CONSERVATION TILLAGE AND CONTROLLED TRAFFIC

ACIAR Project 9209

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Contents

1. Introduction

The following review is an financial assessment of an Australian Centre for International Agricultural Research (ACIAR) conservation tillage and controlled traffic research project which was conducted in China (for the conservation tillage component) and Australia (for the controlled traffic component) during the period 1993–1996, inclusive. The project—No. 9209—was implemented by staff from the Beijing Agricultural and Engineering University and the Shanxi Agricultural Machinery Bureau (in China) and the University of Queensland (in Australia).

The overall aim of the joint project was to develop and evaluate conservation and zone (controlled traffic) tillage techniques for sustainable dryland grain production in China and Australia. Australian dryland conservation cropping techniques and zero-till planting machinery were adapted for maize and wheat production systems in Shanxi Province in northern China, and controlled traffic techniques were tested at Gatton in Queensland. The outcomes from the trials were then successfully extended to Chinese and Australian farmers. The techniques developed in China increased yields, decreased costs and conserved soil and water on small plots of crop land. Controlled traffic farming in southern and central Queensland increased cropping intensity, conserved soil and water, and increased yields and returns.

Chinese and Australian results and benefits are identified in the Review and used as the basis of the financial analysis.

2. ACIAR Project 9209[1]

2.1 Project Overview

The project developed from the recognition of complementary interests in dryland and conservation farming in China and Australia following a visit to Australia in 1989 by Professor Gao Huanwen from the China Agricultural University (now the Beijing Agricultural Engineering University—BAEU). Professor Gao met with Dr Jeff Tullberg from the University of Queensland's Farm Mechanisation Center (located at

[1]Adapted from the Termination Report prepared by Dr. Jeff Tullberg, July, 1995.

Gatton) during this visit, and despite major differences in climate, soils, current levels of technology and socio-economic contexts, agreed that researchers in northern China and Australia (particularly northern Australia) faced similar problems in their efforts to improve the productivity and sustainability of dryland grain production in semi-arid areas. Soil degradation (in both countries) and large inputs of labour (China) and energy and capital (Australia) were considered to be the major challenges faced by dryland croppers in the late 1980s.

At this time, mechanisation and conservation tillage were both at relatively early stages of development. Chinese scientists recognised that some traditional tillage practices, such as zone tillage (an early form of controlled traffic), had high conservation values and that these systems were incompatible with the conventional mechanisation systems which China was adopting in the late 1980s. However, conservation tillage had been widely adopted in Australia and some Australian conservation cropping technology appeared to be adaptable to the conditions in China. Therefore the research priority in China was to develop, assess and extend the adoption of conservation tillage systems in an environment where the soil degradation consequences of mechanisation were not yet significant.

Conversely, the research objective in Australia was to investigate the mechanisation-induced problems of conservation tillage. Whilst conservation tillage research in Australia and China had demonstrated the importance of reducing soil disturbance, the impact of this outcome was reduced under the highly mechanised systems in Australia due to the problems of tractor, implement and harvester wheel tracks. The negative effect of wheel traffic on soil condition, crop production and tillage energy requirements were known, but not researched under Australian conditions and extended to the farming community.

Therefore the project represented a chance to develop more sustainable crop production technologies, and to capitalise on the different perspectives of scientists from China and Australia. The project also provided an opportunity for China to demonstrate that the benefits from mechanisation could be achieved without the problems of excessive energy requirements and soil degradation which have incurred in Australia under traditional cropping systems. The economic importance of grain production, and established national priorities for reducing soil degradation in both countries underpinned the potential value of joint research on conservation/zone tillage for dryland farming.

2.2 Project Objectives

The overall project goal was to develop and evaluate conservation and zone tillage techniques for sustainable dryland grain production in China and Australia.

Objectives in China

The specific objectives in China (during the first three-year phase of the project) were to:

- assess the suitability of a range of Australian ground tools, planter units and residue treatments for conservation tillage in Shanxi Province in northern China;
- identify and assess appropriate conservation systems for wheat and maize production;
- evaluate conservation tillage systems in terms of energy, residue soil moisture storage, and crop yields; and
- assess the effects of deep tillage and traffic on soil moisture storage.

In a one-year extension, the additional objectives in China were to:

- determine the effects of cover, tillage and traffic on hydrological processes using rainfall simulation;
- quantify treatment effects on soil moisture, temperature and soil biological activity, and identify other factors affecting crop performance;
- improve yield assessment procedures and agronomic monitoring generally;
- investigate machine costs, specifically for rotary hoeing and subsoiling, including the depreciation element; and
- assess the scope to downsize equipment.

Objectives in Australia

The specific objectives in Australia (during the first three-year phase of the project) were to:

- develop a low power control traffic conservation tillage system for wheat production;
- evaluate traffic effects on soil and crop performance under three surface management regimes;
- develop zone tillage technology for grain production with minimal inputs of energy and herbicides; and
- assess the potential of zone tillage in systems based on gantry units or modified conventional equipment in relation to sustainable crop production systems.

In the one-year extension, the additional objectives in Australia were to:

- monitor the growth of maize and wheat crops to increase the data set on wheel compaction/ tillage/ system/infiltration relationships;
- use a rainfall simulator to assess the broad applicability of the compaction infiltration results to current Australian agriculture;
- quantify the precision achieved using bed-following techniques and investigate the relationship between residue level and windrow spacing for two residue types; and
- assess the influence of precision/mechanical weed control and interplanting possibilities to indicate the value of precision in terms of current and forthcoming guidance technology.

2.3 Results and Discussion—China

Overview

Conservation tillage was central to the work in China, with the objective of reducing energy use and soil erosion while improving productivity, all of which are of particular importance in China’s north-western provinces. The major emphasis was thus on the development of conservation tillage equipment and systems, and evaluation of these in comparison with traditional wheat and maize production methods. While development and assessment were independent activities, feedback between the two resulted in modifications to both during the course of the project.

The field work in China was conducted by personnel from the Shanxi Agricultural Machinery Bureau (SAMB), using village personnel as machine operators. Staff from BAEU worked in partnership with SAMB and visited the trial and extension sites at planting and harvesting times. This process meant that local farmers were constantly involved and able to observe the advantages and disadvantages of different conservation tillage methods, and to discuss outcomes and possible modifications with the Chinese and Australian experts.

This implementation strategy, which encompassed an extension element, was a major strength of the project because it resulted in rapid uptake of the more practical and positive outcomes of the program. An immediate and beneficial consequence has been the adoption of reduced tillage and retention of crop residues over quite large areas of maize production in Shanxi, and some adoption of the same techniques for wheat production. Another major, but non-quantifiable, benefit has been reduced burning of crop residues. This has had a significant impact on air quality in areas where the old practice has ceased.

As discussed in Section 2.3.2 an ongoing constraint has been ‘planting quality’, the terminology used by the Chinese to describe the problems associated with poor seedling emergence and establishment, which probably result from the inability of adapted Australian planters to handle large quantities of surface trash and lumpy, structureless loess soils. This remains the major constraint to be overcome before the resulting technology can be extended widely across the dryland cropping zone in Shanxi Province. The Review recommends continued expenditure by ACIAR to resolve the problems with planter adaptation and ‘seedling quality’ (see Section 4).

Another equally fundamental issue stems from the heavy emphasis by Chinese farmers, leaders and their research/extension system on improving crop yields. This is understandable, given China’s history of serious food shortages within living memory of many of the farmers involved in the field trials. However, this focus tended to divert attention away from the question of cropping efficiency and the mechanisms which underly the results, i.e. the Chinese counterparts tended to concentrate only on yield increases rather than yields, costs and sustainability as a package.

The other issue which arose in China relates to field size, tractor power and labour availability. While medium-size (30–50 kW) tractors are quite common in government or collective machinery stations, the major increase in mechanisation in China (and Shanxi) is in the form of smaller (9–15 kW) tractors. This situation has ramifications in terms of the longer-term viability of the subsidised Agricultural Machinery Centers (AMCs) and their ability to service the majority of small farmers (with perhaps 0.5–1.0 ha of arable land). This, in turn, indicates the urgent need to develop wheat and maize planters which are compatible with the smaller and considerably more numerous 9–15 kW tractors. This tractor compatibility problem and the issue of 'seedling quality' are the two main deficiencies which the project has not yet overcome.

Equipment Development

A description of equipment development in China is given in Section 3.1.1 from Dr Jeff Tullberg's Termination Report. Because the outcomes from this component do not impact directly on the economics of the project, this Review does not contain details on the development of conservation planters in China.

The main conclusion in terms of the outcome from developing small wheat and maize planters is that the machines developed for both medium and small tractors operate successfully in most conditions, except where there are high levels of crop residues at the time of planting (the ideal situation). At the time of the Review, this problem remained as the major limitation to the widespread extension of conservation cropping in Shanxi. The Review therefore recommends (refer Section 4) that additional resources be allocated to the resolution of this problem.

Crop Production Systems

Maize

Field trials with maize were conducted on the elevated plateau in north-central Shanxi Province near the town of Shouyang. The first experiment compared traditional conventional tillage/bare fallow (control) with tillage + residue, zero tillage + residue (standing and pressed) and a subsoiled treatment (also with pressed residue). A second, more favourable site (also in Shouyang) was initiated in 1994 in which zero tillage with standing, pressed and chopped stubble was compared with subsoiling with chopped stubble and a traditional control. Project demonstrations were also established at two other sites and equipment used to plant larger areas with the treatments favoured by local farmer consensus, and compared with a traditional control.

The Project Completion Report concluded that mean yields for all treatments and locations demonstrated a general improvement in yields for most conservation tillage methods, in most years, compared with the control. Details on yields and water-use efficiency for maize are given in Table 1. It should be noted that because of problems with plot randomisation and replication, none of the treatments are significantly different from the control. However, if treatment NTSS (no-till and standing straw) is ignored, yields for the four treatments SBCS (subsoiling with chopped straw), NTCS (no-till with chopped straw), SBPS (subsoiling with pressed straw) and NTPS (no-till with standing straw) increased by an average of 21% over the traditional control treatment, and varied from a 12% to a 31.9% increase.

Table 1. Maize yields and water-use efficiencies at the Shouyang sites[a].

Site	Item	CK	SBCS	NTCS	SBPS	NTPS	NTSS
Zongai (1993)	Yield (t/ha)	2.6			3.1	3.1	3.0
	Yield % of CK	0			18.4	21.3	14.5
	WUE	6.3			8.2	8.3	7.5
Zongai (1994)	Yield (t/ha)	5.2			5.5	5.5	5.2
	Yield % of CK	0			5.7	5.7	0.3
	WUE	10.8			12.5	11.9	11.9
Yanjiaping (1994)	Yield (t/ha)	6.7	8.8	8.0		8.4	7.3
	Yield % of CK	0	31.9	20.4		25.5	9.2
	WUE	15.2	19.4	18.3		18.0	14.5
Average yield (% of CK)		0	31.9	20.4	12.1	17.5	8.0
Average WUE (% of CK)		0	28.0	20.8	21.7	19.8	10.4

[a]CK = Traditional control, SBCS = Subsoiling with chopped straw, NTCS = No-till with chopped straw, SBPS = Subsoiling with pressed straw, NTPS = No-till with pressed straw, NTSS = No-till with standing straw, WUE = water-use efficiency (expressed as kg/ha.mm effective rainfall).

Source: Chinese Project Completion Report, page 6, before adjustments for fertility gradients.

Wheat

The wheat experiment was located near Linfen in south-central Shanxi Province. The initial work was designed to compare traditional production methods with zero-till and subsoiling, with varying residue treatments. The Australian Project Completion Report concluded that the wheat trials showed a general improvement in yields and water utilisation efficiencies with most conservation tillage systems in most years. However, weed problems eventually lead to manual weeding. Table 2 details the results of the wheat production trials. The yields for the three acceptable treatments (SBCS, NTCS and SBPS—ignoring the SBSS [subsoiling with standing straw] treatment) increased by 4.9% to 16.7% over the traditional control by an average of 11%. (The SBSS treatment failed for both wheat and maize probably due to problems with ground temperature and 'seedling quality').

As with the maize trails, the results are not significantly different. However, observations by the Reviewer during April, 1998 indicated that there was a distinct 'biological difference' between the traditional control and the various forms of conservation tillage which the Chinese farmers and technicians had developed from the initial experimental treatments.

Table 2. Yields and water-use efficiency for wheat trials at Linfen[a].

Site	Item	CK	SBCS	NTCS	SBPS	SBSS	NTSS
June 1994	Yield (t/ha)	3.0	3.5	3.3	3.2	2.4	3.0
Trial 1	Yield % of CK	0	15.1	9.8	6.3	–24.6	14.5
	WUE	11.9	13.7	13.2	12.6	9.2	7.5
June 1995	Yield (t/ha)	2.3	2.6	2.3	2.7	1.9	5.2
Trial 1	Yield % of CK	0	9.6	–1.4	15.4	–20.1	0.3
	WUE	11.7	12.0	12.2	13.7	9.8	11.9
June 1995	Yield (t/ha)	1.6	2.0	1.7			7.28
Trial 2	Yield % of CK	0	27.9	6.3			9.2
	Yield (t/ha)		1.8				14.5
	Yield % of CK		14.1				
	WUE	8.0	10.6	8.1			
	WUE % of CK	0	9.1	1.3			
Average yield (% of CK)		0	16.7	4.9	10.9	–22.4	8.0
Average WUE (% of CK)		0	15.1	6.4	11.5	–21.4	10.4

[a]CK = Traditional control, SBCS = Subsoiling with chopped straw, NTCS = No-till with chopped straw, SBPS = Subsoiling with pressed straw, SBSS = subsoiling with standing straw, WUE = water-use efficiency (expressed as kg/ha.mm effective rainfall).

Source: Chinese Project Completion Report, page 9, before adjustments for fertility.

Comments on the results

Results of the work on conservation tillage in wheat and maize are generally similar with those achieved in Australia during the introduction of the techniques in the 1970s. Compared with traditional methods, relatively small yield increases were achieved in most years, together with clear advantages in terms of sustainability, and reduced inputs and costs. However, during the latter part of the project, there was clear evidence of depressed emergence and reduced plant populations in all conservation tillage treatments in both wheat and maize—the 'seedling quality' problem referred to earlier. Low soil temperatures at planting appear to be a significant factor in determining the success of conservation tillage for maize, and poor separation of seed and fertiliser could be the main problem for conservation wheat planting.

A key feature of the adoption patterns in China has been farmers' interest in and willingness to try to adapt various treatments to their particular fields and financial circumstances. Many farmers interviewed during the Review had firm opinions on why some treatments had performed better than others, and had conducted their own 'trials' based on their perceptions of the positive outcomes from the project-supported trials and demonstrations. This ongoing development of 'local' conservation cropping techniques (usually based on reduced tillage and some retention/non-burning treatment of crop residues) indicates an element of sustainability for the overall project, provided that the technical problems with the planters are overcome.

As mentioned above, another major benefit from the project has been the widespread cessation of the practice of burning crop residues after harvest.

2.4 Results and Discussion—Australia

Rainfall runoff

Table 3 lists the rainfall run-off for wheeled and controlled traffic plots which were cropped using conventional, minimum and zero tillage.

Table 3. Treatment effects on total run-off (mm).

	Wheeled	Controlled traffic	Mean
Conventional	703	455	579
Minimum tillage	702	471	587
Zero tillage	630	445	538
Mean	678	457	568

Source : Australian Project Termination Report, page 10.

Crop yields

This section outlines the crop yields and energy requirements for the various compaction treatments, which are important from the point of view of an economic assessment of the project.

The mean grain yield from the controlled traffic plots over the full term of the project was 16% greater than the yield from wheeled plots, as shown in Table 4 which illustrates the consistent improvement in crop performance which occurs when soil is not subject to annual wheel traffic. The traffic-related yield differences were significant ($P<0.05$) in all crops and the mean yields of zero-till plots was 6% greater than the tilled plots, but these differences were rarely significant.

Table 4. Treatment effects on yield of winter and summer crops (t/ha).

	Wheeled	Controlled traffic	Mean	Wheeled	Controlled traffic	Mean
	1994 Wheat			1995 Sorghum		
Conventional	1.29	1.52	1.41	5.17	5.47	5.32
Min tillage	1.26	1.56	1.41	5.19	5.57	5.38
Zero tillage	1.14	1.45	1.30	5.38	5.48	5.43
Mean	1.23	1.51		5.25	5.51	
	1996 Wheat			1996 Maize		
Conventional	1.56	1.86	1.71	6.38	7.24	6.81
Min tillage	1.43	1.88	1.66	6.09	7.59	6.84
Zero tillage	1.73	1.97	1.85	6.97	7.51	7.24
Mean	1.57	1.90		6.48	7.45	
	Winter crops			Summer crops		
Overall mean	1.40	1.71		5.87	6.48	

Source : Australian Project Completion Report, Table 2.

In terms of energy requirements for cultivation under the different compaction treatments, the most important result was that the traffic effect increased tyre draft at normal operating depth by a factor of approximately two. Consideration of these data in terms of common ratios of tyre width:implement width indicates that approximately 25% of implement input energy is used to undo the wheeling effects imposed during the tillage/planting operation. When these data are combined with the established knowledge of tractor efficiency, this can be used to show that an efficient modern tractor is normally using more that 50% of its output power to create and partially destroy soil compaction in its own wheel tracks. This obviously has major considerations in terms of capital investment and operating costs.

2.5 Financial Benefits

The financial benefits to Chinese and Australian farmers from the expenditure on research which produced the above-listed results are outlined, analysed and discussed in Section 3.2.

3. Impact Assessment

3.1 Assessment Framework

As reported in ACIAR's Economic Assessment Series No. 12, a range of research evaluation frameworks has been used to assess the impact of research. The following paragraphs contain comments on how Project No 9209 fits into a particular evaluation framework.

Some evaluations have used simple models which estimate the value to society of the research as the expected increase in product output valued at the current or expected price, plus or minus cost reductions which result from the research. Others have used the welfare-theory based measures of the impact of technology with multi-stage, multi-regional traded good models incorporating research spillovers between regions to estimate the potential value of the research to society. Whether a simple or more complex evaluation framework is chosen depends largely upon the use which is to be made of the information generated, and the appropriateness of the latter (and more complicated model) for the situation to be analysed. For some decision-making situations the information generated by a simple framework will be all that is required while for others more complex inter-regional interactions will be important.

It should be remembered that the prime objective of Project 9209 (in China) was to increase wheat and maize production and to protect the agricultural environment. Therefore, in simplistic terms the project can be evaluated by determining the value of increased production and the costs saved, and assessing the net outcome against project costs. This simplistic approach is illustrated in Figure 1.

Even if a simple framework is accepted as appropriate, the choice of the framework and particularly the estimation procedures adopted need to be considered carefully, especially the estimated value of the increased output. Figure 2 illustrates two possible options for a simple measure of the gains from research, and represents a single region, non-traded good model (as is the case for increased wheat and maize production in Shanxi).

Figure 1. Simplistic approach to project evaluation.

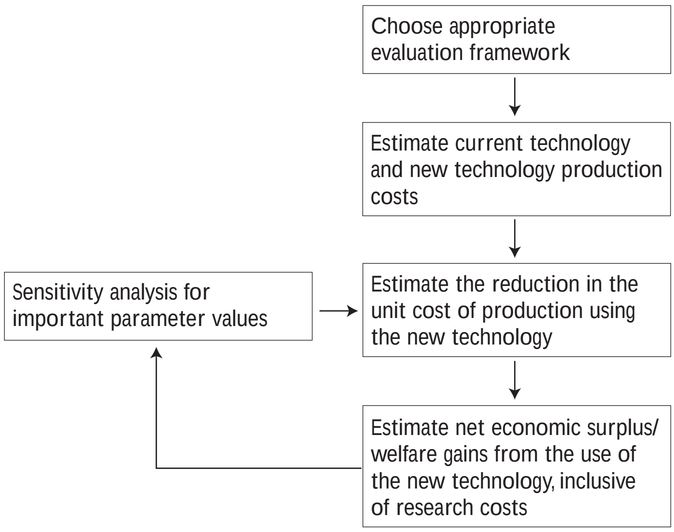
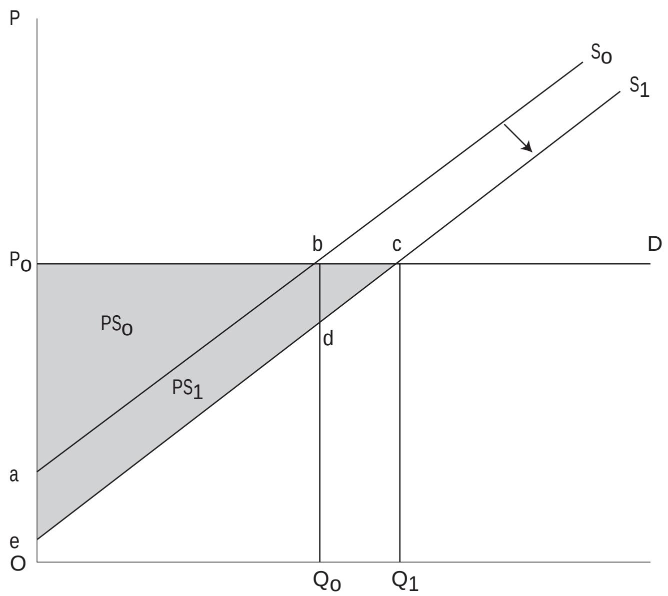


Figure 2. Options to measure the gains from research (see text for explanation of symbols).



In Figure 2 the demand for the product is represented by *D*. Before research the product supply is represented by supply curve S_0. After research the cost of producing the product is reduced, theoretically shifting the supply curve to S_1. However, in terms of the outcome from research into conservation cropping techniques in Shanxi Province in northern China, supply will not increase to S_1 because of decreased production costs, but because of increased yields.

In simple terms, society's gain from the project is represented by the area P_0cQ_1O (the gross value of production after the project) less P_0bQ_0O (the gross value of production before the project) plus/minus the difference between (Q_0 times before project unit costs of production, minus Q_1 times after project unit costs of production).

The welfare-theory based measures of the gains from research suggest that the area *abce* is a close approximation of society's gains. For a given cost reduction due to research, in this case *bd*, the area *abfe* will remain the same regardless of the demand characteristics of the product involved. The remainder of the welfare gains (express as *bcd*) will change depending on the supply and demand characteristics. Note that Project 9209 (operating in one province and expanding slowly) will not have any significant impact on China's national supply and demand curves for wheat and maize.

Because of the supply and demand conditions for wheat and maize in China, and owing to the impact of the project on costs and yields, the simplistic model referred to at the beginning of this section has been used to determine the expected gains from research. In addition, the analyses have been completed at the margin, i.e. per hectare costs saved plus per hectare increased values of output have been scaled up over the area of crop land which is likely to be influenced by the project over a 30 year period, and compared with project costs to determine net project benefits. The Review has not considered spill-over effects into other Chinese provinces or other countries which rely heavily on dryland crop production, because there remains a degree of uncertainty in terms of planting quality and the ability of planters to handle high levels of trash.

This assessment uses current (1998) prices and costs for inputs and production and adjusted project costs (Australian and Chinese).

3.2 Farm-Level Financial Benefits

China

Maize production

Table 5 details the with and without project results (in financial terms) from the application of the project's conservation farming techniques to one mu (1 mu = 667 m^2) of dryland maize in Shanxi Province. The data in the table were extracted from the Chinese Project Completion Report and crossed-checked during this Review. It should be noted that it is always difficult to collect 'true cost' information in China, because prices and costs are distorted by subsidies and controls. However, the information in Table 5 is an accurate reflection of the costs and prices which are applicable at the farm-level for maize production in Shanxi Province.

Because cooperating farmers have opted to use a mix of conservation farming techniques, for example some use reduced tillage with some stover retention, and others a combination of subsoiling and full retention of stover, the analysis in Table 5 is based on an 'average treatment' effect. Observations during the Review confirmed that adopting farmers are using their initiative to adapt the project's recommended conservation techniques to their own particular circumstances and therefore it is not possible to define precisely the impact of the individual treatments.

Wheat production

Table 6 shows the same information as Table 5, but for dryland wheat production in Shanxi Province. The source of information is also the same. Note that the negative results for treatment SBSS have been excluded from the calculation of the treatment averages.

Table 5. Net (per mu [1 mu = 667 m^2]) incomes for maize production in Shanxi Province[a].

		Treatment					Treatment average
		CK[e]	NTCS	SBCS	NTSS	NTPS	
Income	Yield (kg/mu) a/ b/	444	535	586	4v85	558	
	Unit price (Y/kg)	1.0	1.0	1.0	1.0	1.0	
	Income (Y/mu)	444	535	586	485	558	
Costs	Seed (Y/mu)	11.9	7.8	7.8	7.8	7.8	
	Fertiliser (Y/mu)	52.3	52.3	52.3	52.3	52.3	
	Herbicides (Y/mu)	0.0	3.8	3.8	3.8	3.8	
	Labour (Y/mu)	150.0	55.2	55.2	55.2	55.2	
	Draft (Y/mu)	40.5	9.0	9.0	9.0	9.0	
	Machines (Y/mu)	12.0	15.0	25.0	10.0	13.0	
	Ag.taxes (Y/mu)	12.0	12.0	12.0	12.0	12.0	
	Total costs (Y/mu)	278.7	155.1	165.1	150.1	153.1	
Net Income (gross margin)	Income –Costs (Y/mu) c/ compared with CK (%)	165.3	379.9	420.9	334.9	404.9	385.2
	(extra margin/mu)		214.6	255.6	169.6	239.6	219.9
Net Income (gross margin)	Cost–Income (Y/mu) d/ compared with CK (%)	315.3	435.1	476.1	390.1	460.1	440.4
	(extra margin/mu)		119.8	160.8	74.8	144.8	125.1

[a]From Table 1; [b]Yield adjusted for soil fertility index; [c]Including labour; [d]Excluding labour;[e]CK = Traditional control, NTCS = no-till withchopped straw, SBCS = Subsoiling with chopped straw, NTSS = no-till with standing straw, NTPS = No-till with pressed straw.

Source : Derived from information and data collected during evaluation visit to Shanxi, 1998.

Extension and spread of technology

In terms of calculating the net benefits for China (see Section 3.4) the next step in the analysis is to estimate how many mu will be treated with improved conservation cropping techniques in Shanxi Province (the overall potential target is 13.0 million ha of dryland maize and wheat production [rainfall of less than 600 mm] in China’s northern and western provinces). However, given the problems with planter performance, the current (1998) small number of operational planters (wheat—16 small and 5 middle sized, and maize—11 small and 6 middle sized) and the likely decline in direct farmer support from the AMCs as government budgets and department staffing levels are reduced under the current reform processes, it is unlikely that the adoption rate will escalate rapidly.

Table 6. Net (per mu [1 mu = 667 m^2]) incomes for wheat production in Shanxi Province[a]

		Treatment					Treatment average
		CK	SBCS	SBSS	SBPS	NTCS	
Income	Yield (kg/mu) a/ b/	200	230	151	213	220	
	Unit price (Y/kg)	1.4	1.4	1.4	1.4	1.4	
	Income (Y/mu)	280	322	211	298	308	
Costs	Seed (Y/mu)	25.0	25.0	25.0	25.0	25.0	
	Fertiliser (Y/mu)	33.2	33.2	33.2	33.2	33.2	
	Herbicides (Y/mu)	0.0	5.9	5.9	5.9	5.9	
	Labour (Y/mu)	47.7	10.8	10.8	10.8	10.8	
	Draft (Y/mu)	29.9	3.9	3.9	3.9	3.9	
	Machines (Y/mu)	20.0	42.0	42.0	42.0	32.0	
	Ag.taxes (Y/mu)	16.0	16.0	16.0	16.0	16.0	
	Total costs (Y/mu)	171.8	136.8	136.8	136.8	126.8	
Net Income (gross margin)	Income –Costs (Y/mu) c/ compared with CK (%)	108.2	185.2	74.6	161.4	181.2	
	(extra margin/mu)		77.0	-33.6	53.2	73.0	67.7
Net Income (gross margin)	Cost–Income (Y/mu) d/ compared with CK (%)	155.9	196.0	85.4	172.2	192.0	186.7
	(extra margin/mu)		40.1	–70.5	16.3	36.1	30.8

[a]From Table 1; [b]Yield adjusted for soil fertility index; [c]Including labour; [d]Excluding labour;[a]CK = traditional control, SBCS = subsoiling with chopped straw, SBSS = subsoiling with standing straw, SBPS = subsoiling with pressed soil, NTCS = no-till with chopped straw.

Source : Derived from information and data collected during evaluation visit to Shanxi, 1998.

The extension of new agricultural production technology is China often very fast, such as the use of plastic mulch to improve early spring germination, but only when financial returns are much higher than those estimated for the application of conservation cropping techniques for maize and wheat production in Shanxi Province. However, observations during the Review (for winter wheat and the newly planted spring maize crop) indicate that farmers are adopting elements of the recommended conservation cropping practices and that the techniques will continue to spread naturally. Cost savings (refer to Tables 5 and 6) will drive this process as farmers become more cost conscious and grain support prices decline to levels which reflect world markets.

Another confounding factor is the cumulative effects of the application of conservation farming techniques, that is the on-farm financial benefits detailed in Tables 5 and 6 will not be achieved in the first year in which cropping practices change. It often takes three to five years before increased yields are sustained. This lag effect also needs to be taken into account when determining the gross benefits from improved crop production technology.

The stream of Chinese net on-farm benefits listed in Table 8 is based on the following assumptions:

Maize:	
Net benefit per hectare (see Table 5)	$507
Proportion of research gain realised on-farm	50%
Proportion of net gain due to project	100%
Area planted in 1998 (base year) (ha)	1500 ha
Rate of area increase (% per year compound)	10%
Wheat:	
Net benefit per hectare (see Table 6)	$156
Proportion of research gain realised on-farm	50%
Proportion of net gain due to project	100%
Area planted in 1998 (base year) (ha)	1500 ha
Rate of area increase (% per year compound)	10%

Australia

Overview

Various types of conservation farming have been practiced throughout Australia's cropping zones since the 1970s. Whilst zero-till was introduced in the 1970s, it took years before the practice became wide-spread in some production systems. The introduction of controlled traffic techniques was much later, and its application is still confined to areas where specific projects have extended the practice. This phased development of conservation cropping and controlled traffic techniques means that it is extremely difficult to determine 'causes and effects' in terms of 'which project was responsible for farm-level acceptance of the new techniques'.

In the case of promotion of controlled traffic, the technique is currently supported by funding from the Grains Research and Development Corporation, National Heritage Trust, Queensland Department of Primary Industries (QDPI), AgWest etc., as well as Project 9209. There is no doubt that Project 9209 has confirmed the scientific basis of the controlled traffic techniques (for the sub-tropical zone) but it is difficult to allocate a specific proportion of on-farm benefits to this one project. Furthermore it is not possible to determine the impact of Project 9209 on (for example) conservation tillage and controlled traffic practices in Western Australia where there has been a major change in cropping techniques in the past 15 years. Again, the results from the trials at Gatton may have contributed to some of the gains in crop production in Western Australia, but is it is impossible to quantify these and be confident of strong ‘cause and effect linkages’.

On-farm results

Table 7 details the farm operating profit for a 550 hectare farm in the Burnett District of Central Queensland using two crop production systems: (a) some conventional till and some zero-till (with no controlled traffic); and (b) all zero-till and controlled traffic. The table is based on information supplied by the QDPI and was derived from on-farm results which have been modified using a probability model.

Table 7. Farm operating profit for a 550 hectare farm in the Burnett District of Queensland.

	With control traffic		Without control traffic	
	Total ($)	$/ha	Total ($)	$/ha
Cropped area (ha)	549		549	
Property area (ha)	449		449	
Total labour (hr)	761	1.69	1 281	2.85
Gross income	318 925	710.31	249 848	556.46
Variable costs				
Machinery				
Fuel/oil	7 075	15.76	12 275	27.34
R. & M.	4 824	10.74	7 553	16.82
Labour				
Seed	16 601	36.97	16 991	37.84
Fertiliser	28 895	64.35	20 268	67.41
Fallow herb	17 529	39.04	7 241	16.13
In crop herb	12 578	28.01	12 578	28.01
Insecticide	4 518	10.06	5 167	11.51
Fungicide				
Aerial spraying	1 608	3.58	1 734	3.86
Chipping				
Contract harvest	26 546	59.12	26 546	59.12
Total variable costs	120 173	267.65	120 352	268.05
Gross margin	198 752	442.66	129 497	288.41
Fixed costs				
Machinery costs	18 288	40.73	26 490	59
Total fixed costs	18 288		26 490	
Farm operating profit	180 465	401.93	103 007	229.42

Source : Data provided by Queensland Department of Primary Industries from a case study.

The data in Table 7 demonstrate the large gains which can be made from the application of zero-till and controlled traffic practices in a multiple cropping situation in the sub-tropics. The key figures are: (a) gross income increased from $556 to $710 per ha (increase of 28%); (b) gross margin increased from $288 to $442 per ha (increase of 53%); (c) farm operating profit increased from $229 to $402 per ha (increase of 76%); and (d) the total farm operating profit increased from $103 000 to $180 000.

Extension and adoption of results

Australian farmers will continue to adopt some or all of the cumulative elements which make up the zero-till and controlled traffic story. Therefore it would be unrealistic to apply the on-farm benefits listed in Table 7 to the total area cropped in Australia. Indeed it would be unrealistic to assume that all farmers in the Burnett District in Central Queensland will adopt total zero-till and controlled traffic practices because of differing attitudes to risk, financial constraints (especially the cost of new/adapted machinery), concerns about the over-use of chemicals, and perceived problems with weeds and pests.

It is necessary, however, to estimate an adoption rate and the level of net on-farm benefits which might flow from a steady increase in the application of zero-till and controlled traffic if the returns from Project 9209 are to be calculated and assessed against project costs. One acceptable technique is to determine a break-even point. This is determines the area (ha) to which the new techniques must be applied (given a fixed per ha net benefit) in order to generate an acceptable return to the funds invested in developing the technique. This break-even area (ha) can then compared with the total potential area which might be subject to the new production system, and comments made on the likelihood of achieving this level of coverage given the availability of funding for technology extension.

For example, if it is assumed that Project 9209 generated 30% of the per ha net benefits listed in Table 7 (this figure is chosen because other projects also invested in and extended the technology) and that the technology would be applied to 25 000 ha over the next 20 years, would this be a sufficiently high adoption rate to generate (say) a 15% return on the research funds? The same approach could be used to analyse the returns from investing in research in China.

The net benefit flows in Table 8 attributable to the adoption of controlled traffic practices in Australia are based on the following assumptions:

Net benefit per hectare (see Table 7)	$173
Proportion of research gain realised on-farm	50%
Proportion of net gain due to project	20%
Area planted in 1998 (base year) (ha)	5000 ha
Rate of area increase (% per year compound)	10%
Benefit flows commence	1998

3.3 Project Costs

Table 8 details total project costs for the period 1992 to 1995 for both Australian expenditure (as advised by ACIAR) and Chinese expenditure (extracted from the Chinese annual reports—about renminbi yuan (RMB.Y) 250 000 per year expressed as A$). Because the project is ongoing in terms of the extension efforts required to extend the conservation farming technology in China and promote controlled traffic in Australia, and the need to adjust and refine the maize and wheat planters, Table 8 indicates that from 1996 onwards a fixed annual cost A$250 000 (based on $150 000 per year for Australia and $100 000 per year for China) has been included for the next 30 years. In addition a cost of $50 000 per year for the period 1996–1998 has been included to reflect that some expenditure in China and Australia would have been ongoing during the interim period between the completion of Project 9209 and the commencement of the follow-on project (the latter project is not included in this Review).

The costs in Table 8 also reflect the need to construct additional maize and wheat planters in China as the areas of crop increase. Because some farmers will use their locally-built planters and others will only use some elements of the improved cropping techniques, it has been assumed that one additional small maize or wheat planter (three row maize and six row wheat) is capable of sowing 70 ha per year. These additional planters will cost $770 (maize) and $615 (wheat). There is no need to allow for additional machinery costs when determining the incremental flow of benefits from controlled traffic practices in Australia because the on-farm budgets in Table 7 take into account the cost of conversion or buying the required equipment.

The costs in Table 8 also reflect the recommended additional one-off expenditure of $100 000 in 1999 by ACIAR to make sure that the problems with planter performance in China are overcome.

Table 8. Project costs and benefits.

	C1 Year number	C2 Year date	CPI	C3 Annual benefits in China in RMB - nominal	C4 Annual benefits in Australia in RMB - nominal	C5 Annual benefits for China in $A - nominal	C6 Annual benefits for Australia in $A - nominal	C7 Research costs in $A - nominal	C8 Net annual benefits in $A - nominal	C9 Annual benefit flows $A1998 - adjustment factor	C10 Net annual benefits in $A1998	C12 Discounted net annual benefits in $A1998
Year 1 = start year	1	1992	124	-	-	-	-	(168 298)	(168 298)	1.14	(191 371)	(191 371)
	2	1993	126	-	-	-	-	(352 722)	(352 722)	1.12	(394 713)	(394 713)
	3	1994	128	-	-	-	-	(318 191)	(318 191)	1.10	350 507)	(350 507)
	4	1995	132	-	-	-	-	(169 582)	(169 582)	1.07	(181 144)	(181 144)
	5	1996	138	-	-	-	-	(50 000)	(50 000)	1.02	(51 087)	(51 087)
Year project ended	6	1997	139	-	-	-	-	50 000)	(50 000)	1.01	(50 719)	(50 719)
Year benefits started	7	1998	141	3 235 830	63 908	497 820	86 755	(50 000)	534 575	1.00	534 575	534 575
	8	1999		3 559 413	620 298	547 602	95 431	(352 968)	290 065	1.00	290 065	268 578
	9	2000		3 915 354	682 328	602 362	104 974	(253 265)	454 071	1.00	454 071	389 293
	10	2001		4 306 890	750 561	662 598	115 471	(253 591)	524 478	1.00	524 478	416 348
	11	2002		4 737 579	825 617	728 858	127 018	(253 950)	601 926	1.00	601 926	442 434
	12	2003		5 211 337	908 179	801 744	139 720	(254 345)	687 119	1.00	687 119	467 641
	13	2004		5 732 470	998 997	881 918	153 692	(254 780)	780 831	1.00	780 831	492 056
	14	2005		6 305 717	1 098 896	970 110	169 061	(255 258)	883 914	1.00	883 914	515 755
	15	2006		6 936 289	1 208 786	1 067 121	185 967	(255 784)	997 305	1.00	997 305	538 813
	16	2007		7 629 918	1 329 664	1 173 834	204 564	(256 362)	1 122 035	1.00	1 122 035	561 297
	17	2008		8 392 910	1 462 631	1 291 217	225 020	(256 998)	1 259 239	1.00	1 259 239	583 271
	18	2009		9 232 201	1 608 894	1 420 339	247 522	(257 698)	1 410 163	1.00	1 410 163	604 795
	19	2010		10 155 421	1 769 783	1 562 372	272 274	(258 468)	1 576 179	1.00	1 576 179	625 922
	20	2011		11 170 963	1 946 762	1 718 610	299 502	(259 314)	1 758 797	1.00	1 758 797	646 706

	C1 Year number	C2 Year date	CPI	C3	C4	C5	C6	C7	C8	C9	C10	C12
	21	2012		12 288 059	2 141 438	1 890 471	329 452	(260 246)	1 959 677	1.00	1 959 677	667 194
	22	2013		13 516 865	2 355 582	2 079 518	362 397	(261 270)	2 180 644	1.00	2 180 644	687 430
	23	2014		14 868 551	2 591 140	2 287 469	398 637	(262 397)	2 423 709	1.0	2 423 709	707 458
	24	2015		16 355 407	2 850 254	2 516 216	438 501	(263 637)	2 691 080	1.00	2 691 080	727 315
	25	2016		17 990 947	3 135 279	2 767 838	482 351	(265 001)	2 985 188	1.00	2 985 188	747 040
	26	2017		19 790 042	3 448 807	3 044 622	530 586	(266 501)	3 308 706	1.00	3 308 706	766 667
	27	2018		21 769 046	3 793 688	3 349 084	583 644	(268 151)	3 664 577	1.00	3 664 577	786 228
	28	2019		23 945 951	4 173 056	3 683 992	642 009	(269 966)	4 056 035	1.00	4 056 035	05 755
	29	2020		26 340 546	4 590 362	4 052 392	706 210	(271 963)	4 486 638	1.00	4 486 638	825 275
	30	2021		28 974 600	5 049 398	4 457 631	776 831	(274 159)	4 960 302	1.00	4 960 302	844 815
TOTAL				286 362 305	49 904 306	44 055 739	7 677 586	(7 244 865)	44 488 459		44 377 711	

NPV (over 30 years) 13 433 119

IRR 26%

Exchange Rate - RMB:$A 6.5

3.4 Project Benefits and Return

Table 8 also outlines the estimated project benefits from incremental wheat and maize production in China, and increased on-farm profits from the application of controlled traffic techniques in Australia. These streams of benefits have been used to calculate the net present value (NPV) of net benefits using an 8% discount rate. The internal rate of return (IRR) of the benefit stream has also be calculated. The adoption rates used to calculate project benefits are outlined in Sections 3.2.1 and 3.2.2.

Table 9 details the results of the financial analyses completed as part of the Review. The table also shows the results of sensitivity analyses which test the robustness of the project in terms of the impact on NPVs and IRRs of changes in key parameters, such as reductions in the proportions of on-farm gains from research, and lower rates of technology adoption.

Table 9. Financial and sensitivity analyses.

Scenario 1—Major parameters remain unchanged				
		China wheat	China maize	Australia
Benefit ($A/ha)		156.3	507.46	173.51
Proportion of gain realised on-farm		0.5	0.5	0.5
Proportion of gain due to project		1	1	0.2
Area planted (1998 base) (ha)		1 500	1 500	5 000
Rate of area increase (%/year)		10	10	10
Discount rate (%)	8			
IRR (%)	26			
NPV ($)	13 433 119			
Scenario 2 — Reduction in the proportion of gain realised on-farm				
		China wheat	China maize	Australia
Benefit ($A/ha)		156.3	507.46	173.51
Proportion of gain realised on-farm		0.3	0.3	0.3
Proportion of gain due to project		1	1	0.2
Area planted (1998 base) (ha)		1 500	1 500	5 000
Rate of area increase (%/year)		10	10	10
Discount rate (%)	8			
IRR (%)	19			
NPV ($)	6 446 746			

Table 9. (cont'd) Financial and sensitivity analyses.

Scenario 3 — Reduction in both the proportion of gain realised on farm and the rate of area increase		China wheat	China maize	Australia
Benefit ($A/ha)		156.3	507.46	173.51
Proportion of gain realised on-farm		0.3	0.3	0.3
Proportion of gain due to project		1	1	0.2
Area planted (1998 base) (ha)		1 500	1 500	5 000
Rate of area increase (%/year)		5	5	5
Discount rate (%)	8			
IRR (%)	13			
NPV ($)	2 226 381			

4. Conclusions

The foregoing indicates that Project 9209 has the potential to be very successful in China and Australia, provided that the planter problems are overcome and ongoing funding is committed to extension programs in both countries. The analyses in Section 3.4.2 are based on the key assumption that ACIAR will commit additional funds to the China program and further assist with planter modification, and that both countries will continue to fund demonstration and extension programs which will promote the conservation cropping in China and controlled traffic practices in Australia. If this assumption is not correct, then the expenditure of about $1.16 million on the development of excellent and relevant technology for China and Australia will have been wasted. The marginal returns from the recommended incremental expenditure in China and Australia on problem resolution and technology extension will be very high.

The overall conclusions from the Review are:

- The new technology developed as a result of the project is very relevant to the cropping conditions in China and Australia, and will be widely accepted once the remaining planter design problems have been overcome.

- The potential for the new technologies to spread in China and Australia are enormous because of the large and increasing area of dryland wheat and maize production in China's more marginal semi-arid zones, and increasing acceptance of conservation tillage and controlled traffic practices throughout Australia's main cropping regions.

- The standard of scientific rigour in China could be improved, but the results obtained have been sufficiently impressive for Chinese farmers to adopt at least elements of the improved crop production practices. The outcome has been the development of a suite of practices which all contribute to the twin objectives of increasing yields and reducing costs under a sustainable production system.

- Results from controlled traffic trials in Australia have confirmed the hypothesis that cropping intensity can be increased, soil and water conserved, costs reduced and profits increased if the practice is applied on a whole-farm basis. The foundation has been laid for a revolution in the way crops are planted, managed and harvested throughout Australia.

Bibliography

ACIAR 1992. Conservation/zone tillage research for dryland farming—project document. Canberra, ACIAR.

Beijing Agricultural Engineering University 1995. Conservation/zone tillage research for dryland farming: a comprehensive research report—China side review report No. 2. Beijing, Beijing Agricultural Engineering University.

Beijing Agricultural Engineering University and Agricultural Mechanisation Bureau of Shanxi Province 1993. Conservation/zone tillage research for dryland farming—Annual Report for 1993. Beijing, Beijing Agricultural Engineering University.

Beijing Agricultural Engineering University and Agricultural Mechanisation Bureau of Shanxi Province 1994. Conservation/zone tillage research for dryland farming—Annual Report for 1994. Beijing, Beijing Agricultural Engineering University.

Beijing Agricultural Engineering University and Agricultural Mechanisation Bureau of Shanxi Province 1995. Conservation/zone tillage research for dryland farming—Annual Report for 1995. Beijing, Beijing Agricultural Engineering University.

China Agricultural University Mechanical Engineering College and Shanxi Agricultural Machinery Bureau 1996. Sustainable mechanised dryland grain production—Annual Report for Year 1996. Beijing, China Agriculatual Univeristy Mechnical Engineering College.

China Agricultural University Mechanical Engineering College and Shanxi Agricultural Machinery Bureau 1997. Sustainable mechanised dryland grain production—Annual Report for Year 1997. Beijing, China Agriculatual Univeristy Mechnical Engineering College.

Chudleigh, P.D. 1991. Breeding and quality analysis of canola (rapeseed). ACIAR Economic Assessment Series No. 6, ACIAR, Canberra.

Gaffney, J. 1996. The impact of sustainable farming practices on profitablility—the dryland farming systems of the central Darling Downs. Toowoomba, Department of Primary Industries.

McKenney, D.W., Davis, J.S., Turnbull, J.W. and Searle, S.D. 1991. The impact of Australian tree species research in China. ACIAR Economic Assessment Series No. 12, ACIAR, Canberra.

Smith, G., Tao, D.L. and Liu, X. 1995. Conservation zone tillage research for dryland farming—ACIAR Project Review.

The Conservation Farmers Inc. 1997. The Conservation Farmer, 8 (7).