WATER AND NITROGEN MANAGEMENT IN WHEAT–MAIZE PRODUCTION ON THE NORTH CHINA PLAIN

LWR1/1996/164

David Harris
D.N. Harris & Associates

October 2004

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

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

▶▶▶▶ 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.

▶▶▶▶ Communications regarding any aspects of this series should be directed to:
The Manager
Impact Assessment Unit
ACIAR
GPO Box 1571
Canberra ACT 2601
Australia
tel +612 62170500
email aciar@aciar.gov.au

David Harris, *Water and nitrogen management in wheat–maize production on the North China Plain*, Impact Assessment Series Report No. 28, September 2004.

This report may be downloaded and printed from <www.aciar.gov.au>.

ISBN 1 86320 407 5 (printed)
ISBN 1 86320 408 3 (electronic)

Editing and typesetting by Clarus Design

Foreword

ACIAR's impact assessment reports provide information on project impacts which helps to guide future research activities. While the main focus of these commissioned reports is on measuring the dollar returns to agricultural research, emphasis is also given to analysing the impacts of projects on poverty reduction.

The North China Plain supports a large number of highly intensive small farms that produce winter wheat traditionally followed by a summer crop of maize. Higher applications of fertiliser and water have increased crop yields, but there were concerns about economic and environmental implications of over-use of these inputs.

ACIAR funded a five-year project from 1998 aimed at improving the efficiency of water and fertiliser use in this wheat–maize production system. The project increased understanding of the dynamics of water and nitrogen use in this system, and produced recommendations that would help smallholders use water and fertiliser inputs more efficiently.

This study was commissioned to assess the economic and environmental benefits of project outputs at farm and community level. The analysis predicts significant poverty reduction effects for smallholders in parts of the North China Plain from cost savings in fertiliser and water applications and changes in crop yields.

This report is also available on our website at <www.aciar.gov.au>.

Peter Core
Director
Australian Centre for International Agricultural Research

Contents

Tables

Figure

Acknowledgments

The project evaluation contained in this report was based on consultations with a large number of people. This report could not have been prepared without the contributions made by these people.

The ACIAR program manager, Dr Ian Willett, provided background material as well as useful advice on the development of the project. Dr Deli Chen from the University of Melbourne was the project leader in Australia. He provided reports and other material that were essential to the preparation of this report. The advice and assistance provided by Dr Chen was greatly appreciated.

In China, a number of people made important contributions. The evaluation involved a week of consultations and site visits in China. Professor Jiabao Zhang from the Institute of Soil Sciences of the Chinese Academy of Sciences (CAS) in Nanjing was the project leader in China. He contributed generously with his time in coordinating various meetings in China. His efforts in translation and providing advice on numerous technical aspects of the project were essential for completing the evaluation.

Professor Zhang provided technical information on the Fengqiu research activities and project dissemination in the Xinxiang City District. The consultations provided by Mr Shudong Wang, Vice-Secretary General of the Xinxiang Municipal People's Government, were extremely valuable. His generosity was greatly appreciated. The contribution of the Director of the Fengqiu Research Station is also gratefully acknowledged.

Dr Yuming Zhang and her colleagues from the Shijiazhuang Institute of Agricultural Modernisation of the Chinese Academy of Sciences (CAS) provided technical information on the Luancheng research activities and project dissemination. The help of the farmers from the Luancheng research site who gave their time in answering questions on applying the project advice is gratefully acknowledged.

Dr Baoguo Li and Dr Guitong Li from the College of Resources and Water Sciences of the China Agricultural University (CAU) in Beijing provided technical information on the Quzhou research activities and project dissemination. Their assistance in clarifying various technical aspects of the project was a valuable contribution.

Mr Guanglin Wang and Ms Lydia Li of the ACIAR Office at the Australian Embassy in Beijing provided valuable assistance in organising the consultations and site visits in China. Their follow-up support during the preparation of this report was also greatly appreciated.

Details of project evaluated

ACIAR project ID	LWR1/1996/164 – Water and nitrogen management to increase agricultural production and improve environmental quality
Collaborating organisations	University of Melbourne (UMelb), Australia; Victorian Department of Natural Resources and Environment (DNRE), Rutherglen, Australia; China Agricultural University (CAU), Beijing, China; Chinese Academy of Sciences (CAS), Nanjing, China
Project leaders	Professor Robert White (UMelb); Associate Professor Zhang Jiabao (CAS)
Linked projects	LWR1/94/46, LWR1/94/54, LWR1/95/07, LWR2/94/32
Principal researchers	Dr Li Baogou (CAU); Dr Deli Chen (UMelb); Dr Anna Ridley (DNRE)
Duration of project	1 January 1998–30 June 2003
Total ACIAR funding	AUD881,253
Project objectives	The overall objective of the project was to increase the efficiency of use of nitrogen in the North China Plain (NCP), to improve crop production and decrease contamination of groundwater with nitrate and to reduce emission of greenhouse gases. A parallel study was undertaken as part of a larger, more-comprehensive project in northeastern Victoria. 1. *Quantifying water, N and P losses from the soil–plant systems to the environment* (a) To quantify the water balance of irrigated wheat and maize, and estimate drainage losses below the root zone in relation to time, soil type and crop at three experimental sites (1 ha each) on the NCP. (b) To measure N losses by drainage below the root zone under irrigated wheat and maize, and gaseous N losses to the atmosphere, at the three sites on the NCP. (c) In Australia, to estimate deep drainage below the root zone and partition run-off into surface and subsurface flow (interflow) for pastures with three levels of input on two soil types (six catchments). (d) In Australia, to measure N and P losses in surface, subsurface flow and deep drainage in these pastures. 2. *Systems modelling and practices for crop, water and nutrient (N and P) management* (a) To collect data on water, N and P inputs, crop uptake, product removal and other losses, which are required as input variables for a dynamic process model of the experimental production systems at three sites (China) and in six catchments (Australia). (b) To simulate water, N and P losses using appropriate parameter values in a dynamic model for these production systems in Australia and China. (c) To define the ranges of input variables and parameter values for the simulation of water and N losses using soil, land use and meteorological data for three areas (up to 3000 ha) centred on the experimental sites in the NCP. (d) To integrate the dynamic process models for water, N and P into a geographic information system at an appropriate scale to simulate the production systems identified in 2(a). (e) To check outputs from these simulations against observations made over larger areas under these production systems, as identified in 2(c) for China, and for similar catchments in Australia (through the SGS program). (f) To identify practices in the production systems under study which contribute to increased productivity and minimise impacts on the quality of receiving waters. 3. Training, information dissemination and policy advice (a) To train Chinese and Australian scientists (including postgraduate students) in research methodology for studying water and nutrient management and simulation modelling of processes at a range of scales. (b) To demonstrate how a spatially referenced, dynamic model can be used to guide decisions aimed at sustainable crop production and better environmental management over heterogeneous areas at different scales in Australia and China. (c) Together with the sponsoring bodies and collaborating organisations, establish procedures for the effective dissemination of new technical information on water and nutrient management to appropriate end-users, and the adoption of preferred management practices.
Location of project activities	Fengqiu County, Henan Province, China; Maindample and Ruffy, northeastern Victoria, Australia.

Summary

The ACIAR project LWR1/1996/164, *Water and nitrogen management to increase agricultural production and improve environmental quality,* was designed to investigate the efficiency of traditional rates of nitrogen and water use in wheat–maize production on the North China Plain (NCP).

Farmers have pursued yield improvements by increasing the use of both inputs. Wheat and maize yields have improved, but preliminary investigations suggested many growers used excessive amounts of nitrogen and water. There have been growing concerns about the environmental implications of the high levels of input use. The traditional approach was to apply fertiliser by 'surface broadcast' followed by lengthy periods of flood irrigation. Substantial amounts of nitrogen and water were being wasted. There were substantial atmospheric losses of nitrogen fertiliser through ammonia volatilisation under the traditional application method. Over-watering increased nitrogen losses through leaching into the watertable. Large amounts of water were draining into the watertable with no beneficial effect on crop yields.

The project objective was to improve the efficiency of water and fertiliser use in the NCP wheat–maize production system in order to:

- improve producer net returns
- reduce groundwater contamination
- reduce gaseous nitrogen losses.

The project was focused on improving environmental outcomes by changing traditional farming methods. To achieve this, an economic objective of improved farmer returns was required. The research was designed to identify reductions in input use that raised net returns without reducing crop yields.

The project involved three research activities:

- quantifying water and nitrogen losses from soil–plant systems to the environment
- developing a spatially referenced model to simulate water and nitrogen dynamics
- developing decision-support tools and information dissemination programs to facilitate adoption of input efficiency improvements.

The project was a multifaceted study involving the coordination of six institutions across two countries. It involved managing research trials across three experimental sites in the NCP and two in northern Victoria, Australia.

ACIAR funded the project from April 1998 to June 2003. Total ACIAR funding was A$1,031,240. There were, in addition, cash and in-kind funding contributions from other collaborating organisations. Total project expenditure was approximately A$2.94 million.

Valuations of the project benefits had to account for regional differences in research results. Primary research was carried out at research sites in three localities. This defined the project impact area as wheat–maize production in:

- Quzhou County
- Luancheng County
- Fengqui County (Xinxiang City District).

The project will have significant environmental benefits. The economic benefits relate to farm-level productivity improvements. There were three components:

- cost saving in fertiliser applications
- cost saving in water applications
- changes in wheat and maize yields.

Annual reductions in fertiliser use were around 20–23%. Annual cost savings from reduced water-pumping costs were between A$10 and A$45 per ha. Yield improvements ranged from no change to 4% per year.

In present value terms, the net benefits of the project were A$216.2 million. They represent the economic benefits that accrue to farmers growing wheat and maize on selected areas of the North China Plain. The benefit–cost ratio is 77 to 1. A progressive project evaluation up to the end of 2003–04 assessed the net benefits at A$24.9 million. The progressive benefit–cost ratio is about 10 to 1.

The project will have significant poverty-reduction effects. For an average sized farm, input costs fall by 12–18%. Project benefits are equivalent to an increase in income of between A$50 and A$109 per year.

1 Background

Agriculture is an important component of the Chinese economy. In a population of 1.3 billion people, almost half of the total labour force is employed in agriculture or a related activity. The agricultural sector is based mostly around family farms operating small farm plots. Many farms retain a portion of their grain harvest for home needs, with excess output traded in local markets for a cash income.

Modest rates of economic growth in rural areas have limited the rate of improvement in household incomes. The gap between rural and urban incomes has been widening. The average disposable income in rural areas is around 35% of the average disposable income in urban areas. Some farm households rely on income support from family members working in urban areas.

The North China Plain (NCP) supports a large farming population. Farming is highly intensive, with an average farm size of around 8 mu (0.53 ha). Traditionally, NCP farms have operated a double-cropping system of winter wheat and a summer crop such as maize. In part this reflected policies of the central government that encouraged cereal production in line with the national goal of grain self-sufficiency.

The small holdings have been a key factor in the level of rural poverty on the NCP. In recent years, policy reform and changes in relative returns have seen some diversification in land use. Some farmers have switched into other products or altered summer crop rotations. But the wheat–maize crop rotation remains a strong focus of the NCP rural sector.

Restricted land use rights have limited the incentive for farmers to increase the size of their farms and expand cropping areas (Lohmar 2001). This has restricted the opportunities for increasing farm incomes through expanding the scale of production. Farm development has focused on increasing crop yields from existing farm areas.

Over time, NCP cereal production has become progressively more intensive. Farmers have pursued yield improvements by adopting better seed varieties. They have also increased the use of fertiliser and water, the key inputs to production. Wheat and maize yields have improved considerably, although the rate of improvement has slowed in recent years.

There have been growing concerns about the environmental implications of NCP farming methods involving high levels of inputs. Contamination of the watertable with nitrates has become an important issue. Increased use of water and fertiliser inputs has been a key factor behind the rise in environmental degradation.

Preliminary investigations suggested water and fertiliser were not used efficiently and were applied in excessive quantities. Application methods, the rate of application and the timing of input use have limited their effectiveness in raising crop yields. More efficient input use could potentially raise farmers' incomes and reduce the environmental costs of traditional farm-management practices.

This project involved an investigation of the efficiency of traditional rates of input use in wheat–maize production. Analysis of the interaction between nitrogen and water inputs on the soils of the NCP has provided valuable policy advice for farm advisers. Changes in farming methods can provide a 'win' for the environment and a financial 'win' for the cereal farmer.

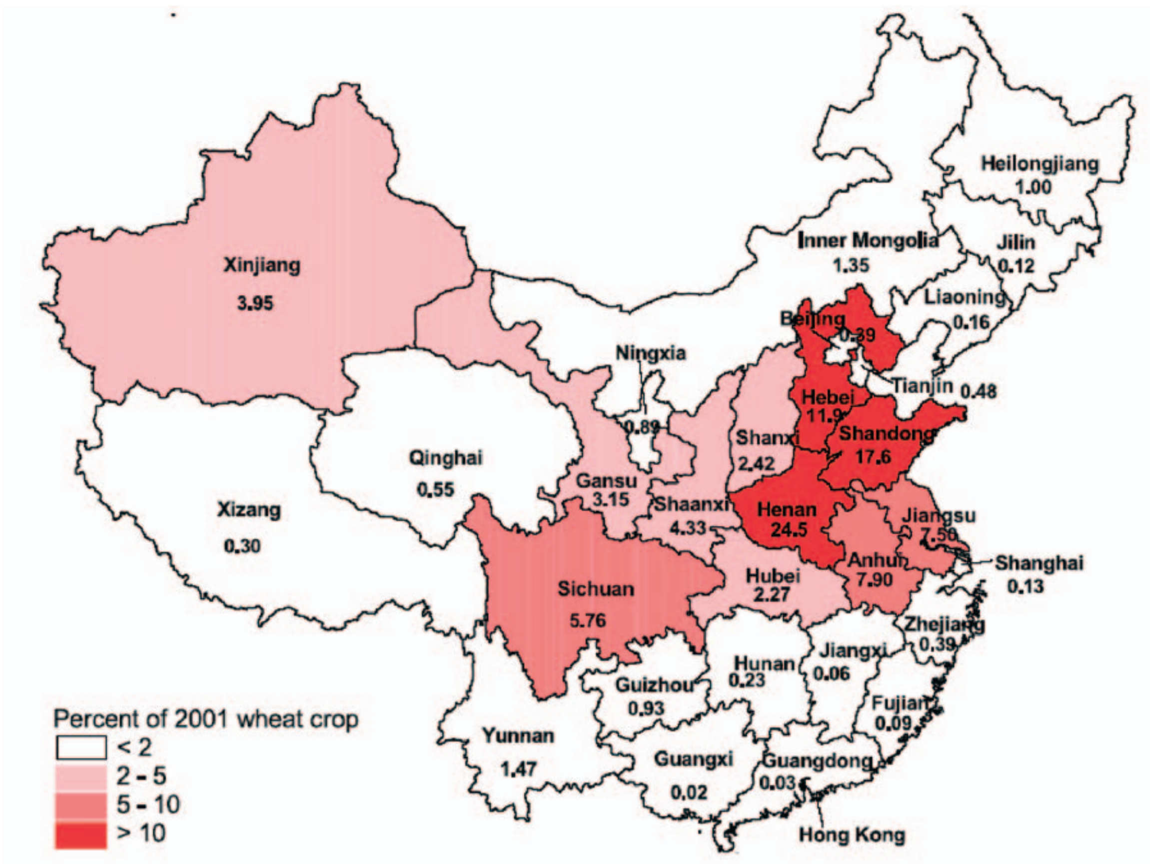
Research projects that help to alleviate poverty and introduce environmentally sustainable farm-management practices are particularly appropriate at this stage of China's economic development. The ACIAR project LWR1/1996/164, *Water and nitrogen management to increase agricultural production and improve environmental quality,* is an example of research that focuses on these issues.

2 Cereal farming on the North China Plain

The North China Plain (NCP) is the primary wheat-growing area in China. The region is based around three main provinces — Henan, Hebei and Shandong. Collectively, these provinces account for about half of China's wheat production (Figure 1). The region is composed mostly of small-scale family farms. Productivity improvements are the key factor in raising farm incomes and improved living standards.

The central government's policy of grain self-sufficiency constrained the development of the agricultural sector in the NCP. The policy required each province to produce enough grain to meet its consumption requirements. It restricted the flexibility of farm production decisions and limited the opportunities for farmers to earn higher incomes.

Figure 1. Distribution (percentages) of China's wheat production, 2001 (Lohmar 2004).



2.1 Wheat–maize production on the North China Plain

The wheat–maize cropping enterprise on the NCP relies on flood irrigation and application of large quantities of inorganic fertilisers. The farming operation is labour intensive with limited capital inputs. Over time, farmers have pursued farm productivity improvements through higher crop yields. This has involved using more fertiliser and water.

In recent years, the traditional focus on wheat and maize production has been changing. Policy reforms and a more commercial approach to farming have contributed to a change in cropping areas. Grain delivery quotas for the payment of taxes have been removed in most provinces. Farmers have become more responsive to changes in the relative returns for alternative products.

Some farmers have been switching out of wheat and into higher-value crops such as vegetables and horticulture. There have also been changes in the choice of summer crops, with a decline in maize cropping areas. Some farmers have maintained their winter wheat production but opted for alternative crops over the summer (e.g. cotton and peanuts).

Low returns are the primary cause for the movement from wheat–maize cropping to other agricultural outputs. Until recently, the producer price of wheat has typically varied around 1 to 1.1 yuan/kg (A$230–255/tonne). Maize prices have varied between 0.8 and 0.9 yuan/kg (A$185–210/tonne).

Horticulture crops offer significantly higher returns, and the introduction of genetically modified cotton has improved the profitability of cotton production. In some cases, maize has been replaced by short-season cotton varieties. In other cases, the wheat–maize cropping system has been replaced by the longer-season, spring-sown cotton varieties.

Since the late 1990s, China's wheat production has been falling. Current production is around 90 million tonnes per year. The decline in output has been due largely to reductions in planting areas. The rate of improvement in crop yields has also tailed off in recent years (Lohmar 2004):

- average wheat yields have been relatively constant since 2000
- there have been similar yield and production trends for maize.

2.2 Effects of increasing input use

Preliminary investigations suggested that many cereal growers used excessive amounts of nitrogen fertiliser and water. Farm-management practices involved inefficient application methods that contributed to the overuse of both inputs. The traditional approach was to throw the fertiliser on the ground (surface broadcast) and follow this with a lengthy period of flood irrigation.

Large amounts of nitrogen and water were being wasted during the crop-growing process under this approach. There were substantial atmospheric losses of nitrogen through ammonia volatilisation due to the application method, high soil pH in the region and the delay in watering. Over-watering increased nitrogen losses through leaching into the watertable, and large amounts of water had no beneficial effect on crop yields:

- excess irrigation water was draining into the watertable once the soil had absorbed the maximum amount of moisture.

This represented a significant economic loss to producers. There was also a potentially substantial cost to the environment. Increased input use was also degrading the quality of water resources. The watertable was rising in some areas, and nitrate concentrations in the groundwater were increasing.

Flood irrigation has contributed to an over-exploitation of water resources. For example, farmers in Shandong Province rely on the Yellow River as a primary source of irrigation water. Shandong is China's second-largest wheat-producing province at the downstream end of the Yellow River. In peak irrigation periods, the river has sometimes dried up before reaching the ocean. The problem steadily worsened throughout the 1990s (Lohmar 2004).

Inefficient application methods showed that farmers did not understand the dynamics of water and nitrogen and their interaction in the crop-growing process. Crop yields are determined by the effectiveness of nitrogen and water inputs for particular soil types. The traditional farming approach implied a simple, linear relationship between crop yields and input use. Farmers believed that high levels of fertiliser and water use would translate directly into higher crop yields.

Further intensification of the production process increased the risk of waterlogging, soil salinity and contamination of drinking water. Farmers had no direct concern for the environmental impact of their decisions on input usage. They did not have secure title to their land. This diminished the incentive to make investments that would improve the effectiveness of input use and improve environmental management.

NCP cereal farmers are sensitive to changes in crop yields because of the direct effect on farm incomes. Reduced input use may have environmental benefits but it could also affect crop yields. Given the circumstances, a project aimed at improving environmental outcomes would have to demonstrate a financial benefit for farmers. To be successful, the research had to demonstrate that more efficient input use would not reduce crop yields.

3 The ACIAR project

The aim of the project was to evaluate the efficiency of water and fertiliser use in the wheat–maize cropping system of the North China Plain (NCP). It involved a scientific analysis of the mechanisms of nitrogen fertiliser losses. The results were used to identify potential changes in the method and application rate of fertiliser and water inputs. Adoption of the recommended changes would increase the effectiveness of both inputs, and reduce the adverse impact on the environment.

3.1 Project objectives

The overall project objective was to improve the efficiency of water and fertiliser use in the NCP wheat–maize production system in order to:

- improve producer net returns
- reduce groundwater contamination from nitrate and phosphate leaching
- reduce gaseous nitrogen losses.

The primary focus of the project was to improve environmental outcomes by changing the traditional approach to input use in cereal production. However, to achieve the environmental objective the project incorporated an economic objective of improving farmer returns.

In designing the study, the project leaders were conscious of the sensitivity of farmers to changes in input use that reduced crop yields. Adoption of the research results would be limited if this occurred. Therefore, the project was designed to identify reductions in input use that would:

- reduce input expenditures and raise net returns
- would not lead to a significant reduction in crop yields.

A further objective was to develop analytical tools to assist policy makers in identifying strategies to improve farm productivity and environmental outcomes. To achieve this objective, the project had to account for the regional variations in climatic conditions and soil types that existed across the NCP. It required a mechanism to adapt the results from scientific trials to a wider area.

The expected outcomes of the project were:

- economic benefits for NCP cereal producers from more-efficient use of water and fertiliser inputs

- regional environmental benefits by minimising the costs of degradation of land and water resources by countering excessive extraction of water and the incidence of soil salinity, erosion and acidification
- environmental improvements by reducing greenhouse gas emissions
- increased awareness of policy makers and farmers on what is required for an environmentally sustainable cereal-production system.

3.2 Dimensions of the project

The project had three discrete research activities. The first step involved collecting detailed experimental data on the dynamics of water–nitrogen interaction in growing wheat and maize. The data were used to quantify the water and nitrogen losses from soil–plant systems to the environment:

- nitrogen losses from water drainage below the root zone, i.e. nitrate leaching
- water drainage losses below the root zone
- atmospheric nitrogen losses from traditional application methods, i.e. ammonia volatilisation
- nitrogen losses from denitrification and nitrous oxide emissions.

The second step involved developing a modelling framework to analyse the effects of farm-management practices on crop yields and water–nitrogen dynamics. Micro-level data were collected on water and nitrogen inputs, crop uptake rates, product removal and the avenues of nitrogen and water losses. The data were used to validate the model.

The model was then used to simulate the water and nitrogen losses in the soil surface and subsurface areas for alternative application rates and methods of fertiliser and water application. Various 'what if' simulation scenarios were used to assess a range of management options for input use and crop yields. The analysis was used to identify strategies to maintain or increase productivity and minimise the impact on the environment.

The third step involved training and information dissemination programs to facilitate the adoption of input efficiency improvements across the NCP. A user-friendly decision-support tool was developed to help farm advisers identify optimal input management of water and fertiliser. Project leaders conducted numerous workshops and site visits to encourage the adoption of the research advice.

The project included training for Chinese scientists and postgraduate students in the research methodology for studying water and nitrogen use in intensive cereal production. The aim was to encourage further research and the development of follow-on projects for other areas of the NCP. The training also showed how a modelling framework can be used to provide advice on sustainable crop production and environmental management issues.

3.3 Project management and collaboration

The project was a multifaceted study involving the coordination of six institutions across two countries. It required the integration of research methodologies across several disciplines. It also involved the coordination of scientific research trials across five experimental sites, three on the NCP and two in northern Victoria, Australia.

Capacity-building in applied scientific research and farm extension was a key feature of the project. The project involved extensive collaboration among scientists from the Chinese Academy of Sciences at Nanjing, as well as researchers of the China Agricultural University at Beijing and Quzhou.

In Australia, three research institutions participated in the project:

- the Institute of Land and Food Resources, University of Melbourne
- the Department of Natural Resources and Environment, Victoria
- the Centre for GIS and Modelling, University of Melbourne.

In China, three research institutions participated in the project:

- the Institute of Soil Science, Chinese Academy of Sciences, Nanjing, Jiangsu Province
- the China Agricultural University, Beijing
- the Shijiazhuang Institute of Agricultural Modernisation, Chinese Academy of Sciences, Shijiazhuang, Hebei Province.

The primary research involved intensive field measurements of wheat and maize production at three field sites in China — Quzhou, Luancheng and Fengqui. This required the adoption of common experiment and data protocols. It also required the adaptation of three modelling approaches to bring experimental results into a framework that was suitable for policy makers.

3.4 Project expenditures

Project funding was provided for the period from April 1998 to June 2002 (4.5 years). The funding came from several sources, including the ACIAR contribution of A$881,253 (Table 1). There were cash and in-kind funding contributions from other organisations collaborating in the project. The project received a funding extension of A$150,000 for July 2002 to June 2003. Total ACIAR project expenditure was A$1,032,240.

Total project expenditure was estimated at A$2.94 million. After adjusting for inflation, the total expenditure was approximately A$3.1 million in 2001–02 dollars. The ACIAR funding was verified against records of actual budget expenditures. It was not possible to verify the other funding contributions.

Table 1. Estimated project expenditures (A$).

	1997–98	1998–99	1999–00	2000–01	2001–02	2002–03	Total
ACIAR[a]	106,987	386,186	168,397	145,497	74,186	149,987	1,031,240
Other contributions[b]	456,625	431,731	413,851	413,851	190,026	0	1,906,084
Total expenditures	563,612	817,917	582,248	559,348	264,212	149,987	2,937,324

[a] ACIAR project expenditures.
[b] Cash and in-kind contributions from other organisations collaborating in the project.
Source: Melbourne University, pers. comm.

3.5 Review of project achievements

ACIAR commissioned an independent project review in March 2001. The review focused on the scientific research and the contribution it would make towards improvements in social, economic and environmental outcomes. The review team had a range of skills including nitrogen dynamics and soil microbiology, soil physics and hydrology, and experience in agricultural systems modelling.

The review team travelled to China for site visits and a range of technical presentations on research activities and scientific results. It also included presentations from various local and provincial government representatives on the expected outcomes of the project in terms of changing farmer behaviour.

The overall assessment was the project had a high potential for improving economic and environmental performance of intensive cereal production in the NCP. The review concluded the project had delivered on all the stated objectives. It had been successful in:

- improving the understanding of the dynamics of water and nitrogen use in two contrasting environments
- developing spatial modelling interpretation tools that would be useful in policy development
- building research capacity in Chinese institutions that would extend the adoption of input efficiency improvements throughout the NCP.

4 Valuing the economic benefits

The project involved the collaboration of several research institutions. The economic benefits are assessed for the project in China. Supporting research was conducted in Australia, but this study is concerned with the benefits that accrued in particular regions of the North China Plain (NCP).

The time horizon for estimating project benefits is 30 years. The project commenced in 1997–98. Benefits began to accrue from the time farm extension activities commenced. Project results are being used to make recommendations on fertiliser and water use for a wheat–maize annual cropping enterprise.

The approach used in valuing the project benefits involved several steps:

- defining the project impact area
- calculating the arable land used for double-cropping of wheat and maize
- defining the nature of the benefits and estimate the average farm-level impact

- developing assumptions for the time horizon of farmer adoption rates
- applying the farm-level impact to the wheat–maize cropping areas adjusted for the level of adoption.

4.1 Project impact area

In valuing the economic benefits it is important to recognise regional differences in the project results. The primary research was carried out at research stations in three different localities. The collaborating partners obtained different farm-level results from their respective research sites. The research stations were located in:

- Quzhou County
- Luancheng County
- Fengqiu County.

Project results have been communicated to farmers in the counties where the research stations are located. Project leaders, county officials and farm advisers have cooperated in running field days and advising farmers of the benefits from changing the way water and nitrogen inputs are used. Therefore, the project impact area is limited to a portion of the NCP area for wheat–maize production.

The structure of government responsibilities in China defines the project impact area. China is divided into provinces:

- each province is divided into several city regions — previously called districts
- each city region is divided into several counties
- each county is composed of several communes — Fengqiu County, for example, has 20 communes
- a commune is made up of several villages.

It was assumed the trial results were directly applicable to the potential benefits that could be achieved in the respective counties. Luancheng County and Quzhou County are located in the Hebei Province, which is north of the Yellow River. Fengqiu County is part of the Xinxiang City Region, which is located further south in Henan Province.

The project impact area was defined as Quzhou and Luancheng counties and the entire Xinxiang City Region. The impact area for the Fengqiu research extends beyond the county because project results have been disseminated throughout the city region. There were strong links between the Fengqiu project team and the Agriculture Extension Department of the city government:

- the Xinxiang City Region has seven counties and the central City District
- the Vice Secretary-General of the Xinxiang Municipal People's Government was interviewed as part of the project evaluation process.

Estimates of the project impact area are provided in Table 2. Regional project leaders provided estimates on the farming areas allocated to wheat–maize production at the start of the farm extension activities — the 2001–02 crop year:

- the impact area for Quzhou County included an estimate of wheat areas that were partially double-cropped with maize.

The evaluation assumed project benefits would accrue to only those land areas that were double-cropped to wheat and maize. This implies that land used for wheat and alternative summer crops did not gain any benefits from the project. While some farmers might adapt the project advice for other cereal cropping areas, where this occurred it would be a flow-on benefit that is not directly attributable to the project:

- research activities and extension advice specifically related to the combination of wheat and maize production in specific areas of the NCP.

4.2 Project benefits

Adoption of the project advice on the application of fertiliser and water inputs will have two types of benefits. There are farm-level economic benefits from reductions in input expenditures. There is also the potential for significant environmental benefits if the changes in input use are widely adopted.

Table 2. Project impact area.[a]

	Quzhou County	Luancheng County	Xinxiang City District[b]	Project impact area
Total cereal cropping area (ha)	32,200	18,333	380,000	430,533
Fully double cropped to wheat and maize				
Proportion (%)	70.0	86.0	50.0	–
Wheat–maize area (ha)	22,540	15,765	190,000	–
Partially double cropped to wheat and maize				
Diversified cropping area (ha)	9,660	–	–	–
Proportion[c] (%)	66.7	–	–	–
Wheat–maize area (ha)	6,443	–	–	–
Allocation of total cereal cropping area				
Wheat–maize area (ha)	28,983	15,765	190,000	28,983
Other cropping area[d] (ha)	3,217	2,568	190,000	208,982

[a] Based on 2001–02 cropping areas.
[b] Includes Fengqiu County and other counties in the Xinxiang City District.
[c] Proportion of diversified cropping area allocated to wheat–maize.
[d] Evaluation assumes the remaining area of diversified farm use does not adopt the project advice.
Sources: China Agricultural University and Chinese Academy of Sciences, pers. comms.

Environmental benefits will come from reduced contamination of groundwater supplies, reduced soil degradation (i.e. salinity) and lower greenhouse gas emissions. Estimating the value of these benefits is a complex issue and would involve a substantial analytical effort. It is beyond the scope of this evaluation to value these benefits and they have not been included in the calculation of the project net benefits.

The economic benefits relate to farm-level productivity improvements. Using less inputs to produce the same level of output will reduce the per unit average cost of production. Farmers who adopt the project advice will benefit from improved net returns. It will help reduce rural poverty, as poor farmers will gain more net revenue for the same level of wheat and maize production.

There are three components to the economic benefits:

- cost saving in fertiliser applications
- cost saving in water applications
- changes in wheat and maize yields.

These benefits are valued separately for each of the three project impact areas. They are measured against a 'baseline' situation of no project. The baseline assumes no change in the areas sown to wheat–maize in the project impact areas for the duration of the evaluation period. It also implicitly assumes no change in market returns, input costs and other factors that affect crop yields.

4.3 Approach in valuing the economic benefits

The project benefits are determined by the farm-level cost savings on input use and the value of changes in crop yields. Estimation of the benefits was complicated by the way in which the project results were communicated to farmers. Extension advice was disseminated in two stages during the course of the project.

Initially, farmers were advised to make changes in fertiliser use. The advice was to change the application method and reduce the amount for fertiliser used for each crop. The traditional approach of depositing fertiliser on the ground (surface broadcast) with no follow-up watering was a highly ineffective application method. There were substantial nitrogen losses through ammonia volatilisation.

Surface broadcast followed by an immediate watering would reduce the nitrogen losses through volatilisation. Direct drilling of fertiliser into the ground was an alternative approach that would also reduce nitrogen losses. A simple, home-made tool was developed and used by farmers to direct drill the fertiliser.

Reduced nitrogen losses increased the effectiveness of fertilising both crops. Farmers were advised that the application rate could be reduced without affecting crop yields if the method of application was changed. Recommendations on application rates varied according to the biophysical characteristics of the crop land:

- in some cases, crop yields increased despite a reduction in fertiliser use.

The second stage of disseminating project results involved changes in water use. Research trials and practical results showed a significant reduction in water use could be achieved without affecting crop yields. The nature of this advice varied for each of the three research sites. In general, farmers were advised to irrigate the crops more often, but to apply smaller amounts during each watering.

The project demonstrated that over-watering during each irrigation application increased the leaching of nitrogen out of the soil. Large quantities of water were also being wasted, as the soil was unable to absorb any more moisture once a certain point was reached. The net effect of the advice was a reduction in total water use during the growing season for the two crops.

Farmers were advised that water application rates could be reduced without affecting crop yields. Recommendations on water applications rates varied between the three research sites. Assessing the average reduction in water use was less definitive than the change in fertiliser use. Annual variations in rainfall affected the amount of irrigation water required under the project recommendations:

- in some circumstances there could be a negative effect on crop yields.

Project benefits have been evaluated separately for the two components of extension advice. Extension programs on fertiliser use began in the 2001. It was assumed that farmer adoption of the advice began to occur in the 2001–02 crop year. Extension programs on water use began in 2003, with the initial adoption effect to occur in the 2003–04 crop year.

Before the extension programs were initiated, there were differences in the traditional application rates for fertiliser and water inputs in each of the three project impact areas. The corresponding advice on recommended application rates was different in each case. The regional project leaders also indicated there were differences in the rates of adoption of project advice.

Valuation of the project benefits had to account for these differences in the three project impact areas. Assumptions were developed for each area on the basis of discussions with regional project leaders. Information provided by the project leaders was supplemented by other economic data. Valuation of project benefits did not include farm extension activities, because the project advice was provided as part of existing extension programs.

4.4 Farmer adoption rates

A time path of farmer adoption rates was developed from estimates provided by project leaders (Table 3). Farm extension programs have been active since 2001 and operating throughout the impact areas. Village leaders have been advising county officials on the level of uptake. This provided a reasonable indication of adoption levels up to 2003–04.

Table 3. Farmer adoption (percentages) of project advice.[a]

	Quzhou County			Luancheng County			Xinxiang City District[b]		
	Fertiliser advice	Irrigation advice	No change	Fertiliser advice	Irrigation advice	No change	Fertiliser advice	Irrigation advice	No change
2000–01	0	0	100	0	0	100	0	0	100
2001–02	20	0	80	20	0	80	20	0	80
2002–03	40	0	60	40	0	60	40	0	60
2003–04	55	10	45	55	25	45	55	10	45
2004–05	70	20	30	70	35	30	70	20	30
2005–06	75	25	25	75	40	25	75	25	25
2006–07	75	30	25	75	45	25	75	30	25
2007–08	75	35	25	75	50	25	75	35	25
2008–09	75	35	25	75	50	25	75	35	25
2009–10	75	35	25	75	50	25	75	35	25
2011–2027	75	35	25	75	50	25	75	35	25

[a] Farmer training on fertiliser use commenced in 2001. Farmer training on water use management commenced in 2003.
[b] Includes Fengqiu County and other counties in the Xinxiang City District.
Sources: China Agricultural University and Chinese Academy of Sciences, pers. comms.

Adoption rates vary over time. Typically, the initial adoption rate is limited. It then accelerates rapidly as farmers observe the outcomes of early adopters. The rate of adoption tails-off as the maximum level of adoption is approached.

Initial adoption of advice on fertiliser use has been substantial. In general, farmers are convinced about the cost-reduction benefits and that crop yields may rise in some situations. The benefit can be achieved with a relatively minor change in the application method. Government officials expect to achieve adoption levels of 90%. Widespread adoption is likely to occur, but the evaluation has assumed a more conservative final adoption level of 75%.

Adoption of advice on water use has been more variable. Farmers are less convinced about the cost-reduction benefits and are concerned about possible reductions in crop yields. The exception was Luancheng County, where initial adoption was reportedly as high as 45%. Government officials expect to achieve adoption levels as high as 70–80%.

Given the experiences elsewhere, a more conservative set of assumptions was used for adoption levels in Luancheng County. The evaluation assumes a 50% final adoption level due to the relatively strong initial response. Advice on water use has had only limited initial acceptance in Quzhou County and the Xinxiang City District. The evaluation assumes a final adoption level of 35% for those two areas.

4.5 Valuing the project benefits

Farm-level benefits are expressed in terms of cost savings and changes in crop yields. The changes have to be valued at the 'economic price' of the inputs and outputs. Subsidies and taxes can distort market prices, which may therefore not be a good reflection of the economic value. In these circumstances, 'shadow prices' (see below) are used to value the project benefits.

Before 1998, the central government controlled two thirds of China's grain marketing. Grain policies were designed to support grain self-sufficiency objectives, improve farmer incomes and ensure affordable food prices in urban areas. Half the market transactions were conducted at market prices and the remainder occurred at controlled prices.

In 2000, a series of policy reforms was implemented. Procurement prices for spring wheat grown in selected northeastern provinces were eliminated. They were also terminated for all types of wheat grown south of the Yangtze River (Hsu et al. 2001). Despite the reforms, procurement programs and import restrictions continue to distort domestic grain prices.

Policy arrangements have also distorted domestic maize prices. In the late 1990s, domestic prices were substantially higher than the world price. The central government was providing export subsidies to reduce a growing stockpile of surplus maize (Gale 2001). China agreed to eliminate maize export subsidies after joining the World Trade Organization in late 2001. However, imports were constrained by a tariff-quota, and domestic prices still exceeded the world price by a significant margin (Gale 2004).

The evidence suggests marketing arrangements and trade policies may still be distorting domestic prices for wheat and maize in China (Gale 2002). In 2001–02, the farm-gate price for wheat was around US$121/tonne and maize prices were around US$97/tonne. In the same year, US grain export prices averaged:

- US$127/tonne for hard red winter wheat (ordinary), fob, Gulf ports
- US$103/tonne for no. 2 yellow maize, fob, Gulf ports.

These prices are a reasonable indicator of world grain prices. An equivalent farm-gate price in China requires a discount of around 15% for transport and handling costs. This suggests an 'economic price' of US$108/tonne for wheat and US$88/tonne for maize — equivalent to A$206/tonne for wheat and A$168/tonne for maize (A$1 = US$0.52 in 2001–02). These shadow prices were used to value the changes in crop yields.

The issue of input price distortions in Chinese agriculture is less obvious. It is not possible to determine if there are significant subsidies that reduce the cost of fertiliser and electricity for farmers. The fertiliser industry might benefit from some government assistance but, if so, it is not clear if this would flow through to farm-gate prices.

Accordingly, the evaluation uses Chinese market prices for fertiliser and electricity to value the benefits of reduced input use. The changes in nitrogen fertiliser use were adjusted to a urea-equivalent basis.

4.6 Production response

The improvement in net returns from cost reductions and changes in crop yields is likely to lead to some production response. Econometric estimates of supply elasticities for wheat and maize production in China were not readily available. Statistical estimation work has been constrained by concerns about the accuracy of data.

Estimates of supply elasticities for grain production in other countries have typically ranged from 0.1 to 0.4. Historically, the supply response in the NCP has been constrained by policies that limited the incentive for farmers to change land use. In recent years, policy reforms have encouraged farmers to become more responsive to relative returns.

The NCP supply response to the project benefits is likely to be relatively small. Arable land use in the three project impact areas is still heavily focused on wheat and maize production. Land available to switch into double-cropping of wheat and maize is limited. For that reason, the evaluation assumed an elasticity of 0.1 for cereal-cropping areas:

- the supply impact of the improvement in net returns will vary over time, in line with changes in the level of farmer adoption
- it assumes a lag of one year in the response to a change in net returns.

The increased production from yield gains and the area supply response are unlikely to have any significant impact on wheat and maize prices for domestic consumers. Yield changes are relatively small, because the project focused on input changes that would not lead to lower crop yields. The project impact area is also limited to a small portion of the NCP:

- in 2001–02, China produced approximately 93.9 million tons of wheat and 114.1 million tonnes of maize (USDA 2003)

- around half of China's total wheat production is sourced from the NCP
- the maximum annual effect of the project on total grain supplies is less than 0.04 million tonnes of wheat and 0.02 million tonnes of maize.

4.7 Estimates of project benefits

Trials at the three research stations provided site-specific measurements of the changes in input use that could be achieved. The data were derived from farm plots at the research stations and demonstration farms in near-by villages. The results reflected changes from the typical application rates used by farmers in the region.

The sizes of the reductions in fertiliser and water use varied at each site. They reflected differences in the traditional rates of water and nitrogen use in the surrounding region. They also reflected regional differences in the physical characteristics of farm land — soil types and the corresponding interactions in water and nitrogen use.

The research trials identified the optimal level of water and nitrogen use for the wheat–maize cropping system. Model simulations were used to assess the effect of alternative scenarios for reductions in input use on different soil types. The project results were supplemented with field trials by farmers in the surrounding region.

The project results were used to develop recommendations on input use for policy makers to use in extension programs to farmers. This advice and the expected impact on crop yields were used to make assumptions for valuing the project benefits. Project leaders also provided information on the average changes that were likely to occur across their respective project impact areas.

Research results often do not translate directly to real-world situations. Some additional survey data were obtained to help validate the assumptions. In each of the three counties, a group of farmers from a particular village was interviewed about its experiences in adopting the project advice:

- the data used to develop assumptions on the project impact in each area are summarised in an appendix to this report.

4.7.1 Economic benefits in Quzhou County

Quzhou County is a major producer of wheat and maize, with almost 29,000 ha devoted to the double-cropping enterprise. The average farm size is around 0.53 ha, and most families retain a substantial portion of their wheat crop for home consumption. Most of the maize crop is sold in local markets to provide cash income:

- the average farm income is around 8500 yuan per year (A$1890).

Research at the Quzhou site showed ammonia volatilisation from maize was the primary cause of nitrogen losses. Nitrate leaching from over-watering was also identified as a major issue, especially in growing maize. In some cases, up to 40% of a single water application was wasted as the water passed through to groundwater.

The project recommendations for Quzhou County had four components:

- change the fertiliser application method to either direct drilling or surface broadcast followed by an immediate watering
- reduce the fertiliser application rate
- reduce the amount of water used and change the timing of flood irrigation during the course of the growing season
- retain and mulch the straw by-products into the soil.

The research trials were concerned with changing the amount of nitrogen applied to the two crops. In urea-equivalent terms, the traditional fertiliser application rate averages around 975 kg/ha. Field results suggested an annual reduction of 225 kg/ha (23%) could be achieved without a significant effect on crop yield. It was assumed that the 23% reduction in fertiliser use applied throughout Quzhou County.

Recommendations on irrigation applications implied a reduction in water use of around 500 m^3 per year. The reduction in electricity use for pumping water was around 35 kW for an average farm size of 0.53 ha. Based on prevailing electricity prices, the reduction in energy costs was around 45 yuan/ha per year. There was no significant change in labour requirements from adjusting flood-irrigation applications.

Traditionally, soil preparation after harvest involved the removal of cereal by-products from the farm plot. Retention of the cereal straw as mulch would improve soil fertility and nitrogen retention. This would be reflected in the recommended reductions in fertiliser use. Additional benefits come from cost savings in farm labour and transport. These were estimated at around 94 yuan/ha per year.

The benefits from input-cost reductions in Quzhou County are summarised in Table 4. Most of the cost savings come from reductions in fertiliser use. This partially reflects the lower adoption of advice on changing water use and crop by-product management.

The impact on crop yields of these changes was relatively benign. In 2001–02, the average wheat yield in Quzhou County was around 6000 kg/ha and maize yields averaged around 6975 kg/ha. The project advice caused wheat yields to decline marginally and maize yields to rise slightly. The benefits from yield improvements are summarised in Table 5:

- the net effect implies no change in grain production for an average-size farm.

Table 4. Project benefits from change in input costs, Quzhou County.

	Double cropping area[a]	Fertiliser use			Water and crop by-product use			
		Change in application rate[b]	Adoption rate	Cost of input use[c]	Change in pumping costs[d]	Change in by-product costs[e]	Adoption rate	Cost of input use[c]
	(ha)	(kg/ha)	(%)	('000 yuan)	(yuan/ha)	(yuan/ha)	(%)	('000 yuan)
2001–02	28,983	–225	20.0	–1800	–45	–94	0.0	0
2002–03	29,002	–225	40.0	–3602	–45	–94	0.0	0
2003–04	29,020	–225	55.0	–4956	–45	–94	10.0	–403
2004–05	29,038	–225	70.0	–6311	–45	–94	20.0	–806
2005–06	29,056	–225	75.0	–6766	–45	–94	25.0	–1008
2006–07	29,063	–225	75.0	–6768	–45	–94	30.0	–1210
2007–08	29,065	–225	75.0	–6769	–45	–94	35.0	–1411
2008–09	29,068	–225	75.0	–6769	–45	–94	35.0	–1412
2009–10	29,068	–225	75.0	–6769	–45	–94	35.0	–1412
2011–2027	29,068	–225	75.0	–6769	–45	–94	35.0	–1412

[a] Cropping area adjusted for producer supply response.
[b] Assumed 23% annual reduction in nitrogen fertiliser use expressed in urea-equivalent terms.
[c] Valued at average price paid by farmers for urea fertiliser.
[d] Based on electricity costs for pumping water and the change in water application rates.
[e] Energy and labour-cost savings from mulching and retaining cereal straw in the soil.
Source: China Agricultural University, Beijing, pers. comm.

Table 5. Project benefits from change in crop yields, Quzhou County.

	Double cropping area[a]	Wheat crop			Maize crop		
		Change in yield[b]	Adoption rate[c]	Crop revenue[d]	Change in yield[b]	Adoption rate[c]	Crop revenue[d]
	(ha)	(kg/ha)	(%)	(yuan)	(kg/ha)	(%)	(yuan)
2001–02	28,983	–150	20.0	–777	150	20.0	632
2002–03	29,002	–150	40.0	–1555	150	40.0	1265
2003–04	29,020	–150	55.0	–2139	150	55.0	1740
2004–05	29,038	–150	70.0	–2724	150	70.0	2216
2005–06	29,056	–150	75.0	–2921	150	75.0	2376
2006–07	29,063	–150	75.0	–2921	150	75.0	2376
2007–08	29,065	–150	75.0	–2922	150	75.0	2377
2008–09	29,068	–150	75.0	–2922	150	75.0	2377
2009–10	29,068	–150	75.0	–2922	150	75.0	2377
2011– 2027	29,068	–150	75.0	–2922	150	75.0	2377

[a] Cropping area adjusted for producer supply response.
[b] Assumes average reduction in wheat yield of 2.5%, and average increase in maize yield of 2%.
[c] The change in crop yields is related to adjustments in fertiliser use.
[d] Valued at shadow prices derived from world prices of wheat and maize.
Source: China Agricultural University, Beijing, pers. comm.

4.7.2 *Economic benefits in Luancheng County*

In Luancheng County, most of the arable cropping land is used for wheat and maize. In 2001–02, around 15,800 ha was allocated to the double-cropping enterprise. The average farm size is around 0.53 ha. Most of the wheat crop is retained for home consumption and most of the maize crop sold for cash income:

- the average farm income is around 8000 yuan per year (A$1780).

The Luancheng research identified ammonia volatilisation as the main cause of nitrogen fertiliser losses. Up to 27% of the nitrogen content of urea applied to a maize crop was lost by volatilisation. Nitrate leaching from over-watering was also identified as a major issue. In some situations, water use could be reduced by up to 40% without significantly lowering crop yields.

Project recommendations for Luancheng County had three components:

- change the fertiliser application method to either direct drilling or surface broadcast followed by an immediate watering
- reduce the fertiliser application rate

- reduce the amount of water used and change the timing of flood irrigation during the course of the growing season.

Research trials focused on the change in nitrogen use that would not significantly reduce crop yields. In urea-equivalent terms, the traditional fertiliser application rate averaged around 900 kg/ha. Field results recommended reducing fertiliser use by 180 kg/ha (20%) per year. It was assumed the 20% reduction in fertiliser use applied throughout the county.

Recommendations on irrigation application implied a reduction in water use of around 1500 m^3 per year. The reduction in electricity use for pumping water was around 140 kW for an average farm size of 0.53 ha. Based on rural electricity prices, the reduction in energy costs was around 205 yuan/ha per year. There was no significant change in labour requirements from adjusting flood-irrigation applications.

The benefits from input-cost reductions in Luancheng County are summarised in Table 6. There are substantial cost savings from reductions in fertiliser use and irrigation. The adoption of advice on changing water use has been significantly higher in this county than in the other project impact areas.

Table 6. Project benefits from change in input costs, Luancheng County.

	Double cropping area[a]	Fertiliser use			Water and crop by-product use		
		Change in application rate[b]	Adoption rate	Cost of input use[c]	Change in pumping costs[d]	Adoption rate	Cost of input use[c]
	(ha)	(kg/ha)	(%)	('000 yuan)	(yuan/ha)	(%)	('000 yuan)
2001–02	15,765	–180	20.0	–783	–206	0.0	0
2002–03	15,789	–180	40.0	–1569	–206	0.0	0
2003–04	15,813	–180	55.0	–2160	–206	25.0	–815
2004–05	15,839	–180	70.0	–2754	–206	35.0	–1143
2005–06	15,860	–180	75.0	–2955	–206	40.0	–1308
2006–07	15,868	–180	75.0	–2956	–206	45.0	–1473
2007–08	15,870	–180	75.0	–2957	–206	50.0	–1637
2008–09	15,871	–180	75.0	–2957	–206	50.0	–1637
2009–10	15,871	–180	75.0	–2957	–206	50.0	–1637
2011–2027	15,871	–180	75.0	–2957	–206	50.0	–1637

[a] Cropping area adjusted for producer supply response.
[b] Assumed 20% annual reduction in nitrogen fertiliser use expressed in urea-equivalent terms.
[c] Valued at average price paid by farmers for urea fertiliser.
[d] Based on electricity costs for pumping water and the change in water application rates.
Source: Chinese Academy of Sciences, Luancheng, pers. comm.

The changes in input use had a small, positive effect on crop yields. In 2001–02, the average wheat yield in Luancheng County was around 5775 kg/ha and maize yields averaged around 7725 kg/ha. The project advice caused wheat yields to rise by 225 kg/ha and maize yields to rise by 300 kg/ha. The benefits from yield improvements are summarised in Table 7:

- this implies a 4% rise in grain production for an average-size farm.

Table 7. Project benefits from change in crop yields, Luancheng County.

	Double cropping area[a] (ha)	Wheat crop			Maize crop		
		Change in yield[b] (kg/ha)	Adoption rate[c] (%)	Crop revenue[d] (yuan)	Change in yield[b] (kg/ha)	Adoption rate[c] (%)	Crop revenue[d] (yuan)
2001–02	15,765	225	20.0	634	300	20.0	688
2002–03	15,789	225	40.0	1270	300	40.0	1377
2003–04	15,813	225	55.0	1748	300	55.0	1896
2004–05	15,839	225	70.0	2229	300	70.0	2418
2005–06	15,860	225	75.0	2391	300	75.0	2594
2006–07	15,868	225	75.0	2393	300	75.0	2595
2007–08	15,870	225	75.0	2393	300	75.0	2595
2008–09	15,871	225	75.0	2393	300	75.0	2596
2009–10	15,871	225	75.0	2393	300	75.0	2596
2011–2027	15,871	225	75.0	2393	300	75.0	2596

[a] Cropping area adjusted for producer supply response.
[b] Assumes average reduction in wheat yield of 4%, and average increase in maize yield of 4%.
[c] The change in crop yields is related to adjustments in fertiliser use.
[d] Valued at shadow prices derived from world prices of wheat and maize.
Source: Chinese Academy of Sciences, Luancheng, pers. comm.

4.7.3 *Economic benefits in Xinxiang City District*

In the Xinxiang City District, about half of the arable cropping land is used for wheat and maize. In 2001–02, the double-cropping area was around 190,000 ha, with Fengqiu County accounting for about 67,500 ha. The average farm size is around 0.53 ha. On average, Xinxiang farmers use about 40% of their grain harvest for home use:

- the average farm income is around 8000 yuan per year (A$1780).

The Fengqiu research identified ammonia volatilisation as the main cause of nitrogen loss. Up to 48% of the nitrogen content of urea applied to a maize crop was lost by volatilisation. Nitrate leaching from over-watering was identified as another major issue.

Project recommendations for Fengqiu County were applied throughout the Xinxiang City District. There were three components:

- change the fertiliser application method to either deep placement or surface broadcast followed by an immediate watering
- reduce the fertiliser application rate
- reduce the amount of water used and change the timing of flood irrigation during the course of the growing season.

The research identified the change in nitrogen use that would not significantly reduce crop yields. In urea-equivalent terms, the traditional fertiliser application rate averages around 1035 kg/ha. Field results indicated that an annual reduction of 210 kg/ha (20%) could be made without a significant effect on crop yields. It was assumed that a 20% reduction in fertiliser use applied throughout the Xinxiang City District.

Recommendations on irrigation applications were for a reduction in water use of around 28% per year. The reduction in electricity use for pumping water was around 35 kW for an average farm size of 0.53 ha. Based on prevailing electricity prices, the reduction in energy costs was around 47 yuan/ha per year. There was no significant change in labour requirements from adjusting flood-irrigation applications.

The benefits from input-cost reductions in the Xinxiang City District are summarised in Table 8. There are substantial cost savings from reductions in fertiliser use and irrigation. Adoption of advice on changing water use has been significantly lower in the Xinxiang City District than in the other project impact areas.

The changes in input use had a significant positive effect on crop yields. Average wheat yield in the Xinxiang City District was around 5250 kg/ha in 2001–02. Maize yields averaged around 5550 kg/ha. The project advice caused wheat and maize yields to each rise by around 225 kg/ha. Yield improvement benefits are summarised in Table 9:

- the net effect implies a 4% rise in grain production for an average-size farm.

Table 8. Project benefits from change in input costs, Xinxiang City District.

	Double cropping area[a]	Fertiliser use			Water and crop by-product use		
		Change in application rate[b]	Adoption rate	Cost of input use[c]	Change in pumping costs[d]	Adoption rate	Cost of input use[c]
	(ha)	(kg/ha)	(%)	('000 yuan)	(yuan/ha)	(%)	('000 yuan)
2001–02	190,000	–210	20.0	–11,012	–47	0.0	0
2002–03	190,386	–210	40.0	–22,070	–47	0.0	0
2003–04	190,774	–210	55.0	–30,407	–47	10.0	–894
2004–05	191,078	–210	70.0	–38,762	–47	20.0	–1791
2005–06	191,382	–210	75.0	–41,597	–47	25.0	–2243
2006–07	191,486	–210	75.0	–41,619	–47	30.0	–2693
2007–08	191,492	–210	75.0	–41,621	–47	35.0	–3142
2008–09	191,499	–210	75.0	–41,622	–47	35.0	–3142
2009–10	191,499	–210	75.0	–41,622	–47	35.0	–3142
2011–2027	191,499	–210	75.0	–41,622	–47	35.0	–3142

[a] Cropping area adjusted for producer supply response.
[b] Assumed 20% annual reduction in nitrogen fertiliser use expressed in urea-equivalent terms.
[c] Valued at wholesale price of urea fertiliser.
[d] Based on electricity costs for pumping water and the change in water application rates.
Source: Chinese Academy of Sciences, Fengqiu, pers. comm.

Table 9. Project benefits from change in crop yields, Xinxiang City District.

	Double cropping area[a]	Wheat crop			Maize crop		
		Change in yield[b]	Adoption rate[c]	Crop revenue[d]	Change in yield[b]	Adoption rate[c]	Crop revenue[d]
	(ha)	(kg/ha)	(%)	(yuan)	(kg/ha)	(%)	(yuan)
2001–02	190,000	225	20.0	7,639	225	20.0	6,214
2002–03	190,386	225	40.0	15,310	225	40.0	12,454
2003–04	190,774	225	55.0	21,094	225	55.0	17,159
2004–05	191,078	225	70.0	26,890	225	70.0	21,874
2005–06	191,382	225	75.0	28,856	225	75.0	23,474
2006–07	191,486	225	75.0	28,872	225	75.0	23,486
2007–08	191,492	225	75.0	28,873	225	75.0	23,487
2008–09	191,499	225	75.0	28,874	225	75.0	23,488
2009–10	191,499	225	75.0	28,874	225	75.0	23,488
2011–2027	191,499	225	75.0	28,874	225	75.0	23,488

[a] Cropping area adjusted for producer supply response.
[b] Assumes average reduction in wheat yield of 4.3%, and average increase in maize yield of 4.1%.
[c] The change in crop yields is related to adjustments in fertiliser use.
[d] Valued at shadow prices derived from world prices of wheat and maize.
Source: Chinese Academy of Sciences, Fengqiu, pers. comm.

5 Project net benefits

Estimates of the annual project benefits are presented in Table 10. Benefits are expressed in real (2001–02) Australian dollars. Over the 30-year evaluation period, the total benefits are estimated at just over A$453 million. They represent the economic benefits that will accrue to farmers growing wheat and maize on selected areas of the North China Plain (NCP).

Table 10. Annual project benefits (A$'000).[a]

	Quzhou County	Luancheng County	Xinxiang City District	Total benefits
2001–02	368	468	5,526	6,361
2002–03	718	914	10,804	12,436
2003–04	1,049	1,400	14,712	17,161
2004–05	1,364	1,763	18,431	21,558
2005–06	1,455	1,862	19,361	22,678
2006–07	1,460	1,850	18,987	22,297
2007–08	1,463	1,836	18,611	21,910
2008–09	1,427	1,791	18,157	21,376
2009–10	1,393	1,748	17,715	20,855
2011–2027	19,096	23,965	242,906	285,967
Total	29,794	37,596	385,210	452,600

[a] Converted to Australian dollars using 2002 exchange rate of A$1 = 4.5 yuan. Benefits expressed in real terms—inflation rate of 2.5% assumed for post 2002–03 period.

The evaluation has not attempted to value the environmental benefits of the project. Widespread adoption of advice on irrigation practices will reduce nitrate leaching into the groundwater and improve water quality. The environmental benefits will be substantial if the project research is replicated for other areas of the NCP and farmers adopt the advice.

5.1 Estimated net benefits

The present value of the future stream of net benefits was estimated over a 30-year time horizon at a discount rate of 5%. The project will deliver net benefits of A$216.2 million (Table 11). In present value terms, the project costs were A$2.8 million (in 2001–02 dollars) and the project benefits A$219 million:

- this yields a benefit–cost ratio of about 77 to 1.

The estimated net benefits for the full evaluation period are sensitive to assumptions on future levels of adoption. A progressive project evaluation can assess the project gains that have been achieved to date. In present value terms, the net economic benefits realised so far are around A$24.9 million. This reflects the adoption of project advice up to the end of 2003–04:

- this yields a progressive benefit–cost ratio of about 10 to 1.

Table 11. Estimated net benefits of project (A$m).[a]

	Project costs	Project benefits	Net benefits
Full project evaluation[b]	2.8	219.0	216.2
Benefit–cost ratio	–	–	77.1
Progressive project evaluation[c]	2.8	27.8	24.9
Benefit–cost ratio	–	–	9.8

[a] Expressed in present value terms—discount rate of 5%. Benefits and costs valued in real 2001–02 dollars.
[b] Evaluation of net benefits for 30-year time horizon, 1997–98 to 2026–27.
[c] Evaluation of net benefits realised to date, 1997–98 to 2003–04.

5.2 Sensitivity analysis of project net benefits

It is worthwhile considering the sensitivity of the estimated net benefits to different assumptions for the future level of adoption of project advice. Some county officials expect the fertiliser advice will eventually be adopted by 90% of farmers. This is a realistic expectation as farmers can achieve a significant financial gain for a relatively minor adjustment in crop management:

- the evaluation used a more conservative final adoption rate of 75%.

However, it is possible that the assumptions on adoption levels will overstate the actual level of uptake. Village reports and the views of county officials may have an overly optimistic view of future adoption levels. Reporting requirements for farm extension activities can sometimes encourage administrators to develop a more positive view of the future success of these types of programs.

At the same time, it is possible that future adoption of water management advice may be higher than the assumption used for the evaluation. Farmers are concerned about the possible effects of changing water applications on crop yields. But practical applications should increasingly demonstrate that crop yields are not adversely affected. More farmers may be convinced about the benefits of changing the way they use flood irrigation.

The project evaluation has been based on adoption levels that are more conservative than the advice provided by project leaders. To assess the sensitivity of these assumptions, project net benefits were calculated for alternative adoption levels. The sensitivity analysis used adoption levels that were 20% higher and 20% lower than those used for the estimate reported in Table 11.

These sensitivity factors were applied to the assumptions used for adoption of fertiliser and water advice in all project impact areas from 2004–05. For example, adoption of advice on fertiliser use could reach a maximum of either 60% or 90%, around the original assumption of 75%. Similarly, adoption of advice on water use in Luancheng County could reach a maximum of either 40% or 60%, instead of the original assumption of 50%.

Changing the assumptions on adopting the project advice had a significant effect on the size of the project net benefits. In present value terms, the project net benefits were A$178 million and A$255 million for the alternative assumptions (Table 12). This means the estimated net benefits would be around A$38 million lower (higher) if the assumption used for adoption levels proved to be overly optimistic (pessimistic).

Table 12. Sensitivity analysis of project net benefits (A$m).[a]

	Farmer adoption levels		Reduction in fertiliser use	
	20% lower	20% higher	20% lower	20% higher
	Net benefits	Net benefits	Net benefits	Net benefits
Full project evaluation[b]	177.8	254.6	196.3	236.0
Benefit–cost ratio	63.6	90.6	70.1	84
Progressive project evaluation[c]	24.9	24.9	22.3	27.5
Benefit–cost ratio	9.8	9.8	8.9	10.7

[a] Expressed in present value terms — discount rate of 5%. Benefits and costs valued in real 2001–02 dollars. Sensitivity analysis for farmer adoption levels applied from 2004–05; all other assumptions were unchanged. Sensitivity analysis for the size of the fertiliser reduction applied from 2001–02; all other assumptions were unchanged.
[b] Evaluation of net benefits for 30-year time horizon, 1997–98 to 2026–27.
[c] Evaluation of net benefits realised to date, 1997–98 to 2003–04.

The size of the reduction in fertiliser use is another key assumption used in the project evaluation. The assumptions used were based on the change from the typical application rates in each of the project impact areas. It is an average effect, with individual farmers making bigger or smaller adjustments according to their traditional application rates.

The project evaluation has been based on average changes in fertiliser use that were provided by project leaders. To assess the sensitivity of these assumptions, project net benefits were calculated for fertiliser reductions that were 20% higher and 20% lower than those used for the estimate reported in Table 11.

- 180 kg/ha (20% lower) and 270 kg/ha (20% higher) for Quzhou County instead of the 225 kg/ha used for the project evaluation
- 144–216 kg/ha for Luancheng County instead of 180 kg/ha
- 168–252 kg/ha for the Xinxiang City District instead of 210 kg/ha.

Changing the assumptions for the reduction in fertiliser use had a smaller effect on the size of the project net benefits. In present value terms, the project net benefits were A$196 million and A$236 million for the alternative assumptions (Table 12). This means the estimated net benefits would be about A$20 million lower (higher) if the assumption used for reductions in fertiliser use proved to be overly optimistic (pessimistic).

5.3 Impact on rural poverty

Farm household poverty is a significant issue on the North China Plain. Many families have limited cash incomes and often rely on income supplements from family members with salaried jobs in urban areas. This project will have a significant poverty-reduction effect for farmers engaged in double-cropping of wheat and maize.

Estimates of the per farm effects of the project advice show a substantial fall in input costs for cereal production (see Appendix):

- in Quzhou County, input costs for an average-size farm growing wheat and maize fall by 17% if advice on fertiliser and water use is fully adopted
- in Luancheng County, input costs fall by 18%
- in the Xinxiang City District, input costs fall by 12%.

As crop yields are either unchanged or marginally higher, the reduction in costs is a direct annual financial benefit for farmers. Small yield improvements also provide some additional income benefits for some farmers. For an average farm size of 0.53 ha, the annual financial gain would be approximately:

- A$50 for Quzhou farmers, made up of A$53 cost savings and a A$3 loss from reduced grain output
- A$109 for Luancheng farmers, made up of A$54 cost savings and A$55 from increased grain output
- A$88 for Xinxiang farmers, made up of A$40 cost savings and A$48 from increased grain output.

These estimates valued the change in grain yields at domestic market prices instead of the shadow prices used for the project evaluation. This is because the market price reflects the real income effects for farmers. Farm household average incomes were in the range A$1780–1890 per year in the three project impact areas. The poverty-reduction benefits from adopting the project advice are equivalent to an increase in income of:

- 3% in Quzhou County
- 6% in Luancheng County
- 5% in the Xinxiang City District.

6 Conclusions

This project was a multifaceted study that focused on the dynamics of water and nitrogen use in cereal production on the North China Plain (NCP). The research demonstrated the potential gains that could be achieved from increased efficiency in input use. Widespread adoption of the project advice will substantially improve the economic and environmental performance of cereal farming in the NCP.

Changing application methods and the rate of application for fertiliser and water inputs will have two benefits. There are economic benefits for farmers from reducing input expenditures. There will also be important environmental benefits if the changes are widely adopted.

The economic benefits relate to gains in farm-level productivity. Using fewer inputs to produce the same level of output will lead to higher net returns. The increased farm incomes will help reduce poverty among NCP farmers. Environmental benefits include less contamination of groundwater supplies, reduced soil degradation and lower greenhouse gas emissions.

Initial adoption of advice on changes in fertiliser use has been encouraging. Farmers are convinced about the cost-reduction benefits that can be achieved, and crop yields may rise in some situations. The fact that achievement of these benefits requires a relatively minor change in application methods suggests the final level of adoption will be high.

The initial adoption of advice on changes in water use has been more variable. Farmers are concerned about possible negative impacts of crop yields. However, over time, many farmers are likely to adopt this advice and gain significant additional economic benefits.

Partial or full adoption of the project advice will produce important complementary benefits for the environment. In present value terms, the estimated net benefits of the project will be around A$216 million. The project has a benefit–cost ratio of about 77 to 1.

The project has made a significant contribution towards building China's capacity in applied scientific research and farm extension. There has been extensive collaboration among scientists from several research institutions. It has required the integration of research methodologies across several disciplines and the coordination of research trials across several experimental sites. In future years, the approach is likely to be used to develop similar projects in other areas of the NCP.

References

Gale, F. 2001 Subsidised corn exports helps prices rebound. In: Hsu, H. and Gale, F., ed., China: agriculture in transition. Washington DC, USDA Agriculture and Trade Report WRS-01-2, 13–16.

—2002. China's corn exports: business as usual despite WTO entry. Washington DC, USDA Electronic Outlook Report FDS-1201-01.

—2004. Is China's corn market at a turning point? Washington, DC, US Department of Agriculture (USDA) Electronic Outlook Report FDS-0C-041.

Hsu, H., Lohmar, B. and Gale, F. 2001. Surplus wheat production brings emphasis on quality. In: Hsu, H. and Gale, F. ed., China: agriculture in transition. Washington DC, USDA Agriculture and Trade Report WRS-01-2, 17–25.

Lohmar, B. 2001. Changes in labor, land, and credit markets lead China's farmers on the path toward modernisation. In: Hsu, H. and Gale, F., ed., China: agriculture in transition. Washington DC, USDA Agriculture and Trade Report WRS-01-2, 9–12.

—2004, China's wheat economy: current trends and prospects for imports. Washington DC, USDA Electronic Outlook Report, WHS-04D-01.

USDA (United States Department of Agriculture) 2003. Grain: world markets and trade. Washington DC, Foreign Agriculture Service Circular Series, FG-01-03.

Appendix — Per farm impact of project advice

Table A1. Farm level impact of project advice in Quzhou County.[a]

	Gong Cun Village		Quzhou County
	Field results[b]	Survey [c]	
Crop area (mu/farm)	7.5	7.5	8.0
Wheat price (yuan/kg)	1.0	1.0	1.0
Maize price (yuan/kg)	0.8	0.8	0.8
Urea fertiliser price (yuan/kg)	1.35	1.38	1.38
Electricity price (yuan/kw)	0.69	0.69	0.69
Crop yields and fertiliser use for traditional farming methods			
Wheat yield (kg/mu)	400	401	400
Maize yield (kg/mu)	463	463	465
Fertiliser application rate[d] (kg/mu)	60.0	65.1	65.0
Crop yields and fertiliser use after adopting project advice			
Wheat yield (kg/mu)	391	391	390
Maize yield (kg/mu)	473	473	475
Fertiliser application rate[d] (kg/mu)	45.0	49.2	50.0
Revenue gain from change in crop yields			
Wheat production (kg)	–68	–80	–80
Maize production (kg)	75	75	80
Crop revenue (yuan)	–8	–20	–16
Cost saving from change in fertiliser use			
Fertiliser use[d] (kg)	113	119	120
Fertiliser costs (yuan)	152	165	166
Cost saving from change in water use			
Electricity use (kw/year)	35	35	35
Electricity costs (yuan)	24	24	24
Cost saving from change in use of crop by-products[e]			
Labour costs (yuan)	20	20	20
Energy costs (yuan)	30	30	30
Annual benefits of adopting project advice			
Household income (yuan)	5770	5800	8500
Project benefit (yuan)	218	219	224
Change in income (%)	3.8	3.8	2.6

[a] Data and impact estimates for the 2001–02 crop year. Area conversion factor of 15 mu = 1 ha.
[b] Results from project research station and surrounding farms.
[c] Random survey of 30 farms — includes equal numbers of higher, average and lower performing farmers.
[d] Total annual application of nitrogen across both crops expressed in urea-equivalent terms.
[e] Imputed cost saving from ending the traditional practice of removing crop straw before sowing.
Source: China Agricultural University, Beijing, pers. comm.

Table A2. Farm level impact of project advice in Luancheng County.[a]

	Bei Shibei and Wen Jiazhuang Villages		Luancheng County
	Field results[b]	Survey [c]	
Crop area (mu/farm)	8.0	7.8	8.0
Wheat price (yuan/kg)	1.0	1.0	1.0
Maize price (yuan/kg)	0.8	0.8	0.8
Urea fertiliser price (yuan/kg)	1.38	1.38	1.38
Electricity price (yuan/kw)	0.79	0.79	0.79
Crop yields and fertiliser use for traditional farming methods			
Wheat yield (kg/mu)	433	370	385
Maize yield (kg/mu)	517	440	515
Fertiliser application rate[d] (kg/mu)	60.0	60.0	60.0
Crop yields and fertiliser use after adopting project advice			
Wheat yield (kg/mu)	450	400	400
Maize yield (kg/mu)	533	480	535
Fertiliser application rate[d] (kg/mu)	47.7	48.0	48.0
Revenue gain from change in crop yields			
Wheat production (kg)	133	234	120
Maize production (kg)	133	312	160
Crop revenue (yuan)	240	484	248
Cost saving from change in fertiliser use			
Fertiliser use[d] (kg)	98	94	96
Fertiliser costs (yuan)	136	129	132
Cost saving from change in water use			
Electricity use (kw/year)	140	185	140
Electricity costs (yuan)	110	145	110
Annual benefits of adopting project advice			
Household income (yuan)	8000	9520	8000
Project benefit (yuan)	486	758	490
Change in income (%)	6.1	8.0	6.1

[a] Data and impact estimates for the 2001–02 crop year. Area conversion factor of 15 mu = 1 ha.
[b] Results from project research station and surrounding farms.
[c] Random survey of 30 farms — includes equal numbers of higher, average and lower performing farmers.
[d] Total annual application of nitrogen across both crops expressed in urea-equivalent terms.
Source: Chinese Academy of Sciences, Luancheng, pers. comm.

Table A3. Farm level impact of project advice in the Xinxiang City District.[a]

	Fengqiu Research Station Village		Xinxiang City District
	Field results[b]	Survey [c]	
Crop area (mu/farm)	7.5	2.0	8.0
Wheat price (yuan/kg)	1.0	1.0	1.0
Maize price (yuan/kg)	0.8	0.8	0.8
Urea fertiliser price (yuan/kg)	1.38	1.38	1.38
Electricity price (yuan/kw)	0.71	0.71	0.71
Crop yields and fertiliser use for traditional farming methods			
Wheat yield (kg/mu)	350	400	350
Maize yield (kg/mu)	370	500	370
Fertiliser application rate[d] (kg/mu)	69.4	60.5	69.0
Crop yields and fertiliser use after adopting project advice			
Wheat yield (kg/mu)	365	417	365
Maize yield (kg/mu)	385	520	385
Fertiliser application rate[d] (kg/mu)	55.6	48.5	55.0
Revenue gain from change in crop yields			
Wheat production (kg)	113	34	120
Maize production (kg)	113	40	120
Crop revenue (yuan)	203	66	216
Cost saving from change in fertiliser use			
Fertiliser use[d] (kg)	104	24	112
Fertiliser costs (yuan)	144	33	155
Cost saving from change in water use			
Electricity use (kw/year)	35	35	35
Electricity costs (yuan)	25	25	25
Annual benefits of adopting project advice			
Household income (yuan)	8000	8000	8000
Project benefit (yuan)	371	125	396
Change in income (%)	4.6	1.6	4.9

[a] Data and impact estimates for the 2001–02 crop year. Area conversion factor of 15 mu = 1 ha. Includes Fengqiu County and other counties in the Xinxiang City District.
[b] Results from project research station and surrounding farms.
[c] Random survey of 30 farms — includes equal numbers of higher, average and lower performing farmers.
[d] Total annual application of nitrogen across both crops expressed in urea-equivalent terms.
Source: Chinese Academy of Sciences, Fengqiu, pers. comm.

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

IMPACT ASSESSMENT SERIES

23	McLeod, R. (2003)	Improved methods for the diagnosis and control of bluetongue in small ruminants in Asia and the epidemiology and control of bovine ephemeral fever in China	AS1/1984/055, AS2/1990/011 and AS2/1993/001
24	Palis, F.G., Sumalde, Z.M. and Hossain, M. (2004)	Assessment of the rodent control projects in Vietnam funded by ACIAR and AUSAID: adoption and impact	AS1/1998/036
25	Brennan, J.P. and Quade, K.J. (2004)	Genetics of and breeding for rust resistance in wheat in India and Pakistan	CS1/1983/037 and CS1/1988/014
26	Mullen, J.D. (2004)	Impact assessment of ACIAR-funded projects on grain-market reform in China	ANRE1/1992/028 and ADP/1997/021
27	van Bueren, M. (2004)	Acacia hybrids in Vietnam	FST/1986/030

ECONOMIC ASSESSMENT SERIES (DISCONTINUED)

No.	Author and year of publication	Title	ACIAR project numbers
1	Doeleman, J.A. (1990a)	Biological control of salvinia	8340
2	Tobin, J. (1990)	Fruit fly control	8343
3	Fleming, E. (1991)	Improving the feed value of straw fed to cattle and buffalo	8203 and 8601
4	Doeleman, J.A. (1990b)	Benefits and costs of entomopathogenic nematodes: two biological control applications in China	8451 and 8929
5	Chudleigh, P.D. (1991a)	Tick-borne disease control in cattle	8321
6	Chudleigh, P.D. (1991b)	Breeding and quality analysis of canola (rapeseed)	8469 and 8839
7	Johnston, J. and Cummings, R. (1991)	Control of Newcastle disease in village chickens with oral V4 vaccine	8334 and 8717
8	Ryland, G.J. (1991)	Long term storage of grain under plastic covers	8307
9	Chudleigh, P.D. (1991c)	Integrated use of insecticides in grain storage in the humid tropics	8309, 8609 and 8311
10	Chamala, S., Karan, V., Raman, K.V. and Gadewar, A.U. (1991)	An evaluation of the use and impact of the ACIAR book *Nutritional disorders of grain sorghum*	8207
11	Tisdell, C. (1991)	Culture of giant clams for food and for restocking tropical reefs	8332 and 8733
12	McKenney, D.W., Davis, J.S., Turnbull, J.W. and Searle, S.D. (1991)	The impact of Australian tree species research in China	8457 and 8848
	Menz, K.M. (1991)	Overview of Economic Assessments 1–12	