.

The extension work must be ongoing and committed, and should not be viewed as being an automatic or inevitable consequence of producing results from sound scientific research.

# References

Bhatia V.S., Singh P., Wani S.P., Kesava Rao A.V.R. and Srinivas K. 2006. Yield gap analysis of soybean, groundnut, pigeonpea and chickpea in India using simulation modeling. Global Theme on Agroecosystems Report No. 31. International Crops Research Institute for the Semi-Arid Tropics: Patancheru 502 324, Andhra Pradesh, India.

Gordon J. and Davis J. 2007. ACIAR impact assessment, guidelines for practitioners. ACIAR: Canberra.

Rogers J. 2007. Management of white grubs in peanut cropping systems in Asia and Australia (CS2/1994/050). Pp. 23–29 in 'Adoption of ACIAR project outputs, studies of projects completed in 2002–2003', ed. by J. Gordon and J. Davis. ACIAR: Canberra.

Rogers J., Ward A. and Wightman J. 2005. Damage potential of two scarab species on groundnut. International Journal of Pest Management 51, 305–312.

Thyer R. 2006. Peanuts without poison. Partners in Research for Development, Winter 2006, 6–7. ACIAR: Canberra.

Yadava C.P.S. 1998. Latest implementable technological options for white grub management in India. In: 'Ecofriendly management of white grub and leaf miner pests of groundnut, proceedings of a diagnostic workshop, 8–9 October 1997', ed. by J.A. Wightman, H. Lanting and R. Devi Kolli. AME Foundation: Bangalore.

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Impact of improved management of white grubs in peanut-cropping systems in India





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