ACKNOWLEDGEMENTS

This Manual has been put together with the objective of assisting actions by the diverse groups of human beings who intervene in the conservation of the natural resources, particularly soil and water resources and in the context of each continent, country, region or zone. The Manual is based on world practice on conservation agriculture and the results of project named “Sustainable agricultural practices in the drought affected region of Karakalpakstan”, supported by the Food and Agricultural Organization of the United Nations (FAO) through a FAO/TCP project in Uzbekistan (FAO/TCP/UZB/3102), and implemented by the Ministry of Agriculture and Water Resources (MAWR) of Uzbekistan from October 2004 to September 2007.

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I firmly believe that the results of this project would be very useful in improving soil productivity and agricultural production in Uzbekistan. It has been published in four languages (English, Russian, Uzbek and Karakalpak) for the benefit of wider audience.

Finally, I would like to thank all the Government officials and farmers associated with the project activities for their very active sincere participation.

Aziz Nurbekov
FOREWORD

Conservation agriculture is one of the most promising land use options that have been developed in our times. It is more an approach than a technology, as it consists in a variable and varying array of techniques that aim at minimizing soil disturbance, soil water and nutrient losses, and that preserve many of the ecological functions a natural soil has to offer in a natural ecosystem. Conservation agriculture has many proven benefits and it covers millions of hectares in South and North America, as well as in parts of Asia.

Conservation agriculture rests on three major principles: minimal disturbance of the soil, the health and productivity of which is at the basis of every farming operation; permanent soil cover with plant residues or living crops in order to reduce water loss, erosion, and protect the soil from harsh climate extremes; and the diversity of crops in time (rotations) and space.

Conservation agriculture also has economic benefits to the farmers who apply it. Generally, an immediate cost reduction due to decreased farming and machinery operations can be felt right after the introduction of the technology. This is important for poor farmers – for any farmer! - in times of steeply rising costs of fossil energy sources. Saving fuel also helps improving the carbon balance of land use.

Whether or not the yields will increase with the introduction of conservation agriculture depends on a wide variety of factors, and generally the effect is not that immediate, as the natural soil fertility will build up only slowly. But if correctly managed, a few years of conservation agriculture will lead to similar yields as before, and often the yields will be even higher.

Conservation agriculture is therefore also an important land use option that should not be lost on the farmers in Central Asia, and it is therefore a pleasure for us to introduce this book to the reader. It is a manual that represents proven technologies for the introduction of conservation agriculture. The book is a result of the project “Sustainable agricultural practices in the drought affected region of Karakalpakstan” and comes at a timely moment, as farmers in countries of Central Asia and the South Caucasus region are now becoming increasingly aware of conservation agriculture as a new, promising technology. However, introducing conservation agriculture often requires the change of a mindset: Plowing is too deeply enrooted in many farmer’s perception of “good land management” practice in order for it to be abandoned lightly. It is therefore important that scientists and farmers collaborate in developing and demonstrating the benefits of this approach to the farmers. This manual will help introducing the concept. We wish wide distribution to this booklet!

---

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I. INTRODUCTION
1.1. The Scope of the Manual

Degradation of soil resources is widespread and is a direct threat to the sustainability of agricultural production. Dramatic changes in soil management concepts are needed to counter the threat. Conservation agriculture proposes options for such changes through addressing a very broad variety of issues related to soil management concepts, water resources management and erosion control, mechanization and tillage, mulching, etc.

This Manual brings together a collection of concepts, experiences and practical suggestions that can be of immediate use for identifying problems and for formulating, executing and evaluating actions so as to benefit and improve the productivity and conservation of soil and water resources. The publication serves as a guide that will allow researchers, specialists and farmers to jointly discover ways to solve the problems and the limitations created by soil salinization and drought during the vegetative period of crops. This manual is meant for researchers of research institutes, agricultural specialists, extension personnel as well as farmers, and deals with the management and conservation of agricultural land. It is hoped that the Manual will help to attain the ultimate objective of improving the productivity of the soils and water in a rapid, efficient and sustainable manner.

This publication shows how conservation agriculture can increase crop production while reducing erosion and reversing soil fertility decline, improving water saving technologies, enhancing rural livelihoods and restoring the environment.

ICARDA was requested to provide technical backstopping to the project on conservation agriculture and to prepare this manual as per a Letter of Agreement between FAO and ICARDA.
2. CONSERVATION AGRICULTURE

2.1. Principles and Methods of Conservation Agriculture

Farmers are becoming increasingly conscious of the importance of soil health, water quality, and energy conservation.

Conservation Agriculture (CA) or resource effective agriculture is practices of farming, which helps in conserving the land and environment while achieving desirably sustainable yield levels. It is based on the integrated management of soil, water and agricultural resources to achieve the objective of economically viable, ecologically sound and socially acceptable agricultural production.

There are three main principles:
- minimal soil disturbance, which makes ploughing unnecessary;
- permanent rational soil cover with crops or crop residue;
- efficient crop rotation.

maximize biological control of weeds either by light suppression or by allelopathy;
- allows a reduction of the production costs;
- reduction of time and labour, particularly in peak times like planting;
- reduces in mechanized systems the costs for investment and maintenance of machinery in the long term.

A porous soil structure, as a result of No-till method, allows more water to the crops’ roots, instead of running off the surface and taking valuable soil with it.

Effects:
- better developed crops; and
- less erosion.

At CA method pests can be controlled through integrated pest management (IPM), exposing undesirable organisms to their natural enemies, minimizing the use of chemicals.

Both CA and IPM assist to protect against environmental degradation, including wind and water erosion. Yields and incomes rise, fuel and labour are no longer needed for tilling, and flooding is reduced.

CA is particularly useful in dry areas with low rainfall, and enables the soil to store more of the precipitation that falls during the fallow period, and farmers can consider more intensive crop rotations. The fallow period should be shortened.

Non-traditional rotations, such as barley, food and forage legumes and also sunflower, sorghum and millet depending on available moisture being considered.

Results of crop residues left in place:

---

BOX 1

Key features of Conservation Agriculture

- no ploughing, discing or seed bed preparation;
- green manure/cover crops are integrated into the cropping system;
- crop, weed and cover crop residues applied as mulch permanently protect the soil;
- direct seeding or planting;
- no burning of crop residues or fallow vegetation;
- no uncontrolled grazing;
- nutrient cycling through the biomass in and above the soil;
- surface application of lime and fertilizers;
- specialized equipment for seeding and mulch management;
- continuous use of crop land;
- crop rotations and cover crops are used to
- Slowing evaporation of precious soil moisture because residues are slower to degrade;
- No-tilling also conserves soil moisture, so more organic matter is produced, outweighing the initial loss of feed.

The reduced leaching of soil nutrients and farm chemicals together with the reduced soil erosion leads to a significant improvement of the water quality in watersheds where CA is practiced.

**Benefits of CA method:**

- Farm power and energy for field production is reduced by up to 60% compared to conventional farming due to elimination of most power intensive operations, such as tillage;
- Additional equipment investment, particularly the number and size of tractors, is reduced;
- Use of agrochemicals and mineral fertilizer is declined;
- Adaptation to climate change - Increased soil organic matter levels improve the water holding capacity and enable plants to get through extended drought periods;
- Mitigation to climate change (carbon sequestration) - The soils can retain carbon from carbon dioxide and store it safely for long periods of time (25 to 50 years before reaching a new plateau of saturation);
- Consumption of fossil fuel for agricultural production is significantly reduced and burning of crop residues is completely eliminated, which also contributes to reduction of greenhouse gas releases;
- Soils under no-tillage, depending on the management, might also emit less nitrous oxide.

### 2.1.1. No-till

Soil is a limited natural resource on which agrarian activities (agriculture, livestock and forestry) are carried out. It is interconnected with other natural resources, which are also essential for human life, such as the air, water, fauna and flora. Unfortunately, erosion has destroyed the productivity of much of land, and has, in only the last 100 years, removed roughly 50 percent of the topsoil from much of
the highly productive soils mainly due to unprotective cultivation practices associated with conventional tillage systems (Mahsudov – 1989, Mirzayanov – 1978).

No-tillage, including direct seeding practices that leave plant material of the previous crop on the soil surface, assists to control soil erosion and conserve our soil resource indefinitely as the residue mulch protects the soil surface from high winds and rainfall and prevents loosening and carrying away of soil elements. Thus, plant nutrients and soil organic matter remain in the field.

In the zero- or no-till system, inverted-T coulter or a chisel opener is attached to a normal seed-cum-fertilizer drill. This coulter makes a narrow groove/slit in the soil for the placement of the seed and fertilizer in one pass. Soil is disturbed in a very narrow groove of 5 cm wide and 5 to 7 cm deep. For proper seed germination, wheat should be planted at slightly more than field capacity soil moisture content. High moisture keeps the soil strength low and allows good germination and good root penetration. If planted into drier soil to keep sowing time right, then first irrigation must be given within a few days or depending upon germination a week before the crown root stage. This technology spreads rapidly in rice-wheat systems resulting in increased zero-till area in India and Pakistan.

Soil changes its structure in No-till system:
- Macro pores, established in no-till system, facilitates water infiltration and aeration of the soil as well as root penetration into deeper zones;
- Soil organic matter contents increases near the surface, gradually declining as depth increases;
- Soil macro- and micro- fauna and flora are re-established.

### 2.1.2. Tillage and crop yield

The results of experiments conducted in Uzbekistan show that average fall stand counts of wheat over two year were about 10% lower in the no-till plots as compared to the plants in conventional till plots when planted at the same rate. However, the head counts made at maturity were significantly higher under the no-tillage planting.

The wheat yield at the experimental site was in general lower irrespective of the tillage practice due to high soil salinity levels. However, the yield under no-till system was numerically higher than conventional till practice (Figure 1). This can be explained as the evaporative losses of water from no-till plots are lower than that of conventional till and with reduced evaporation, the accumulation of salts in root zone decreased.

![Figure 1. Effect of tillage on grain yield of winter wheat](image)
that facilitates in proliferation of roots and in turn greater yields. In long-run, no-till practice with retention of crop residues helps in lowering down the salinity levels due to combined effects of reduced evaporation and recycling of organic matter.

2.1.3. Improved biological properties of soil

Improving soil physical and chemical properties is important for both conventional and CA production, but improving biological properties is particularly important for CA as the biological environment of soil is greatly modified by type and degree of tillage. No-till soils are generally wetter and less aerobic than conventional counterparts, especially in humid climates;

- Soil microbial populations and enzyme activities are greater with no-till and the amount of potentially mineralizable N in the surface of no-till soils averaged 35% greater than in conventional till soils, thereby indicating a greater conservation of N in organic forms;
- Increased soil-microbial populations, stimulated by greater organic matter and water contents with reduced tillage, could compete with the crop for available N. Also, soil denitrifier populations of no-till soils are significantly greater than those of conventional till soils.

Biological properties of soil:
- microbial biomass;
- microbial communities;
- rate of organic matter decomposition.

Nutrients released through the decomposition of plant and animal residues are an important factor for plant nutrition in CA. Beetles, insects, worms, fungi, and bacteria are involved in decomposition process.

Soil physical properties are important to maintain the productivity of the land. The degradation of these properties has considerable consequences for plant growth, yield and quality of crops regardless of the soil plant nutrient level.

Under reduced tillage and direct seeding systems soil biota can build and maintain soil pore networks.

Creating a stable soil habitat is the first step towards having your soil function to your advantage.
2.1.4. Weed control

Weed control has been effective under minimum tillage practice. CA Farmers mentioned the ability of cover crops and herbicides to reduce the number of weeding by at least one in a crop season.

The overall weed infestation observed in conventionally tilled spring wheat was essentially equal to that found in no-till wheat.

2.1.5. Integrated pest management

We must protect our health, comfort, aesthetic values, and freedom from annoyance of pests, but protecting domestic

Oil' the engine room of your farm by:

- Avoiding high application rates of acidulated, salt-based and nitrogenous fertilizers;
- Applying conditioner ("smart") fertilizers and other additives that promote, rather than retard, soil life;
- Maintaining good soil aeration.

When you are standing on the ground you are really standing on the roof top of a whole other world (Jose Benites, 2005; Jill Clapperton and Megan Ryon, 2001).
animals, crops, forests, and other property is important too.

Unfortunately, the farmers have little resources to use chemical pesticides, a most valuable tool among plant protection techniques, when pest populations reach damaging levels.

We can use some old (use of naturally occurring biological control agents, regulatory procedures, cultural controls, and pest-resistant and tolerant cultivars/crops) and newly developed approaches (use pheromone traps (biological attractants)).

Traditional pest control practices, which are wasteful, could lead eventually to a decline in our ability to control pests. In that case we most probably will gamble with food production stability. Therefore, IPM, even though not perfect, is our route to stability.

### 2.1.6. Long-term soil effects

Differences in the soil characteristics might begin to separate according to tillage treatments.

**Soil physical properties**

Soil in good physical condition is porous like a sponge, rather than tightly packed like a ball of modelling clay, which provides several benefits for plant growth:

- Plant roots can grow through the soil without restriction (decreased penetration resistance);
- Decreased compaction (bulk density of soil) as observed in experiment, Figure 2;
- Air, water, and nutrients can move through the soil with relative ease;
- Water from rainfall or irrigation seeps into the soil (increased infiltration), rather than flowing over the soil surface as runoff;

Soil organisms involved in decomposition and mineralization of plant and animal residues are able to thrive and disperse throughout the soil.

---

**Table 1. Soil organic matter in the two tillage systems, 2006**

<table>
<thead>
<tr>
<th>Tillage treatment</th>
<th>Organic Matter (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-10 cm</td>
</tr>
<tr>
<td>Conventional till</td>
<td>2.24</td>
</tr>
<tr>
<td>No-till</td>
<td>2.61*</td>
</tr>
</tbody>
</table>

* Organic matter was significantly higher at this depth

**Table 2. Soil pH by depth (cm) in the two tillage systems**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Soil pH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-10 cm</td>
</tr>
<tr>
<td>Conventional till</td>
<td>7.7*</td>
</tr>
<tr>
<td>No-till</td>
<td>6.9</td>
</tr>
</tbody>
</table>

*pH was significantly higher at this depth*
Soil chemical properties

Tillage had significant influence on soil organic matter (SOM) content. The organic matter of soil in the 0-10 cm depth was significantly higher with no-till wheat, but was lower at the 10-15 cm depth (Table 1). This is explained by differentiation of soil fertility at conservation tillage when soil is not turned up.

Findings of the experiment revealed that no-till system helps in lowering down the pH of surface soil compared to conventional till (Table 2), which is mainly ascribed to the fact that in no-till, all the nitrogen is placed on the soil surface and the nitrogen acidifies the soil. Whereas the tilled plots had dilution effect due to mixing of nitrogen fertilizer.

2.1.8. Temperature and wheat growth

The climate of Karakalpakstan is classified as severe continental with hot summers and cold winters. The average summer temperature is +30°C and often surpass +45°C; the average winter temperature in January is about -15°C, with absolute minimum as low as -40°C. According to the data of the Chimbay Meteo Station, located in Chimbay district, the annual long-term precipitation is 110 mm, distributed as 18 mm in fall (September-November), 60 mm in winter (December-March), 24 mm in spring (April-May), and 8 mm in summer (June-August).

In 2005, there was no difference in the vegetative growth between the two tillage systems and there was only little difference in temperatures most of the time (Figure 3). But in 2006, there was very cold winter which negatively influenced the wheat yield.

2.1.7. Soil moisture

CA improves the water efficiency of soils by:

- increasing amount of continuous vertical macro-pores through infiltration of rain water into the ground;
- reducing the unproductive evaporation of water because of the permanent soil cover and no-tillage;
- improved water quality due to less leaching and erosion;
- more organic matter holds more available water in soils (1% OM = 150 m³/ha);
- reduced water losses (evaporation), better water efficiency (requirements - 30%).

As a result, the water requirements for a crop are reduced by about 30%, regardless of irrigation or rainfall conditions.

2.2. Soil Cover

Through protection of the soil surface the mulch reduces evaporation, suppresses weed growth and reduces problems experienced in direct seeding or zero tillage.

Mulching is one of the simplest and most beneficial practices for protection of soil. Organic mulches, such as manure, grass clippings, straw, and similar materials have numerous benefits.
Results of the experiments (Table 4) revealed that crop residue retention remarkably increased the moisture content by 28% in surface (0-10 cm) soil compared to without residues. Further, the bulk density of surface soil was decreased with residue retention compared to residue removal.

Fresh cleared soil profile was stuck to the flat emulsified side of photo paper and was covered with the soil which would be packed up to ordinary position. Extracted photo paper was washed to remove from the contaminations and was dried in the shade. The protease activity of the soil was studied in August 2005 was found higher in the soil with crop residue than in the field without crop residue.

Plant residue positively influences the soil quality:
- decreases soil density;
- increases soil moisture;
- increases biological (protease) activity of the soil and its fertility.

Manure, as a fertilizer for farming, is rich in nitrogen and other nutrients which facilitate the growth of plants. Manure from cattle is spread on fields using a manure spreader. Poultry droppings are harmful to plants when fresh but are valuable after composting. Organic manure/amendments are important for improving physical, chemical and biological properties of soil. With application of organic amendments, the water holding capacity of the soil improves due to better soil structure that facilitates in better growth and development of plants and higher crop yields.

2.3. Double cropping

Multi-cropping (growing two or more crops in one growing season) offers much opportunity to provide additional production. Multi-cropping may be the most important of today’s modern agricultural developments.

No-tillage system, herbicides and residue management lead to increase double-cropping:
Table 3. Effect of wheat systems on the yield of no-till succeeding crops

<table>
<thead>
<tr>
<th>Year</th>
<th>Tillage system in wheat</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No-Till</td>
<td></td>
<td>Conventional</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mungbean (kg/ha)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>905</td>
<td></td>
<td>978 N.S.*</td>
</tr>
<tr>
<td>2006</td>
<td>954</td>
<td></td>
<td>983 N.S.*</td>
</tr>
<tr>
<td>Average</td>
<td>929</td>
<td></td>
<td>980</td>
</tr>
<tr>
<td>Sorghum (kg/ha)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>1003</td>
<td></td>
<td>990**</td>
</tr>
<tr>
<td>2006</td>
<td>1011</td>
<td></td>
<td>999**</td>
</tr>
<tr>
<td>Average</td>
<td>1007</td>
<td></td>
<td>994</td>
</tr>
</tbody>
</table>

* Means no significantly statistical differences
** Statistically different at the 0.1% level

- Two crops can be planted with the same fuel required for one conventional crop;
- Output is increased, while the overall cost of production is reduced;
- Equipment is used more frequently and labour requirements spread more evenly through the year.
Table 4. Influence of crop residue on soil moisture and bulk density

<table>
<thead>
<tr>
<th>Field number</th>
<th>Soil depth, cm</th>
<th>Moisture, %</th>
<th>Bulk density, Mg m⁻³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Residue</td>
<td>No residue</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Residue</td>
<td>No residue</td>
</tr>
<tr>
<td>7</td>
<td>0-10</td>
<td>12.2</td>
<td>9.7</td>
</tr>
<tr>
<td>8</td>
<td>0-10</td>
<td>10.6</td>
<td>6.8</td>
</tr>
<tr>
<td>Average</td>
<td>0-10</td>
<td>11.4</td>
<td>8.2</td>
</tr>
</tbody>
</table>

Yields of succeeding crops (mungbean and sorghum)

Mungbean and sorghum were taken as succeeding crops after winter wheat and were grown under no-till system after two tillage practices in wheat. The mungbean is double-cropped after the wheat, and corn (maize) was planted the next spring before the wheat planted in the fall. The yield of sorghum was significantly higher (8.9%) under double no-till (no-till wheat followed by no-till sorghum) compared to no-till sorghum after conventional till wheat (Table 3). Whereas, tillage practices of preceding wheat crop did not produce significant yield variation in no-till mungbean. The added advantage of no-till systems is reduced cost of production and hence higher farm profitability.

In double-cropping, timing of planting the second crop becomes limited along with pressures of harvesting the mature crop. No-tillage system reduces the time element while retaining soil moisture present, and reducing runoff, soil erosion and evaporation.

2.4. Crop Rotation

Benefits of efficient and compatible crop rotation:
- efficient use of resources;
- increases yield;
- helps in insect and disease control;
- assists in maintaining or improving soil structure and organic matter levels;
- reduces weed pressures;
- spreads the workload;
- protects against soil erosion;
- makes the soil structure more stable;
- sustainability put into practice.

Mono-cropping (for example, cotton) will result in the build-up of diseases and insects specific to that crop, and cause a reduction in crop yields. The more often a crop has been grown in the field in the past, the greater this impact will be.

Multiple cropping (sequential and intercropping) systems have potential benefits over mono cropping for resource conservation and higher efficiency.

Legume crops in the rotation have become more valuable with the increased cost of nitrogen.

Within a crop rotation, different root systems influence different soil horizons and improve the efficiency of the soil nutrient use.

The fibrous root systems of cereal and forage crops are excellent for building soil structure. Benefits of including wheat, and especially wheat plus mung bean, may persist beyond just the following year.
<table>
<thead>
<tr>
<th>Crop to be grown</th>
<th>Cotton</th>
<th>Winter wheat</th>
<th>Sorghum</th>
<th>Proso millet</th>
<th>Sunflower</th>
<th>Sesame</th>
<th>Legumes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>NR yield depression root rots</td>
<td>C slugs may cause damage in no-till</td>
<td>May increase density of rice stink bug O. pugnax</td>
<td>R</td>
<td>C yield depression</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>R</td>
<td>NR yield depression root diseases</td>
<td>C yield depression weed escapes may be difficult to control</td>
<td>C yield depression</td>
<td>R</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>Sorghum</td>
<td>R</td>
<td>R</td>
<td>NR yield depression</td>
<td>R</td>
<td>C yield depression</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Proso millet</td>
<td>R</td>
<td>R</td>
<td>R wireworms</td>
<td>NR yield depression</td>
<td>C leaf diseases yield depression</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Sunflower</td>
<td>NR increased risk of Fusarium head blight</td>
<td>C yield depression</td>
<td>R</td>
<td>NR take-all, leaf diseases</td>
<td>NR take-all leaf diseases yield depression</td>
<td>R</td>
<td>C</td>
</tr>
<tr>
<td>Sesame</td>
<td>R</td>
<td>R</td>
<td>R slugs may cause damage in no-till</td>
<td>R</td>
<td>R</td>
<td>NR yield depression root rots</td>
<td>R</td>
</tr>
<tr>
<td>Legumes</td>
<td>C slugs may cause damage in no-till check for herbicide carryover</td>
<td>R check for herbicide carryover</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>C white mould</td>
<td>NR white mould, blackleg, root rots yield depression check for herbicide carryover</td>
</tr>
</tbody>
</table>

Legend: (R) Recommended, (C) Caution, (NR) Not Recommended
In choosing the crop to grow, one should be aware of any potential insect or disease problems that could affect crops later in the rotation. Table 5 shows various crop rotations and their potential impacts.

### 2.5. Cover Crops

Cover crops known as "green manures" are grown and incorporated (by tillage) into the soil before reaching full maturity or retained on soil surface after in-situ knock down (Brown manuring) during the season or after maturity under no-till systems, and are intended to protect soil from erosion, conserve water, suppress weeds, regulate hydro-thermal properties of soil, improve soil fertility and quality and control soil salinity.

Cover crops can improve soil quality by increasing soil organic matter levels through the input of cover crop biomass over time.

Cover crops can help reduce compaction and improve soil structure. The addition of the plant top and especially root matter helps to improve water infiltration and holding ability. It can also decrease soil bulk density.

Dense cover crop stands physically slow down the velocity of rainfall before it contacts the soil surface, preventing soil splashing and erosive surface runoff. Additionally, vast cover crop root networks help anchor the soil in place and increase soil porosity, creating suitable habitat networks for soil macrofauna.

Rye is commonly used to cover and protect the soil surface from wind and water erosion. The top growth covers the soil surface while the roots bind and stabilize the soil particles. Cover crops may be planted over a whole field for erosion protection or they may be selectively planted in the most erosion-prone areas, such as sandy knolls for wind erosion, water runs or low areas for water erosion.

The rising cost of nitrogen fertilizers has revived interest in nitrogen-fixing legumes. Organic growers often include this type of cover crop in order to produce nitrogen for the rest of the crop rotation. Deep-rooted cover crops can bring nutrients up from deep in the soil profile.

Cover crops are used to manage a range of soil macronutrients. For example, Mucuna Pruiriens (velvet bean) used as a cover crop in Nigeria, has been found to increase the availability of phosphorus in soil after the application of rock phosphate.
2.6. Bed Planting

The bed-planting technology is growing crops on raised beds (Figure 4) and using the beds permanently with consecutive crops which adds to the benefits of zero-till to bed planting and is a more sustainable system. Most research in the RWC has used beds about 70 cm apart (two beds can be made between the two tractor tires).


Two to three rows of wheat have been tested. Two rows have equal yields to that of three rows give additional advantage that the weeds between the two rows of wheat can be managed mechanically, fertilizer can be placed as a top dress application between the rows (increasing efficiency) and there is less lodging. Bed planting also has the advantage of lower seed rates, bolder seed and greater panicle length, an important issue for hybrid seed multiplication programs (Yadav, 2002).

The main benefit of bed planting is water savings. Almost all farmers reported 30-35 per cent less irrigation time in tube well irrigated areas. Therefore under high production situations, bed planting exceeds the yields possible on the flat bed.

Bed-planting system offers great potential for intercropping maize and mung bean in wheat growing season. In rice-wheat areas raised beds work best in partially reclaimed alkali soils, low-lying areas where water-logging and weeds are problems, and in cracking soils.

Figure 4. Configuration of raised beds and planting arrangements of wheat
(http://www.rwc.cgiar.org)
BX 2

Conservation Agriculture technologies – direct seeding

Direct seeding machines are capable of placing seeds at the required depth (3 to 6 cm) into the untilled soil in the presence of evenly scattered residues on the surface and for high stubble load, disc or chisels type furrow openers can be used.

**Disc openers:**
- equipped with one, two or three discs per furrow-opener body;
- discs can be smooth, toothed or convoluted.
  Advantage: no blockage by vegetative residues and soil.
  Disadvantage: weight of seeders (up to 200 kg per cutting disc) required to penetrate hard soil; problems with cutting of thick or moist straw layers.

**Chisel openers:**
- Advantages: good penetration into soil of any density without application of additional weight; placement of seeds at the necessary depth under any soil condition.
  Disadvantages: stronger loosening of soil causes increased moisture evaporation; blockage by long straw more likely than with discs; higher energy requirement.

Bed planting improves the percentage of germination of seed in the field conditions. Also, seed rate can be reduced and the field can be cultivated once with fertilizer application during the vegetation period of wheat. Lodging control of irrigated wheat can be achieved through bed planting practices.
Conventional tillage operations are as follows:
• the beds are destroyed after the harvest of each crop;
• several tillage operations before new beds are formed for planting the succeeding crop;
• this tillage is often accompanied by widespread burning of crop residues;
• most farmers apply over 75% of the total N fertilizer to wheat during winter period.

Permanent beds help to save water in three ways:
• the soil conserves more moisture at planting;
• the crop is ready for harvest before the hot season arrives;
• irrigation water flows faster over a field that has not been tilled, so less water is pumped. As much as 30 to 50 percent of water can be saved through raised-bed planting practices that increase the amount of moisture.

At the bed planting system one can know when and where fertilizers can be used most efficiently.

The seeding of 2-4 defined rows of wheat on top of the bed makes inclusion of wheat far more feasible but it was soon established that not all wheat varieties were appropriate for bed planting and cooperation with wheat breeders helped to identify appropriate wheat plant types for bed planting. Seed rates could also be reduced by one third, saving the cost of this valuable input of the farmers.

Bed planting would provide the benefits of water saving in systems of surface irrigation. Under CA, the beds would be converted into permanent beds whereas any soil tillage would be limited to a periodic cleaning and reshaping of the furrows. The same permanent bed system would be applicable under CA also for crop rotations, which include crops grown on beds, for example for drainage purposes. Precondition for such a permanent bed system is the harmonization of the furrow distances and bed width for all crops in the rotation and for all mechanized traffic operations.

As farmers increasingly adopt resource conserving farming practices, there is a need for wheat that better adapts to the new agronomic practices. Water use efficiency is important in Uzbekistan in view of the limited water resources in the country.

Conversion from conventional tillage to a reduced/zero tillage system with residue retention may require several crop cycles before potential advantages/disadvantages begin to become apparent.

The benefits of planting sorghum on beds in irrigated systems in terms of yield and water savings from various farms of project demonstration site are given in Table 6. Water savings, as indicated are significant and range from 24-32%.

Table 6. Sorghum yield (t/ha) as affected by raised bed planting

<table>
<thead>
<tr>
<th>Farm</th>
<th>Sowing method</th>
<th>Extra yield, (t/ha)</th>
<th>Water saving using bed vs. flat, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raised bed t/ha</td>
<td>Conventional t/ha</td>
<td></td>
</tr>
<tr>
<td>Satniyaz</td>
<td>4.11</td>
<td>3.69</td>
<td>0.42</td>
</tr>
<tr>
<td>Kipchakbay</td>
<td>3.73</td>
<td>3.42</td>
<td>0.31</td>
</tr>
<tr>
<td>Kuvvat</td>
<td>3.57</td>
<td>3.12</td>
<td>0.45</td>
</tr>
</tbody>
</table>
2.7. Laser Land Leveling

Laser land-leveling is really a laser-guided land-leveling. The idea of moving soil to level land is very old. What is important with laser land-leveling is that the actual surface finish can be controlled to very tight tolerances. Lasers are devices that produce a very concentrated beam of light. Where a common household light bulb produces diffused light, a laser produces a single, very thin, high energy beam.

Laser leveling is a process of smoothening the land surface from its average elevation using laser equipped drag buckets to achieve precision in land leveling. Precision land leveling involves altering the fields in such a way as to create a constant slope of 0 to 0.2% (Fig. 5). This practice makes use of large horsepower tractors and soil movers that are equipped with global positioning systems (GPS) and/or laser-guided instrumentation so that the soil can be moved either by cutting or filling to create the desired slope/level.

Laser land-leveling in itself can improve irrigation efficiency by reducing high spots in a field that back up water, or filling low spots that contribute to excess irrigation. Laser land-leveling is advisable to install the best irrigation gradients. Also, one must consider the placement of any tail water return sumps and the length of the furrows.

Effective land-leveling reduces the work in crop establishment and crop management, and increases the yield and quality.

The leveled land improves water coverage that:
- improves crop establishment;
- reduces weed problems;
- improves uniformity of crop maturity;
- decreases the time to complete tasks and saves on fuel and energy in field operations;
- reduces the amount of water required for land preparation.

Before starting the laser land levelling process the field should be ploughed and a topographic survey should be carried out. One of the measures to improve irrigation efficiency is zero-grade levelling for agricultural crop production. Zero-grade fields can be flushed or drained more quickly.

The soil preparation for planting winter wheat started in the project site from subsoiling and laser levelling.

A rotating laser light source
A receiver is mounted on the leveling equipment

Diagram 5. Major components of a laser leveling system (J.F. Rickman et al.)

Direct seeded rice in a laser-leveled field (M.L. Jat et al.)

Laser-leveled field prepared for rice transplanting (M.L. Jat et al.)
Other benefits

Improved water coverage from better land leveling reduces weeds by up to 40%. This reduction in weeds results in less time for crop weeding. A reduction from 21 to 5 labor-days per hectare is achieved. This represents a reduction of up to 16 person-days per hectare – a 75% decrease in the labor required for weeding.

2.8. Conventional Agriculture and poverty

In conventional agriculture most of practices are based on soil tillage; i.e., inversion tillage such as mouldboard ploughing or disk harrow, or vertical tillage. Soil tillage drastically alters its original structure, breaking up its natural aggregates and burying the residues of the previous crop, and hence, the bare soil becomes unprotected and exposed to the action of the wind and rain, which leads to water and soil erosion and sediment runoff. Furthermore, with tillage, soil organic matter and biodiversity are reduced and unnecessary emissions of CO2 into the atmosphere take place. Also, the conventional tillage practices lead to soil compaction. In-turn conventional tillage practices lead to lower biomass production, lower crop productivity, higher production costs and lower net farm income leading to poverty. Figure shows the poverty cycle of the conventional agriculture. (This Part written by M.L. Jat).

Water saving

With sprinklers, a perfectly levelled field conserves water by reducing runoff and allowing uniform slope to use water most efficiently. The Laser-leveling of fields saves 25-30% of water.

Increase in yield

The Laser-leveling of fields increases yields by 10%. A large part of this increase is due to improved weed control and uniformity in crop establishment. This increased yield should help the farmer as an additional income.
Figure 6. The poverty cycle of conventional agriculture (M.L. Jat)
3. EFFECT OF CONSERVATION AGRICULTURE
TECHNIQUES ON SOIL AND WATER CONSERVATION

3.1. Effect on Soil Erosion and Salinity

Almost everybody recognizes that soil erosion is harmful, but few realize the extent of its harmfulness. Soil erosion results in higher fertilizer and fuel requirements, and lower yields. The benefits of soil erosion control are sometimes obscure, but the costs of erosion are real.

Erosion reduces productivity by modifying soil properties and is more harmful to soils that are:
- shallow;
- devoid of thick top soil;
- poor quality sub-soils.

Any combination of these characteristics greatly increases the damage from erosion. Most soils have some undesirable properties which lead to lower crop production, since erosion causes more subsoil to be incorporated into the plough layer.

Erosion removes a field's original topsoil, causing the subsoil to mix with the remaining topsoil during annual ploughing. In mature soils, this subsoil material has more clay, less organic matter, lower available water-holding capacity and lower fertility status.

Also, the soil structure is likely to be coarser, less stable and subject to more damage by rainfall impact, tillage or traffic.

Soil erosion removes the lighter and more easily dislodged particles. This means that organic matter is one of the more easily erodable constituents.

Soil bulk density also increases with erosion. This increases problems associated with tillage, tillth and seedbed preparation.

Soils with shallow depth and more undesirable soil properties. Erosion usually reduces the plant available water holding capacity of a soil. Two things cause this reduction in plant available water holding capacity. As the clay increases and organic matter decreases, the amount of water a soil can make available to the plant decreases.

Erosion removes the nutrient rich portion of the soil. Significant nutrients such as nitrogen, phosphorus, potassium are lost during erosion. Soils with high inherent fertility or with higher fertilizer inputs will result in greater fertility losses. If the soil is inherently poor in

Windy Erosion (John Passiura, 2007)

Water Erosion on a recently tilled field
fertility status, the erosion will cause a loss of the added nutrients and increase the fertility requirements of the soil. The loss can be considerable and should not be ignored. Fortunately, the fertility can be replaced, but the cost must be recognized and taken into account.

Erosion reduces not only the fertility, but also the productivity of many soils by affecting the soil properties and depth. The most important yield-limiting effect of erosion is probably the decrease in plant available water holding capacity. The overall effect of erosion is an economic loss which accumulates with time as erosion continues.

3.2. The Effect of Salinity on Plant Available Water

Salinity acts to inhibit plant access to soil water by increasing the osmotic strength of the soil solution. As the soil dries, the soil solution becomes increasingly concentrated, that further limits the plant access to soil water.

In the project area, the yield of both sorghum and wheat was reduced in the salt-affected field compared with the non-salt-affected field. Possible explanations for this are that the effect on yield is due to salt toxicity and that this occurs in a salted field than the osmotic effect of salinity on the agronomic traits of the plant which consequently decreases the yield, or that the metabolic demands of maintaining plant water balance and extracting soil water under saline conditions result in reduced yield.

Yield of the bread wheat variety “Dostlik” was higher than other varieties planted in the neighbouring farms: in a Satniyaz farmer’s field without soil leaching it was 1.9 t/ha and with leaching it was 3.0 tons per hectare. In the neighbouring farmer’s field, in “Shokharik” farm the wheat yield was 1.4 t/ha and 1.9 t/ha, respectively. A total of 4000 m³/ha water was saved (Figure 6).
4. MACHINERY FOR CONSERVATION AGRICULTURE

4.1. No-till Seeders

New machinery for sustainable agricultural practices (three no-till planters from Brazil) were made available under the project to the farmers of the project demonstration pilot site. Weight of the no-till seeder is 810 kg.

Row crop version for precision planting

Precision planter for sunflower:

It is a four row planter spaced at 60 cm. For each row there is a unit comprising seed hopper, metering mechanism including the drive mechanism and a line of furrow openers. Each row is independently metering the seed for accurate seed spacing in the row and has also independent furrow opener units allowing accurate depth placement of the seed. In case some rows are not used, for example for maize, the entire hopper and furrow openers of the unused unit (with the seed metering disk) should be removed to avoid wear. In this planter, the seed rate can be regulated at 16 kg/ha and fertilizer at 125...
kg/ha. For row crops the speed should be maintained maximum at 6 km/h to avoid seed breakage. With high and hard residues, high speed helps in cutting the residues, but more than 6 km/h could break seeds.

The planter can accommodate 5 row crop units in total. Good seed placement and soil contact is important to achieve a healthy crop development and even germination. The sets are compared of a support in which plastic reservoirs are fixed with the horizontal seeds distributing mechanism and motor system of the set. The set is fixed in the machine by screws and nuts. For corn planting, it should be isolated through the non-use of seeds distributing sets with reservoirs of the intermediate lines (unused reservoirs), removing the line distribution discs. The first function is to place the seed in a soil environment that allows for rapid establishment of healthy, vigorous plants. Deep seed placement with good seed-to-soil contact provides the best seedbed environment for most direct-seeded crops.

Table 7. Calibration calculation

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of plants by linear meter</td>
<td>N</td>
</tr>
<tr>
<td>Final population for hectare (estimated)</td>
<td>50,000 plants</td>
</tr>
<tr>
<td>Spacing between lines (cm)</td>
<td>60 cm</td>
</tr>
<tr>
<td>1 hectare</td>
<td>10,000 m²</td>
</tr>
<tr>
<td>Seed germinating power (GP)</td>
<td>96%</td>
</tr>
<tr>
<td>Approximate skidding percentile</td>
<td>5%</td>
</tr>
<tr>
<td>Wheel perimeter</td>
<td>1.76 m</td>
</tr>
</tbody>
</table>

**Precision planting-seed metering system for row crops**

When doing the calibration for precision planting, that requires a precise number of seeds per hectare, the correct setting of the planter is of utmost importance for obtaining an appropriate final stand for the crop to be established, considering the variety to be sown and the germination percentage. Another important factor is (of) obtaining good stands is the correct choice of the seed distributing disks that should be determined from the form and size of the seeds.

**Seed dosing disc replacement:**

Each disc comes with a bottom ring, which can have different shapes and thicknesses, depending on the size of the seeds and the thickness of the seed-disc. The space where
the disc is placed at the bottom of the seed hopper is of 8.5 mm. The disc and the ring to be used together should not be thicker than 8.5 mm. As a simple rule the soya discs are thicker, going with thinner rings. All the other discs are thinner, using thicker rings, which could have different profiles in the ring to accommodate different seed diameters.

Seed hopper assembly and kick wheel changing:

The kick wheel work position should be in the centre of the metering disk hole, because, if used out of work position, it will cause the wear and tear of the disks and create problems in the seed distribution. There are kick wheels for 1 and 2 rows holes on the disk and for different hole spacing. The plant population or number of plants per hectare can be calculated for the planting (Table 7).

For row crops

\[ 1 \text{ ha} = 10,000 \text{ m}^2 \frac{1}{50,000 \text{ plants}} \]
\[ = 10.56 \text{ m}^2 \frac{1}{10.000} \text{ Calibration area for 10 wheel turns in sq m} \]
\[ *10.56 \text{ m}^2 = \text{Spacing X wheel perimeter X number of wheel turns} \]
\[ *10.56 \text{ m}^2 = 0.60 \times 1.76 \times 10 \]

\[ 10.56 \times 50,000 = 10,000 \]

\[ N = 90 \text{ m} = 3 \text{ plants/linear meter} \]
\[ **17.6 = \text{wheel turns X perimeter} \times 1.76 \]

Germinating Power Correction (Percentage)
\[ N = 3 \text{ plants/linear meter} \]
\[ N \frac{96\%}{100\%} \]

Skidding Correction (Percentage)
\[ N = 3.125 \text{ plants/linear meter} \]
\[ \text{Correction} \frac{100\%}{5\%} \]

\[ N = 3.28 \]

3.28 is the number of plants/linear meter that should be used in the sowing regulation

| Amount of the seeds per hectare | 200 kg |
| Spacing between lines (m) | 0.17 m (17 cm) |
| Driving wheel perimeter | 1.76 m |
| Number of turns of the driving wheel | 10 |
| 1 hectare | 10000 |
| Seed germinating power (GP) | 93% |
Sets for wheat planting

The usual range of available opener spacing is from 15 to 20 centimetres, which is the conventional spacing for wheat. Some farmers double-drill forages in two directions for a closer effective spacing. A few drills are available with spacing down to 10 cm for high-yield wheat. This is a desirable spacing for forage, but presents problems in spacing no-till coulters. To get close spacing with planters and drills, the openers usually must be staggered by mounting on two or more parallel bars. Staggering ground-engaging components helps to negotiate trash (residue) without acting like a rake, in addition to allowing physical space for components.

Seeds distribution system — wheat

The wheat seeds metering is done by a gouged rotor, which can be moved side wards allowing a larger or smaller amount of seeds to be distributed. Each row has one metering roller.

The regulation procedure is done by the displacement of the axis increasing or decreasing the opening work of the rotors inside the distribution box, through the lever. After obtaining the desired seeds outlet, fasten the regulator lever through the fastening nut. The amount of seeds in kg/ha can be calculated (Table 8).

At first calculate the number of seeds or the g of seed required per linear meter of row. Then multiply this with 17.6 m to get the number for each row for 10 wheel turns. Seeds per ha X row spacing (m) X germination rate) / 10 000 = number of seeds per linear meter of row.

As an example for wheat

\[
\frac{200 \times 17 \times 93}{10000} = 0.31 \text{g/m}^2
\]

\[
200 \text{ kg/ha} \times \frac{10000 \text{ m}^2}{2.99} = \text{Spacing x wheel perimeter x number of wheel turns}
\]

*2.99 m²: Spacing x wheel perimeter x number of wheel turns

*2.99 m²: 0.17 x 1.76

X = 200 kg/ha x 2.99

10000

X = 0.0598 kg/ha

X = 0.0598 x 1000g = 59.8 grams per row in 10 turns of the driver Wheel

Germinating power correction (Percentage)

59.8 grams \times 93\% \times 100\% = 64.3 \text{ grams by line in 10 turns of the driving wheel}

The sowing depth of seeds is very important, once it is one of the factors that interfere in the plants emergency and germination.

The limiting wheels copy the soil unevenness, which allows keeping a great uniformity in the depth. The wheels set is mounted in a strategic position, right behind the seed dephased double disks. Besides the limiting function, the wheel mounted in a “v” replaces the removed straw and does a lateral compacting of the seeds, avoiding the formation of air bubbles in the furrows.
4.2. Bed Planters

A raised-bed planter includes a planter body having three furrow openers which form beds for growing of the crops, separated by furrows. The planter body has an open top end and an open bottom end. Collectively, the four seats allow a gardener to reach all portions of the planting area when used in turn. A soaker hose is connected to the planter body and suspended within the planting area of the planter body. The soaker hose has a connector configured to accept the attachment of a common garden hose thereto and is in fluid connection therewith. A weed control barrier line the open bottom end of the planter body.

Raised-beds are particularly favourable for seed multiplication and crop production using hybrid seed, as they significantly reduce seed rates. Therefore, the bed-planting system lowers production costs.

This system is best designed for systems where each succeeding crop is planted into the previous crop residue. This would need a good and varied crop rotation to introduce diversification into the system and reduce pest and diseases.

The Indian bed-planter has advantages and disadvantages; as noticed under farmer participatory field trials on different crops. The advantages of the bed-planting system are as follows:
- Saves about 50% seed;
- Saves 30-40% water;
- Yields are higher than those with conventional systems;
- Lodging is reduced;
- Facilitates mechanical weeding and hoeing of wheat by tractor;
- Offers opportunity for a last irrigation at grain filling that helps in maintaining canopy temperature which is very important at this stage;
- Avoids temporary water-logging problems;
- Allows subsurface basal and top dress fertiliser placement, reducing nitrogen losses;
- Promotes rainwater conservation;
- Permanent beds save on production costs.

The bed planter is good and suitable for mounting in all tractors. Some seeds are planted inside of furrows due to packing problem. The Indian bed-planter should be redesigned for packing device and a capacity for simple adjustment to plant in differing field configurations.

4.3. Weed and Pest Control

The application of agro-chemicals is necessary to achieve higher and economical production, but it can bring risks to human beings, environment and the crops. So a concern is always there for proper use of a boom sprayer in an efficient and safe way. In CA practices, application of chemicals is a critical issue because no tilled-land will tend to be weeded.
4.3.1. Spray application technology

A successful spray application does not depend only on a good sprayer or correct use of the chemicals but also on factors to be determined in the field under specialized orientation. Among these factors, some concepts should be part of a criterion for evaluation so that positive results may be attained within the pest control program.

Ideal time

The ideal time for spraying should be chosen according to the chemical product characteristics as well as to the field conditions:
- Infestation level of pests, diseases and weeds;
- Infection level of diseases;
- Growing stage of weeds;
- Weather conditions.

Correct application rate

Any type of application requires that a correct rate be maintained during the whole spraying work. This will be possible only with a good sprayer which is properly calibrated.

Control valve

This is a two-stage pressure regulating control that provides greater sensibility to the calibration. The first stage is for calibration from 0.7 to 2.4 kg/cm² (10 to 60 psi), normally used on herbicide application. The second stage is for calibration from 4.2 to 10.5 kg/cm² (60 to 150 psi), for application of insecticides, fungicides and foliar fertilizers. To avoid misreading, the pressure gauge has an extended scale, which provides more sensibility both in low and high pressure calibration. The sprayer can be calibrated through the formula below:

Calculating the spray volume

\[ V = F \times \frac{600}{S} \times A (l/ha) \]

Where:
- \( V \) – Spray volume (l/ha)
- \( F \) – Nozzle flow rate (L/min)
- \( A \) – Nozzle spacing (m)
- \( S \) – Tractor speed (km/h)
- 600 – Conversion unit

Example

Nozzle flow rate ................. 0.68 l/min at 30 psi (110-UF-02)
Nozzle spacing .................. 0.50 m
Operating speed ................... 4.0 km/h
\[ V = \frac{F \times 600}{S \times A} (l/ha) \]
\[ V = 0.68 \times \frac{600}{0.5 \times 4} (l/ha) \]
\[ V = 408/2(l/ha) = 204 l/ha \]
5. ASSESSING THE POSSIBILITIES FOR IMPROVING CONSERVATION AGRICULTURE PRACTICES

5.1. Physical Potential

In the area, where the soil density is very high, ploughing was considered as a way to reduce the soil bulk density. Another issue is soil salinity which becomes a main constraint for high crop productivity.

5.2. Social possibilities

A complete understanding is required of all the social and economic results of the CA farming system. Rights of tenure and rights of access, e.g. to water supplies, crop diversification, to fuel, or cultivation rights i.e. planting of crops without tilling or no-tillage are usually complicated. “There are a lot of changes necessary to adopt zero tillage (and conservation agriculture) but the biggest challenge is in the “mind set”, said a Brazilian farmer Franke Dijkstra, Pioneer Brazilian zero tillage farmer who started conservation agriculture practices in his own land 26 years ago.

6. BENEFITS OF CONSERVATION AGRICULTURE

6.1. Short-term benefits (benefits that are apparent soon after initiation of the new system)

- Reduced cost of production and higher farm profitability;
- Increased water infiltration largely due to the protection of the soil surface from the explosive effect of raindrops. Increases in water infiltration rate may be seen in the first season of CA;
- Reduced soil erosion, both from water and wind, due to the protection of the mulch and the absence of pulverised soil.

6.2. Long-term benefits (may take 3-5 years or more to be evident)

**Increased carbon sequestration:**
- Increased soil organic matter (SOM) content due to the reduced rate of decomposition of crop residues and plant roots and the continual accumulation of organic matter into the soil by fauna and flora.

**Increased nutrient availability and soil water-holding capacity due to the increased SOM.**

**Improvement in soil physical properties:**
- Improved soil structure due to the lack of tillage, increased SOM and improved soil aggregation.
Increased soil bio-diversity:

- Increased biological activity both above and below the ground, due to the continuous presence of the residues as a food source and habitat. Increased below-ground biological activity is vital for the improved soil structure. Increased aerial biological activity may result in more pests, but generally results in higher populations of predators and thus, more biological pest control.

- Reduced weed competition as weed seed is not incorporated into the soil, the seed bank is exhausted, residues impede weed germination and growth, and increased biological activity results in lower weed seed viability.

Environmental benefits:

Reduced fuel consumption in farming for tillage, water pumping, reduced residue burning, reduced oxidation of soil organic matter and reduced losses of fertilizers under CA practices lead in remarkable reduction in emission of greenhouse gases (GHGs) that leads to eco-friendly farming practices.

6.3. Problems with Conservation Agriculture

- Weed control in the early years of adoption. Weed control is one of the principal reasons for tillage. Weed control in CA requires an integrated approach using mechanical and chemical weed control methods, crop rotations and possibly green manure cover crops (left on the surface – not incorporated);

- Competition for crop residues. Smallholder farmers generally manage mixed crop/livestock systems where crop residues are used as animal feed. Strategies need to be developed to ensure sufficient (and better quality) feed while at the same time leaving enough on the land to overcome soil organic matter decline;

- Mind set – overcoming the culture of the plough;

- More effort is needed in dissemination and local manufacture of the adapted equipment;

- Improving the access of small farmers to information and knowledge on CA and other technologies;

- Slight nitrogen deficiency may be evident in some conditions, due to the slower rate of decomposition of SOM and is a necessary component of achieving sustainability;

CA improves water infiltration and reduces evaporation.
7. CONCLUSIONS & RECOMMENDATIONS

7.1. Conclusions

In view of the prepared manual and considering critical needs for required improvements, specific conclusions are made for various elements of the conservation agriculture, which are as follows:

1. The fall stand counts over a two-year average showed about 10% less plants in the no-till plots as compared to the conventional plots when planted at the same rate. In 2006, stand counts were higher in both tillage methods, it was 8% less in no-till than the tilled method of planting;

2. There were no differences between the yields of no-tillage and conventionally-planted wheat in on-farm trials;

3. Fungicide applications were provided for intensive production on all the treatments although no differences were observed in diseases among the treatments;

4. The soil densities for both the till systems were very similar and were in excellent condition for crop growth. The soil strength measurements were all low enough and were in the range for excellent crop growth;

5. Both mungbean and sorghum were successfully no-tilled after the two tillage systems. The mungbean can be double-cropped after wheat;

6. Protease activity of the soil with crop residue was higher than in the fields without crop residues;

7. Identified new crop rotations with mungbean, sorghum and studied their Potential Negative Impacts for use in conservation agriculture. It is not a comprehensive listing of crop problems, but it does highlight the main impacts to be aware of;

8. Retention of crop residues may be essential to ensure the required enrichment of critical levels of the chemical, physical and biological soil parameters that are crucial to ensure and achieve sustainable long-term production. Retention of rational amount of residues will be essential before attempting to adopt permanent raised-bed planting systems even though the primary goal may be to simply realize lower production costs, which is common with reduced tillage intensity;

9. The raised-bed planter is good and suitable to be mounted on the all tractor types. Some seeds are planted inside of furrows due to packing problem. The Indian bed planter should be redesigned for packing device and capacity for simple adjustment to plant in differing field configurations;

10. Zero tillage and raised-bed planting technologies proved to be suitable for local conditions and can provide similar or higher crop yields but saving considerable resources including fuel, seeds and labour.

7.2. Recommendations

The following recommendations could be made for establishing conservation agricultural practices and its strong programme in the country:

- In CA practices soil cover management (crop residue in the field with stubble stems and chopped straw or cover crops), is a must to harness the potential benefits of CA. Consequently, the salts will not be accumulated in upper layer of the soil due to decreased evaporation;

- Cover crops should be grown and the residues should be used as mulch for better
crop growth, minimizing weed problem and to reduce moisture loss. Under adverse conditions and a shortage of forage due to drought or winterkill, some cover crop species can make quite acceptable hay or pasture;

- The improved equipment needs situation-specific adjustments for their compatibility for local soil and climatic conditions. Local manufacturing of conservation tillage equipment should be promoted for meeting the local requirements and minimizing costs;

Location-Specific crop diversification (as single crops and double crops) is essential to improve sustainability of farming and income generation at the local, regional and national levels.
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ABBREVIATIONS

PFU - Project Facilitation Unit
IPM - Integrated Pest Management
ICARDA - International Center for Agricultural Research in the Dry Areas
CGIAR - Consultative Group International Agricultural Research
WRC - Wheat Rice Consortium
TCP - Technical Cooperation Program
FAO - Food and Agricultural Organization of the UN
CAC - Central Asia and Caucasus