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Introduction of conservation tillage methods into dryland graingrowing districts in Shanxi Province, PRC

M.K. Wegener¹, J.N. Tullberg², and L.E. Pearson³

1. School of Natural and Rural Systems Management, The University of Queensland, 4072.
2. School of Land and Food, The University of Queensland, Gatton College, Lawes, 4343.
3. School of Natural and Rural Systems Management, The University of Queensland, Gatton..

Abstract

Dryland grain farmers in some 30 counties in Shanxi Province, Peoples Republic of China, are now practising some form of conservation tillage farming following a successful research and technology transfer project. While this represents only 5 percent of graingrowing land in the province, it marks the start of a trend that will lead to major changes in farming in China if the apparently attractive economics of conservation farming are confirmed. As well as the trend to conservation tillage farming in Chinese agriculture, there are other fundamental changes occurring. With the introduction of mechanisation, there are incentives to increase farm size and the structural changes that could flow from this could see farm workers displaced.

The cost savings from conservation tillage are significant since a number of costly, time-consuming farm operations can be eliminated. There is a consensus view that more moisture is stored in the soil under a conservation tillage system but the extent to which crop yields will be increased by the practice has not been established at this stage. While farmers have had access to conservation tillage planters and other equipment at low cost during the experimental phase of the work, they have indicated a willingness to implement the technology given reasonable commercial costs for the equipment.

International transfer of technology across cultural, language, and other barriers is not often successful. This has been a successful project from which a number of lessons can be learned.

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Introduction

There is much evidence that much of Chinese agriculture is in a state of transition and change. Recent observations of sugarcane growing in Guangdong province, south China, horticultural and graingrowing industries in Shandong province in north-eastern China and dryland graingrowing in Shanxi province in central-western China show how mechanisation and modifications to long-standing traditional practices are being introduced. Australian sugarcane growing machinery has been introduced by Guang Qian State Farm at Zhangjiang in south China, paddy cultivation is being mechanised with small diesel-powered paddy tractors while both locally-made tracked rice harvesters as well as machines imported from Japan are being introduced. Rice planting techniques are being modified to reduce the labour input. Rice seedlings are raised in seedling trays for transplanting and agricultural engineering staff at South China Agricultural University have designed machinery to fill and plant rice seedling trays automatically. The next stage in the process of growing the young seedlings has been commercialised in factory-sized greenhouses. The farmers recognise the benefits of good quality seedlings and the earlier planting times that are possible from these seedlings grown in greenhouses and are prepared to pay a commercial price for seedlings rather than raise their own. The labour input into planting the seedlings is being reduced with a form of broadcast planting used where bunches of seedlings are pulled from the seedling trays and flung into the air, landing in a semi-circle around the person doing the planting. Gaps in the planting are usually filled by women throwing rice seedlings into the larger spaces, like darts. These techniques are being used alongside the traditional planting methods where plants are still set into the paddy in neat rows.

There has been an enormous expansion of greenhouse fruit and vegetable production, especially in Shandong province. The simple, three-sided mud or baked brick constructions with a plastic roof sheeting face the south and allow temperatures to be increased substantially and permit early-season production or extension of production beyond normal cropping limits. A large range of crops including tomatoes, beans, capsicums, strawberries, and even nectarines and indoor ornamental plants are being grown in these greenhouses for local consumption, export throughout China, and export to international markets, for example in Russia.

In graingrowing areas, traditional clean cultivation methods involved removal or burial of stubble, cultivation with a single-furrow mouldboard plough, followed by harrowing to produce a fine seedbed. Conservation tillage methods involving stubble retention and tyne cultivation are being trialled. An Australian ACIAR project has been instrumental in introducing conservation tillage technology into the dryland graingrowing areas of Shanxi province. The economic evidence in favour of conservation tillage methods is convincing.

ACIAR project in Shanxi province

The ACIAR project (No. 9209) that led to the introduction of conservation tillage methods and experiments with controlled traffic in graingrowing areas in Shanxi province in China has been managed by the agricultural mechanisation staff from The University of Queensland, Gatton College and carried out in collaboration with staff from the China Agricultural University, Beijing and the Agricultural Mechanisation Bureau in Shanxi Province. Agricultural economists from UQ have been involved in its economic evaluation.

The overall aim of the project was to develop and evaluate conservation tillage machinery and controlled traffic tillage techniques suitable for sustainable dryland grain production in China (Young 1998). Australian dryland conservation cropping techniques and zero-till planting techniques were adapted for wheat and maize production systems in Shanxi province while controlled traffic techniques were tested experimentally at Gatton in Queensland and later at two sites in China.

The project developed from the recognition of complementary interests in dryland conservation farming in China and Australia following a visit to Australia by Professor Gao Huan Wen from the China Agricultural University, Beijing in 1989. Despite the major differences in climate, soils, current levels of technology and socio-economic conditions, the project has been particularly successful in transferring Australian technology into this dryland grain-growing area of China. Both countries faced similar problems in their efforts to improve productivity and sustain production in semi-arid grain growing areas. Soil degradation in both countries and large inputs of labour in China and energy and capital in Australia were considered to be the major challenges faced by dryland crop farmers in these areas.

The research activity in the project was to “develop, assess and extend the adoption of conservation tillage systems in an environment where the consequences of soil degradation from mechanisation were not yet significant” (Young 1998, p2). The project represented an opportunity to develop more sustainable crop production technology appropriate to Chinese farming systems and to capitalise on the different perspectives of scientists from China and Australia. The project also provided an opportunity for Chinese researchers to demonstrate that the benefits of mechanisation could be achieved without the problems of excessive energy consumption and soil degradation that are incurred in farming systems in grain-growing countries like Australia, Canada, and the United States. The economic importance of grain production in China meant that the techniques developed had to maintain yield as one of the most important objectives.

An economic evaluation of grain-growing practices under both traditional and the new conservation tillage techniques was attempted following a visit to Shanxi province in April 1999. The experimental program in China supported by field demonstrations and extension sites has provided a lot of experience in conservation tillage practices which can be compared with the results achieved from conventional cultivation. The economic advantages focus on short term cost savings from the reduced number of operations that are involved in crop production and yield improvement from moisture conservation. Long term benefits from soil structural improvement and reduced soil losses from wind and water erosion are also possible.

Experimental program

The implementation of conservation tillage practices in China required that appropriate planting equipment be developed. This development has been documented elsewhere but it essentially meant the adaption of Australian parallelogram-mounted grain planters with coulter discs, narrow planing boots, and press wheels to compact the soil over the planted seed to prevent moisture escape to the small (15-25 hp) tractors that are predominantly available to farmers in the dryland grain-growing areas of China. Thus ability to clear trash and weight restrictions were important constraints that had to be overcome. Chinese grain crops (maize and wheat) are higher yielding than their Australian counterparts with

considerably more residue left after harvest to deal with. Since 1994, field trials with maize were conducted near Shouyang and trials with wheat near Linfen in Shanxi province. The experimental program has been supported with extensive local field trials and extension demonstration plots conducted principally by staff from the local agencies of the provincial Agricultural Mechanisation Bureau. For the wheat experiments conducted with small tractors, small yield increases have been obtained in non-compacted soil which are expected to be sustainable. The number of operations for conservation tillage practices has been reduced. In maize, the experiments were conducted with larger tractors and not managed as well as the wheat trials in the early stages. There was little difference in yield between the compacted and uncompacted plots

Comparison of traditional and mechanised grain growing

While it is easy to accumulate anecdotal evidence that mechanised crop production may be more economic than conventional methods, it is harder to make direct comparisons. In this paper, the analysis will be confined to maize but similar estimates of the cost savings and changes in potential income from conservation farming can and should be made for other crops.

Maize is the most widely grown crop in Shouyang county where the maize experiments are located, accounting for 450 000 mu out of 1.0 mu cultivation with sorghum accounting for only 30 000-60 000 mu. In conventional maize growing in Shouyang county, the farmers in April plough in stubble left after the previous harvest with either animal power or a tractor although instances of using draft animals are becoming quite infrequent. They usually harrow to break down the clods. Some farmers may use a simple bar drawn behind the tractor-drawn mouldboard plough or a gang of small discs to partly level the field after ploughing. In the traditional method, planting was done by opening a furrow into which one person dropped the seeds while another put in the fertiliser. The farmer then ploughed back in the opposite direction to cover the seeds but all of the maize in the county is now planted by machine. A small planter costs Y2 400 and these planters work well where land has been prepared in the traditional way. Farmers may still use the conventional planter in reduced tillage situations where they use a rotary cultivator, more like a mulcher than a conventional Australian rotary hoe, to chop the stubble. In the reduced tillage situation where a rotary cultivator is not used, it is necessary to plant with the conservation planter to clear the amount of trash left on the soil surface. A rotary cultivator costs Y6 400 and is used behind a 40-50 hp tractor. The cost of the operation is Y7-10 per mu.

Planting costs Y6-8/mu and there is no difference in cost between the cost of using a conventional planter or the conservation planter. Seeding rate is 3.5 kg/mu, maize seed costs Y6 per kg, and 40kg/mu of fertiliser (34% nitrogen and 20% phosphorus) is also applied at planting at a cost of Y30 per mu. After planting, there are two operations, thinning and weed control. This is done by hand. Weedicide application with a knapsack spray is practised on 15% of the land. Atrazine a pre-emergence weedicide is applied after planting for weed control at a rate of 2 kg/ 5 mu (6kg/ha).

Maize is harvested in late-September to mid-October in this province, mostly by hand. Labour inputs for the whole crop where it is grown traditionally may involve 12-13 days of labour at a cost estimated to be Y10 per day. Labour costs are estimated to fall to Y70 for a mechanised operation. For conservation tillage, the total input cost for labour may be only

Y50. Generally for mechanised production, four operations are involved while for conservation tillage, only two operations are involved.

There are two common ways to deal with stubble after maize harvest which are locally known as “reduced tillage” and “zero tillage”. The zero tillage method involves leaving the stubble standing in the field. It is a low cost operation but it may cause problems at planing. The alternative course of action is to roll the stubble down at a small cost (Y2 /mu and a work rate of 200 mu/day for the machine. There are two problems with either of these approaches. Soil temperature may be reduced and planting delayed or there can be blockages during planting.

Average farm size in this county is 20-25 mu, that is a land allocation of 5 mu per person with an average 4-5 people per family. Some families do cultivate up to 200-300 mu. Maize yields average 460 kg/mu for the county and the price in April 1999 was Y1.06 per kg (for sale to the government).

Five percent of farmers in Shouyang were estimated to be using conservation tillage methods in 1999. All of this was claimed to be due to the project and efforts of the staff of the Agricultural Mechanisation Bureau in the area. Since coal is plentiful in Shanxi, most families do not use stubble for cooking. It was estimated that about 50% of the stubble was incorporated into the soil in some way, and about 40% of the stubble was used for animal feeding.

Table of operating costs

Operation	Cost
Rotary cultivation (use with 40-50 hp tractor)	Capital cost Y6 400 (10 year life, change blades annually) Y7-10 per mu
Flail mulcher (also requires large tractor)	Capital cost Y7 000 Y13 per mu
Mouldboard plough	Capital cost Y3 800 Y15 per mu (Y12 per mu with small tractor)
Harrowing	Y5 per mu
Planting	Y6-8 per mu

The capital cost of a large tractor (55 hp) is Y60 000 while a medium size tractor (45 hp) costs Y45 000 and a small tractor (25 hp) costs 20 000. A very small tractor (15 hp) suitable to use with a small planter costs Y8 600. A small rotary cultivator suitable to use with a small tractor costs Y3 200.

Farmers pay an agricultural tax of Y6 per mu.

Commercial experience

The leader of a commercial farming operation comprising 7 500 mu cultivation worked by over 700 families supporting 2 900 people was enthusiastic about conservation tillage. He noted that over 90% of the families that were involved in this operation were using conservation tillage practices although not everyone recognised the advantages when the

technology was introduced. They were planting maize on this farm using reduced tillage methods on the day we visited.

Last year their crops yielded 600 kg/mu which was the best yet from conservation tillage. It was claimed that they would only get about 400 kg/mu without conservation tillage in this 300-500 mm rainfall environment. They apply 42 kg fertiliser per mu and less than 50 kg/mu of manure. They have had four year's experience with conservation tillage and yields of maize have improved annually, from 350 kg/mu in the first year that they tried it. This farmer claimed that they might get good yields from conventional tillage in good rainfall years but conservation tillage was better than conventional tillage in dry years. At the time of planting (15 April 1999) they had had little rain since last season apart from 20 mm in two falls about 10 days previously. The soil was in good condition with adequate moisture for germination.

Operations since last harvest had involved a flail mower to chop the stubble (Y7/mu) and a disk harrowing (Y6 /mu). The land was then ready for planting. Stubble retention and reduced tillage keeps more water in the soil. This farmer considered that the cost savings due to conservation tillage were about Y30 per mu over conventional cultivation. This farmer told us that conservation farming would show advantages in a dry year. He was confident about its advantages, increased yield and decreased cost and had no suggestions for further improvement. Several adjacent villages were doing the same thing as they were and some other villages have visited to see how they use the technology. The cost of the equipment (Y4 500 for a 3-row planter, Y10 000 for a larger 6-row unit) has been provided by the Agricultural Mechanisation Bureau but this village leader thought that farmers would buy this kind of planter if they had to. There is an opportunity for family members to buy a machine and do contract work. That way they can plant quite a large area and earn money.

Farmers paid Y8 /mu to the village for planting and Y10 for ploughing. Price for maize is Y1.2 per kg. It is mainly used within the province for animal feeding.

Generally, the consensus view was that conservation tillage had a good future in this county. Initially, the local farmers did not recognise the advantages of retaining stubble and they burned it. Now the concern is about the impact of lower soil temperatures on seed germination. It was generally agreed that the farmers need something like conservation tillage to manage the soils in these areas. The future for conservation tillage seemed to depend on continuing machine developments.

Economic evaluation of conservation tillage in China

We are witnessing a massive change in Chinese agriculture generally. Not only has the conversion to conservation tillage methods begun in the grain industry, but there are other fundamental changes occurring in agriculture at the same time. These changes are reminiscent of the changes that occurred in countries like North America and Australia with the introduction of mechanisation and the areas farmed by individual families and by other groups will undoubtedly increase. There are many indications that this is starting to happen. The part of the rural labour force that is not needed on farms when operations are carried out with machinery is likely to move to the cities. Already, this seems to be happening and the casual observation is that there are few young people living and working in rural areas and there is a concentration of young people in fast-growing, middle-sized towns. Farming in

China in the future is also likely to have a more commercial orientation rather than the self-supporting, traditional, life-style activity that it has been in the past.

There are now 30 counties with farmers practising some form of conservation tillage in Shanxi province as a result of activities associated with ACIAR project 9209 and subsequent activities. This still represents only 5 percent of the total grain area but it is a start and the trend to conservation tillage practices should continue if the economics of the practice are confirmed to be as attractive as they currently appear.

The cost savings from conservation tillage are impressive (of the order of ¥30 per mu). The farmers that we spoke to told us repeatedly that it costs less to grow a crop under conservation tillage than with the conventional cultivation system. The number of farm operations can be reduced saving fuel, tractor hours, labour time, etc. We were given plenty of examples of the cost savings possible and these are obviously driving the adoption of conservation tillage practices by farmers. A number of farmers indicated that they would invest in conservation tillage planters if they needed to. Most of the farms using this technology to date have had access to machines provided by the Agricultural Mechanisation Bureau and have not had to make the capital outlay.

The consensus view is that more moisture is stored in the soil under a conservation tillage system but we are still not sure of the extent to which crop yields might benefit. This is especially the case with the most controlled form of conservation tillage, namely controlled traffic, and the current experiments should be continued for several more seasons to get a better grasp of the relationship between crop yield and seasonal conditions where this form of conservation tillage is practised. It would be helpful to try to model the experimental crop yields (with a model like Perfect or APSIM) to see if the response of crops to seasonal conditions can be modelled successfully. Whether controlled traffic will eventually be adopted as a general farming practice is probably dependent on final yields from this system and whether yields in the cropped zone will improve sufficiently in the absence of compaction to compensate for the lack of crop in the traffic zone.

Yields from conservation tillage seem to be higher than conventional farming in drier years while the advantages may be less in years with normal rainfall. It is therefore rather speculative at this stage to try to estimate the differences in economic returns from the various tillage systems. Because of the variability in seasonal conditions, the experimental work being carried out in China needs to be continued for several more years to include a wider range of seasonal conditions and to enable the long-term differences between conservation tillage practices to be quantified.

The Chinese are obviously concerned that any practices to be introduced do not affect yield adversely. This view may change in the future. No shortage of food was witnessed anywhere that I visited in China. Even the smallest, remote rural villages had much food available for sale in the street markets although there generally seemed to be few buyers and little of the produce on offer was actually being traded. In the China Daily newspaper while I was there, I saw reports from well-informed economists that "every industry in China is now producing a surplus". The immediate problem is what to do with the vast stocks of consumer goods that are not finding ready sales. I suspect the same situation exists with food commodities. The price of pigs in China is currently very low and this indicates a large supply of feed grains and that probably means adequate supplies of food grains as well. There is evidence that the Chinese are now farming a more restricted area than they did in the

past. Many of the small terraces in the mountainous areas are abandoned or at best cropped intermittently. In the past, China apparently sought to increase food production by cultivating more land and often the only land available was in mountainous or remote areas. The tendency in the past few years has obviously been to concentrate production on the more accessible, better class land and boost yields with the use of better varieties, more inputs such as fertiliser and irrigation water, and with technological inputs such as pesticides and herbicides. Mechanisation is another technology that has a place in this transition.

There are some significant concerns about this rapidly evolving system. Firstly, the over-exploitation of resources often seems to go unnoticed. Water and air pollution are severe and some other farming practices are unsustainable, especially from an environmental point of view. There was evidence of abandoned irrigation channels in a number of the places visited although, like all things in China, one should understand the reasons why these facilities lie abandoned before jumping to conclusions. Still there appear to be plenty of cases where river diversion schemes cannot be used because the over-exploitation of water resources in the upper parts of the catchment and falling watertables in irrigated areas that should be cause for immense concern. Even some of the practices that have evolved into the conservation tillage methods for grain production are clearly not sustainable.

Two practices that have crept into the grain production system, along with the adoption of conservation tillage farming and which are not sustainable, are “rotary hoeing” and plastic mulching. What is known as rotary hoeing is more like a mulching operation but it is still an energy intensive operation that has no place in a long-term, sustainable farming system. It could damage soil structure (but Chinese soils seem highly insensitive to structural damage), chops the residue into small pieces and, in the long term, may be shown to be unnecessary with the successful development of planting machinery that can work in high residue conditions.

Plastic mulching is not a sustainable practice if both environmental and economic factors are considered. Even under conditions where a good response from plastic mulching is achieved, the economic advantages are marginal. The value of possible yield increases from plastic mulched crops over conservation tillage may be about equal to the cost of laying and recovering the mulch. If the environmental costs of manufacturing plastic mulch film are considered (original petro-chemicals used to make it and energy consumption used in manufacture, transport and laying it, and the costs of retrieving and disposing of it), then these costs could tip the balance (economically) against plastic film. The cost of environmental pollution of plastic film left in fields, burnt to dispose of it, or even dumped in landfill sites is high and hard to calculate. These costs should certainly be considered in working out the attractiveness of plastic film mulching in the grain industry.

There is also a potentially serious risk in adopting technology such as plastic film mulching with doubtful economic and environmental benefits if there are likely to be a change in institutional arrangements for the marketing of the crop. Grain is currently sold in China at administratively fixed prices and the usual downward sloping demand curves, which determine the producer and consumer surplus in a conventional benefit cost analysis, do not apply. With grain production reaching surplus levels, there is a chance that yield-boosting technologies will affect the overall price that farmers receive for grain the grain, not just have an impact at the margins.. Thus farmers may not only receive lower market prices for the marginal or added production, they could end up receiving markedly lower prices for all of their production. That would alter the economics of many farming practices entirely. The

cost savings from conservation tillage would then be extremely important if such a reduction in grain prices were to occur and some break-even analyses should be carried out, using the results from the present experimental work, to confirm what the long-term break-even price and yield combinations might be.

Technology transfer

This project is an excellent example of technology transfer, adaptation and adoption. It has involved the transfer of technology across major barriers including

- different types of cropping systems (extensive agriculture on large scale farms in Australia to small scale intensive farms in China);
- different soil types (heavy clay soils in Australia to light unstructured soils in China)
- large tractors with trailed machinery to small compact tractors using three-point linkage planters etc
- language and cultural differences

It is pertinent to ask why it worked so well.

There were a couple of key supporters for the concept of conservation tillage in Prof. Gau at Beijing Agricultural University and Dr Jeff Tullberg at UQ Gatton College. Graduates of Beijing Agricultural University held key positions in the provincial agricultural machinery bureau, and the capacity to construct and modify machinery was available. In addition, finance for research (Australian Government ACIAR project and the provincial government in Shanxi, allowed an interchange of personnel from each country. The farmers were interested farmers, perhaps even cynical at first, but now enthusiastic about conservation tillage and this technology was available at a time of great transition in Chinese agriculture.

The research staff of the provincial agricultural mechanisation bureau need special mention. They have made the potential transformation of dryland grainfarming to a more sustainable basis, in provinces such as Shanxi, possible. They have developed and experimented with planters for conservation tillage farming so that they can plant into retained crop residue. Without these machines to implement conservation farming practices, these more conservative farming systems would not be possible in China. These people learned the principles of these machines in Australia and took the technology back to China, largely as ideas and concepts, and then made and modified actual machines that work in their conditions. Due to their efforts, there is probably a greater range of conservation tillage machinery available in China now than there is in Australia.

Conservation tillage is now practised to some extent in 30 counties in Shanxi province. While this represents only 5 percent of the total area of grain crops in the province and there is still a long way to go to ensure the complete change-over in tillage systems to a more sustainable basis, there is every indication that this will occur. However, it will require continuing support with research and extension activities to ensure that this desirable conclusion is achieved.

International transfer of technology does not always work as well as it has obviously done in this case. The technology was available at an opportune time when agriculture in China was in a state of enormous transition and the methods used to transfer the technology have been particularly successful.

Benefit/cost analysis

A convenient spreadsheet program such as the one developed by Ross McLeod (e SYS Development Pty Limited, Sydney) should be used to try to evaluate the economic benefits of this project. Costs from the ACIAR project are well defined but the investments made in the project from Chinese sources are not so easily identified. It could possibly be argued that these costs would be incurred anyhow by way of normal university and agricultural mechanisation bureau activities and they have simply been re-allocated from other projects to this one. While this would ease the analytical burden, it does ignore any benefits that these funds may have returned in their alternative uses.

References

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