From: Corbishley, J. and Pearce, D., *Growing trees on salt-affected land*.
ACIAR Impact Assessment Series Report No. 51, July 2007

Growing trees on salt-affected land

IMPACT ASSESSMENT SERIES **51**

Australian Government
Australian Centre for International Agricultural Research

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Growing trees on salt-affected land

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July 2007

Australian Government
Australian Centre for International Agricultural Research

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

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

In order to monitor the effects of its projects, ACIAR commissions independent assessments of selected projects. This series reports the results of these independent studies.

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Foreword

Salinity and waterlogging are significant problems in a wide range of agricultural areas throughout the world. Australia, Pakistan and Thailand have disproportionately large areas affected by salinity.

In Pakistan especially, significant areas of agriculture have been or are close to being abandoned due to salinity. Hydrological and chemical methods of land reclamation can be effective but are usually found to be very expensive and not financially feasible.

It has been found that there are Australian trees, such as species in the genera *Eucalyptus* and *Acacia*, that are adapted for not just surviving but thriving in these types of environments. Bioremediation using such trees has therefore often been suggested as a potentially lower-cost alternative to physical methods, and there are Australian scientists who have a comparative advantage in this area of research.

The Australian Centre for International Agricultural Research (ACIAR) has funded a series of research activities in this area, including project FST/1993/016, 'Tree growing on salt-affected land in Pakistan, Thailand and Australia', the subject of this report. The project was selected for impact assessment this year as part of a random-sampling process, rather than being identified as an obviously successful project with a high rate of return.

The impact-assessment study has found that, although the research clearly demonstrated that growing short-rotation trees can result in reclamation of abandoned land, adoption of the outcomes has not been high. To date, only 7,000 ha in Pakistan and 5,000 ha in Thailand have been treated. Moreover, the adoption was directly tied to development assistance provided by aid donors or the partner-country governments. Little privately funded farmer adoption was found.

The gross welfare gains from adoption of the strategies developed were found to be high (a present value of around A$300 million for the study areas). However, the development costs and relatively long investment periods before receiving a return mean that the net gains are low.

The overall results of the impact assessment study show that the return on the research investment was positive but relatively low. The net present value of research benefits was A$2.4 million, with a benefit:cost ratio of 1.12:1 and an internal rate of return of 5.7%. While this is significantly lower than many other areas of technology-oriented research activities, it is not uncommon to find that environmental research does not have high rates of return. This is often due to the long lags in achieving impacts.

Peter Core
Director
ACIAR

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Summary

High levels of salt and a watertable close to the surface reduce the productivity of land, in some cases rendering it useless, with agricultural yields insufficient to induce farmers to undertake further work. In Pakistan and Thailand, salinity has resulted in significant areas of land on the fringe of productivity or completely abandoned.

Beginning in 1989, ACIAR funded a series of research activates examining the feasibility of bio-agriculture approaches to reducing the impact of salinity. One of these, beginning in 1994, was ACIAR project FST/1993/016, 'Tree growing on salt-affected land in Pakistan, Thailand and Australia'. This and other projects focused on selecting appropriate Australian tree species to grow on saline and waterlogged land.

This report provides an economic impact assessment of this series of research, specifically focused on project FST/1993/016, but also including the benefits generated by the related research. Project FST/1993/016 was initially randomly selected for evaluation as part of a broader study into the returns from ACIAR-funded research.

Adoption of the research findings has been limited. To date, 7,000 hectares in Pakistan and 5,000 hectares in Thailand have been treated. This has led to a gross benefit of $23.2 million (using a discount rate of 5% over 50 years).

Including total ACIAR research costs and the follow-on development costs (together coming to $20.8 million), the total net benefit is $2.4 million, implying a benefit:cost ratio of 1.12 (at a 5% discount rate) and an internal rate of return of 5.7%.

These findings illustrate that the sort of very long-term environmental remediation that this ACIAR-funded research was concerned with—where there is little incentives for the farmers to adopt the findings without further subsidies—generates a relatively low rate of return to the initial investment.

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1 Introduction

Salt-affected land is a major problem across many parts of the world. Soil salinity, sodicity, waterlogging and combinations of these have rendered large tracts of land largely unproductive for agricultural purposes, and the problem is growing. This is particularly so in Australia, Pakistan and Thailand. Improving the prospects for production on such land is considered to have potential for improving farm incomes.

To that end, the Australian Centre for International Agricultural Research (ACIAR), as part of its forestry program, funded a project in Pakistan and Thailand that aimed to reduce the negative consequences from salt-affected land. Between 1994 and 1997, project FST/1993/016, 'Tree growing on salt-affected land in Pakistan, Thailand and Australia', predicted growth opportunities of selected *Eucalyptus* and *Acacia* tree species through the use of scientific calculations and tree plantings on trial sites. Adding to the knowledge base available, the project worked with farmers and land managers to mitigate and transform otherwise unproductive land to land again viable for agricultural production.

This report provides an economic impact assessment of that ACIAR project and other closely related ACIAR projects and development activities. In contrast to most impact assessments, the project was not chosen on the basis of a prior expectation of significant benefits, but by a random selection process as set out in Pearce et al. (2006).

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2 Salinity in Pakistan, Thailand and Australia

Salinity is a worldwide problem, with more than 3% of the world's total land mass affected by salinity and over half the world's countries having at least some quantity of land affected. The impact on rural livelihoods is significant.

Salinity is a problem

Saline soil occurs naturally on low-lying sites and is caused by accumulation of free salts in the soil profile. Typically, it is a problem of the semiarid and arid zones of the world, with the majority of countries affected by salinity being in a broad belt extending from the African Sahara through the Middle East and into central Asia.

It is widespread…

Globally, there are over 4,000,000 square kilometres affected to some degree by salinity (FAO 2006). The impact on particular countries is far from even: Djibouti stands out with almost 50% of its total land affected by salinity. Note that these figures are total salinity, not just human-induced salinity.

On average, almost 6% of all land in the Asia–Pacific region is affected to some extent by salinity (Figure 1).

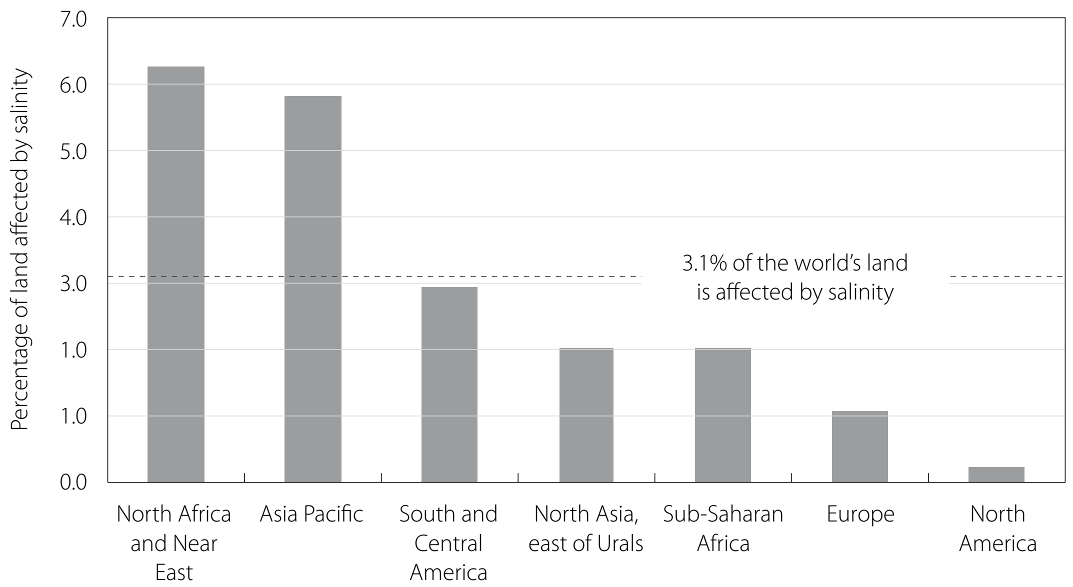

Figure 1. Salinity is a major international problem. Source: FAO (2006)

Australia, Pakistan and Thailand—the three project countries—have disproportionately high areas of saline land. Together they account for 6.8% of the world's land mass, but have over 10% of the world's land affected by salinity (Figure 2).

In terms of absolute size affected, Australia ranks third-largest with 254,000 square kilometres of land affected, Pakistan eighth and Thailand forty-fifth (FAO 2006).

It reduces incomes…

Salinity imposes direct economic costs through reduced crop yields and the halt to production on abandoned land, and indirect costs through the substitution away from the most economically efficient crop into other, less-profitable crops.

In Pakistan, salinity is one of the country's most serious environmental problems, caused by human-induced soil erosion and long-term mismanagement of irrigation. Of the 25% of all irrigated land affected by some level of salinity, approximately 1.4 million hectares of all agricultural land has now been abandoned (World Bank 2006a).

The total annual cost of crop losses from salinity in Pakistan have been estimated at between 15 and 55 billion rupees (Rs) (A$340 million to A$1.2 billion) per year. This is in addition to the Rs15 billion (A$340 million) estimated to have been lost from the land that has been rendered unproductive. Taking the average cost of reduced yields as Rs35 billion (A$790 million) per year, the costs of salinity in Pakistan are equivalent to 0.6% of gross domestic production in 2004 (World Bank 2006a; authors' calculations).

In Australia, dryland salinity adversely affects agricultural or pastoral yields on approximately 3.3 million hectares, while another 5.7 million hectares are considered to be 'at risk'.

The economic impact of salinity and soil-health problems in Australian agriculture has been estimated at approximately A$200 million per year in 2000, increasing to A$300 million by 2020. This measure considers only the yield gap; that is, the difference between agricultural profits with and without soil health. The off-farm impacts have been estimated to be as high as A$90 million a year, increasing to A$150 million per year by 2020. In present value terms, the on-farm and off-farm effects over the 20 years are estimated to cost Australia around A$2.5 billion and A$1.3 billion, respectively (NHT 2002).

While imposing a significant cost, reclamation of saline soils is generally uneconomic or impractical, owing to the cost or unavailability of non-saline water. At the same time, schemes to reclaim highly saline soils are costly, resulting in most affected land becoming economically unviable. Mildly saline soils can be used for salt-tolerant crops.

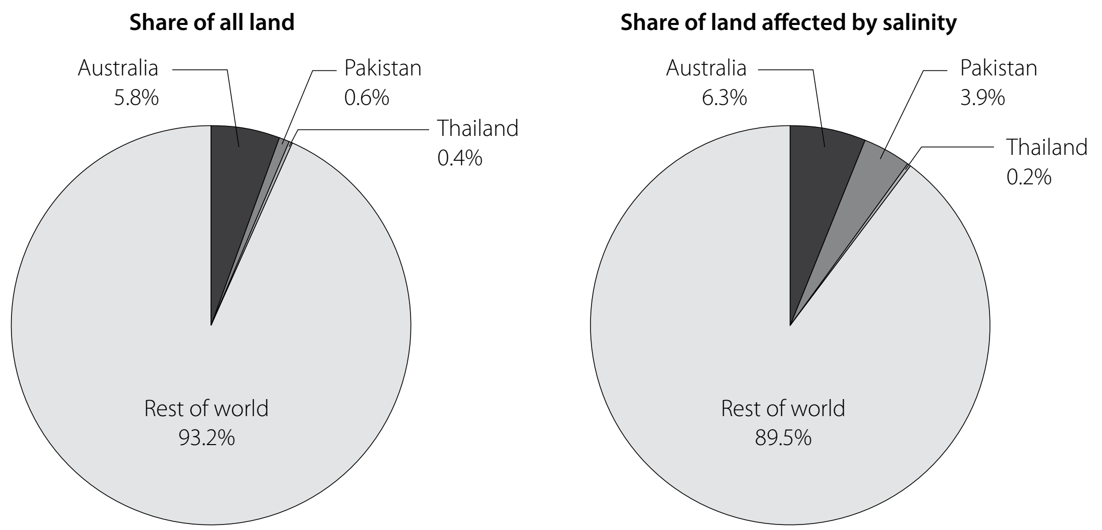

Figure 2. Australia, Pakistan and Thailand are disproportionately affected by salinity. Source: FAO (2006)

It may contribute to poverty

Consistent with the make-up of global poverty, rural areas in Pakistan and Thailand have higher rates of poverty than their urban counterparts. While both rural and urban rates of poverty have been falling through time, rural poverty rates are approximately 13 percentage points higher than urban poverty rates for both countries (Figure 3).

While rural poverty levels are falling, a worsening salinity problem may increase the discrepancy between rural and urban poor. Potentially, any reduction in the incidence and impact that salinity has on agriculture will reduce rural poverty rates. This is because the poor tend to be more vulnerable to the effects of air and water pollution, and end up bearing a disproportionately high impact of environmental degradation in the form of lower crop yields and reduced productivity of agricultural land (ADB 2002). This disproportionately high burden is further magnified by the higher rates of rural poverty. For example, despite the southern Punjab region (centred around the divisions of Multan, Dera Ghazi Khan and Bahawalpur) having Pakistan's highest cultivated area per capita and 100% irrigation, it is still one of the poorest in the country, with a rural poverty rate of almost 40% in 1999 (ADB 2002).

Saline agriculture is an effective method of reducing the impact of salinity

There are a range of approaches to reclaiming and rejuvenating land affected by salinity, although the specific approach required differs according to soil type (Box 1).

In general, however, the range of treatment options includes:

- hydrological approaches using physical drains to reduce water levels and through that reduce salinity levels in discharge zones
- physical reclamation methods such as deep ploughing or drilling vertical holes in the soil to open it up and improve soil permeability
- chemical approaches including the addition of chemicals and organic matter (compost, manure) to change soil composition

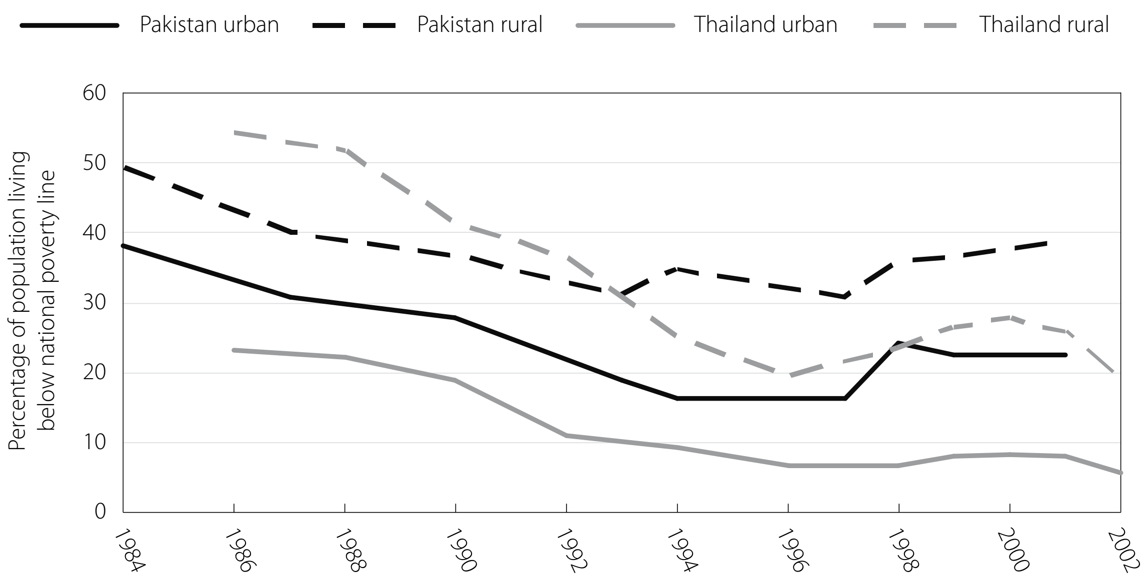

Figure 3. While falling, rural poverty exceeds urban poverty in Pakistan and Thailand.
Sources: ADB (2002), NESDB (2004), World Bank (2004)

- biological reclamation and saline agriculture, involving the cultivation of salt-tolerant plant species that both change the soil type as well as provide farm income during the treatment phase with produce output either sold for fuel or used to feed livestock.

While hydrological and chemical methods are effective at improving soil conditions, they are generally more expensive than using saline agriculture to treat degraded and abandoned land affected by waterlogging (DMC 2002). Saline agriculture, however, requires that salt-tolerant and other appropriate species be previously identified as suitable for particular environments. It has been found that Australian tree species such as the eucalypts and acacias are, to a large extent, adapted to not just survive but to thrive in these environments, giving Australian scientists a relative international advantage in salinity-alleviation research.

There are a number of elements that need to be considered and trials must be conducted to determine the appropriateness of a particular species in a particular region. This ranges from climatic conditions to water use and salinity tolerance.

It is this research that ACIAR funded as part of the 'Tree growing on salt affected land' project in the mid 1990s.

Box 1. Characteristics of salt-affected soils

Saline soils

These soils contain soluble salts in such quantity that they interfere with the growth of most crop plants. The salts present in saline soils consist mainly of neutral salts, such as chlorides and sulfites of sodium, calcium and magnesium.

The negative impact on plant growth is almost always directly related to total salt concentration, and is largely independent of the type of salts present. Plants that do manage to survive in saline soils are identifiable by their stunted growth and sometimes considerable variability in plant size within a field. With saline soils, foliage is often a deep green colour with possible tip-burn on leaves.

Saline-sodic soils

Saline-sodic soils contain sufficient quantities of both soluble salts and absorbed sodium, which reduces the yield of plant growth.

Where soils lack gypsum, leaching causes the soil to become sodic and strongly alkaline, with a pH above 8.5. This results in the soil being unfavourable for the entry and movement of air and water vital for tillage and plant growth.

Sodic soils

Sodic soils contain sufficient exchangeable sodium to interfere with the growth of the majority of crop plants. As the proportion of exchangeable sodium increases, the soil tends to become dispersed and less permeable to water. These soils are usually plastic and sticky when wet and form large clods on drying. Their crusting tendency is a hazard to seedling emergence and accounts for a poor stand of crops, reducing yield.

Waterlogged soils

Soils are considered waterlogged when the watertable fluctuates within the crop or plant root zone for a period long enough to affect plant germination. Typically, when the water table reaches within 1.5–2 metres of the ground surface, the soils are considered waterlogged or potentially waterlogged. Waterlogged soils can be saline, saline-sodic and sodic soils.

Source: DMC (2002)

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3 The ACIAR project

With salinity affecting the agricultural sectors in Pakistan and Thailand, both of them developing countries, and Australia, ACIAR recognised the possibility of benefits from better managing and rejuvenating salt-affected land and the potential contribution to the alleviation of poverty.

Tree growing on salt-affected land

In 1993, ACIAR began funding for project FST/1993/016, 'Tree growing on salt affected soils in Pakistan, Thailand and Australia'.

The CSIRO Division of Forestry and Forest Products was commissioned by ACIAR to implement the project, which was led by Dr Nico Marcar of CSIRO. The collaborating organisations in the partner countries were:

- the Nuclear Institute for Agriculture and Biology (Pakistan)
- the Atomic Energy Agricultural Research Centre (Pakistan)
- the University of Karachi
- the Department of Land Development (Thailand).

The project ran from January 1993 until June 1997, and was aimed at:

- providing an increased range of tree and shrub species for planting on salt affected sites in Pakistan, Thailand and Australia to provide fuel wood and other wood products
- defining appropriate establishment techniques for different species under a range of environmental conditions.

The project was mainly focused on Pakistan, with work trial sites also implemented in north-east Thailand and Australia.

Flow-on and related activities

The project's work was not undertaken in isolation; related projects both preceded and followed it.

This is a crucial point. 'Tree growing on salt-affected land' was one project in a chain of activities funded by ACIAR and others for the rehabilitation of salt-affected land in Pakistan and Thailand. Beginning in the 1980s, these activities included the following projects:

- 'Forage shrub production from saline and/or sodic soils in Pakistan' (FOG/1986/019), which evaluated halophytic (salt-tolerant) forage species, especially *Atriplex* (saltbush) species, for use in revegetating salt-affected land in Pakistan
- 'Australian woody species for saline sites in Asia' (FST/1986/033), which undertook research into extending the range of salt-tolerant trees and shrubs, and to identify nutritional constraints that limit establishment and early growth on these soils
- 'Forage shrub production from salt-affected soils in Pakistan' (LWR1/1993/002), which undertook analysis into the role of salt-tolerant forage shrubs in small farms of the Punjab and Peshawar valleys and the use of saltbush forage by grazing animals.

The link between this project and others is set out in Figure 4. The development activities set out in Figure 4 involved specific aid funding (by the Australian Agency for International Development (AusAID) and other international agencies) to establish areas of controlled salinity.

Attributing the project gains

As identified, 'Tree growing on salt-affected land' was one of a number of ACIAR and other projects working in this area. As a result, attributing specific benefits from the series of salt-land projects to any specific project is problematic. It may even be that the benefits directly related to 'Tree growing on salt-affected land', measured in terms of improved soil conditions or increased farm incomes, are minimal, with limited land treated during the project with the systems developed. This is typical of research-focused projects, as the research findings and small-scale proof-of-concept work undertaken during the research phase can lead to significant benefits being achieved during the implementation phase. Without the research elements, no gains are possible as the implementation phase would not have been undertaken.

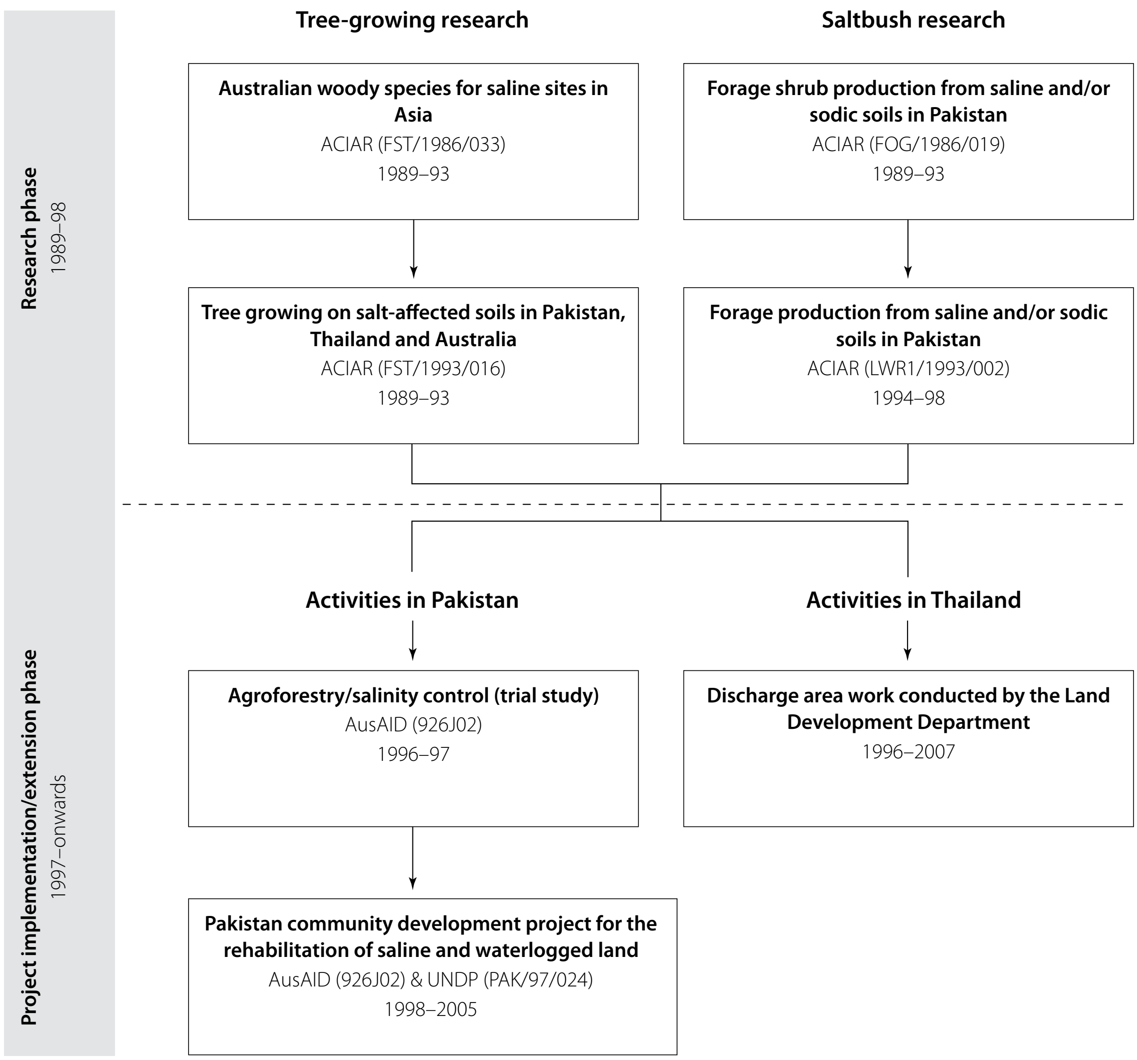

Figure 4. The project 'Tree growing on salt-affected land' is part of a broader research program. Source: Based on discussions with Dr Nico Marcar (CSIRO Australia), Dr Arunee Yuvaniyama (Land Development Department, Thailand) and Mr Ali Hassan Shah (Pakistan Community Development Project, Pakistan)

This is the case with this series of research and implementation activities. Consultations with project managers in Australia, Pakistan and Thailand confirm that the first AusAID and United Nations Development Programme projects went ahead because the scientific viability of the approach had been demonstrated in the ACIAR-funded research. At the same time, the research would not have had any impact without project development subsequently funded by the aid agencies.

Using the attribution guidelines set out in Gordon and Davis (2007), we note the research being examined here is a case where the research and development outputs were necessary but not sufficient to achieve the outcomes. In this case, Gordon and Davis recommend attributing the benefits to the ACIAR-funded research using the share of costs of that research. We adopt this approach by including the total costs of all of the research when calculating the net benefits of the outcomes.

Measuring the impacts

The economic assessment of 'Tree growing on salt-affected land in Pakistan and Thailand' needs to consider the broader impact of the project than simply at the farm level.

This requires identifying the benefits and costs and working from the bottom up to build a model based on fundamental data, and applying the benefits on a per hectare basis to all land treated under the series of projects outlined earlier. This approach requires the establishment of a baseline—the 'without project'. From this, the benefits are calculated as the difference between the baseline and the new 'with project' outcomes.

Inputs

Project funding for 'Tree growing on salt-affected land' was from a range of sources, with roughly half made up from ACIAR funds (Table 1).

Table 1. Costs (nominal $) of project FST/1993/016, 'Tree growing on salt-affected land'

	1993–94	1994–95	1995–96	1996–97
ACIAR expenditure				
Personnel	45,196	101,270	101,704	47,141
Supplies and services	44,850	89,700	33,700	12,350
Travel	28,986	59,550	41,550	26,400
Other	2,000	6,000	6,000	4,000
ACIAR total	121,032	256,520	182,954	89,891
Other support (cash and in-kind)				
Commissioned organisations	58,782	120,698	123,242	62,843
Australian collaborators	26,500	15,000	15,000	7,500
Developing country partners	20,200	37,100	34,800	17,500
Other support total	105,482	172,798	173,042	87,843
Total	226,514	429,318	355,996	177,734

Source: ACIAR (1993)

In addition to the costs associated with the ACIAR project, there are the costs associated with the remaining research and implementation projects in the suite. The total ACIAR and other support costs for the research projects are set out in Table 2.

The implementation project costs for the activities undertaken in Pakistan and Thailand are set out in Table 3.

The information in the Table 1–3 relates to only the research and development phases.

Objectives

The primary objectives of 'Tree growing on salt-affected soils in Pakistan, Thailand and Australia' were:

- to improve the productivity of key tree species on salt-affected land, by
  - identifying superior genetic materials in species, provenances and progeny trials and establish seed orchards for key species
  - further evaluating the effects of nutritional imbalance on plant growth
  - evaluating the impact of improved rhizobia strains on the growth of acacias
  - determining the impact of size and age of seedlings on the response to salt application under controlled conditions
- to determine the water use of key species on salt-affected land
  - by determining daily and annual water use by single trees and plantations of key species, and validating models for predicting water use from tree size, soil and climate variables
  - determining seasonal variation in root-zone soil moisture, salinity and watertable depth beneath plots of key species irrigated with saline water
- to develop a tree and shrub performance database for salt-affected land and provide predictions of growth by
  - collecting, collating and entering trial data from salt-affected sites in Pakistan, Thailand, Australia and other countries into a PC tree-performance database
  - predicting site suitability and potential growth of key species for specific regions in Pakistan, Thailand and Australia using simulation modelling
  - updating the publication 'A bibliography of forage halophytes and trees for salt-affect land: their use, culture and physiology' produced by projects FOG/1986/019 and FST/1986/033 (ACIAR 1996).

Table 2. Funded and in-kind costs (nominal $) for the three other research projects

Financial year	FST/1986/033	FOG/1986/019	LWR1/1993/002	Total cost
1989–90	128,066	130,274		258,340
1990–91	179,915	185,861		365,776
1991–92	121,117	166,216		287,333
1992–93	160,160	180,469		340,629
1993–94	130,141	46,194		176,335
1994–95			246,218	246,218
1995–96			384,375	384,375
1996–97			220,958	220,958
1997–98			149,188	149,188

Source: ACIAR project documents

Outcomes

The overall outcome of the four research projects was an enhanced ability of researchers, land managers and others, particularly in Pakistan but also in Australia and Thailand, to better manage salt-affected land through improved knowledge of appropriate tree and shrub species able to withstand salinity and produce timber that can be used as fuelwood.

Specific, component outcomes were:

- identification and demonstration of the most productive germplasm of proven tree species of *Eucalyptus* and *Acacia* for a variety of salt-affected soils
- refining cultural techniques for optimising tree survival and growth on salt land
- evaluation of water use of trees in saline conditions and their likely impact on shallow, saline water tables
- evaluation of the correct water-management procedures for sustainable tree growing on a variety of salt-affected soils
- development of a greater ability to predict how well a range of tree species and provenances will grow on salt-affected sites in specific regions of Pakistan, Thailand and Australia.

The first and fifth outcomes were the primary contributors to the projects benefits. The identification and demonstration of the most efficient tree varieties to survive on saline soils allows farmers and land managers to implement effective practices to restore land to production.

It needs to be stressed that the outcomes of the research projects themselves result in no uptake of the research findings. This requires specific development activities. Without dissemination of the most appropriate germplasm to grow in saline conditions, no benefit comes from the research activities (ACIAR 1996).

Table 3. Funded and in-kind costs for the development activities in Pakistan and Thailand

Financial year	Agro-forestry / salinity control A$	Pakistan community development project US$	Discharge area work Thai baht	Total cost[a] A$
1996	35,481		25,000,000	1,295,495
1997	35,481		25,000,000	1,106,697
1998		226,307	25,000,000	1,319,940
1999		413,440	25,000,000	1,665,585
2000		533,334	5,000,000	1,158,054
2001		763,874	5,000,000	1,693,524
2002		536,521	5,000,000	1,201,901
2003		611,756	5,000,000	1,128,196
2004		251,031	5,000,000	510,214
2005		128,977	5,000,000	332,350
2006			5,000,000	175,150
2007			5,000,000	168,963

[a] Exchange rate used is the average exchange rate for the period as specified by the IMF International Financial Statistics (1994 and 2006). Future exchange rates have been taken as the average of the 2004, 2005 and 2006 exchange rates.

Note: currency values are in nominal Australian dollars, US dollars and Thai baht.

Sources: AusAID (1999), IWASRI (2005) and based on discussions with Dr Arunee Yuvaniyama (Thailand)

4 Assessing the research impacts

The research outcomes have been used to treat salt-affected land in Pakistan and Thailand. This has had a direct impact on land productivity which, in turn, has had an impact on farm-household incomes and property values, with flow-on benefits to the broader economies of both countries.

The ACIAR-funded research in action

In Pakistan, approximately 5.8 million hectares of agricultural land are salt-affected. Of this area, 2.0 million hectares in the canal command areas have been abandoned due to severe salinity and waterlogged conditions (DMC 2002).

In Thailand, approximately 2.9 million hectares of low-lying land in the Khorat region (north-east Thailand) is saline or saline-sodic to some extent. Of this area, 280,000 hectares is considered extremely saline and has been abandoned. A further 590,000 hectares is moderately saline (LDD 2007).

The findings of the four research projects have enabled farmers and land managers to utilise the identified tree and shrub species to treat marginal and abandoned land. Using Australian eucalypts and acacias, the research activities identified which subspecies have high salt tolerance and are best able to survive in highly waterlogged soils. That is, findings identified particular *Eucalyptus* and *Acacia* subspecies with the capacity to:

- initially survive and thrive in the salt-affected and waterlogged environment
- consume significant quantities of water.

Increases in the quantity of water consumed at the surface can have a direct impact on lowering the watertable. And, as the watertable is lowered, the level of surface salt concentration can be reduced through time, improving productivity (see Box 2). In the interim, or where reductions in the watertable are not possible, income can be derived from using the land to grow eucalyptus and acacia species and selling the harvested wood as fuelwood.

While eucalypts and acacias perform different functions, planting these species is a necessary first step in the reclamation and rejuvenation of otherwise unproductive or marginally productive land.

The uptake of the research

Outside of the aid-funded development activities, there is no evidence to suggest a broader uptake of the research findings, either in Pakistan or Thailand. Thus, for the purposes of the calculations below, the maximum uptake rate is taken as the 6,961 hectares under treatment in Pakistan and the 5,000 hectares under treatment in Thailand (Table 4).

For the *Eucalyptus* species, treatment is based on research findings indicating the success eucalypt plantations have in lowering the watertable by up to 3 metres (DMC 2002). The specific process of reclamation involves planting eucalypts at fixed intervals, generally in 2 metre rows with 2 metres between saplings. These trees are grown for up to 8 years. In addition, tree thinning is undertaken during years 4 and 6, yielding 15% and 25%, respectively, of the final harvest in those years (DMC 2002). Following treatment, based on soil assumptions that salinity is reduced during the tree phase, there is a 10% chance the ground is considered treated and normal crops can be grown (Dr Nico Marcar, CSIRO, pers. comm.).

From the initial planting rates in Table 4 and using rotation lengths, crop thinning and land conversion rates in Pakistan, the first year in which fuelwood is harvested is 2001, while the first in which wheat – seed-cotton rotations are harvested is 2006 (Table 5).

In Thailand, there are two approaches to land treatment. The first involves using acacia trees on severely salinised discharge zones to lower the watertable and reduce salinity. For *Acacia ampliceps*, research findings highlighted the success of the species at surviving in highly saline conditions, though with less impact on the watertable than planting eucalypts. However, rather than actively attempt to lower the watertable and reduce waterlogging, research findings highlighted the attractiveness of using acacia as a

Box 2. Discharge and recharge zones and the watertable

Groundwater is water that is located below the soil surface, as opposed to surface water such as creeks and rivers.

Any point where groundwater has accumulated to the extent that the soil becomes fully saturated with water is considered to be part of the watertable. Generally, the shape of the watertable mimics the contours of the land above, with groundwater on slopes 'flowing' downhill. Soil and rock conditions, as well as the slope and nature of the land contours, will impact on the direction and rate of flow.

It is helpful to consider groundwater in terms of its inputs and outputs. Groundwater levels are replenished from rain and other water sources, absorbed into the soil in recharge zones (an input). Recharge zones are typically found on slopes. This water then flows downhill to basins and flats, and emerges on the surface in the forms of springs and seeps. These are known as discharge zones (an output). Where the watertable has increased to within 2 metres of the surface, the land is considered waterlogged. Lowering the watertable below the root zone is a prerequisite for reclamation of such soils.

With water flowing in from recharge zones, increases in water inflows without any increase in water outflows from the discharge zone will result in the watertable rising. Similarly, removing crops and tree species that consume water has the same effect. As the watertable rises, any salts diluted in the watertable or in the soil above the watertable will be moved closer to the surface. This increases the level of salinity in soils closer to the surface.

Conversely, a lowering of the watertable in a discharge zone means that, in time, natural dilution of the soil from water flowing from the surface to the watertable below (from rain, for example) will result in salt concentration levels being reduced.

Aside from recharge and discharge zones, groundwater can also be extracted biologically and mechanically. The planting of crops and tree species with deep root systems and high water requirements will, through time, lower the watertable (holding all other elements constant), while mechanical pumping of the water from bores will also lower the watertable (assuming the water is consumed on the surface and does not flow back to the watertable).

The exact impact of each of the inputs, outputs, land contours and soil types can be modelled with the help of computer software. This is done by solving a system of equations initially in equilibrium, in response to one or more variables changing. These models are mathematically similar in structure to other system-of-equation models, such as meteorological and economic models.

Table 4. Areas (hectares) of salt-affected land planted with salt-tolerant *Eucalyptus* and *Acacia* species in Pakistan and Thailand

Year	Pakistan	Thailand	
	Eucalyptus camaldulensis	***E. camaldulensis***	***Acacia ampliceps***
1997	0	480	20
1998	870	960	40
1999	1,740	1,440	60
2000	2,610	1,920	80
2001	3,480	2,400	100
2002	4,350	2,880	120
2003	5,220	3,360	140
2004	6,091	3,840	160
2005	6,961	4,320	180
2006	6,961	4,800	200

Sources: IWASRI (2005) and based on discussions with Dr Arunee Yuvaniyama (Land Development Department, Thailand)

Table 5. Area (hectares) of land producing output each year in Pakistan

Year	Eucalyptus plantations in 4th year	Eucalyptus plantations in 6th year	Eucalyptus plantations in 8th year	Land converted to wheat – seed cotton
1997	0	0	0	0
1998	0	0	0	0
1999	0	0	0	0
2000	0	0	0	0
2001	870	0	0	0
2002	870	0	0	0
2003	870	870	0	0
2004	870	870	0	0
2005	870	870	870	0
2006	870	870	870	87
2007	870	870	870	174
2008	870	870	870	261
2009	783	870	870	348
2010	783	870	870	435
2011	783	783	870	522
2012	783	783	870	609
2013 and beyond	783	783	783	696

Source: Centre for International Economics' calculations based on DMC (2002) and discussions with Dr Nico Marcar (CSIRO, Australia) source of fuelwood. These are thus planted for a period of 5 years before harvesting, after which there is a 25% chance the land is suitable for growing traditional crops (based on discussions with Dr Nico Marcar, CSIRO and Dr Arunee Yuvaniyama, Land Development Department, Thailand).

The second approach is to grow eucalypts in conjunction with other crops (agroforestry) on recharge areas. This ensures the productivity of the land maintains its status quo and does not reduce due to salinity, while also allowing other crops to be grown at the same time. For example, eucalypts can be grown along the embankments of, or within, paddy fields to reduce saline groundwater. Under this treatment type, eucalypts are grown for 5 years before harvesting and, during their growth, rice can also be grown and harvested.

Using the initial planting rates in Table 4 and rotation lengths, agroforestry and land conversion rates applying in Thailand, the first year fuelwood is harvested in is 2001, while the first rice crop on converted land is in 2002. Note that land under agroforestry produces rice from the first year (Table 6).

Components of the benefits of the research

It is important to note that, in both Pakistan and Thailand, there are already a number of Australian *Eucalyptus* and *Acacia* species being used on saline and waterlogged land. Thus, the benefits of the project come from two elements:

- the marginal increase in productivity of growing eucalypts and acacias associated with the identification of the most appropriate subspecies
- the improvement in the productivity of land associated with the extension activities discussed in Chapter 3.

Table 6. Area (hectares) of land producing an output each year in Thailand

Year	Eucalyptus plantation	Acacia plantation	Rice harvest area under agroforestry	Rice harvest area on converted land
1997	0	0	480	0
1998	0	0	960	0
1999	0	0	1,440	0
2000	0	0	1,920	0
2001	480	20	2,400	0
2002	480	20	2,880	5
2003	480	20	3,360	10
2004	480	20	3,840	15
2005	480	20	4,320	20
2006	960	35	4,800	25
2007	960	35	4,800	30
2008	960	35	4,800	35
2009	960	35	4,800	40
2010	960	35	4,800	45
2011 and beyond	960	30	4,800	50

Source: Centre for International Economics' calculations based on discussions with Dr Nico Marcar (CSIRO, Australia) and Dr Arunee Yuvaniyama (Land Development Department, Thailand).

This is a crucial point. The improvement in productivity associated with identifying the most appropriate subspecies will yield a welfare gain associated with the gains to both fuelwood and crop production. Furthermore, the development activities will yield a welfare gain (excluding the cost of the development activities) by bringing into production land that was otherwise marginal or abandoned.

In order to quantify the two benefits identified above, it is useful to examine the elements of the project separately. The direct and indirect benefits from applying the research are set out in Table 7.

In order to quantify the net benefits of research, details of the incidence, costs and revenues of each element in Table 7 are required.

Increased fuelwood production

The specific output of the research was to identify specific *Eucalyptus* and *Acacia* species that survive well in saline and waterlogged soils.

The exact size of the productivity improvement differs depending on the location (Pakistan or Thailand) and the trees planted (eucalypts or acacias). Wood yield per unit of area of land for a particular species will vary widely with factors such as seed source, site conditions systems of management (for example, plantation spacing, rotation length and thinning regimes) (ACIAR 1993).

In Pakistan, a possible scenario for *Eucalyptus camaldulensis* grown on waterlogged soils and managed on an 8-year rotation with thinning in year 4 and year 6 will yield 15 cubic metres of wood per hectare per year (ACIAR 1993).

In Thailand, a possible scenario for *Eucalyptus camaldulensis* grown on moderately saline soils and managed on a 5-year rotation is for yields of between 2.5 and 5.0 cubic metres per hectare per year (ACIAR 1993). For *Acacia ampliceps* on moderately to highly saline land, yields between 2.5 and 5.0 cubic metres per hectare are likely (ACIAR 1993).

With improved seed sources and subspecies selection resulting from the project, however, yield improvements of 30% are achievable (ACIAR 1993). We have used a conservative estimate of a 15% increase in yield.

The current and expected yields attributable to the research are identified in Table 8.

In effect, the research has given producers who use these identified species and seeds a productivity gain. In an economic framework of supply and demand, a productivity gain is represented as a vertical shift down in the supply schedule. As landowners and managers in Pakistan and Thailand already have access to *Eucalyptus* and *Acacia* species from pre-ACAIR research, individuals would have undertaken land treatment where there was an economic benefit to do so; that is, where the marginal benefit of planting either eucalypts or acacias exceeded the marginal cost of doing so.

Table 7. Benefits from using the research findings to treat land

	Eucalyptus treatment		Acacia treatment	
	Treatment phase	**Successfully treated land**	**Treatment phase**	**Successfully treated land**
Pakistan	• Income from selling fuelwood from degraded land during treatment	• Income from selling crops following treatment (10% of success)		
Thailand	• Income from selling fuelwood from degraded land during treatment • Income from selling crops from degraded land during treatment	• Income from selling crops following treatment (25% of success)	• Income from selling fuelwood from degraded land during treatment	• Income from selling crops following treatment (25% of success)

Sources: ACIAR (1993) and based on discussions with Dr Nico Marcar (CSIRO, Australia) and Dr Arunee Yuvaniyama (Land Development Department, Thailand)

We assume that those who are now (or will be) planting because of the ACIAR research are doing so because the marginal benefits now exceed the marginal costs. The vertical supply-side shift is equal to the unit cost reduction. In Figure 5, this is measured as the difference between P_0 and B.

Full cost information on the planting, management and harvesting, including capital, land and labour costs, is not readily available in either Pakistan or Thailand. As such, it is not possible to undertake a detailed cost analysis. However, as eucalypts and acacias are already in use in Pakistan and Thailand, the productivity gain can be calculated from the implied cost reduction. With a market in place, at the margin the market price, the marginal benefit will equal the marginal cost. And this marginal cost includes all costs associated with production, including economic returns to capital, labour and land.

The measure of the productivity improvement can therefore be calculated by determining the pre- and post-research production costs per cubic metre implied by the market price and the pre- and post-research yields. Using this approach, the productivity improvement (vertical shift in supply) is calculated as Rp 436 ($9.80) and baht 1,111 ($37.60) per cubic metre in Pakistan and Thailand, respectively (Table 9).

The changes in wood yields for each rotation, pre and post research, are set out in Table 10.

Given that the development activities have all taken place on abandoned land, the increase in fuelwood supply in Pakistan and Thailand is in addition to the market that is already in existence.

As such, it is appropriate to think of supply of fuelwood as coming from a number of different non-homogenous markets—those that are currently producing, and those that are producing only because of the ACIAR-funded research.

In Pakistan, there are two fuelwood supply markets: pre-existing suppliers and those supplying from eucalyptus plantations (Figure 6).

In Thailand, there are three supply markets: the pre-existing suppliers, those supplying from the new eucalyptus plantations and those supplying from the new acacia plantations (Figure 7).

Table 8. Pre- and post-project yields (cubic metres) of wood

Component	Units	Pakistan	Thailand	
		Eucalyptus camaldulensis	***E. camaldulensis***	***Acacia ampliceps***
Pre research				
Yields	m^3/ha/year	7.5	3.8[a]	3.8[a]
Rotation length	years	8	5	5
Thinning	years	4 and 6	None	None
Yield over rotation	m^3/ha	60.0	18.8	18.8
Research				
Yield improvement	%	15%	15%	15%
Post research				
Yields	m^3/ha/year	8.6	4.3	4.3
Rotation length	years	8	5	5
Thinning	years	4 and 6	None	None
Yield over rotation	m^3/ha	69.0	21.6	21.6

[a] Taken as the mid-point between 2.5 m^3 and 5.0 m^3 per year
Source: ACIAR (1993)

The economic-surplus changes in Pakistan from the increased supply of fuelwood are:

- existing producers lose area *a* as prices fall
- eucalyptus producers gain area *b* as supply increases
- consumers gain areas *c*, *d* and *e* as price falls.

Given area *a* is equal to area *c*, the Pakistan economic gain is area *b*, *d* and *e* (Figure 6).

The economic-surplus changes in Thailand from the increased supply of fuel wood are:

- existing producers lose area *f* as prices fall
- eucalyptus producers gain area *g* as supply increases
- acacia producers gain area *h* as supply increases
- consumers gain areas *i*, *j* and *k* as price falls.

As area *f* is equal to area *i*, the Thai economic gain is area *g*, *h*, *j* and *k* (Figure 7).

The exact size of these areas depends on the initial quantities, the relative supply and demand elasticities, and the size of the productivity gain. The elasticities used in this study for fuelwood supply and demand are given in Table 11.

Total production and producer prices for fuelwood in Pakistan and Thailand are given in Table 12.

Using the adoption rates, initial equilibrium positions and the productivity gains attributable to the project identified above, the benefits to Pakistan and Thailand of increased fuelwood supplies are set out in Tables 13 and 14.

Increased wheat, seed cotton and rice production

Improving soil conditions and reducing the impact of salinity on crop yields is the second significant benefit of the project. This yield improvement will increase farm incomes from increased sales. There will also be flow-on benefits to consumers from the increase in supply of agricultural products.

Table 9. Unit cost reduction calculations

Component	Units	Pakistan	Thailand	
		Eucalyptus camaldulensis	***E. camaldulensis***	***Acacia ampliceps***
Pre research				
Yield (a)	m^3/ha	60.0	18.8	18.8
Producer price (b)	local $/$m^3$	3,341	8,519	8,519
Cost (c) = a × b	local $/ha	200,458	159,731	159,731
Cost (d) = c/a	local $/$m^3$	3,341	8,519	8,519
Research				
Yield improvement	%	15%	15%	15%
Post research				
Yield	m^3/ha	69.0	21.6	21.6
Producer price	local $/$m^3$	3,341	8,519	8,519
Cost	local $/ha	200,458	159,731	159,731
Cost	local $/$m^3$	2,905	7,408	7,408
Productivity shift				
Cost saving	%	13.0	13.0	13.0
Unit cost reduction	local $/$m^3$	436	1,111	1,111

Sources: ACIAR (1993), FAO (2007a) and Centre for International Economics' calculations

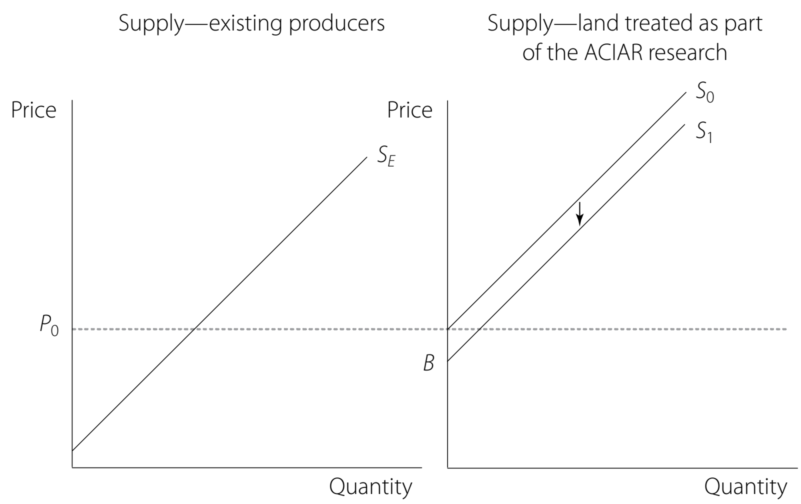

Figure 5. Supply-side productivity improvement due to the ACIAR research

Table 10. Plantation timings and wood yields (cubic metres per hectare) without and with the research

Year	Pakistan	Thailand	
	Eucalyptus camaldulensis	***E. camaldulensis***	***Acacia ampliceps***
Pre-research yield			
Year 1	0.0	0.0	0.0
Year 2	0.0	0.0	0.0
Year 3	0.0	0.0	0.0
Year 4	9.0	0.0	0.0
Year 5	0.0	18.8	18.8
Year 6	15.0		
Year 7	0.0		
Year 8	60.0		
Post-research yield			
Year 1	0.0	0.0	0.0
Year 2	0.0	0.0	0.0
Year 3	0.0	0.0	0.0
Year 4	10.3	0.0	0.0
Year 5	0.0	21.6	21.6
Year 6	17.3		
Year 7	0.0		
Year 8	69.0		

Sources: ACIAR (1993) and DMC (2002)

In Pakistan, there are typically three main crop rotations on normal soil. These are seed cotton – wheat, sugarcane–wheat and rice–wheat, although a broad number of other crops are also grown (DMC 2002). For this study, we have assumed that treated land reverts to a seed cotton – wheat rotation.

In Thailand, the research is being used in agroforestry plantations, combining eucalypts with other crops. Given that the majority of all agricultural crop production in Thailand is rice, we have assumed that all treated land reverts to rice paddies and that all agroforestry is conducted in conjunction with rice.

In Pakistan, there is a 10% chance that using the research will result in the land being sufficiently treated to be able to grow wheat and seed cotton with normal yields. In Thailand, there is a 25% chance that growing acacia on moderately and severely saline land can be rehabilitated and will grow paddy rice with normal yields. Additionally, in Thailand, the use of eucalypts in agroforestry will maintain rice yields on treated land.

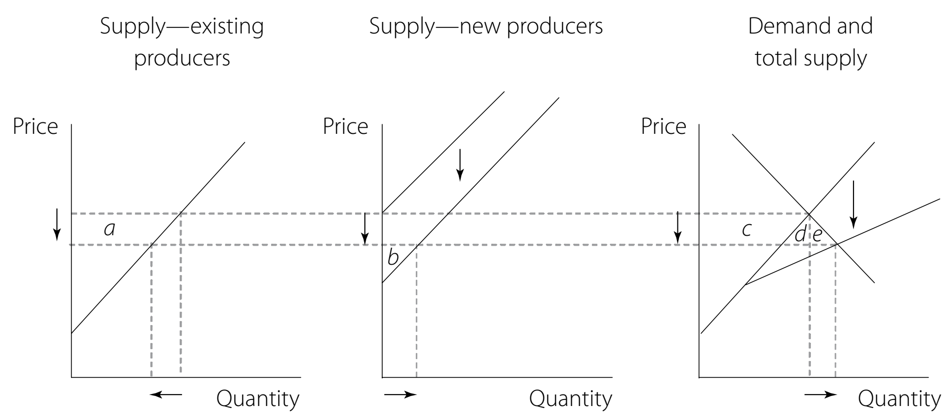

Figure 6. Fuelwood market in Pakistan—a combination of two supply markets

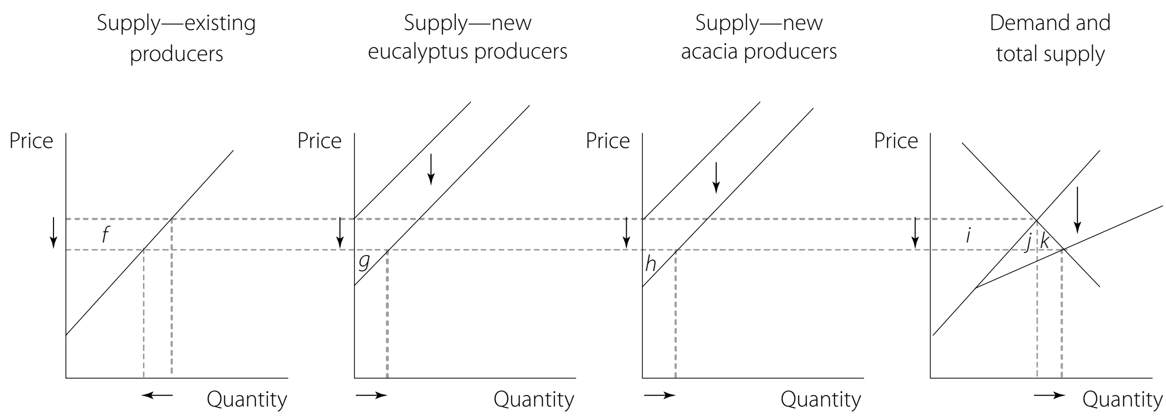

Figure 7. Fuelwood market in Thailand—a combination of three supply markets

Table 11. Demand and supply elasticities for fuelwood in Pakistan and Thailand

Variable	Demand	Supply	Source
Pakistan	−0.40	0.60	ACIAR (1995)
Thailand	−0.40	0.60	ACIAR (1995)

Table 12. Initial production and consumption (cubic metres), and price, of fuelwood

Country	Production and consumption million m^3	Producer price (farm gate) \$ local/m^3
Pakistan	27.7	3,341
Thailand	28.1	8,519

Source: FAO (2007a).

Table 13. Economic benefits from increased fuelwood supplies in Pakistan

Year	Change in supply and demand ('000 cubic metres)			Change in price (rupees per cubic metre)	Change in economic surplus (million rupees)			
	New producers	Existing producers	Consumers		New producers	Existing producers	Consumers	Net surplus
1997	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
1998	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
1999	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
2001	9.0	−5.4	3.6	−1	2.0	−30.1	30.1	2.0
2002	9.0	−5.4	3.6	−1	2.0	−30.1	30.1	2.0
2003	24.0	−14.4	9.6	−3	5.2	−80.2	80.3	5.3
2004	24.0	−14.4	9.6	−3	5.2	−80.2	80.3	5.3
2005	84.0	−50.4	33.6	−10	17.9	−280.0	281.3	19.2
2006	84.0	−50.4	33.6	−10	17.9	−280.0	281.3	19.2
2007	84.0	−50.4	33.6	−10	17.9	−280.0	281.3	19.2
2008	84.0	−50.4	33.6	−10	17.9	−280.0	281.3	19.2
2009	83.1	−49.9	33.3	−10	17.7	−277.0	278.3	19.0
2010	83.1	−49.9	33.3	−10	17.7	−277.0	278.3	19.0
2011	81.6	−49.0	32.7	−10	17.4	−272.1	273.3	18.6
2012	81.6	−49.0	32.7	−10	17.4	−272.1	273.3	18.6
2013 +	75.6	−45.4	30.3	−9	16.1	−252.1	253.1	17.2

Source: Centre for International Economics' calculations

Table 14. Economic benefits from increased fuelwood supplies in Thailand

Year	Change in supply and demand ('000 cubic metres)				Change in price (baht per cubic metre)	Change in economic surplus (million baht)				
	New acacia producers	New eucalyptus producers	Existing producers	Consumers		New acacia producers	New eucalyptus producers	Existing producers	Consumers	Net surplus
1997	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0
1998	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0
1999	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0
2001	0.4	10.4	–6.5	4.3	–3	0.2	5.7	–91.8	91.9	6.0
2002	0.4	10.4	–6.5	4.3	–3	0.2	5.7	–91.8	91.9	6.0
2003	0.4	10.4	–6.5	4.3	–3	0.2	5.7	–91.8	91.9	6.0
2004	0.4	10.4	–6.5	4.3	–3	0.2	5.7	–91.8	91.9	6.0
2005	0.4	10.4	–6.5	4.3	–3	0.2	5.7	–91.8	91.9	6.0
2006	0.8	20.7	–12.9	8.6	–7	0.4	11.4	–182.6	182.9	12.1
2007	0.8	20.7	–12.9	8.6	–7	0.4	11.4	–182.6	182.9	12.1
2008	0.8	20.7	–12.9	8.6	–7	0.4	11.4	–182.6	182.9	12.1
2009	0.8	20.7	–12.9	8.6	–7	0.4	11.4	–182.6	182.9	12.1
2010	0.8	20.7	–12.9	8.6	–7	0.4	11.4	–182.6	182.9	12.1
2011 +	0.6	20.7	–12.8	8.5	–6	0.4	11.4	–181.7	181.9	12.0

Source: Centre for International Economics' calculations (2007)

In essence, the analysis on the economic impacts of the increase in crop supply is similar to the increase in fuelwood supplies discussed above.

In Pakistan, the increase in total wheat supplies will push down the price of wheat. This will benefit wheat consumers while hurting pre-existing wheat producers. Figure 6 sets out this story. The increase in seed cotton supplies will have the same effect.

In Thailand, the increase in rice supplies from agro-forestry and treated land is similar to the story in Figure 7. There are pre-existing producers, with two new non-homogenous producers (treated land and agroforestry) entering. Similarly, the increase in rice supplies will reduce prices, increase consumption and reduce production from the pre-existing producers.

Calculating the changes to economic surplus as a result of the ACIAR research is thus similar to that described earlier. The final result will depend on the size of the productivity improvement, the adoption rates, the initial price and quantity conditions and the relative supply and demand elasticities.

Using the same technique as above, the productivity gains for the different crops are detailed in Table 15.

The initial price and quantity conditions are detailed in Table 16.

The economic benefits of increased crop supplies in Pakistan and Thailand are set out in Tables 17–19.

Table 15. Productivity gains of crops in Pakistan and Thailand

Component	Units	Pakistan		Thailand	
		Wheat	Seed cotton	Land converted to rice	Land converted to agroforestry, with rice
Pre research					
Yield on saline land	tonnes/ha	1.20	1.20	0.78	0.78
Producer price	local $/tonne	8,825	9,250	4,840	4,840
Cost	local $/ha	10,590	11,100	3,781	3,781
Cost	local $/tonne	8,825	9,250	4,840	4,840
Post research					
Yield on normal land	tonnes/ha	2.26	1.87	2.61	1.96[a]
Producer price	local $/tonne	8,825	9,250	4,840	4,840
Cost	local $/ha	10,590	11,100	3,781	3,781
Cost	local $/tonne	4,682	5,951	1,449	1,933
Productivity shift					
Cost saving	%	47.0	35.7	70.1	60.1
Unit cost reduction	local $/tonne	4,143	3,299	3,391	2,907

[a] Rice agroforestry production yields are taken as 75% of the yield on non agro-forestry land due to eucalypts being planted on part of the available land.

Sources: ACIAR (2001), World Bank (2006a) and FAO (2007b,c)

Table 16. Initial production, price, and demand and supply elasticities

Commodity	Production and consumption (million tonnes)	Producer price ($ local/tonne)	Demand elasticity	Supply elasticity
Pakistan				
Wheat	18.2	8,825	−0.11	0.23
Seed-cotton	5.2	9,250	−0.11[a]	0.23[a]
Thailand				
Rice	26.1	4,840	−0.05	0.22

[a] Specific elasticities for seed-cotton for Pakistan are not in the FAPRI database. As such we have used the supply and demand elasticities for wheat.

Sources: FAO (2007a) and FAPRI (2007).

Table 17. Economic benefits from increased wheat supply in Pakistan

Year	Change in supply and demand ('000 tonnes)			Change in price (rupees/ tonne)	Change in economic surplus (million rupees)			
	New producers	Existing producers	Consumers		New producers	Existing producers	Consumers	Net surplus
1997	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
1998	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
1999	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
2001	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
2002	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
2003	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
2004	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
2005	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
2006	0.2	−0.1	0.1	0	0.4	−5.1	5.1	0.4
2007	0.4	−0.3	0.1	−1	0.8	−10.2	10.2	0.8
2008	0.6	−0.4	0.2	−1	1.2	−15.3	15.3	1.2
2009	0.8	−0.5	0.3	−1	1.6	−20.4	20.4	1.6
2010	1.0	−0.7	0.3	−1	2.0	−25.5	25.5	2.0
2011	1.2	−0.8	0.4	−2	2.4	−30.6	30.7	2.4
2012	1.4	−0.9	0.4	−2	2.9	−35.8	35.8	2.9
2013 +	1.6	−1.1	0.5	−2	3.3	−40.9	40.9	3.3

Source: Centre for International Economics' calculations (2007)

Table 18. Economic benefits from increased seed-cotton supply in Pakistan

Year	Change in supply and demand ('000 tonnes)			Change in price (rupees/ tonne)	Change in economic surplus (million rupees)			
	New producers	Existing producers	Consumers		New producers	Existing producers	Consumers	Net surplus
1997	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
1998	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
1999	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
2001	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
2002	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
2003	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
2004	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
2005	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0
2006	0.2	−0.1	0.1	−1	0.3	−4.4	4.4	0.3
2007	0.3	−0.2	0.1	−2	0.5	−8.8	8.8	0.5
2008	0.5	−0.3	0.2	−3	0.8	−13.2	13.2	0.8
2009	0.6	−0.4	0.2	−3	1.1	−17.7	17.7	1.1
2010	0.8	−0.5	0.3	−4	1.3	−22.1	22.1	1.3
2011	1.0	−0.7	0.3	−5	1.6	−26.5	26.5	1.6
2012	1.1	−0.8	0.4	−6	1.9	−30.9	30.9	1.9
2013 +	1.3	−0.9	0.4	−7	2.1	−35.3	35.3	2.2

Source: Centre for International Economics' calculations (2007)

Table 19. Economic benefits from increased rice supply in Thailand

Year	Change in supply and demand ('000 tonnes)				Change in price (baht/tonne)	Change in economic surplus (million baht)				
	New acacia producers	New eucalyptus producers	Existing producers	Consumers		New acacia producers	New eucalyptus producers	Existing producers	Consumers	Net surplus
1997	0.0	0.9	−0.8	0.2	−1	0.0	1.4	−16.8	16.8	1.4
1998	0.0	1.9	−1.5	0.3	−1	0.0	2.7	−33.7	33.7	2.7
1999	0.0	2.8	−2.3	0.5	−2	0.0	4.1	−50.5	50.5	4.1
2000	0.0	3.8	−3.1	0.7	−3	0.0	5.5	−67.3	67.3	5.5
2001	0.0	4.7	−3.8	0.9	−3	0.0	6.8	−84.2	84.2	6.8
2002	0.0	5.6	−4.6	1.0	−4	0.0	8.2	−101.2	101.3	8.2
2003	0.0	6.6	−5.4	1.2	−5	0.0	9.5	−118.3	118.3	9.6
2004	0.0	7.5	−6.2	1.4	−5	0.1	10.9	−135.3	135.4	11.0
2005	0.1	8.5	−6.9	1.6	−6	0.1	12.3	−152.4	152.5	12.4
2006	0.1	9.4	−7.7	1.8	−7	0.1	13.6	−169.4	169.5	13.8
2007	0.1	9.4	−7.7	1.8	−7	0.1	13.6	−169.7	169.8	13.8
2008	0.1	9.4	−7.7	1.8	−7	0.2	13.6	−169.9	170.0	13.9
2009	0.1	9.4	−7.7	1.8	−7	0.2	13.6	−170.1	170.2	13.9
2010	0.1	9.4	−7.7	1.8	−7	0.2	13.6	−170.4	170.5	13.9
2011 +	0.1	9.4	−7.8	1.8	−7	0.2	13.6	−170.6	170.7	13.9

Source: Centre for International Economics' calculations (2007)

From: Corbishley, J. and Pearce, D., *Growing trees on salt-affected land.*
ACIAR Impact Assessment Series Report No. 51, July 2007

5 Determining the research impact

Combining the uptake rates identified with the consumer and producer surplus calculations in Chapter 4, the total benefits and costs to Pakistan, Thailand and Australia can be calculated.

Overall gains of the ACIAR research

In Pakistan, from 2013 onwards, the total economic gain each year will be $507,000 (Table 20). These benefits are assumed to continue from 2013 until 2038. We have assumed that there will be no disadoption of the research findings.

In Thailand, the ACIAR-funded project will return $876,000 each year from 2011 onwards (Table 21). These benefits are assumed to continue from 2013 until 2038. We have assumed that there will be no disadoption of the research findings.

The net benefit of the ACIAR research is the sum of the economic gains in Pakistan and Thailand minus the research and extension costs. Converting the economic gains to Pakistan and Thailand (Tables 20 and 21) to Australian dollars, and subtracting from these the research and extension costs identified in Chapter 3 (Tables 1–3), the net benefit of the ACIAR-funded research can be calculated (Table 22).

Discounting the stream of benefits through time at a rate of 5% per annum gives a total net benefit of $2.4 million. At a 5% discount rate, the break-even year for the project is 2030 (Figure 8).

The internal rate of return on the stream of income is 5.7%, while the benefit:cost ratio has been calculated as 1.12 (at a 5% discount rate) (Table 23).

These calculations suggest that ACIAR's salinity research of the 1990s will return positive net benefits through time across low discount rates. To date (up to the end of 2006), the net return has been negative, with the first year of positive annual returns in 2004. Over 50 years to 2038, the benefit:cost ratio is calculated as 1.12 (at a 5% discount rate), indicating that, for every dollar spent by ACIAR and others on the research and extension, there has been an increase in economic surplus of $1.12. However, increasing the discount rate to 10% yields a benefit:cost ratio of 0.53, indicating that every dollar spent would return only $0.53.

Impact on poverty

From the information available, it is impossible to quantify the impact the research has had on poverty, either absolute or relative, in Pakistan and Thailand. Nor can any conclusion be drawn on the impact the research has had on relative income distributions and income inequality.

Benefits to Australia

The benefits to Australia of FST/1993/016 and related projects were considered in Pearce et al. (1996). The broad conclusions from this analysis are as follows.

Salt in the landscape is a major problem in Australian agriculture. This project, which is in fact one of a large number of ACIAR-funded projects concerned with related problems, looked at one aspect of the problem. It considered which tree and shrub species would best be able to withstand salinity, and therefore would be appropriate for use in agriculture— particularly as an additional crop that would make use of otherwise unproductive land.

This project is an example of ACIAR-funded research contributing to a fundamental knowledge base in an area of broad concern within both Australia and the partner countries for the project (Thailand and Pakistan). Despite considerable progress during the course of the project, the new knowledge has not been finalised and is not as yet embodied in a single package suitable for Australian farmers to adopt if it were to prove profitable. In this case, we were unable to quantify the benefits of this project to Australia.

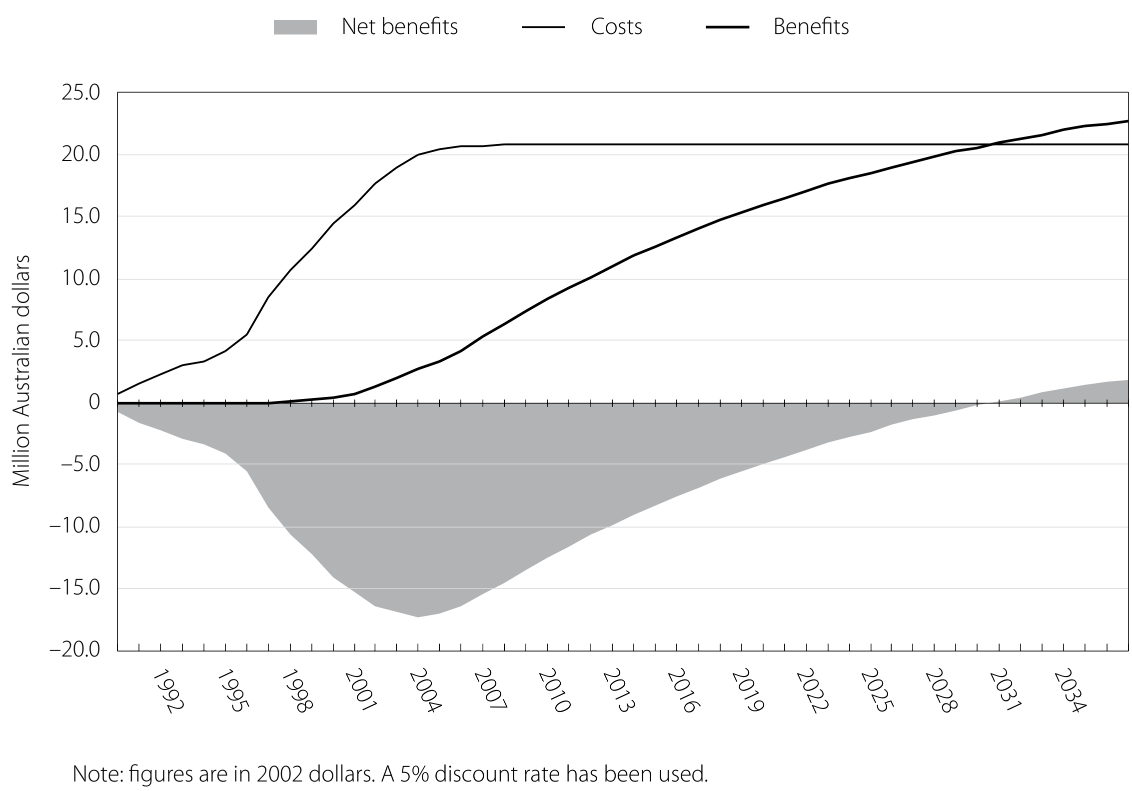

Figure 8. The cumulative stream of benefits, costs and net benefits of the research. Note: figures are in 2002 dollars. A 5% discount rate has been used. Source: Centre for International Economics' calculations

Table 20. Economic gains to Pakistan attributable to the research

Year	Fuelwood (million rupees)	Wheat (million rupees)	Seed cotton (million rupees)	Total gain (million rupees)	Total gain (A$ '000)
1997	0.0	0.0	0.0	0.0	0
1998	0.0	0.0	0.0	0.0	0
1999	0.0	0.0	0.0	0.0	0
2000	0.0	0.0	0.0	0.0	0
2001	2.0	0.0	0.0	2.0	62
2002	2.0	0.0	0.0	2.0	61
2003	5.3	0.0	0.0	5.3	141
2004	5.3	0.0	0.0	5.3	124
2005	19.2	0.0	0.0	19.2	423
2006	19.2	0.4	0.3	19.8	437
2007	19.2	0.8	0.5	20.5	461
2008	19.2	1.2	0.8	21.2	476
2009	19.0	1.6	1.1	21.7	486
2010	19.0	2.0	1.3	22.3	501
2011	18.6	2.4	1.6	22.7	509
2012	18.6	2.9	1.9	23.3	524
2013 +	17.2	3.3	2.2	22.6	507
Source:	Table 13	Table 17	Table 18		

Note: all figures are in 2002 rupees and were converted from nominal to real using the world development indicators (World Bank 2006b) Pakistan price index.

Source: Centre for International Economics' calculations (2007)

Table 21. Economic gains to Thailand attributable to the research

Year	**Fuelwood** (million baht)	**Rice** (million baht)	**Total gain** (million baht)	**Total gain** A$ '000
1997	0.0	1.4	1.4	59
1998	0.0	2.7	2.7	105
1999	0.0	4.1	4.1	168
2000	0.0	5.5	5.5	240
2001	6.0	6.8	12.9	560
2002	6.0	8.2	14.3	611
2003	6.0	9.6	15.7	581
2004	6.0	11.0	17.1	576
2005	6.0	12.4	18.5	602
2006	12.1	13.8	25.9	907
2007	12.1	13.8	25.9	875
2008	12.1	13.9	25.9	876
2009	12.1	13.9	26.0	877
2010	12.1	13.9	26.0	878
2011 +	12.0	13.9	25.9	876
Source:	Table 14	Table 19		

Note: all figures are in 2002 baht and were converted from nominal to real using the world development indicators (World Bank 2006b) Thailand price index.

Source: Centre for International Economics' calculations

Table 22. Total benefits and costs (A$ million) of the ACIAR research and related extension activities over 50 years

Year	Australia	Pakistan		Thailand		Total		
	Research costs (A)	Extension costs (B)	Net welfare gain (C)	Extension costs (D)	Net welfare gain (E)	Gross costs (F) = A + B + D	Gross benefits (G) = C + E	Net benefits (H) = G − F
1989	0.372	0.000	0.000	0.000	0.000	0.372	0.000	−0.372
1990	0.494	0.000	0.000	0.000	0.000	0.494	0.000	−0.494
1991	0.374	0.000	0.000	0.000	0.000	0.374	0.000	−0.374
1992	0.438	0.000	0.000	0.000	0.000	0.438	0.000	−0.438
1993	0.224	0.000	0.000	0.000	0.000	0.224	0.000	−0.224
1994	0.587	0.000	0.000	0.000	0.000	0.587	0.000	−0.587
1995	0.966	0.000	0.000	0.000	0.000	0.966	0.000	−0.966
1996	0.670	0.049	0.000	1.494	0.000	2.213	0.000	−2.213
1997	0.482	0.044	0.000	1.201	0.059	1.726	0.059	−1.668
1998	0.000	0.418	0.000	1.000	0.105	1.418	0.105	−1.313
1999	0.000	0.714	0.000	1.067	0.168	1.781	0.168	−1.613
2000	0.000	1.004	0.000	0.224	0.240	1.228	0.240	−0.988
2001	0.000	1.533	0.062	0.217	0.560	1.751	0.621	−1.130
2002	0.000	0.988	0.061	0.214	0.611	1.202	0.672	−0.530
2003	0.000	0.917	0.141	0.182	0.581	1.099	0.723	−0.376
2004	0.000	0.309	0.124	0.161	0.576	0.471	0.700	0.230
2005	0.000	0.141	0.423	0.149	0.602	0.290	1.024	0.734
2006	0.000	0.000	0.437	0.147	0.907	0.147	1.343	1.196
2007	0.000	0.000	0.461	0.137	0.875	0.137	1.336	1.200
2008	0.000	0.000	0.476	0.000	0.876	0.000	1.352	1.352
2009	0.000	0.000	0.486	0.000	0.877	0.000	1.363	1.363
2010	0.000	0.000	0.501	0.000	0.878	0.000	1.379	1.379
2011	0.000	0.000	0.509	0.000	0.876	0.000	1.385	1.385
2012	0.000	0.000	0.524	0.000	0.876	0.000	1.400	1.400
2013	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2014	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2015	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2016	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2017	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2018	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2019	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2020	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2021	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384

Table 22. (continued)

Year	Australia	Pakistan		Thailand		Total		
	Research costs (A)	**Extension costs (B)**	**Net welfare gain (C)**	**Extension costs (D)**	**Net welfare gain (E)**	**Gross costs (F)** = A + B + D	**Gross benefits (G)** = C + E	**Net benefits (H)** = G – F
2022	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2023	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2024	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2025	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2026	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2027	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2028	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2029	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2030	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2031	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2032	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2033	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2034	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2035	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2036	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2037	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
2038	0.000	0.000	0.507	0.000	0.876	0.000	1.384	1.384
Source:	Tables 1–2	Table 3	Table 20	Table 3	Table 21			

Note: all figures are in 2002 dollars and were converted from nominal to real using the world development indicators (World Bank 2006b) Australian price index.
Source: Centre for International Economics' calculations

Table 23. Discounted net benefits and costs of the ACIAR-funded research from 1989 to 2038

Discount rate	**Gross costs (A)** (A$ million)	**Gross benefits (B)** (A$ million)	**Net benefits (C)** (A$ million)	**Benefit:cost ratio (D)** = B / A Ratio	**Internal rate of return (E)** %
0%	16.9	49.8	32.9	2.95	5.7%
5%	20.8	23.2	2.4	1.12	
10%	26.3	14.0	–12.3	0.53	
Source:	Table 22, discounted sum of column F	Table 22, discounted sum of column G	Table 22, discounted sum of column H		

Note: All dollars in 2002 Australian dollars
Source: Centre for International Economics' calculations

6 Conclusion

This report has examined the impact that the ACIAR research project 'Tree growing on salt affected soils', as well as some closely related ACIAR projects and extension activities, has had in Pakistan and Thailand.

The research identified the benefits of using specific *Eucalyptus* and *Acacia* species to treat salt-affected soils to improve the productivity and value of marginal and abandoned land.

While the uptake of the research has been slow, in part due to the time period between initiating the research and the extension projects being implemented, net discounted benefits from treating salt-affected soils do exist. They exist, however, only at a discount rate lower than 5.7% (the internal rate of return).

At a farm level, the evidence suggests that farmers, while they could benefit from using the research findings to treat salt-affected land, are unlikely to take up the research results without additional subsidies and encouragement.

Without the AusAID funded pilot study and the follow-up 'Pakistan community development project for the rehabilitation of saline and waterlogged land' project, it is possible the research would not have been taken up on a scale sufficiently large enough to justify the research costs.

The low uptake of the research also suggests that alternatives to bioremediation of salinity problems do exist; for example, groundwell drilling and gypsum treatment may be more economically viable than approaches based on eucalypts and acacias. This is evident in the follow-up extension project in Pakistan, the 'Pakistan community development project for the rehabilitation of saline and waterlogged land (phase II)', being funded by the Asian Development Bank and the United Nations Development Programme. Under this project, it is planned to treat 80,000 hectares of salt-affected land.

In addition, the phase II activity under the AusAID-funded pilot study intends to treat the land using gypsum and to *not* rely specifically on the ACIAR research. This switch in emphasis between phases I and II (along with the low adoption rates) implies that it was not cost-effective for farmers to use the research and techniques.

This finding is not unique. Another project undertaken in Pakistan by the United Nations Development Programme found that farmers were not interested in using eucalypt plantations. Rather, they undertook their own benefit–cost analysis and concluded they were better off growing traditional crops (Haider 2002).

Overall, the project has a positive benefit:cost ratio of 1.12 using a 5% discount rate. At this discount rate, the total benefits of $23.2 million exceed the total costs of $20.8 million by $2.4 million. This is equivalent to an internal rate or return of 5.7%.

From: Corbishley, J. and Pearce, D., *Growing trees on salt-affected land*.
ACIAR Impact Assessment Series Report No. 51, July 2007

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From: Corbishley, J. and Pearce, D., *Growing trees on salt-affected land.*
ACIAR Impact Assessment Series Report No. 51, July 2007

IMPACT ASSESSMENT SERIES

No.	Author(s) and year of publication	Title	ACIAR project numbers
1	Centre for International Economics (1998)	Control of Newcastle disease in village chickens	8334, 8717 and 93/222
2	George, P.S. (1998)	Increased efficiency of straw utilisation by cattle and buffalo	8203, 8601 and 8817
3	Centre for International Economics (1998)	Establishment of a protected area in Vanuatu	9020
4	Watson, A.S. (1998)	Raw wool production and marketing in China	8811
5	Collins, D.J. and Collins, B.A. (1998)	Fruit fly in Malaysia and Thailand 1985–1993	8343 and 8919
6	Ryan, J.G. (1998)	Pigeon pea improvement	8201 and 8567
7	Centre for International Economics (1998)	Reducing fish losses due to epizootic ulcerative syndrome—an ex ante evaluation	9130
8	McKenney, D.W. (1998)	Australian tree species selection in China	8457 and 8848
9	ACIL Consulting (1998)	Sulfur test KCL–40 and growth of the Australian canola industry	8328 and 8804
10	AACM International (1998)	Conservation tillage and controlled traffic	9209
11	Chudleigh, P. (1998)	Post-harvest R&D concerning tropical fruits	8356 and 8844
12	Waterhouse, D., Dillon, B. and Vincent, D. (1999)	Biological control of the banana skipper in Papua New Guinea	8802-C
13	Chudleigh, P. (1999)	Breeding and quality analysis of rapeseed	CS1/1984/069 and CS1/1988/039
14	McLeod, R., Isvilanonda, S. and Wattanutchariya, S. (1999)	Improved drying of high moisture grains	PHT/1983/008, PHT/1986/008 and PHT/1990/008
15	Chudleigh, P. (1999)	Use and management of grain protectants in China and Australia	PHT/1990/035
16	McLeod, R. (2001)	Control of footrot in small ruminants of Nepal	AS2/1991/017 and AS2/1996/021
17	Tisdell, C. and Wilson, C. (2001)	Breeding and feeding pigs in Australia and Vietnam AS2/1994/023	
18	Vincent, D. and Quirke, D. (2002)	Controlling *Phalaris minor* in the Indian rice–wheat belt	CS1/1996/013
19	Pearce, D. (2002)	Measuring the poverty impact of ACIAR projects—a broad framework	
20	Warner, R. and Bauer, M. (2002)	*Mama Lus Frut* scheme: an assessment of poverty reduction	ASEM/1999/084
21	McLeod, R. (2003)	Improved methods in diagnosis, epidemiology, and information management of foot-and-mouth disease in Southeast Asia	AS1/1983/067, AS1/1988/035, AS1/1992/004 and AS1/1994/038
22	Bauer, M., Pearce, D. and Vincent, D. (2003)	Saving a staple crop: impact of biological control of the banana skipper on poverty reduction in Papua New Guinea	CS2/1988/002-C
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