Conservation tillage for dryland farming in China

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Abstract
Dryland regions account for above 70% of total nation's farmland in China. These dryland are vital contributors to the total national production of grains, cash crops and animal products. However, the development of dryland farming is constrained by harsh climate, bad economic situation and poor knowledge on land management. Even though the conservation tillage research and application in dryland regions of China has been actively promoted since 1980s, the conventional tillage is still prevalent in these regions. The bottleneck for sustainable agriculture in China is still the lack of knowledge amongst both farmers and extension organizations about practices pertained to sustainable land management. In this paper, we analyzed the regional characteristics and regional adaptation of conservation tillage systems in China's dryland regions; reviewed the research conducted on conservation tillage in China, and discussed the problems faced with the introduction and application of conservation tillage practices in order to gain a better perception of the role of soil conservation tillage and promote application of practical technologies for dryland farming systems in China. To ensure a wider adoption of conservation tillage, several actions should be strengthened. These include: 1) strengthen the on-the ground, pilot field activates and further intensify the demonstration 2) optimize information, instruction, support and guidance of the farmer 3) enact specific legislation for the development, adoption and implementation of conservation agriculture.
Keywords: Research, dryland farming, Conservation tillage, China

1. Introduction

The utilization and development of dryland farming technique is well concerned in the world, and is also a development strategy for China's agriculture. Dry land farming areas cover more than 667 million ha, (>70% of total farmland in China) with 267 million ha of sloping land.
China has a long history and rich traditional experience on dryland farming, As early as the time of Qin and Han Dynasty, farmer living in Yellow River Valley created site adapted farming systems. Plowing, harrowing, and precise leveling were the main measures of fighting against drought, and laid the foundation of dryland farming techniques in Northern China. However, those methods for optimizing use of moisture employ labour intensive

techniques and are no longer economic. Conventional tillage practices with intensive tillage and high application rates of chemical fertilizer now are recognized as being major contributors to the problems of soil erosion, soil surface crusting, impaired hydrology and reduced soil organic matter and biological activity (Vere, 2005).

Conservation tillage was introduced into China during 1980's, but there was resistance by local farmers (but also researchers!) to accept the technology. Main reasons were the risk of yield reductions, limited availability and poor quality of farm machines for small-scale farms. There was also concern about changing tillage practices that had been followed for over 4000 years, particularly the removal of stubble, a practice considered to indicate good farming and clean fields. With more than two decades research, demonstration and extension, the awareness of the importance of conservation tillage practices for the improvement of agricultural production and the ecological environment was increased. This paper, reports on the role of soil conservation tillage and application of suitable technologies for dryland farming systems in China.

2. Dryland farming environment of China

The drylands of China, mainly located in the north, northwest and Northeast, Yungui Plateau, Qinba mountainous and hilly area and the Loess Plateau, are home to about 40% of the total China population. These drylands are vital contributors to the total national production of grains (56% of nation's grain crops), cash crops and animal production. Dryland farming area in China is widely located, including the vast area to the north of Qinling Mountain and Huaihe River where precipitation is not sufficient and the seasonally arid hilly area in the upper and middle reaches of Yangtze River where precipitation is sufficient but water conservancy facilities are rather backward. Some characteristics of the main dryland regions are given by Wang et al. (in press).

Main features of China's dryland regions can be summarized as follows:

Water shortage, but also severe soil erosion.

Periods of drought alternating with short periods of wet conditions are common to many dryland areas of China. The incidence of drought has increased during the last decade, and now occurs nearly two out of three years. Annual precipitation in the area is about 350-550 mm with a wet summer (45-65% of total) and a dry winter (1-3%). Rainfall ditribution is irregular, its intensity can be high.Sometimes more than half of the annual rainfall may fall in a few days. The intense storms cause excessive runoff that leads to severe soil erosion on slopes with little vegetative cover. Rainwater is also rapidly lost during the summer due to high temperatures and in spring and autumn due to strong winds. Re-use of surface water is poor: only 40-50% in general, in some places as low as 30%.

Harsh environment

China's dryland covers a wide range of climatic, agricultural, economic, and social conditions. The majority of their rural residents are poor. The harsh climate severely constrains the use of agricultural land, its productivity, and (as a consequence) the social and economic development

Although high temperatures in the rainy season ensure rapid crop development, erratic rainfall can lead to water shortage, particularly on shallow or coarse-textured soils. Wind may cause mechanical damage to crops, in the northern parts of the drylands. In Henan Province e.g., dry-hot wind is the major cause of immature death of wheat.

Land degradation and declining land productivity

Soils of the drylands are highly variable. Each soil type has its own properties and needs appropriate tillage, such as the soils of the Loess Plateau, that are inherently low in organic matter and clay content. This makes Loess soils relatively easy to cultivate, but very susceptible to wind and water erosion.

Soil infertility is constraining productivity in dryland farming areas. Desertification, water erosion, sand storms and wind erosion, soil salinization and loss of bio-diversity, affects 70% of the arable part of the drylands and accounts for about US$21 million **per day** in lost income due to decline in productivity. Inappropriate tillage practices was recognized as the main cause (Anon., 2002). In the Loess Plateau,grain yields in some areas are less 750 kg per ha compared to 4300 in the southern parts of China.

Lack of exposure to new and sound knowledge and capacity building

The dryland areas suffer from a lack of extension services that hinders the spread and adoption of innovative farming practices. Gaps between experimental plots and farmers' fields are mainly due to failures in the timely delivery of inputs and the reduced applicability of whole technology packages. Furthermore, technological guidelines for local conditions frequently tend to be incomplete and management capacities lag behind actual requirements.

Conventional management practices are based on the use of simple tools to clean and open up the land for growing a crop. Tillage methods involve use of moldboard plows and harrows pulled by animals or tractors and are based on the principle that all crop residues are removed from the fields before a new crop is sown or planted in a fine, loose and smooth soil. The rationale of the farmer is that the advantages are clear: weeds are well controlled and the sowing and planting operation can be done effectively. Cleaning of the land leads to an exposure to wind, rain and sunshine and results in a strong reduction of organic matter in the soil. Organic matter is responsible for a better structure and a higher stability of the soil, it also acts as a buffer for nutrients. Consequently, with less organic matter the farmer tends to apply more fertilizer, not to feed his crop, but to make up for the losses by runoff, erosion and leaching.

3. Conservation tillage practices: application and research

Since the birth of New China in 1949, especially from the Sixth five year (1981-1985) to the Tenth five year (2000-2005), the traditional dryland farming techniques have been enriched though the arduous efforts of leading local farmers and technical workers. Conservation tillage is recognized as a viable concept for sustainable agriculture in China. During the last ten years, a strong increase in research and demonstration activity related to what are loosely termed “conservation” or “reduced” tillage systems has been documented in China. Agricultural scientists, engineers and governmental officials pay more and more attention on the conservation tillage based on their more than two decades research and experiment. An overview of research activities is given in Table 1.

The Chinese Academy of Agricultural Sciences (CAAS) is very active in tillage research and education collaborations. Since the 1980s, CAAS carried out a series of national key projects. During 1980-1985 studies focus on the effects of different tillage methods on soil physical condition, soil water storage and single rainfed wheat and rainfed maize production were conducted in Tunliu (of Shanxi province). During 1986-1990 research was continued at the same site to study the effects of alternative tillage techniques for soil water conservation.

During 1990-1995 studies on conservation tillage in combination with farm machinery use and agronomy in dryland farming were conducted in Linfen and Shouyang, in the south-east and middle areas of Shanxi. Since 1990s field experiments in Shouyang on the effects of reduced tillage and residue management on nutrient cycling in dryland regions have been conducted, and the longer-term studies have shown that application of crop residue was of benefit to soil protection, water conservation, nutrient improvement, and crop yield increase.
The effect of different soil tillage methods on the amount of runoff and soil losses from loess soils, the waterbalance and nutrient erosion in sloping fields has been evaluated in the sino-belgium projects since 1999. The evaluation was done by means of a set of erosion plots which were on one hand under natural rainfall, typically characterized by high intensity rains, and on the other hand under artificial rainfall simulations on the standard plots and in the laboratory. Conclusions were drawn with respect to the most beneficial soil conservation tillage methods to reduce soil losses and runoff. With the runoff water and the sediments, also vast amounts of nutrients are carried away and are lost from the fields as 'nutrient erosion'. The research was expanded slightly towards biological parameters, because reducing tillage intensity was shown to have a very strong impact on soil biological activity.
The Chinese Ministry of Agriculture takes conservation tillage as one of the most important technologies to be extended in the coming 10 years. Now, a national demonstration network composed by scientists, technicians, experts, farms and governors has taken shape. The extension and demonstration of conservation tillage takes place in more than 150 counties. Total area exceeds 400,000 hectares. Chinese technologies, experiences and machines could provide a valuable reference in how to apply conservation tillage in small farms of other developing countries.

4. Prospect of dryland farming in China

The bottleneck for sustainable agriculture in China is still the lack of knowledge amongst both farmers and extension organizations about practices pertained to sustainable land management. The conservation tillage is not a simple technique that can just be handed out to the farmers. It is a package of various measures and alternative approaches. It is not purely a technology but requires the farmers who are going to adopt the system to quite drastically change their way of thinking and looking at agricultural issues. This change of attitude is not without risk for the farmer, particularly in the early stages of conversion from conventional to conservation. It is possible that the farmer faces yield reductions or even crop failure e.g. because of inadequate steps taken, e.g. leading to weed infestations. Sufficient availability of inputs, funds for large-scale extension and trained manpower for extension are solution to mitigate at the root of these problems, in which technical training of farmers has to receive highest priority, as it often suffers from lack of timely technological guidance. Therefore, considerable attention has to be given to an optimum information, instruction, support and guidance of the farmer.

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Table 1 summary detail of experimental study on conservation tillage, China

Location and crop	Project (Year)	Field activity	Major finding	Reference
Tunliu, Shanxi, winter wheat	the National 7th and 8th 5-yr project (1986 -1995)	DP, NT, SS,RM and CT	Fallow water storage up49% with DP, 40-49% with SS, 15% with NT;ET up 2-27% with NT/SS; Yield up13-22% with DP,12-14% with NT/SS; 15-33% with RM; down 5-6% with NT/SS	Gao et al., 1991
Linfen, Shanxi, winter wheat	Sino-Australia project (1992 -2003)	NT, chopped straw; subsoiler, chopped straw; CT being mouldboard plough	Fallow water storage up 3%-16% with NT;2%-12% with SS; WUE up 19%; OM up 35%; Yields up by 18.5%, herbicide usage down 20-30%, runoff & wind erosion down 60%, Developed: to match 15-18hp small tractor – (i) 2BMF-4D maize planter– can handle very heavy crop residues and (ii) 2BBMFY-4D wheat narrow point openers	Li et al., 2000; Gao et al., 2003
Luoyang, Henan, winter wheat	Sino-Belgium program (1999 -2004)	RD, NT, SS, CT	Follow water storage up 3-16% with NT and 2-12% with /SS; WUE up 29-36% with SS; SOM up 1.2% with NT and SS; Yield up 9.4% with SS; NT up yield in drought year significantly; RD no effect on yield, SS and NT down runoff and soil loss 50% and 90%. No effect on saturated hydraulic conductivity.	Wang et al., 2003b
Tunliu, Shanxi, spring maize	the National 7th 5-yr project (1986-1990)	NT, RM, DP+RI, CT	WUE up 1-20% with DP+RI and 15-18 with RM; yield up 2-21% with DP+RI; 17-21% with RM; down 5-14% with NT	Gao et al., 1990; Wang et al., 2003a
Shouyang, Shanxi, spring maize	the National 8th/10th 5-yr project (1991 -1995 /2001 -2005)	NT, SS,DP+RI, CT	Follow water storage up 3-15% with DP+RI and 6-13% with NT/SS;WUE up 29-36% with DP+RI and 10~32% with NT/SS; SOM up 1.2% with RI (11yr average);Yiled up 11-35% with DP+RI; 4-22% with NT/SS; down 11-14% with NT/SS (1995, wet),wind erosion down 60-68% with DP/SS and 79% with NT.	Cai et al., 2002,Wang et al., 2004,Wang and Cai, 2005
Hebei, with extension program for technology transfer in five provinces: Hebei, Shandong, Gansu, Shanxi and Inner Mongoliasummer maize-winter wheat	Sino-Canada project (1991-2003)	Phase 1: introduced concepts of NT, improve WUE and crop yields; 1993: added a socioeconomic component; 1994: resource conservation and integrated pest management Phase 2: Collaborative program on protecting fragile dryland agroecosystems	SOM up 1.37, 1.47and 1.80% with NT wheat (2000, 2001, 2002) annually; Yield up 10-15% with NT maize;no diff. with NT wheat, down 30% after 3yrs	Ren et al., 2003; Jia et al., 2003
Daxing, Beijing, Summer maize	Sino-EU project (1995 -1997)	RM, SS, NT, CT	WUE up 46% with RM and 19% with SS; Yield up 11%-29% with RM, 11-20% with SS, and no different with NT	Ding and Hann, 2000
Wheat: Chen Huang village near Linfen city, Shanxi province	"Conservation / Zone Tillage Research for Dryland	NT into standing stubble, NT after stubble pressed, as before with additional	10 year average yield increases with NT (rel. conv) - maize: 18%, wheat: 15%. Dry years – yiled increases greater. Runoff with rain decreased in NT,particularly	Des McGarry, 2005

Location and crop	Project (Year)	Field activity	Major finding	Reference
Maize: near Zhongai township, Shouyang province (site name: Hoshyan)	Farming"ACIAR China Agriculture University, Shanxi Agricultural Machinery Bureau (commenced 1993)	crop residue (manually applied), subsoiler (standing stubblea), as before with stubble chopped, as before with additional stubble, CT (deep plough and harrow)	with controlled traffic; Water infiltration was a max of 94% of rainfall under NT, residues retained and uncompacted (from wheels). NT equipments pioneered are now locally, commercially available	
Chenghuang village, Linfen City, Shanxi	China agricultural University (commenced 1992)	NT with residues, subsoiling with residues, NT as before but harrowed, mouldboard (CT) with no residues	NT reduced runoff and soil evaporation, hence WUE better by 19% in NT, and even greater in dry years. NT increased wheat yields by 18% and up to 24% in dry years. NT reduced production costs by up to 22%. OM under NT up by 34% and 21% in 0- 10 and 10-20 cm layers, Water stable aggregates greatly increased under NT. The soil originally hardsetting, no longer – better sowing conditions; no clods	Des McGarry, 2005

Note: NT=no-till; DP=deep ploughing; SS=subsoiling; RI=residue incorporated; RM=straw mulching; CT=conventional tillage WUE=water use efficiency