Conservation Agriculture in Mongolia[1]

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Summary

Mongolia is noted for its harsh cold dry continental climate, which places severe limitations on crop production. These constraints and poor crop and soil management techniques have resulted in low crop yields and severe wind erosion. Following a request by the Government of Mongolia, FAO has implemented the TCP project "Improved Cereal Production Technology" from 2000 to 2002. The project's main objective was to introduce Conservation Agriculture (CA) technologies in the wheat-fallow production system of Mongolia in order to improve cereal productivity and farm profitability on a sustainable and environmentally sound basis. Main elements of the new technology are the development of an improved fallow system based on permanent soil cover through crop residue management, and an efficient direct seeding and weed control system. The CA technologies produce significantly higher crop yields, and strongly reduce production cost and wind erosion.
Key words: Direct seeding, Crop residue management, Chemical fallow. Seed production, Diversification

Introduction

The production of spring wheat, the only major crop in Mongolia, is mechanised through the introduction of techniques and farm equipment by Russia in the 1960s. The collective state farms covered large areas of up to 20,000 ha under a centralised management with a paid labour force of some hundred persons. Since 1992 most state farms were privatised, split into smaller units of some 1000 ha and leased to private individual owners or to a group of owners as a shareholder company with leasing periods of up to 20 years. As the wheat area has shrunk, following the abandonment of many marginal state farms, there is presently adequate farm machinery for the cultivated wheat area of some 300,000 ha. At present mounting cost of production, inability of farmers to obtain credit, scarcity and high cost of essential inputs (fuel, herbicides, fertilisers, spare parts etc.), poor condition of farm machinery, low producer prices and crop productivity has resulted in heavy indebtedness of farmers and has pushed them to the brink of bankruptcy.

Following a request by the Government of Mongolia, FAO has implemented the TCP project "Improved Cereal Production Technology". The project was launched in the cropping season 2000 and has terminated in 2002. Its main objective was to introduce conservation agriculture technologies in Mongolia in order to improve cereal productivity and farm profitability on a sustainable and environmentally friendly basis.

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Agricultural production and its major constraints in Mongolia

Mongolia is noted for its harsh cold dry continental climate, which places severe limitations on crop production. Short growing period of only three months (end of May to early September), low and erratic rainfall of 200 to 300 mm and extremely low winter temperatures (-30 degree Celsius) only allow the cultivation of early maturing spring crops such as spring wheat, potatoes and fodder crops. However, one of the most serious environmental problems is created by the high winds particularly during April and May which promote drying of the upper rooting zone and serious wind erosion from unsuitably prepared fallow and arable land both before and after seeding in early May.

Wheat was, and continues to be, the major cereal accounting for 98% of the cultivated cereal area. The wheat area has dramatically decreased by more than 50% from about 650,000 ha in 1990 to some 300,000 ha in 1998. The current cropping system is a spring wheat monocropping system. Average wheat yields of 1.4 t/ha were achieved in the 1980s but have fallen to 0.6 t/ha although yields of 2 t/ha are achievable in more favourable years on better-managed farms. Wheat yields have been dropping for reasons such as poor crop and land management, the use of little or no fertiliser, agro-chemicals, improved seed, and lack of spare parts.

Lack of soil moisture, especially at seeding and during crop establishment in May and June is the primary constraint on wheat yields. Common practice is to fallow one year in two often under strip cropping where cropped and fallowed fields (strips) alternate in order to prevent wind erosion. Wheat grown consecutively on the same land for two years yields only some 0.5 t/ha during the second planting year. The fallow is cultivated up to five times with broad-sweeps and/or discs cultivators, to control weed growth. It is also believed to conserve the accumulated precipitation during fallow as soil moisture for the next year's crop. However, many research results have shown that frequent mechanical cultivation accelerate loss of stored moisture from the rooting profile.

Food security is a major issue for Mongolia. It is a landlocked country and border issues and shortages in international wheat production could disrupt supplies. The Government is particularly concerned because of the continued decline in the crop production sector. In 1995 a Government resolution reconfirmed that self-sufficiency in wheat production is a national priority, flour being the single major staple food. In response to the serious risk of interrupted grain supplies, stocks of wheat and flour have been set aside to act as buffer stocks against shortfalls in production.

Conservation Agriculture (CA) and its impact on crop production

One key to farmers' economic survival in producing cereal crops in a difficult climate is efficient crop and land management. The current practice of frequent cultivation of fallow land is unsustainable both from a technical and financial point of view. Weed control is very poor, soil moisture losses are high and fuel and spares for tractors are scarce and costly. The project's objective was to test and validate resources-saving conservation agriculture technologies which address the major production constraints and to train farm managers and farmers in using these practices for improved and sustainable cereal production.

Creating a healthy soil habitat is the first step to CA. This means using a series of soil and crop management practices such as:

- Soil management practices such as direct seeding, which eliminates any soil disturbance (ploughing, harrowing etc.)
- Management of crop residues and cover crops to improve soil fertility, moisture retention (water and snow), crop emergence, weed control and protect soil surface from the direct impact of rain and sun

- Diversified crop rotations for better managing soil fertility, weeds, diseases, pests, workloads and risks.

Conservation agriculture (CA) has been adopted and validated in many different ecozones of the world. The technology has been adapted to very diverse farming systems from small-scale commercial farming in southern Brazil or larger-scale farming in the Cerrado to the irrigated rice-wheat system of northern India and Pakistan, the large-scale farms of semiarid Texas, or the emergent small-scale mixed farms in Zimbabwe.

Conservation Agriculture - most fully expressed as residue-based zero tillage offer numerous benefits that intensive or conventional tillage cannot match:

- improving soil fertility owing to more plant residue
- protecting the soil surface from sunlight and decreasing the evaporation of water
- promoting the life of soil micro organisms and improving soil structure

These advantages of CA are the main factors for its ability to increase and stabilise yields and decrease the environmental risks.

CA is possible in Mongolia only with an alternative weed control method, which replaces the conventional mechanical fallow cultivation. Similar to the situation in Canada and the Northern Great Plains (USA) the chemical fallow based on the use of non-selective herbicides appears to be an appropriate weed control method. Cover crops for weed control do not seem to fit well into the cropping system especially the fallow because rainfall is low and the fallow is needed to accumulate soil moisture for the subsequent wheat crop.

CA using minimum or no-tillage and direct planting of the crop leads to reduced labour requirements, timesaving, reduced machinery wear and fuel savings. No-till for instance requires as little as one trip for planting compared to two or more soil tillage operations plus planting for conventional tillage. Fewer trips also save on machinery wear and maintenance and fuel cost. Fuel and energy saving in CA systems can range between 30 and 60% (Doets et al. 2000).

Reduced weight and horsepower requirements with no-tillage can help minimise soil compaction. Additional field traffic required by conventional tillage breaks down the soil structure, promoting compaction. No-tillage increases soil particle aggregation (aggregate stability, continuous macro pores) which makes it easier for water to move through the soil and allows plants to use less energy to establish roots.

Crop residues reduce water evaporation from the top few inches of the soil and no-till can make additional water available for growing plants during the season. Crop residues act as tiny barriers to slow water runoff from the field, allowing the water more time to soak into the soil. Channels (macro pores) created by soil macrobiota and old plant roots that are left intact also increase infiltration. All this helps significantly reduce or eliminate field runoff.

Crop residues on the soil surface reduce erosion by water and wind. Depending on the amount of residues present, soil erosion can be reduced by up to 90% compared to an unprotected, conventionally tilled field.

Resources-saving farming is not new to Mongolia and minimum tillage and the appropriate equipment (V-shaped shallow sweeps) have been introduced by scientists from the Soviet Union about 15-20 years ago. Although plowing is officially banned in Mongolia for crops other than potatoes and vegetable, this technology has rarely been fully adopted by farmers because of the serious weed problem, which they tried to control, by frequent fallow cultivation. The introduction of chemical fallow based on non-selective herbicides can solve the weed problem and allow the introduction of the no-till technology.

These proposed technologies, which have been shown to work under similar conditions in North America, had a positive impact on crop production in Mongolia. Since virtually all farm equipment is of Russian origin the project updated mainly Russian-made machinery. The major advantage of the local equipment is its immediate availability, its low price and farmers familiarity with it. Equipment from Western countries are probably more efficient but they are also more sophisticated and require good maintenance and are usually much more expensive than equipment from Russia.

Project activities and results

The project focuses its activities in the Central Cropping Region which is the main cereal growing area in Mongolia, and which is situated north of Ulaanbaatar, the country's capital.

Five large-scale farms were selected for participating in the test and demonstration programme. Each farm allocated 200 ha for the programme of which 100 ha are used for testing conservation agriculture technologies and 100 ha for multiplying quality seed. All selected farms are privately owned and use farm machinery suitable for being adapted to conservation agriculture practices.

Technologies to be tested, adapted and validated together with farmers are the following:

- improved weed control
- improved crop residue management
- no-tillage and direct planting of crops
- seed production and crop diversification.

Chemical fallow (improved weed control)

In Mongolia the main grassy weeds are quack grass (*Agropyron repens),* wild oat (*Avena fatua*) and proso millet (*Panicum miliaceum*). The major broad-leaved weeds are sagebrush (*Artemisia dracunculus*), sagebrush/wormwood (*Artemisia sieversiana*), Canada thistle (*Cirsium arvense*) and Tartary wheat (*Polygonum tataricum*).

Currently most farmers control weeds by cultivating the soil 2-3 times during the fallow period especially against the root spreading weeds (e.g. quack grass: *Agropyrum repens*), which is one of the most harmful weeds and which can reduce yields by 50%. This inefficient and costly cultivation is being replaced by the use of non-selective herbicides (desiccants or burn down herbicides) such as glyphosates (e.g. Roundup). The desiccant is usually applied once during the fallow with an application rate of 2.5 kg/ha and in conjunction with a surfactant, which kills existing vegetation before planting. In case that not all weeds have been properly killed an additional early preplant application of 1.5 kg/ha might be necessary. If there are only broad-leaved weeds growing, then the desiccant can be replaced with 2,4-D to save costs.

The existing boom sprayers are old and in a bad state of maintenance due to lack of spare parts and do not assure the precise and even application of desiccants. Spraying is a much more difficult job than cultivation, and one of the reasons is that mistakes cannot be noticed until the effect of the chemical is seen, and then it may be too late to spray because the weeds are too big. Therefore the projects provided update-kits, which comprise a new pump, distribution system, controls and spraying nozzles, with which participating farmers are upgrading their boom sprayers. The update kits for Russian sprayers are readily available on the international market. The installation and use of the upgraded sprayers was backed up by special training. Farmers are also provided with the non-selective herbicide (Roundup) and the surfactant. For maximum effectiveness farmers are advised to apply the herbicides when the weeds are some 20-cm high.

The chemical fallow has shown good effectiveness in controlling both broad-leaved weeds and grasses. Two sprayings as indicated above have shown to be more effective than one spray. A shift in weed composition from annual to hard-to-control perennials, which is often observed when changing from conventional to conservation agriculture, has not yet been observed but could become a problem in the long-run.

Crop residue management

Efficient residue management is key to good Conservation Agriculture and it begins at harvest. Spring wheat is harvested in Mongolia with combine harvesters in August. Farmers usually cut and thresh in one pass but frequently wheat is swathed before full maturity and threshed at a later stage. Although farmers have to pass twice with their combines over the field, which is an increased expense, this harvesting system has the important advantage that the wheat crop can be harvested early in the season and that early frost in late August or early September does not affect crop yield.

Wheat straw remains in the field but is frequently grazed in winter and summer during the fallow period by livestock from nomadic herders. As a result about half or even less of the crop residue is often not available for residue management under CA.

Another constraint is the uneven distribution of crop residues after harvest especially with the two-stage harvest where the straw of two rows is placed in one line. The accumulation of straw in windrows behind the combine causes a number of problems for planting, resulting in uneven crop stand because of poor performance of direct seed drill and because the seeds take longer to germinate and grow, leading to significant yield reduction. The reasons for that are:

- unsatisfactory weed control from herbicide interception
- poor protection of the soil from soil moisture evaporation and erosion between windrows
- increased demands on planter equipment
- poor seed-to-soil contact
- increased pest infestation
- increased weed seed concentration
- poor plant nutrient uptake.

The project locally developed a straw spreader attached to the combine harvester based on two horizontal rotating disks in order to achieve a uniform straw distribution on the ground. This straw spreading system works relatively satisfactory on fields, which have been harvested with the combine in one pass. The advantages of this modification are as follows:

- Spreads to about 5 meters, which is close to cutting width of the combine.
- Saves energies. Only 5% of power of engine are going to spreading operation compared to up to 30% with a straw chopper.
- Low dependence on wind.
- Spreads quite evenly straw and chaff.
- Construction is locally made and easy to handle.

The disadvantages are:

- The straw spreader was designed for an average straw yield of about 1 t/ha. However, some farmers swathed straw into double windrows thereby doubling the quantity of straw in one line. In this case the spreader had some difficulties in handling the straw quantity requiring strengthened drive belts.
- Some minor defects were that the initial rubber transmission belt was not sufficiently strong with respect to the straw load held at the disk.

Straw chopping by the combine harvester has been considered but does not appear to be a feasible solution because of the high power requirements, the underpowered Russian combines, the almost doubled fuel consumption and reduced labour productivity of the combine.

Direct seeding

Since the no-tillage system practised under the project avoids any soil cultivation during the fallow period, the grain crop is seeded directly into the non-cultivated soil. The project worked with the conventional seeders of Russian origin (SZS 2.1) used by farmers. The seeder has been modified in order to adapt to direct seeding of the grain crop:

- Shortened wings of duck foot or sweep opener to reduce soil disturbance and draft requirements.
- Inserted additional seed spreader in the coulter outlet to spread the seed within the row and reduce the accumulation of seed and fertiliser in a narrow band.

- Replaced sweep with hoe or knife opener.
- Modified press wheels by flattening its conical shape.

Direct drilling with the modified hoe drill has encountered some problems in heavy crop residues when seeders were clogged. Coulters (cutting disks) which cut through crop residue and open the soil need to be mounted. However, in general the modified seed drill works satisfactorily under farmer conditions and some neighbouring farmers started to adapt their own machines likewise.

In addition to the local modification some direct drill coulters were imported from Brazil and installed in a Russian hoe drill. The units comprised a cutting disk coulter and a set of offset double disks or, alternatively, a narrow chisel coulter, followed by a press wheel. Each row unit had independent suspension and was mounted on support bars which had been welded onto the frame of the Russian hoe drill. The advantage of this modification was better residue handling, less soil disturbance and a more uniform depth placement due to the independently suspended row units. The expected results should be less weed germination due to less soil disturbance and a more uniform seed germination, allowing also reduced planting depths (Dambros 2002).

This modification seems to provide a very interesting way to upgrade the existing equipment at a low cost to high quality direct seed drills by replacing only the crucial soil engaging elements with state of the art kits while using the rest of the seed drills without any changes. Similar adaptations of seed drills facilitated also in Brazil the introduction of CA, because of its accuracy of planting and low cost. A complete good quality no till seed drill is often too expensive for farmers planning to adopt CA.

Current conventional seeding rates used by farmers of some 180 kg/ha are high and seeding depth of 7-10 cm is very deep. This practice is the result of the frequent fallow cultivation for weed control, which pulverises and dries out the topsoil before and during planting time. In order to allow the emerging seeds to tap the deeper moist soil layers farmers are forced to sow the seeds at great depth. As a consequence the seed have great difficulties in emerging and develop only weak plants. To compensate for the high percentage of weak and/or non-emerging plants the farmers plant with high seeding rates.

The benefit of the no-till/direct seeding system is obvious; it preserves scarce soil moisture, allows shallow seeding and as a result helps to develop a vigorously emerging grain crop. Participating farmers have already reduced their seeding depth down to a range of 4-6 cm. However, they keep the high seeding rate because they fear the dry spell during crop emergence/early plant development which is typical for Mongolian agro-climatic conditions and which can kill a high percentage of young plants. A lower seeding rate under direct drilling is expected to increase tillering and to save soil moisture. This presupposes, however, a good control of both grass and broadleaf weeds.

Seed production and crop diversification

During the period of transition towards a market economy Mongolia's seed production system has broken down. In the last decade farmers are only using farmer saved seed of low quality and no new varieties are developed by the seed system. The project provides improved wheat seed to the participating farmers and trains them in on-farm quality seed multiplication.

Farmers in Mongolia are monocropping spring wheat because wheat is the only crop, which has a market and which offers farmers a reasonable price. It is also the only crop for which improved seed are sometimes available (imported from the Russian Federation). The permanent monocrop system has contributed to the current low crop production level and the long-term unsustainability of the production system.

The project has identified a need for locally produced malting barley because at present all malt needed for the relatively large local brewing industry is being imported. Spring barley is one of the most suitable grain crops for Mongolia and has been produced by farmers in the past. It is drought-hardier than wheat and also higher-yielding. The project has provided participating farmers with quality barley seed for the 2001-season with the aim to produce malting barley seed for sale to other interested farmers. Other suitable alternative crops are buckwheat, canola, sunflower and chickpeas which, however, need to be tested to identify appropriate varieties.

Impact of Conservation Agriculture on Soil and Farm Productivity

The impact of CA on soil and farm productivity has been measured by the following main parameters:

- soil moisture retention
- bulk density
- humus content
- yield
- farm economics

For measuring the impact of CA on soil physical parameters a local research institution had been engaged for preparing an analytical programme, which consisted of taking soil samples in regular intervals on each of the participating farms from both chemically and mechanically fallowed fields. Samples were taken in 10-cm intervals down to a soil depth of 60 cm before seeding and after crop harvest and were analysed in the research laboratory.

On average, soil moisture content at the various soil depths under chemical fallow was 10% higher compared with mechanical fallow both at the end of the fallow and prior to seeding.

This is related to the fact that reduced or no-tillage and proper residue management generally improves water infiltration. Crop residues slow water runoff from the field, allowing the water more time to soak into the soil. It also prevents wind from blowing away the fertile top soil. As a result both water and wind erosion are strongly reduced.

In three out of the five selected farms there was also an increase of soil bulk density by about 15% from 1.10 to 1.27 g/cm² particularly in the 0-10 cm soil depth. Higher bulk density is usually found under CA and is related to the fact that reduced or no-till increases soil particle aggregation (small soil clumps). This makes it easier for water to move through the soil and allows plants to use less energy to establish roots.

Also with respect to humus content three out of the five farms showed higher humus contents in the 0-20 cm soil depth under chemical fallow and crop residue management compared with mechanical fallow. This result coincides with many research data, which have shown that reduced or no-tillage increases soil organic matter. The more the soil is tilled, the more organic matter is oxidised and carbon released to the air and the less organic matter (carbon) is available to build organic matter for future crops. In fact, carbon accounts for about half of the organic matter.

CA technology also had a significant impact on wheat yields. On average yields increased by some 50% from 0.6 t/ha to 0.9 t/ha. This is the result of improved soil, residue and weed management which results in higher soil moisture retention and soil organic matter content.

The no-tillage technology with its elimination of land cultivation has led to a significant reduction in fuel and labour cost compared with conventional tillage. However, herbicides, required for the chemical weed control, were the most important cost element. Overall costs of CA technology were reduced by some 70% compared with fallow by mouldboard plough and by 40% compared with fallow by wide blade sweep.

Conclusions and Outlook

The FAO project has successfully tested CA technologies under marginal agricultural conditions in Mongolia and could show that these land and crop management practices are able to address some serious agricultural problems in the country. The introduction of effective chemical fallow, of no-tillage system with direct seeding of crop seeds significantly reduced both wind and water erosion, increased soil moisture retention, improved soil structure and fertility, and reduced cost of land management. As a result crop yields and farm profitability were significantly increased, natural resources were protected and preserved and a sustainable production system established.

Farmers participating in the technology testing enthusiastically adopted the new technology because of it immediate direct benefits to them and the relatively low cost of changing from conventional to CA technology. However, in order for the technology to spread widely within the farming community technology testing alone is insufficient and more support from a major donor is required. Currently the Asian Development Bank is preparing a comprehensive Agricultural Sector Development Programme to be launched in 2003, which amongst others includes support for the production of improved quality seed and a credit programme and technical advice for strengthening CA technology adoption and management. Thus the FAO project has also been successful in convincing large multilateral donors to invest substantial funds in the promotion of CA technology.

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