SUSTAINABLE AGRICULTURAL PRACTICES IN THE DROUGHT AFFECTED REGION OF KARAKALPAKSTAN (PHASE II)

FAO/TCP/3102 (A)

FINAL REPORT

Submitted by

Dr. A. Nurbekov, TCP Project Officer,

International Center for Agricultural Research in the Dry Areas (ICARDA)

CAC Regional Office, Tashkent, Uzbekistan

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ACRONYMS

CA – Conservation Agriculture

FAO –Food and Agricultural Organization of the United Nations

FYM – Farm Yard Manure

GoU – Government of Uzbekistan

GP – Germination power

GWL – Ground Water Level

ICARDA – International Center for Agricultural Research in the Dry Areas

KK – Republic of Karakalpakistan

MAWR – Ministry of Agriculture and Water Resources

SANIIRI – Central Asian Research Institute of Irrigation

SOM – Soil Organic Manure

TCP – Technical Cooperation Programme
UNDP – United Nations Development Programme

USSR – Union of the Soviet Socialistic Republics

UZB – Uzbekistan

WUA – Water User Association

EXECUTIVE SUMMARY

After the 1999 drought, in 2000 and 2001, Northwest Uzbekistan experienced the worst drought and water shortage in living memory. The Republic of Karakalpakstan (KK), which is located at the tail-end of the Amudarya River, and includes its delta into the Aral Sea, was particularly affected.

For these reasons, there is an urgent need to pilot changes in irrigation and agricultural practices in the region in order to address the issue of declining water availability - this is a high priority for the Governments of Uzbekistan and KK. Farmers have limited experience in water conservation practices and utilizing salt and more drought tolerant crops. The government does not have the relevant technical expertise, but recognizes the need for radical change in both agricultural policy and practices for the region. It is therefore FAO was requested assistance in introducing conservation-effective water and soil management practices and introducing more drought and salt tolerant crops on a pilot scale, for possible adoption on a wider scale.

It was agreed that a proposed TCP will introduce, on a pilot scale, an integrated package of more sustainable conservation agricultural practices, including maintaining soil cover, direct planting with minimal soil disturbance, appropriate crop rotations, soil mechanization techniques and on-farm water management through improved land leveling, drainage and water saving technologies as well as water control and crop irrigation scheduling using deficit irrigation practices and saline soil leaching, with the primary objective of utilizing the scarce water resources in an efficient and sustainable manner.

The overall objective of the project is to demonstrate alternative, profitable and more sustainable forms of agricultural production methods such as appropriate water and soil conservation practices and Conservation Agriculture (CA) for small individual farmers in KK.

The project has been executed by the MAWR of GOKK, with on-site technical guidance and support provided through the contractual services of ICARDA and competent national and regional institutes and agencies. The contract included assistance in the formation and strengthening of a water user association (WUA), improved on-farm water management, conservation agriculture and integrated crop management.

Conservation agriculture (CA) refers to several practices which permit the management of the soil for agrarian uses, altering its composition, structure and natural biodiversity as little as possible and defending it from degradation processes (e.g. salinization, soil erosion and compaction). CA provides important benefits for the environment but also economic benefits for the farmer. Farmers living in Karakalpakstan have two goals in mind, namely to produce a reliable harvest from their hot and salt affected fields and to do this economically by conserving water and nutrients.

Conservation Agriculture (CA) is defined as a concept for resource-saving agricultural crop production that strives to achieve acceptable profits, high and sustained production levels while concurrently conserving the environment. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals, nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with or disrupt the biological processes.

During the implementation of the project we have conducted an experiment to identify yield potential wheat production on no-tillage system. The objectives of this experiment are to see if high yields can be produced by no-till wheat and to see if no-till wheat is an economical alternative compared to conventionally planted wheat. The second objective is to watch the effects of the wheat tillage treatments on succeeding crops and on the long-term soil effects.

Mulching is one of the simplest and most beneficial practices. Mulch is simply a protective layer of a material that is spread on top of the soil. Mulches can either be organic--such as manure, grass clippings, straw, bark chips, and similar materials--or inorganic--such as stones, brick chips, and plastic. Both organic and inorganic mulches have numerous benefits. Influencing of crop residue for soil humidity and density in the upper layer of the ground were studied.

Recent introduction of new technology such as the no-tillage system, herbicides and residue management offers an opportunity to increase double cropping. Fuel for producing agricultural products has become expensive and no longer is available in unlimited supply. By using no-tillage, multi-cropping technique, two crops can be planted with the same fuel required for one conventional crop. Fuel for harvest, processing and transportation would be higher than in single crop production owing to increased production and the extra harvest.

In choosing which crop to grow, consider the economics of the entire rotation instead of a single crop in isolation. Also, be aware of any potential insect or disease problems that could affect crops later in the rotation. Cover crops in the rotation may also have an impact on diseases and pests, either positive or negative.

Proper seedbed preparation and the selection of seeding rate are important management considerations for successful production of wheat and other agricultural crops in Karakalpakstan. Bed planting of wheat can be taken to improve the percentage of germination of seed in the field conditions. Also seed rate can be reduced and during the vegetation period of wheat field can be cultivated once with fertilizer application. Lodging control of irrigated wheat can be achieved through bed planting practices.

Laser-assisted precision land leveling saves irrigation water, nutrients and agrochemicals. It also enhances environmental quality and crop yields. In spite of the known benefits of precision land leveling, Karakalpak farmers are unable to take full advantages of it and have to rely on traditional methods of land leveling which are labor-intensive and crude, and do not achieve a high level of smoothness of land surface. Laser land leveling technique is well known for achieving higher level of accuracy in land leveling.

New machinery, for sustainable agricultural practices, is provided by the project to the farms which are located in the project demonstration pilot site. During the implementation of the project 3 no-till planters were brought from Brazil.

A raised bed planter includes a planter body having three furrowers which form beds for the growin of the crops, separated by furrows. The planter body has an open top end

and an open bottom end. Four boxes are connected to the planter body at each of the respective four rows. Collectively, the four boxes 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.
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 of evaluation so that positive results may be attained within the pest control program.

A Water Users Association (WUA) is a self-managing group of farmers working together to operate and maintain their irrigation and drainage network, to ensure fair and equitable water distribution, and to increase crop yields. Establishment of WUA encourages greater participation of farmers in management decisions; ensures greater water use efficiency through increased productivity per water unit, and greater participation of farmers in the operation and maintenance of irrigation systems.

In view of the prepared manual and considering critical needed for required improvements, specific recommendations and conclusions were made for various elements of the conservation agriculture in Karakalpakistan.

I. INTRODUCTION

A FAO/TCP/UZB project on "Sustainable agricultural practices in the drought-affected region of Karakalpakstan" (FAO/TCP/UZB/3102) was implemented by the Ministry of Agriculture and Water Resources (MAWR) of Uzbekistan from October 2004 to September 2007 with technical backstopping from the International Center for Agricultural Research in the Dry Areas (ICARDA).

The project was formulated to address the most pressing problem of land degradation in the Republic of Karakalpakstan (KK) that has resulted into reduced agricultural productivity and production and, thus, a serious concern of food shortages adversely affecting the livelihoods of the population which is mainly dependent on agriculture. The major objective of the project was to evaluate different practices of conservation of agriculture (CA) in order to reduce and revert the process of soil and land degradation. The results obtained form the work carried out in the project have been considered very useful by the farmers MAWR, and especially the farmers in the region. Thus, it was considered worthwhile to compile these results into a bulletin form to make them available to the government and development officials, NGOs and farmers in Russian and Uzbek languages for their easy understanding and practical application.

1.1 The Republic of Karakalpakstan

Karakalpakstan is an autonomous republic of the Republic of Uzbekistan (Fig. 1). The area under Karakalpakstan is surrounded with Khorezm and Navoi provinces of Uzbekistan in the southeast, the Republic of Turkmenistan in the south, and the Republic of Kazakhstan in the west, north and east.

Nukus is the capital city of Karakalpakstan located nearly in the centre of Karakalpakstan. The population of Karakalpakstan is estimated at 1,200,000. The Republic is divided into 12 administrative regions, eight cities and eight centers of population. Its surface area is 164.900 km^2 and the density of population is 8.3 persons per km^2. The lands of the Republic are located in the delta of Amudarya river spread on both sides of the river. Later, the river floats into the Aral Sea. Karakalpakstan includes the west side of the Kizilkum Desert, the delta of the Amudarya and the southeastern part of the Ustyurt plateau. The Kizilkum Desert covers a vast area full of sand dunes. Sultan-Ulzdag Mountains extend in the south of the desert with the highest hill of 473 m asl.

The economy of the region is heavily dependent on agriculture and contributes to – 40% of the GDP. The Amudarya delta of Karakalpakstan is heavily populated, and is supported by extensive irrigation-based agriculture since the time immemorial. Cotton, rice and wheat are the major agricultural crops.

1.2. The Problem of Aral Sea in the Region

The Aral Sea is located in the north-western part of Uzbekistan (Republic of Karakalpakstan) and in the south-western part of Kazakhstan. Because the Aral Sea is shrinking this region has lots of environmental and health problems.

In the 1960s, the erstwhile USSR increased the area under cotton in Uzbekistan. To achieve this and because of Uzbekistan's continental climate, it became necessary to redirect water from the two main rivers, the Amudarya and the Sirdarya and, thus, their flow to the Aral Sea decreased. During the 1980s, the inflow was only 10 percent of what it used to be in the 1950s. The loss of inflow, combined with evaporation and little rainfall, caused the shoreline to recede, and, as a result, in 1987 the sea's southern and northern parts got separated, although they are still connected at times by a channel (Khakimov, 1989). By the end of 1996, the total area of Aral Sea had decreased by 57 percent, and the water level of the sea, which receives 80 percent of the inflow from the Amudarya, dropped 15-18 meters.

In the arid conditions of the Aral Sea basin, the depth of ground-water is a key issue. Above a certain critical level, intensive water evaporation begins, water transformation intensifies, and soil salinization occurs. In the Karakalpakstan, for example, the area of land with a critical groundwater situation increased from 72 per cent to 90 per cent during the period 1975-1989 (Khakimov, 1989).

The above problems have seriously affected agriculture and its production in the Republic. This is because of careless use and overexploitation of natural resources, commonly practiced same cropping systems and application of inadequate practices for management of soils and water that land and soil degradation is commonly observed in the Republic. This has had and continues to have detrimental effects on food production and is causing food shortages for the growing population of the Republic.

2. AGRICULTURAL PROBLEMS IN KARAKALPAKSTAN

2.1 General Problems

2.1.1. Erosion

In Karakalpakstan (KK), desertification hits more than 80 percent of the land. Desertification processes are connected with wind, water erosion and secondary salinity.Erosion is the main issue for most of the provinces in Uzbekistan arid zone, including KK. Thus, eroded area in Uzbekistan is 1.772 million hectares or 40% of all the cropland. Of this, the 712,900 ha of land is subjected to irrigation erosion (Mahsudov, 1989), 300,000 ha to wind erosion (Mirzajanov, 1971), and 50,000 ha to gully erosion.

The processes of land erosion in KK have their origin in social, economic and cultural factors that translate into the over-exploitation of the natural resources and the application of inadequate practices for the management of soils and water. The consequences of this are damage to much of the agricultural land, with detrimental effects on food production for the growing population in this region.

Soil degradation from continued rice, cotton and to a lesser extent wheat cultivation continues unabated. In order to reduce soil degradation and improve soil structure in KK, retention and use of crop residues and farmyard manure (FYM) must be encouraged. Both mechanisms also make a very beneficial contribution to the nutrient status and fertility of soils, particularly where fertilizer is in short supply.

2.1.2. Salinity

Planned and large-scale public programs on expansion of large areas with the simultaneous establishment of irrigation and drainage network throughout Uzbekistan, including Karakalpakstan during 1960s to 1970s, were directed to strategical planning of the former USSR.

Simultaneous land-reclamation and irrigation of soils at the big territories, massively and heavily watering, and absence of well-operating and quality collector-drainage systems at the developed areas caused secondary salinity of soils universal for all irrigated areas, particularly in the arid regions. Imperfection of the hydraulic and reclamation constructions, and their underutilization as well as unfounded irrigation systems contributed to salinization in the arid regions (Photo 1).

Photo 1. Salt-affected field in Karakalpakstan.

The area of saline irrigated lands in Uzbekistan amounts to 2,270,700 hectare, including low-saline lands of 1,267,700 hectare, medium-saline lands of 711,200 hectare, and strong-saline lands of 291,800 hectare.

In KK, about 80% of the irrigated land is saline land including 48% with high salinity. At present, share of salinized irrigated areas accounts for 100% in Mo'ynak district and 95% in Shumanay district. The strong- and medium-saline areas increased for the last 24 years from 38.5% to 58.4 % against a background of ineffectively open shallow drainage network. However, against a background of progressive deep under-drainage in Sirdarya province high- and medium-saline areas increased for the same period from 25.7 % to 53.7 % as well. Considering this, if appraisal for salinity is not made for crops with strong salt resistance, then salinization intensity and its damage would be catastrophically unpredictable for the crops with weak-and medium-salt resistance.

2.1.3. Drought

Moderate to extreme drought conditions extend across the southern part and much of the eastern and western part of Uzbekistan. At the height of the drought last year, more than half of the country was affected. According to data taken from the MAWR only the droughts of 2000 and 2001 affected a greater percentage of the country's land mass.

After the 1999 drought, KK in 2000 and 2001 experienced the worst drought and water shortage in living memory. The area is naturally arid and, with an annual rainfall of only 110 mm, humans, animals and agriculture are almost entirely dependent on the residual flow in the Amudarya for survival. River flow fell dramatically and the consequent impact on the rural population, livestock and crop production was disastrous, with an emergency situation prevailing in many areas, particularly in northern districts (Photo 2).

Photo 2. Soil fissures (cracks) caused by drought in 2001.

The origins of this disaster were both man-made and natural. The main cause is mismanagement of water resources in the river basin, compounded by diminishing snow and glacier melt, a declining trend in rainfall, and possible long-term climatic change. There is general consensus amongst scientists and farmers that water availability at the tail end of the Amudarya River is in decline. There are interventions underway in the river basin, aimed at improving efficiency in water management and utilization, and the Government has been providing assistance to vulnerable farmers repeatedly affected by drought in KK.

Last year, precipitation in Karakalpakstan Republic averaged only 20% of normal precipitation in the last 60 days and had about 40% to 80% of normal precipitation.

In 2005 Karkalpakstan's agricultural losses from drought were significant as compared to other years but less than 2000 and 2001 years. The authorities in Chimbay, Shumanay, and Kegeyli rayons informed us they had similar agricultural losses for 2005. Drought already affected on the wheat crop in KK last year and was the smallest since 1991.

Drought can change many long-held convictions. Wheat in Chimbay is normally grown to help the following crops due to rotational benefits, weed control, and moisture accumulation. In 2002, they found wheat yields that were quite high while they looked for ways to salvage some forage from other dryland crops.
The landowners and tenants should discuss how drought may affect production in a particular year and design a lease so that they share the opportunity and risk associated with drought. Discussion should include who decides when drought adversely affects the winter wheat production enough to apply nitrogen at the exact time in order to ensure sufficient moisture in the soil after winter.

2.1.4. Decrease in agricultural production.

In the era of the Soviet Union, KK specialized in rice production, and was one of the main rice-producing regions in the country. After independence, specialization in KK did not change, and continued to be Uzbekistan's largest rice producing region. Because of these water allocation to KK was high, 12 km^3 annually.

Since 1991, the productivity of agriculture in the Karakalpakstan has decreased by 40.0-50.0%. Due to the increasing soil salinity, the region loses billions of Uzbek soums every year.

Three successive years of drought (1999-2001) have inflicted serious damage on the agricultural sector of KK. Gross production of the three main crops – rice, cotton and wheat fell by 75% and 52%, respectively, in 2001 as compared to 2000.

The 1999-2001 droughts had a devastating effect on rice production in KK. Of the 115,000 hectares planted in 2000, "only 45,000 hectares were harvested" (Alimov, 2000). According to the data in AMWR the whole of Uzbekistan the rice area harvested in 1999 was 164,000 ha. This area further shrank in 2000 to only 65,000 hectares, and the total rice production fell from 414,000 in 1999 to 175,000 tons in 2000.

The most critical and contentious agronomic issue, for KK in particular, is related to the continued monocropping of rice without any crop rotation. Crop yields are extremely low and deteriorating season by season, when compared to the country-wide averages (1994-1999) of 2.45 t/ha for rice, 2.05 t/ha for wheat and 2.41 t/ha for cotton.

The three main crops grown in KK are cotton, wheat (under the "State order"), and rice. Cotton still dominates irrigated cropping but not same extent as in the 1980s. Cereal crops have largely replaced cotton, although potatoes, fruit and vegetables are important in some areas as private markets have expanded. Alfalfa growing area has decreased considerably in the last 10 years (1994-2004).

Rice, cotton and wheat are grown either continuously or in crop-rotation together. Before independence, cotton was grown in rotation with alfalfa; three years of alfalfa followed by six years of cotton, which has already led to marginal and hardly sustainable soil fertility management. Crop rotation with fodder legumes or pulses is extremely important for soil health and management of plant diseases. The absence of alfalfa in present crop rotations has diminished humus in the soil and considerable micronutrients. It has also eliminated natural soil humus content and removed the soil structure benefits derived from alfalfa's root system.

2.2. Climate

Uzbekistan has extreme continental type climate, with hot dry summers, unstable weather in winter, and a wide range of variation in seasonal and daily temperatures. The desert and steppes are characterized by short winters with thin and unstable snow cover, and hot dry dusty summers. The mountains (over 600 m asl) have high precipitation (up to 600 mm per year).

The year 2004, in contrast with 2005 and 2006 was characterized by favorable weather conditions for the production of agricultural crops. First rainfalls occurred in the middle of the autumn of 2004. It negatively affected the germination of winter wheat and, as a result, percentage of germination was less compare to the observed in other years. In general, the winter of 2004 was favorable to the winter wheat growth and development and warmer than usual and almost without snow.

The spring of 2006 was characterized by sufficient rainfall that promoted wide growth and development of winter wheat. The spring of 2005 and 2006 were characterized by insufficient rainfall because of which most of the spring crops suffered due to water shortage during the vegetation period (Fig. 2).

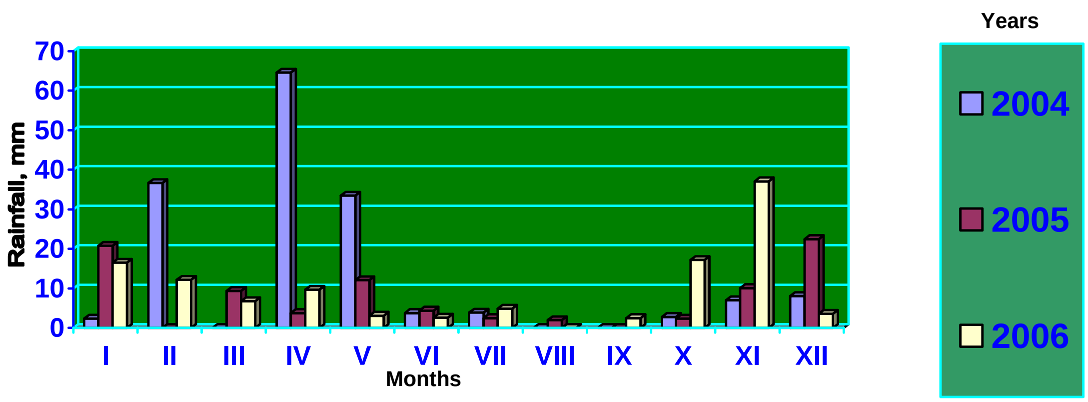

Fig. 2. Mean annual precipitation, Chimbay (2004-2006)

Climatically, Uzbekistan and the Karakalpakstan are part of the dry mid-latitude desert characterised by hot summers and cold winters. Agriculture is dependent on irrigation and concentrated in the river valleys. Drought conditions in Uzbekistan since 1999 have affected the flow of the rivers floating into the Aral Sea Basin. The effect of reduced flows was aggravated by inadequate water management, in particular along the Amudarya, which provided irrigation water to some 500,000 hectares of land in

Karakalpakstan in the past. Now, irrigation area has been considerably decreased due to water shortage. Karakalpakstan, because of its geographic location at the tail-end of the river but also at the tail end of several upstream hydro-electricity and irrigation schemes, has suffered more pronounced impact of the drought more pronounced in these areas than elsewhere in the country.

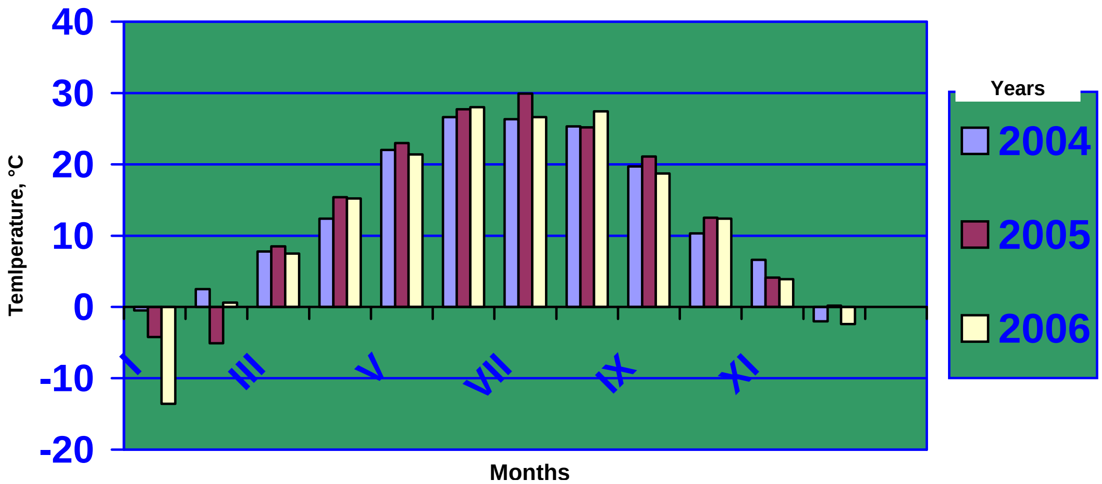

Fig. 3. Average air temperatures in Chimbay district (2004-2006)

The climate of Karakalpakstan is classified as severe continental with hot summers and cold winters. The average summer temperatures is 30ºC often surpass 45°C; the average winter temperature in January is about -5°C, with absolute minimum as low as -40°C (Fig. 2). 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) (Fig. 2).

Water resources are in short supply in most of Chimbay district. The three canals supplying water to Chimbay district are Mayjap, Shokharik and Aytgejap, which originate from large canal Kyzketken of the Amudarya. Ground water resources are polluted by untreated sewage and drainage water, which contains high levels of agrochemicals and minerals.

Humidity deficit is a difference between saturation vapor pressure and actual vapor pressure under a given temperature. Thus, humidity deficit is very climate-sensible indicator of drought. The air humidity deficit fluctuates from 0.5 to 26.2. In 2005, air humidity deficit very often by oftenly observed, and the year was very dry as compared with 2004 and 2005 years (Fig. 4).

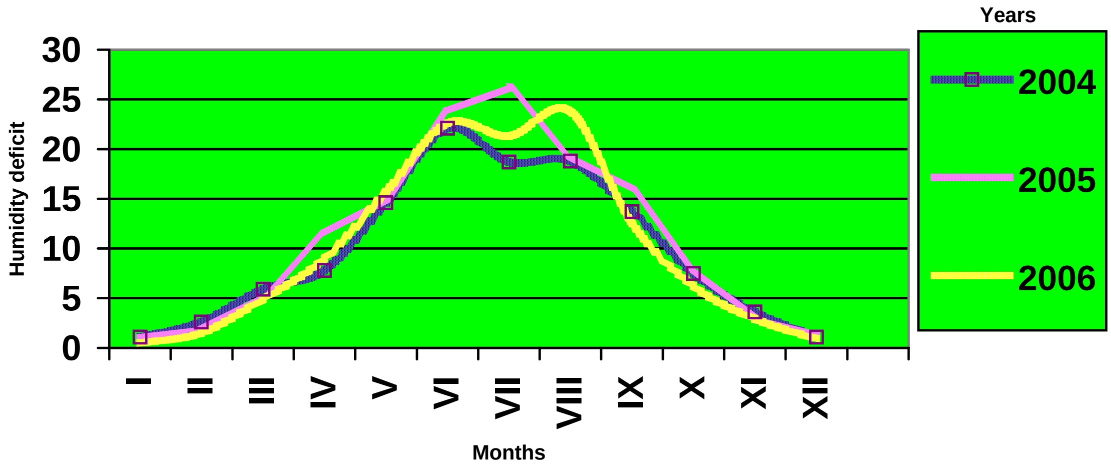

Fig. 4. Percentage of air humidity deficit in Chimbay district

2.3. Soil

On the basis of soil analyses, the agrochemistry maps of the project pilot site for the nutrient components such as nitrogen, phosphorus, potassium and humus were made (Annex: Fig. 2, 3, 4 and 5). The recommendations on fertilizer application to the field were drafted according to the agro-chemistry map. The soil is rather dense with the bulk density fluctuating from 1.4 to 1.6 g/cm³. The highest bulk density was noted in the depth of 20-40 cm.

Over the past 12 years, more than 50% of fields in the whole Chimbay district have been ranked as low to very low in P_2O_5 supply. Phosphorus efficiency is greatest when applied within planting of the agricultural crops. Farmers in the project area actually didn't apply phosphorus fertilizers during 14 years since the collapse of the USSR in 1991. At the project site, an annual dose of phosphorus (ammonium phosphate) was applied with a fertilizer spreader NURI-0.5 at the rate of 100 kg of P_2O_5/ha and the fertilizer application in following years was done according to the agro-chemistry map.

Almost all the irrigated areas of the project pilot site are located between two canals. This is why the ground water table (GWL) goes up to the surface of the soil and takes an active part in the soil formation processes. When both the canals are operated the GWL decreased from 91 cm to 216 cm (Fig. 4). (M) ground water is rather high and fluctuates from 1,9 in the fall up to 5.0 g/l in winter months.

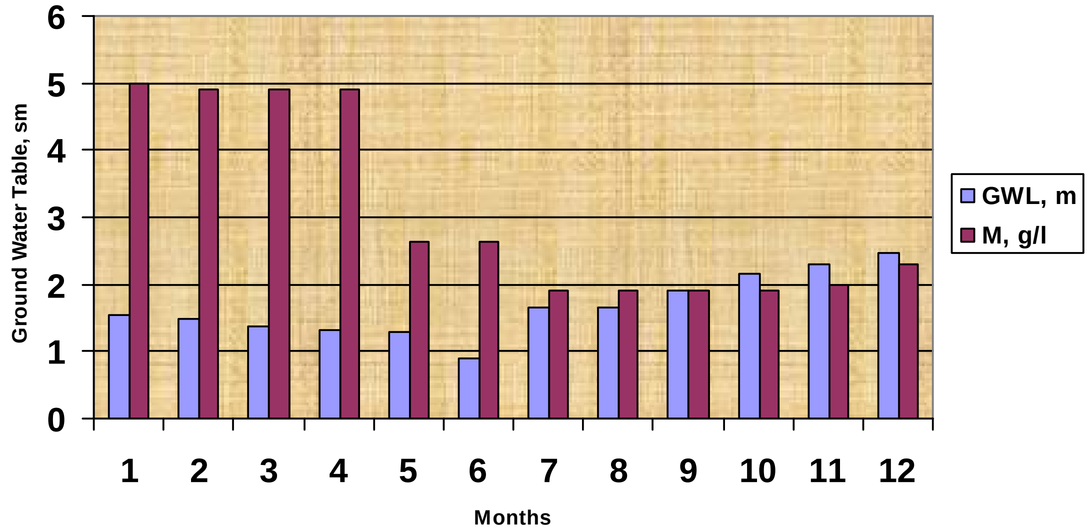

Fig. 5. Level of the Ground water table and its salinity of the pilot site (2004-2006)

The irrigated areas of the project pilot site irrigated areas are considered to be of slightly saline soil and the value of soil salinity fluctuates from 0.199% to 0.637%. The content of Cl ranges from 0.03 to 0,065%, which is close to maximum allowable concentration (0.04%) for these conditions. Salt in the soil is concentrated in the upper 0-20 cm layer and its value goes down in the lower horizons. In general, the salt content in all the territories of the pilot site is not very high, with the exception of Field No 3, where the salt content in the upper layer increased between irrigation periods and reached 1.2 %.

3. CONSERVATION AGRICULTURE

3.1 Principles and Methods of Conservation Agriculture

Conservation Agriculture (CA) is defined as a concept for resource-saving agricultural crop production that strives to achieve acceptable profits, high and sustained production levels while concurrently conserving the environment. Conservation agriculture is based on enhancing natural biological processes both above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals, nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with or disrupt the biological processes.

Conservation Agriculture has three main principles: minimal soil disturbance, maintenance of a permanent soil cover with crops or crop residue, and crop rotation. It starts with reduced-till aiming at no-till agriculture, which makes ploughing unnecessary. This helps maintaining organic matter in the soil and decreases the wind and water erosion. Proper choice of crop rotations is essential in the CA concept.
No-till increases the amount of organic matter in the ground, creating a porous soil structure that allows more water to filter through to the crops' roots, instead of running

off the surface and taking valuable soil with it. The result is better developed crops and less erosion.

The pests, where the CA is applied can be controlled through integrated pest management (IPM), a technique that controls undesirable organisms by exposing them to their natural enemies, minimizing the use of chemical pesticides.

Both CA and IPM result in much greater resistance to environmental degradation, including wind and water erosion. Yields and incomes rise, fuel and labour are no longer needed for tilling, and flooding is reduced - indeed, long-vanished springs may reappear.

Conservation Agriculture is particularly useful in dry areas, where low rainfall is the main constraint to growing crops, and it may help farmers to switch to more productive methods. The use of CA enables the soil to store more of the precipitation that falls during the fallow period, so farmers can consider more intensive crop rotations. The fallow period should be shortened to minimum period or eliminated at all if feasible.
Non-traditional rotations being considered to exploit CA in dry areas include barley, wheat, food and forage legumes and also sunflower, sorghum and millet depending on available moisture.

Leaving at least some crop residues in place can still pay by slowing evaporation of precious soil moisture. This effect is increased in a dry climate because residues are slower to degrade. No-tilling also conserves soil moisture, so more organic matter is produced, outweighing the initial loss of feed or of income from its sale.

In addition to the quantitative benefits 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 applied (Saturnino & Landers, 2002). Conservation agriculture can reduce the overall requirement for farm power and energy for field production by up to 60 % compared to conventional farming. This is due to the fact that the most power intensive operations, such as tillage, are eliminated. Also, the additional equipment investment, particularly the number and size of tractors, is significantly reduced. Long-term experiences with CA show a decline in the use of agrochemicals due to enhanced natural control processes. Natural control of pests and diseases improve over time and also the experience in weed management through crop rotations facilitate this long-term decline in agrochemical use (Saturnino & Landers, 2002). The same is true for mineral fertilizer, as less is lost through leaching and erosion and the different rooting systems recycle more soil nutrients from a larger soil volume resulting into the improvement of overall efficiency of fertilizer use in the long-term. This is reflected in significant reduction of the fertilizer requirements to maintain the production and soil nutrient levels over the crop rotation (Saturnino & Landers, 2002).

Conservation Agriculture can also assist in the adaptation to climate change, by improving the resilience of agricultural cropping systems and hence by making them less vulnerable to abnormal climatic situations. Better soil structure and higher water infiltration rates reduce the danger of flooding and erosion catastrophies after high intensity rainstorms (Saturnino & Landers, 2002). Increased soil organic matter levels improve the water holding capacity and enable plants to get through extended drought periods.

Also, CA can contribute to mitigate against the climate change, at least as far as the release of greenhouse gases is concerned. With the increasing soil organic matter, the soils under CA can retain carbon from carbon dioxide and store it safely for long periods of time. This carbon sequestration will continue for 25 to 50 years before reaching a new plateau of saturation (Reicosky, 2001). The consumption of fossil fuel for agricultural production is significantly reduced under CA and burning of crop residues is completely eliminated, which also contributes to reduction of greenhouse gas releases. Besides, the CA soils under no-tillage, depending on the management, might also emit less nitrous oxide (Izaurralde et al., 2004).

3.1.1. No-till

The soils are a greatest national resource. Technology and management practices developed for clean tillage have allowed production of large amounts of food and fiber on these soils. Clean tillage, however, has exposed the soil to rain and wind and has resulted in potential dangerous erosion rates. Erosion has destroyed the productivity of much of our land, and has, in only the last 100 years, removed roughly 50 percent of the topsoil from much of the highly productive soils in Karakalpakstan.

No-tillage, which includes those direct seeding practices that leave plant material from the previous crop on the soil surface, has the potential to control soil erosion and preserve our soil resource indefinitely. No-tillage controls soil erosion because the plant material 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 where they are most useful for crop production.

Since the soil is never tilled the soil structure changes. A system of continuous macro pores is established, facilitating water infiltration and aeration of the soil as well as root penetration into deeper zones. Soil organic matter contents increases with higher values near the surface, gradually declining at increases depth. Soil macro- and micro-fauna and flora is re-established resulting in better soil fertility.

3.1.2. Tillage and crop yield

During the implementation of the project an experiment to identify yield potential of wheat production in no-tillage system was conducted. The objectives of this experiment were to see if high wheat yields could be obtained under no-till situations and if no-till wheat is an economical alternative compared to the conventionally planted wheat, to watch the effects of the wheat tillage treatments on succeeding crops and on the long-term soil effects. The results showed that 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 high in both tillage methods, but no-till was 8 % less than the tilled method of planting.

The head counts made at maturity were significantly higher under the no-till planting. The numbers of head/m^2 were in the same range whereas high yields might be expected for both tillage treatments. It appears that the wheat plants in no-tillage situation tillered more than the conventionally wheat since fall stands were lower under no-tillage.

There were no differences between the yields of no-tillage and conventional by planted wheat in on-farm trials during two years (2005 and 2006). The yields were not very high in both the cases which is explained by rather high soil salinity levels (See Fig. 6).

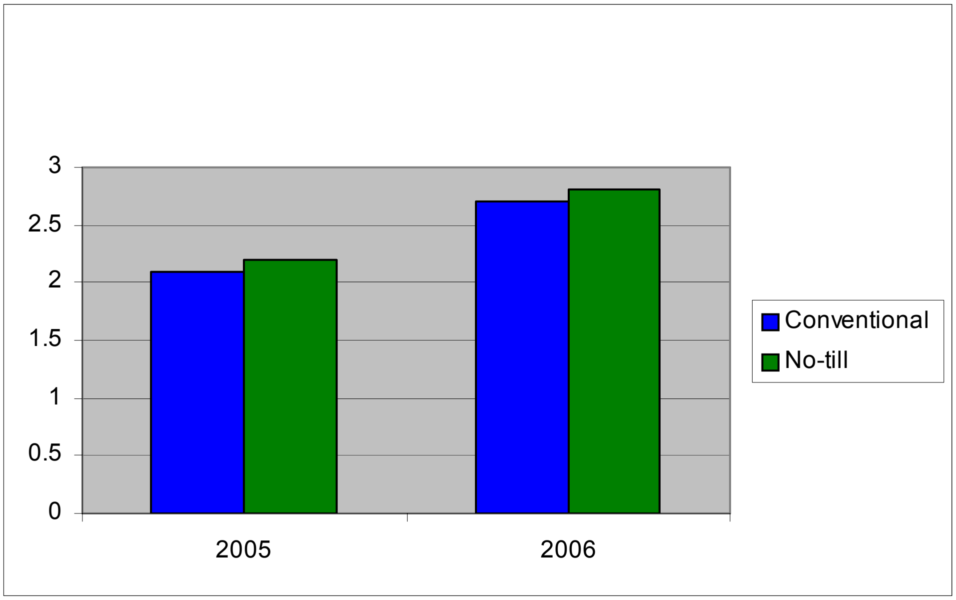

Fig. 6. Winter wheat grain yield (t/ha) as affected by tillage method.

3.1.3. 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. Producers describe soil biological health in terms of "earthy smell," "soil crumbliness," and "greasy feel." Soil scientists measure soil biological health in terms of microbial biomass, microbial communities, and rate of organic matter decomposition.

Nutrients released through the decomposition of plant and animal residues are an important factor for plant nutrition in CA. Decomposition is a biological process involving a variety of soil organisms, including beetles and other insects, worms, nematodes, fungi, bacteria and algae. The National Consultant for soil management, Dr. Bakhitbay Aybergenov, provided a practical training course on Visual Soil Assessment. A Field Guide on Visual Soil Assessment was used to assess soil degradation in the project pilot site. This methodology developed by Graham Shepherd adapted by Benites (2000). 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. Visual soil assessment is based on the visual assessment of key soil properties indicating soil quality (state), termed “indicators”, which are recorded on a score-card. Soil quality is ranked by assessment of the soil indicators alone. Plant indicators require knowledge of crop growing history in a given farm. The knowledge of this information will facilitate the satisfactory completion of the plant indicator score-card, etc.

3.1.4. Monitoring soil nutrient levels

A good nutrient management plan involves on-going monitoring of soil nutrients. Thus, soil samples were provided to the Central Soil Testing Laboratory for standard soil tests. These tests provided an assessment of plant-available nutrients. On the base of soil analyses, the agrochemistry maps of the project demonstration site for the nutrient components such as nitrogen, phosphorus, potassium and humus were made (Annexes

1, 2, 3, and 4). Nitrogen is a major plant nutrient and a central component of organic nutrient management. While most standard soil tests provide an assessment of nitrate [NO3], the level of this soil nutrient is highly affected by the time of sampling and other samples were handled between sampling and the analysis. Nutrient management can not be the same for all farms. It is important to recognize the differences among farms and realize how they affect the choice of appropriate management strategies. Thus, the recommendations on fertilizer application were drafted according to the agro-chemistry map.

Use of fertilizers has made high crop yields possible by which Uzbekistan farmers have achieved self-sufficiency in grain. With rising fertilizer costs, the researchers are studying ways to increase fertilizer use efficiency. To achieve it the soil fertilizer specialists and plant breeders should join forces to find developed plant varieties which use fertilizer nutrients more efficiently.

3.1.5. Nitrogen rate and timing

Nitrogen was managed for intensive production with 1/3 of the N applied at tillering stage and the remainder at jointing stage. The rate of nitrogen had no significant effect on the yields in either of the two tillage systems. The 120 kg/ha rate was as good as the 140 kg/ha in traditional tillage with mouldboard ploughs, while no-till slightly increased grain yield with higher nitrogen rate (Fig. 6).
The rainfall during the winter was below average, so probably not much nitrogen was lost and thus was more available than in years with the above-average rainfall. The 60 kg nitrogen /ha was as good as the 120 kg nitrogen /ha during the 2 years.

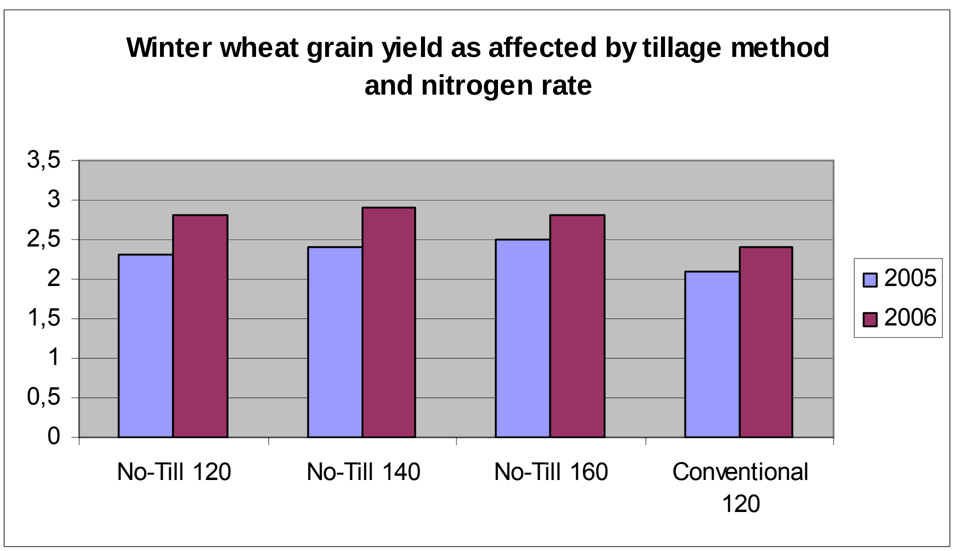

Fig. 7. Winter wheat grain yields (t/ha) as affected by tillage method and nitrogen rate.

In both 2005 and 2006, a split N application of 70-50 in March and April was a better combination than the 60-60 split. Fall N treatments were not helpful (Table 1). The two-year average showed that the fall nitrogen application treatments tended to lower wheat yield (Photo 3).

Photo 3. No-till wheat crop

Table 1. Wheat grain yields as affected by the time and placement of nitrogen application

Time and placement of nitrogen (kg/ha)			Yields (t/ha) 2006	Yields (t/ha) 2005
Fall	February	March		
0	70	50	2.6	2.3
0	60	60	2.4	1.9
20	50	50	2.1	1.8

3.1.6. Weed control

Weed control was evaluated in spring, on April 20, 2006. Bermudagrass *(Cynodon dactylon)*, Red Goosfoot *(Chenopodium rubrum)*, and Many-seeded Goosefoot *(Chenopodium polyspermum)* were the dominant weeds observed. Other species noted in the spring included Eastern dodder (*Cuscuta monogyna)*, Mountain Ironwort *(Sideritis montana)*, Syrian cephalaria *(Cephalaria syriaca)*.

The overall weed infestation observed in conventionally tilled wheat with application of Puma Super in spring was essentially equal to that found in no-till wheat with Dafosat applied in the fall followed by spring-applied Puma Super. The infestation levels of Hen bit and Red Goosfoot tended to be less when Puma super was applied in the fall compared to when it was applied in the spring. Plots treated in the fall with Dafosat at the rate of 5 l/ha had very little Red Goosefoot but did not have other weeds, particularly Mountain Ironwort.

Wheat yields for all weed management practices exceeded 2.0 tons per hectare in 2006. The yields of plots receiving a herbicide treatment were similar and were at least 0.7 t/ha greater than the yields of no-till wheat where no herbicide treatment was used. The two-year averages for wheat yields tended to be less with Puma Super applied in the spring compared to other weed management practices (Table 2).

Table 2. Effect of weed management on the presence of weeds and wheat grain yields

Treatment	Weed species			Grain yields (t/ha)	
	Bermudagrass	Red Goosefoot	**Total Weeds**	**2006**	**2005**
Conventional Till + Puma super	30	25	55	2.3	1.7
No-till +Dafosat	28	27	55	2.4	1.8
No-till + Puma super	36	49	85	2.7	1.8
No-till + Dafosat + Puma super	27	27	54	2.5	1.9
No-till with no herbicide	87	81	168	1.9	1.4

Dafosat at 5 l/ha was applied on September 28, 2005, whereas Spring Puma super at 0.8 l/ha was applied on April 5, 2006.

3.1.7. Integrated pest management

Pest numbers are legion and may take many forms – insects, mites, nematodes, weeds, plant diseases, rodents plus more. Man has always sought means to cope with pest-induced-problems. These operations involve protecting man's health, comfort, esthetic values, and freedom from annoyance, but certainly protecting domestic animals, crops, forests, and other property is one of the most important.

It is obvious to experienced plant protection specialists that chemical pesticides will remain a most valuable tool among plant protection techniques. At this time, the farmers have little resources to use a pesticide when pest populations reach damaging levels. Other approaches are needed and, in fact, some old and newly developed approaches are available and being used in field practices. Some of the old approaches include use and protection of naturally occurring biological control agents, regulatory procedures, cultural controls, and pest-resistant and tolerant crops. Others, such as the use pheromone traps (biological attractants), are playing important role in pest control programs in cotton.

Integrated pest management (IPM), sometimes called integrated control or simply pest management, was the term given to developing management systems. This is simply a program, recognizing the complex biological nature of agricultural crops, in which all possible techniques of managing pests are integrated into a systems approach so and there is decreased reliance upon non-selective methods of pest population control.

Plant protection specialists generally agree that continuing the existing pest control practices, which are recklessly extravagant and wasteful, could lead eventually to a decline in our ability to control pests. If this should happen, we most probably will gamble with food production stability. Therefore, IPM, even though not perfect, is our route to stability.

We should include general recommendations for the control of insect-pests prevalent in KK. Insect-pests were not a significant factor in the experiment of 2007. Plots were monitored weekly for the presence of insect-pests including aphids, cereal leaf beetle and armyworm. However, no populations of any importance were noted.

3.1.8. Long-term soil effects

The plots were in the same treatments for long enough so that differences in the soil physical and chemical characteristics might begin to separate according to tillage treatments.

Soil physical factors

Producers describe soil's physical conditions using terms such as "softness," "mellowness," "workability," or "tilth." Soil scientists measure soil physical conditions using the terms "bulk density," "penetrability," "water infiltration rate," "water holding capacity," and "erodibility." Soil that has good physical condition is porous like a sponge, rather than tightly packed like a ball of modeling clay. Soil in good physical condition provides several benefits for plant growth.

- Plant roots can grow through the soil without restriction.
- Air, water, and nutrients needed by plants and soil organisms can move through the soil with relative ease.
- Water from rainfall or irrigation seeps into the soil, 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. According to the results of visual soil assessment one project field got a score of 20. This field needs to improve soil fertility.

Fertile soil is a key element in every aspect of Karakalpak agriculture. Its structure and fertility provide the basis for all crop and livestock production. Throughout the historical publications of the Karakalpak Research Institute of Farming, researchers and educators have been concerned with the protection of this vital resource.

There appears to be little difference in the soil physical factors between the two tillage systems as determined by the measurements that were made (Fig. 8). The soil densities for both tillage systems were very similar and in an excellent condition for crop growth. The soil strength measurements were all low enough and were in the range for excellent crop growth. The 0-10 and 10-15 cm depths showed higher soil strength in the no-tillage treatments, but the measured values should not affect crop growth. The higher soil strengths reflect a stronger and well established soil structure in no-tillage that allows controlling traffick of the plots when it is possible in the tilled plots under wetter conditions.

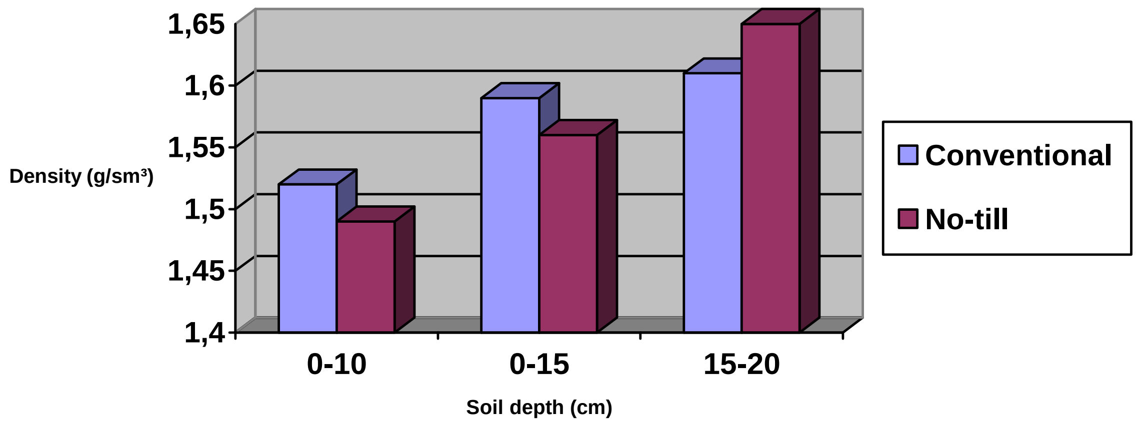

Fig. 8. Bulk density by depth (cm) sampled in April 2006 (2 years)

Soil chemical factors

Organic matter was higher with no-till wheat in the 0-10 cm depth, but lower at the 10-15 cm depth in Table 3. This is explained by well known fact of differentiation of soil fertility as a result of conservation tillage when soil is not turned up. Overall, the no-till treatment had significantly more organic matter.

There was a small, but significantly lower pH in the top 10 cm of the no-till system (Table 4). This is to be expected since all the nitrogen is placed on the soil surface and the nitrogen acidifies the soil. The tilled plots mixed and diluted this effect. There were no differences in the phosphorus and potassium soil tests between the two tillage systems.

Table 3. Organic matter in the two tillage systems, 2006

Tillage treatment	Organic Matter (%)		
	0-10	10-15	15-20
Conventional	2.24	1.72*	1.45
No-till	2.61*	1.59	1.51

* Organic matter was significantly higher at this depth.

Table 4. Soil pH by depth (cm) in the two tillage systems

Treatment	Soil pHpH	
	0-10	10-20
Conventional	7.7*	7.5
No-Till	6.9	7.5

* pH was significantly higher at this depth.

Yields of succeeding crops (mungbean and sorghum)

Crop diversification is a new issue in Karakalpakstan agriculture. Farmers got used to think only about monocropping of cotton. For other crops, they had no equipment, and had lack of knowledge about growing and marketing, and no resources to buy inputs. Cotton and wheat production in KK are controlled by the Government which in turn provides credit to buy subsidized inputs. For crops other than cotton and wheat one has to go to market and purchase seeds and inputs which is problematic under the present circumstances.

Both mungbean and sorghum are grown no-tilled after the two tillage systems in which wheat was grown (Photo 4). The mungbean is double-cropped after the wheat, and corn (maiza) was planted the next spring before the wheat would be planted in the fall. These crops were harvested for yield to determine the effects of tillage systems of wheat. It appears that both sorghum and mungbean tend to yield more where wheat was grown in no-till situation. The mungbean provided 30 kg/ha (3.3%) yield advantage after the no-till wheat, which were consistent but not significantly different. The average yield advantage in sorghum was 60 kg/ha (8.9%) more after the no-till wheat, which was consistent but not significantly different.

Photo 4. No tilled Sorghum crop.

Although the reason for the yield differences in the two tillage systems is not known, it is probably related to soil water availability. Even with no significant differences in crop yields no-till system has an advantage in reduced cost of production. Also, important conclusion is that there is no justification of the present recommendation to farmers on deep ploughing for double crops in KK.

3.1.9. Soil moisture

Conservation agriculture is known to improve the water efficiency of soils. The increased amount of continuous vertical macropores facilitates the infiltration of rain water into the ground and hence a recharge of the aquifer. The increased soil organic matter levels improve the availability of water accessible to plants. One/percent of organic matter in the soil profile can store water at a rate of 150 m^3 ha^{-1}. The permanent soil cover and the avoidance of mechanical soil tillage reduce the unproductive evaporation of water. As a result, the water use efficiency is increased and the water requirements for a crop can be reduced by about 30%, regardless of whether a crop is grown under irrigation or rainfed conditions (Bot & Benites 2005).

The reason for higher yields of no-till soybean and corn grown after no-till wheat are not clear at this time. There are a number of changes which take place in the soil with a true no-tillage system. It is felt that these changes would alter the amount of water available to the plant. To better understand this, the amount of water in the top 25 cm of soil was monitored in the no-till corn during the late-vegetative and early-reproductive stages of growth. The results presented in the following table showed that significantly more water was found at each date of sampling in the no-tillage treatment (Table 5). The moisture on June 24 was similar due to irrigation. However, the moisture declined in the no-till treatment at a slower rate indicating that the moisture was more efficiently used in the no-till treatment (Table 5).

Table 5. Soil moisture in the top soil with no-till corn in the late-vegetative and early-reproductive stages of growth in 2006

Date	Soil moisture (%)	
	Tilled Wheat	No-till wheat
June 10	13.95	15.51
June 24	16.73	17.01
July 9	13.09	14.51
July 23	10.33	11.72

3.1.10. Temperature and wheat growth

Temperature loggers were placed at different heights and depths within the soil and wheat canopy to develop a temperature profile that might help answer questions concerning the differences between tilled and no-tilled wheat on growth vigor and winterkill.

Table 6. Effect of wheat systems on the yield of succeeding crops

Year	Type of tillage system	
	No-Till	Conventional
	Mungbean (kg/ha)	
2005	905	978 N.S.*
2006	954	983 N.S.*
Average	**929**	**980**
	Sorghum (kg/ha)	
2005	1003	990**
2006	1011	999**
Average	**1007**	**994**

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

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 (Table 6). But in 2006, there was very cold winter which negatively influenced the wheat yield (Fig. 2).
The temperatures in both the tillage systems at the two different farms in the project pilot site declined in December at the same rate and began rising in late February at the same rate.

3.2. Soil Cover

3.2.1. Characteristics

The permanent soil cover through crops, mulch or green manure cover crops complements the zero tillage effects by supplying substrate for soil organic matter build up and for the soil life which is facilitated by not disturbing the soil. Through protection of the soil surface the mulch reduces evaporation and avoides crusting. It also suppresses weed growth and reduces problems experienced in direct seeding or zero tillage when applied in isolation. In addition, the application of zero tillage and direct seeding technology facilitates the management of residues which in conventional systems are often considered a problem.

Mulching is one of the simplest and most beneficial practices. Mulch is simply a protective layer of a material that is spread on the top of the soil. They can either be organic such as manure, grass clippings, straw, bark chips and similar materials or inorganic such as stones, brick chips, and plastic. However, both organic and inorganic mulches have numerous benefits.

Influencing of crop residue for soil humidity and density in the upper layer of the ground were studied (Table 7). Results indicated that the crop residue increased soil moisture by 3.2% and decreased bulk density by 0.1 g/cm^3 in the soil upper layer. Obviously, bulk density decreased due to better development of secondary roots which are located in the upper layer of the soil (Table 7).

Table 7. Influence of crop residue on soil moisture and bulk density

Field number	Soil depth (cm)	Moisture, %		Bulk density, g/cm^3	
		Residue	No residue	Residue	No residue
7	0-10	12,2	9,7	1,49	1,60
8	0-10	10,6	6,8	1,56	1,60
Average	0-10	11,4	8,2	1,50	1,60

Biological activity of the soil is one of the main characteristics to be assessed for the soil fertility. The method of Mishustin, Nikitin, and Vostrovs was used to assess soil fertility and to determine the soil biological activity. 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 (Photos 5 and 6).

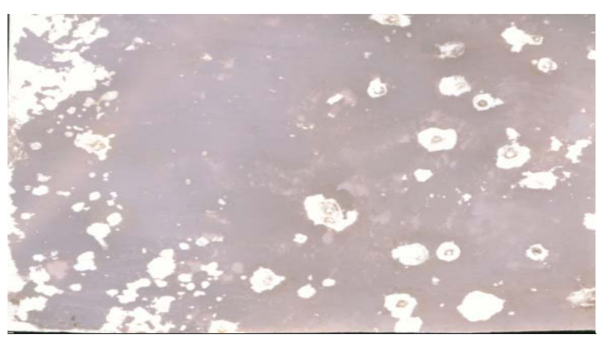

Photo 5. Protease activity of soil without crop residue.

Photo 6. Protease activity of soil with plant residue.

Plant residue positively influences the soil quality, decreases soil density, increases soil moisture and increases biological (protease) activity of the soil. That is why, preservation of crop residues, straw chopping and tossing the straw on the surface of the field with appropriate machines such as harvester combines can improve physiological and biological properties of the soil, which significantly increases the soil fertility.

Soil mulching is an agro-technical operation in which the soil surface is covered with materials in order to conserve water, prevent soil salinity, exterminate weeds, etc. In this experiment, different rates of manure as mulching materials (10 t/ha, 15 t/ha, 20 t/ha), also mungbean and sorghum straw were applied. Wheat yield in treatments with manure application was 0.6-0.7 t/ha higher than in control plots, which was 1.63 t/ha.

Taking into account the slow decomposition of organic manure and crop residue it is too early to make general conclusions but nevertheless the results obtained are encouraging. The humus content increased remarkably but the effect of organic manure and crop residue on the soil fertility should be further tested in the future.

In June 2005, humus, nitrogen, and phosphate contents in 0-10 cm soil layer were analyzed (Fig. 7 and Photo 5). The results showed that the soil of pilot site had low organic matter content and very low to low phosphorus content (except the 1st field). On the basis of soil nutrient studies an agrochemical maps have been made (Annex Fig. 1, 2, 3 and 4).

3.2.2. Manure

Manure has been used for centuries as a fertilizer for farming, as it is rich in nitrogen and other nutrients which facilitate the growth of plants. Liquid manure from cattle and other animals is usually knifed (injected) directly into the soil to reduce the unpleasant smell. Manure from cattle is spread on fields using a manure spreader. Poultry droppings are harmful to plants when fresh but are valuable fertilizers after a period of composting. The dried dung of animals has been used as fuel throughout the history of mankind and it still is an important fuel source in the rural areas of Karakalpakstan. A large number of Karakalpak farmers are using green manure as fertilizer to be applied for the plant and also to improve soil fertility of their fields in their areas.

Studies have revealed that the application of manure brought a significant increase in grain and straw yield of wheat. The significant effect was also noticed on such yield contributing characters like spike length and number of grains per spike. The increase of manure level from 10 t/ha to 20 t/ha also brought a significant increase in yield and yield contributing characters (Table 8). The application of mulch or mungbean and sorghum resulted in significantly higher content of soil moisture in 0–15 cm soil depth as compared to the control which was simultaneously reflected in yield and yield contributing characters.

Each year (2005 and 2006) soil bulk density was studied on three fields of the project demonstration pilot site: 3, 6, 7 (Table 9 and 10).

During the year starting from sowing time onwards, bulk density in the beds increased by 0.19 g/cm^3, and in the furrow by 0.16 g/cm^3 while soil in the beds was less compacted than in the furrow (Table 9). Soil bulk density after 9 months went up in compacted soils according to physical properties of the irrigated soils of Uzbekistan (Umarov and Ikramov, 1983) which is satisfactory for growth and development of many crops.

Table 8. Organic manure, humus content, agronomic traits and winter wheat yield (2005-2006)

№	Treatment	Humus content, %	Plant height, cm	Spike length, cm	Grains per spike	Yield t/ha	Yield increase t/ha
1	Manure, 10 t/ha	0.35	52,1	7.15	32,5	2,24	0,61
2	Manure, 15 t/ha	0.28	56,8	7,4	33,2	2,31	0,68
3	Manure, 20 t/ha	0.35	62,6	9,2	35,5	2,49	0,86
4	Residue of mungbean, 10 t/ha	0.34	52,5	6,8	27,4	1,85	0,22
5	Residue of sorghum, 10 t/ha	0.31	48,8	6,4	24,0	1,59	-
6	Control	0.21	47,1	6,2	24,6	1,63	-

LSD_{05}-3,6; Sx%-6,6

The soil bulk density in the fields, which had been planted for 2004-2006 years with beds, and in fields under a regime of conventional tillage was compared. All fields were irrigated by floating method, and planted with different crops. The samples were taken just before the first spring tillage event in 2004 to eliminate the effect of recent management practices. In the beds, bulk density was lower than in furrow (Table 10). These data indicate that compaction may decrease in some cases when beds are retained with the minimum-tillage operations as compared with conventional practices.

Table 9. Bulk density of the surface layer of loamy soil for beds and furrows

Field №	Bulk density, g/cm^3 2004 (November)		2005 (August)	
	In furrow	On the bed	In furrow	On the bed
3	1.39	1.36	1.48	1.47
6	1.39	1.34	1.51	1.52
7	1.38	1.27	1.63	1.54
Average	1.38	1.32	1.54	1.51

Preserving of crop residue in the field (growing stage) positively influenced the bulk density in the upper layers of the soil. Many small secondary roots in the upper layer of the soil were found, which positively affected bulk density (Table 10).

As indicated before, the main terms in CA practices are creating of crop residue in the field with stubble stems and chopped straw, which provide full effect of mulching. Consequently, the salts will not be accumulated in upper layer of the soil due to decreased evaporation. Mulching with sorghum, mungbean crop residues and also with organic manure are decreasing the dry salt contents in 0-10 cm soil layer (Table 11). Soil mulching with plant residue and manure decreased the salt content in 0-10 cm soil layer up to 1.6-4 times.

The study on soil moisture showed that, soil dried up by the end of June in the conventional tillage, and soil moisture was better conserved in no tillage practices (Table 12). This shows that CA preserves crop residue on the soil surface, especially zero tillage, decreases bulk density, reserves soil moisture, decreases evaporation and reduces salt content in the upper layers of the soil.

Table 10. Bulk density in 0-10 cm soil layer as affected by crop residue

Field No.	Bulk density, g/cm^3	
	with residue	no residue
7	1.49	1,60
8	1.56	1,60
10	1.44	1,45
Average	1.49	1,55

Table 11. Dry salt content as affected by mulching

Treatment	% from air-dry mass of the soil
Control (no mulching)	0.80
Manure	0.25
Mung bean crop residue	0.50
Sorghum crop residue	0.20

Table 12. Soil moisture (%) as affected by the tillage method

Soil depth, cm	Conventional tillage before and after irrigation				Conservation agriculture with no irrigation			
	1 field		10 field		2 field		12 field	
	25 June	10 August	25 June	10 August	25 June	25 July	25 June	25 July
0-5	1.7	17,5	2,1	15,3	4,3	2,8	9,3	3,6
5-20	4.5	19,6	4,7	21,4	9,1	8,0	11,1	8,9
20-40	9.9	24,5	10,1	23,0	13,1	13,1	13,2	10,8
40-60	11.8	29,0	11,0	27	16,2	20,7	13,9	15,1

3.3. Crop Rotation

Multi-cropping offers much opportunity to provide additional production from present land resources. This system can be described as growing two or more crops in one growing season, utilizing climatic patterns in different geographic areas to increase total production per unit of land. The multi-crop potential may be the most important of today's modern agricultural developments.

Recent introduction of new technology such as the no-tillage system, herbicides and residue management offer an opportunity to increase double-cropping. Fuel for producing agricultural products has become expensive and no longer is available in unlimited supply. By using no-tillage and the multi-cropping technique, two crops can be planted with the same fuel required for one conventional crop. Fuel for harvest, processing and transportation would be higher than in single crop production owing to increased production and the extra harvest. Farmers and researchers agree that double-cropping can add grain or forage production in Karakalpakstan. Besides increased output, the overall cost of production is reduced. Equipment is used more frequently and labor requirements spread more evenly through the year.

As farmers move to double-cropping, timing of planting the second crop becomes limited along with pressures of harvesting the mature crop. The no-tillage system, by eliminating ploughing and preparation, reduces the time element while retaining soil moisture present, and reducing runoff, soil erosion and evaporation. These items are essential given the intensive cultivation characteristics of a multi-cropping system. Long-term advantages include improving or at least maintaining soil structure under the stress of planting and harvesting two crops every year. Besides, double-cropping plays important role in conservation agriculture as it allows covering land surface with crop canopy otherwise kept weedy fallow.

Crop rotation is an integral part of the crop production system. The greatest benefit to a good crop rotation is increased yields. A well-planned crop rotation will help in insect and disease control and will aid in maintaining or improving soil structure and organic matter levels. Using a variety of crops can reduce weed pressures, spread the workload, protect against soil erosion and reduce risk. Legume crops in the rotation have become more valuable with the increased cost of nitrogen. Research and experience have proved that a good crop rotation will provide more consistent yields, build soil structure and increase profit potential.

Within a crop rotation, different root systems influence different soil horizons and improve the efficiency of the soil nutrient use. In general, the soil structure becomes more stable (Bot & Benites, 2005).

The basic rule of crop rotation is that a crop should preferably not follow itself. Continuous cropping (monocropping) of any crop 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. For example, the practice of growing two or more years of cotton and wheat is becoming increasingly common. Perhaps, the greatest impact of back-to-back years of cotton has been the accelerated spread of cotton boll weevils. The increased number of years of cotton in the rotation is also increasing the susceptibility of Karakalpakstan's soils to erosion. In fact, the structure of soils in cotton-wheat rotations is actually poorer than that of soils that were previously in cotton-alfalfa crop rotations.

Besides the phytosanitary and weed management objectives, crop rotations serve to open different soil horizons with different rooting types. While conventional agriculture is “cultivating the land”, the CA by using science and technology to dominate nature tries to “least interfere” with natural processes.

Table 13. Wheat Yield Response to Rotation

Rotation	**Wheat grain yields (t/ha)**[1]		
	Kuvvat (2005-06)	**Ayap usta (2005-06)**	**Bakht (2005-06)**
Cotton-wheat	2.78	2.56	2.10
Cotton-sorghum-wheat	2.47	2.51	2.30
Cotton-sorghum-wheat (mungbean)	3.35	2.65	3.15

[1] All wheat treatments were fertilized with 140 kg/ha of N.

Table 14. Recommended various crop rotations and their potential negative impacts

Crop to be grown	Previous crop						
	Cotton	**Winter Wheat**	**Sorghum**	**Proso millet**	**Sunflower**	**Sesame**	**Legumes**
Cotton	**NR** • yield depression • vascular wilt and other root diseases	**C** • slugs may cause damage in no-till	• May increase density of rice stink bug *O. pugnax*	**R**	**C** • yield depression	**R**	**R**
Winter Wheat	**R**	**NR** • yield depression • root diseases	**C** • yield depression • weed escapes may be difficult to control	**R**	**C** • yield depression	**R**	**R**
Sorghum	**R**	**R**	**NR** • yield depression	**R**	**C** • yield depression	**R**	**R**
Proso millet	**R**	**R**	**R** • wireworms	**NR** • yield depression	**C** • leaf diseases • yield depression	**R**	**R**
Sunflower	**NR** • increased risk of Fusarium head blight	**C** • yield depression	**R**	**NR** • take-all • leaf diseases	**NR** • take-all • leaf diseases • yield depression	**R**	**C**
Sesame	**R**	**R** • slugs may cause damage in no-till	**R**	**R** • slugs may cause damage in no-till	**R**	**NR** • yield depression • root rots	**R**
Legumes	**C** • slugs may cause damage in no-till • check for herbicide carryover	**R** • check for herbicide carryover	**R**	**R**	**R** • slugs may cause damage in no-till	**C** • white mould	**NR** • white mould • blackleg • root rots • yield depression • check for herbicide carryover

Legend:	(**R**) Recommended	(**C**) Caution	(**NR**) Not Recommended

The greatest benefit from crop rotation comes when crops grown in sequence belong to totally different families. The response of wheat yield to crop rotation provides an example of the type of response to crop rotation that is possible (Table 13).

The fibrous root systems of cereal and forage crops (including mungbean) are excellent for building soil structure. Studies have shown that the benefits of including wheat, and especially wheat plus mungbean, may persist beyond just the following year. Double cropped mungbean after wheat resulted in yield increases compared to when mungbean was not included in 3rd rotation system.

In choosing the crop to grow, the economics of the entire crop rotation instead of a single crop in isolation should be considered. Also, one should be aware of any potential insect or disease problems that could affect crops later in the rotation. Cover crops in the rotation may also have an impact on diseases and pests, either positive or negative. Results in Table 14 show various crop rotations and their potential negative impacts and indicate various crop rotations that are recommended, cautioned against or not recommended depending on their impact on the crop production system. It is not a comprehensive listing of crop problems, but it does highlight the main impacts which one should be aware of.

3.4. Cover Crops

Cover crops are used to manage a range of soil macronutrients. For example, *Mucuna Pruriens* (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 (Vanlauwe *et al.* 2000).

Cover crops can do exactly what their name implies: cover the soil. Cover crops may play an important role in Karakalpakstan by providing ground cover to reduce erosion and by adding organic matter to improve the soil quality. They can also perform a number of other functions. A very important function is control of salinity. The soils of KK should never be left bare, and ideally there should always be some growing crop to avoid evaporation and replace it with transpiration.

A cover crop such as 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.

Cover crops known as “green manures” are grown and incorporated (by tillage) into the soil before reaching full maturity, and are intended to improve soil fertility and quality. They are commonly leguminous, meaning they are part of the leguminaceal (legumes) family. This family is unique in that all of the species in it set pods, such as common chickpea bean, lentil, lupins and alfalfa. Leguminous cover crops are typically high in nitrogen and can often, to varying degrees, provide the required quantity of nitrogen for crop production that might normally be applied in chemical fertilizer form (called fertilizer replacement value) (Thiessen-Martens *et al.,* 2005).

Cover crops can improve soil quality by increasing soil organic matter levels through the input of cover crop biomass over time. Increased soil organic matter enhances soil structure, as well as the water and nutrient holding and buffering capacity of soil (Patrick *et al.* 1957). It can also lead to increased soil carbon sequestration, which has been promoted as a mitigation strategy to help offset the rise in atmospheric carbon dioxide levels (Kuo *et al.,* 1997; Sainju *et al.,* 2002; Lal, 2003).

Although cover crops can simultaneously perform multiple functions in an agroecosystem, they are often grown for the sole purpose of preventing soil erosion, a process that can irreparably reduce the productive capacity of an agroecosystem. Dense cover crop stands physically slow down the velocity of rainfall before it contacts the soil surface, preventing soil splashing and erosive surface runoff (Romkens *et al.,* 1990). Additionally, vast cover crop root networks help anchor the soil in place and increase soil porosity, creating suitable habitat networks for soil macrofauna (Tomlin *et al.,* 1995).

The practice of sustainable agriculture is built upon soil fertility management and the protection of soil health. For centuries, farmers around the world have been employing these basic techniques to keep their soil productive. During the Soviet era, Uzbekistan researches guided the “kolkhozs” and “sovkhozs” in the use of alfalfa and the preservation of soil organic matter.

At the beginning of the 21st century, farmers are becoming increasingly conscious of the importance of soil health, water quality, and energy conservation. The rising cost of nitrogen fertilizers has revived interest in nitrogen-fixing legumes.
Legume cover crops can fix nitrogen for a subsequent crop. Organic growers often include this type of cover crop in order to produce nitrogen for the rest of the crop rotation. Some cover crop species are credited with making more phosphorous available to other crops through the action of the roots. Deep-rooted cover crops can bring nutrients up from deep in the soil profile.

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. Deep-rooted cover crops can help decrease the impact of soil compaction. Growing cover crops and working in the residues improves soil structure. Cover crops can be grown and the residues used to mulch the crop and help reduce moisture loss. In addition, some cover crop species can make quite acceptable hay or pasture under adverse conditions and a shortage of forage due to drought or winterkill.

Cover crops have an unparalleled range of potential to improve the sustainability of agro-ecosystems. Various forms of cover cropping have been utilized historically by different groups around the world. However, cover crops were popularized by the organic agriculture movement, which has been experiencing phenomenal growth as an industry. This exposure has attracted substantial cover crop research attention, and has led to the advancement of findings which are likely to provide some of the building blocks for the successful integration of cover crops into agro-ecosystems to ultimately improve their sustainability.

3.5. Bed Planting

Proper seedbed preparation and the selection of seeding rate are important management considerations for successful production of wheat and other agricultural crops in Karakalpakstan. Bed planting of wheat can be done to improve 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.

Most farmers practice conventional tillage by which the beds are destroyed after the harvest of each crop followed by several tillage operations before new beds are formed for planting the succeeding crop. This tillage is often accompanied by widespread burning of crop residues although some maize and wheat straw is baled-off for fodder and, when turn-around-time permits, some crop residues are incorporated during tillage. In addition, most farmers apply over 75% of the total N fertilizer to wheat (average N rate for wheat is about 275 kg N ha^{-1}) as an incorporated, basal application prior to planting which results in a low, apparent N uptake efficiency estimated to be about 30-35% (Meisner *et al.*, 1992).

In some articles that are published in foreign countries have given some recommendations for using progressive technology with water saving furrow irrigation technology.

The Yaqui Valley is located in the state of Sonora in northwest Mexico and includes about 255,000 ha of irrigated land using primarily gravity irrigation systems to transport water through fields from either storage reservoirs (over 90%) or deep tube wells (around 10%). Over the past 25 years, more than 95% of the farmers have changed from the conventional technology of planting most of their crops on the flat with flood and basin irrigation to planting all crops including wheat, which is the most widely grown crop on beds. Irrigation water is delivered through the fields by furrows between the beds, which range in width from 70-100 cm from furrow to furrow, depending on the distance between the tractor tires. Wheat yields for the Yaqui Valley have averaged over six tons per ha for the past several years (Aquino, 1998).

A single row is planted on top of each bed for row crops like maize, soybean, cotton, sorghum, safflower and dry bean; 1-2 rows per bed are planted for crops like chickpea and canola; but 2-4 defined rows, spaced 15-30 cm apart depending on bed width, are used for wheat. Even though most farmers still use conventional tillage, remaking the beds for each new crop, those that now grow wheat on beds obtain about 8% higher yields, use approximately 25% less irrigation water and encounter at least 25% less operational costs as compared to those still planting conventional tilled wheat on the flat, using flood irrigation (Aquino, 1998).

Raised-bed planting helps to save water in three ways: the soil conserves more moisture at planting, the crop is ready for harvest before the hot season arrives, and 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.

The bed planting system offers simplicity for field access that can be used to improve the effectiveness of many field operations including providing placement of fertilizers, especially N fertilizers, when and where they can be used most efficiently, easier application of herbicides (tractor wheels follow the furrows) and ease in rouging for seed multiplication. Bed planting provides an opportunity for natural, controlled traffic when tillage is reduced since all implements can be designed to track in the bottom of the furrows with only potential soil disturbance on the surface of the bed by the seeding operation, thereby concentrating compaction in the furrow bottoms and reducing compaction in the immediate area on the top of the beds where crops are seeded. The seeding of 2-4 defined rows of wheat on top of the bed as opposed to the solid seeding pattern normally associated with wheat and other small grains, 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 (Sayre and Ramos, 1997). Seed rates could also be reduced by a third, saving the farmer the cost of this valuable input.

In systems where surface irrigation is applied bed planting would provide the benefits of water saving. 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. However, the 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. In this way, a permanent bed system leads also to controlled traffic taking additional advantage of the resource conservation technology (RCT).

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 not only in Karakalpakstan but in whole Uzbekistan as well. Bed planting practices were started in the project pilot site in 2005 when the Indian bed planters were used on the project farmers' fields.

Table 15. Winter wheat yield (t/ha) as affected by planting method

Farm	Sowing method		Extra yield, (t/ha)	Reduced production cost, %	Water saving using bed vs flat, %
	On raised-bed, t/ha	Conventional, t/ha			
Satniyaz	2,75	2,50	0,25	28	25
Kipchakbay	2,62	2,41	0,21	24	27
Kuvvat	2,85	2,67	0,18	31	31

Bed width was 120 cm and three rows of winter wheat were planted. The winter wheat variety, Dostlik, was sown at a rate of 140 kg ha^{-1} for the 2005/2006 season. According to the results obtained, bed planting practices improve yields, increase fertilizer efficiency, reduce herbicide use, save seed, save on an average of 30% water, and reduce production costs by 25-35% when permanent beds were used. Widespread adoption of one or several of these reduced tillage methods will bring significant environmental benefits (Table 15).

Table 16. Sorghum yield (t/ha) as affected by raised bed planting

Farm	Sowing method		Extra yield, (t/ha)	Water saving using bed vs. flat, %
	Raised bed, t/ha	Conventional, t/ha		
Satniyaz	4,11	3,69	0,42	25
Kipchakbay	3,73	3,42	0,31	24
Kuvvat	3,57	3,12	0,45	32

It is common that 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 (Blevins *et al*., 1984).

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 16.

Water savings, as indicated are significant and range from 24-32%, which is an extremely crucial issue in the conditions of Karakalpakstan.

The estimated variable costs for the conventional tilled beds and the permanent beds using the current 2005/2006 production cost estimates were calculated. Average variable production costs were 27% higher for the conventionally tilled beds compared to permanent beds. Here also, a comparison of the returns over variable costs for the average yield of comparable management practices for both conventional tilled and permanent bed was made. Average returns over variable costs were 75% higher for the permanent beds. When the comparison was made using the highest yielding treatment in each tillage system, the returns over variable costs were 48% higher for permanent beds. Both the agronomic yield performance results as well as the economic comparisons clearly demonstrate the striking advantages of the new permanent bed technology, and the verification/demonstration module were managed on a large enough scale (nearly 1 hectare per plot) to readily convince farmers.

The bed planting system for wheat and other crops has not been widely adopted by farmers in Karakalpakstan including project demonstration site in Chimbay. The results reported here indicate that extensive tillage with its associated high cost and long turn-around-time can be dramatically reduced by the use of permanent beds. The results, however, also indicate that retention of crop residues may be essential to ensure that the required enrichment of critical levels of the chemical, physical and biological soil parameters, that are crucial to ensure long-term production sustainability, can be achieved. Farmers must clearly realize that some residue retention will be essential before they attempt to adopt permanent bed planting systems even though the primary goal may be to simply realize lower production costs associated with tillage reductions.

3.6. Laser Land Leveling

Laser land-leveling is really a laser-controlled land-leveling. The idea of moving soil to level land is very old (although in agriculture most of the time we are talking about putting a smooth surface with a specific slope on the ground). 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. Instruments can be made that respond to the energy of a laser beam.

A laser-controlled land-leveling system could be described as follows. A rotating laser light source (like a miniature lighthouse) is located somewhere in the field. As the laser rotates rapidly, a virtual "plane" of light is produced in the field (Photo 7). A "receiver" is mounted on the leveling equipment and connected hydraulically to the actual earthmoving blade (Photo 8). When activated, the receiver (and thus, the blade) will "lock on" to the laser source, thus, providing a smooth surface. If the earthmover has to climb over a high spot in the field, the blade will dig in as the receiver tries to stay locked onto the laser source. If the earthmover goes over a low spot, the blade will lift up, again keeping locked onto the laser source, and dump soil into the low spot If the rotating source is tilted according to the prescribed grade, a grade can be installed in the field. Laser setups like this are also used to quickly survey fields.

Photo 7. A rotating laser light source.

Photo 8. A receiver is mounted on the leveling equipment.

Again, the source is set up in the field. A receiver is mounted on a truck with a stationary staff gauge. As the truck drives over a preset grid, the receiver will move up or down as it stays locked on the laser source. The movement of the receiver against the stationary staff gauge is then read to record the differences in elevation throughout the field.

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. But if the money is to be spent for laser land-leveling, it is advisable to install the best irrigation gradients. Also, one must consider the placement of any tailwater 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 (i) improves crop establishment, reduces weed problems, (ii) improves uniformity of crop maturity, (iii) decreases the time to complete tasks, and (iv) reduces the amount of water required for land preparation (Rickman J, F. 2002).

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 leveling for agricultural crop production. Zero-grade fields can be flushed or drained more quickly.

According to the approved FAO technical workplan, the soil preparation for planting winter wheat started from sub-soiling and laser-levelling. In Chimbay district, cotton is the most widespread crop grown continuously. In the project site, farmers agreed to plant some winter wheat after cotton on 13 ha. Before landleveling activities in the cotton field, cotton stubbles were removed by hand to ensure quality of land-levelling work. On the “Satniyaz” farm, carrot field was cleaned by hand before ploughing of ground surface of soil.

Water saving

With sprinklers, a perfectly leveled 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. The quality of land-leveling in zero-slope fields can be estimated through the standard deviation (SD) of soil surface elevation.

Increase in yield

The Laser-leveling of fields helps in increased yields by 10%. This increased yield should help the farmer as an additional income.

Other benefits

Apart from above, other benefits of Laser-leveling include weed control, labour saving, time saving, land saving, etc. as described earlier.

4. EFFECT OF CONSERVATION AGRICULTURE TECHNIQUES ON SOIL AND WATER CONSERVATION

4.1.1 Effect on Soil Erosion and Salinity

Almost everybody recognizes that soil erosion is harmful, but few realize the extent of its harmfulness. Certainly, there are costs to society for clean-up and repair from soil and its constituents polluting the water and air. However, the greatest costs are borne by the landowner and producer. 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 (i) shallow, (ii) poor quality subsoils, and (iii) without a thick topsoil. Any combination of these characteristics greatly increases the damage from erosion. Deep soils with better subsoil properties are virtually unaffected by soil erosion. More fertilizer would be required to replace the fertility loss, but the production potential would change little, if any. However, most soils have some undesirable properties which lower production, since erosion causes more subsoil to be incorporated into the plow layer.

Erosion removes a field's original topsoil, causing the subsoil to mix with the remaining topsoil during annual plowing. In mature soils (like much of those in Karakalpakstan), 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. As more and more of the subsoil is mixed into the topsoil by tillage, it adds more and more of these characteristics to the topsoil.

Soil erosion removes the lighter and more easily dislodged particles. This means that organic matter is one of the more easily erodable constituents. Moderate erosion of a sirosem soil in Karakalpakstan was found to have reduced the topsoil organic matter content from 1.7 to 1.5 percent.

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

The most limiting factor on crop production in Karakalpakstan is water. Erosion usually reduces the plant available water holding capacity of a soil. In a study of project demonstration pilot site field number 6 and 7 soils, the plant available water holding capacity decreased from 29 to 24% in the 6^{th} field soil and from 24 to 20% in the 7^{th} field soil because of erosion of project fields. Two things cause this reduction in plant available water holding capacity --a shallower soil and more undesirable soil properties. As the clay increases and organic matter decreases, the amount of water a soil can make available to the plant decreases. This is probably the single most important effect of erosion on soil productivity.

Soil erosion removes the part of the soil which is usually richest in plant nutrients. Erosion on soils which are highly fertile, naturally or by fertilizer addition, will result in greater fertility losses. All nutrients are lost during erosion but the most economically significant losses will probably be that of nitrogen, phosphorus, potassium.

If the soil is naturally low in fertility, then erosion will cause a loss of the added nutrients and increase the fertility requirements of the soil. The 6^{th} field at project demonstration pilot site Chimbay, which is naturally low in fertility, was studied to determine the effect of moderate erosion. More fertilizer would be required to raise and maintain the soil test when erosion is allowed to occur as the greater the erosion, the greater would be the fertility loss. It has been estimated that the value of plant available nutrients lost from a highly fertile soil in project demonstration pilot site could range from $3 to $14 per hectare (considering 2006 fertilizer prices and a soil loss of 14 tons/hectare). It is difficult to put a real value on the soil nutrients lost due to erosion as it depends on the soil fertility level and the availability of the nutrients in the soil. Regardless, 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 the productivity of many soils by affecting the soil properties and depth. This reduction is substantial and long-lasting, and can not be reversed over a lifetime, even with conservation management, low intensity use or high fertility amendments. The most important yield-limiting effect of erosion is probably the decrease in plant available water holding capacity. The soil fertility status may be significantly decreased by erosion but can be replenished by additions of lime and fertilizer, although with greater expense and lower efficiency than for the uneroded soil. The overall effect of erosion is an economic loss which accumulates with time as erosion continues. The cost of erosion, over time, will probably outweigh any costs associated with erosion control practices.

4.1.2. 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, further limiting plant access to soil water. An experiment was conducted to examine the effect of salt on plant available water in a heavy clay soil, using a relatively salt-tolerant variety, sorghum, 'Boy jo'khari' and a more salt-sensitive variety, wheat 'Dostlik'. The plants were then grown in the salt-affected field. Once permanent wilting point was reached plants were harvested, and soil water content was measured.

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 m^3/ha water was saved (Figure 8).

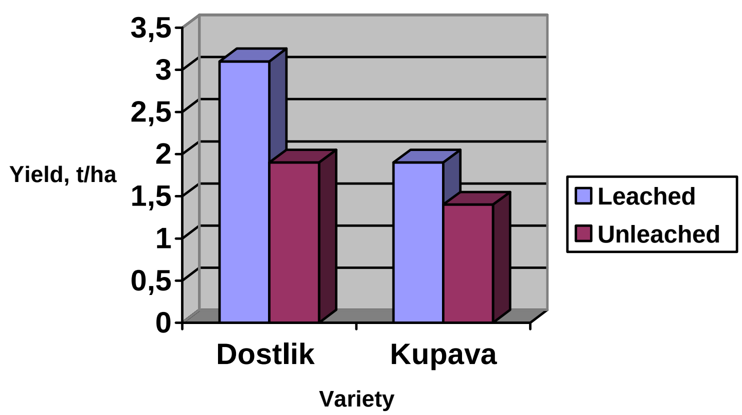

Fig. 8. Yield (t/ha) of wheat varieties Dostlik and Kupava in farmers' field with and without soil leaching.

5. MACHINERY FOR CONSERVATION AGRICULTURE

5.1. No-till Seeders

New machinery for sustainable agricultural practices (three no-till planters from Brazil) was provided by the project to the farmers who are located in the project demonstration pilot site. Machinery data for the weight approximately is 810 kg.

Row crop version for precision planting

A set for sunflower planting is as follows: number of lines 4; spacing, 60 cm; seed rate, 16 kg/ha; fertilizer, 125 kg/ha. Speed: for row crops the speed should be maximum 6 km/h to avoid seed breakage. It can be slower, with difficult residue high speed helps cutting, but more than 6 could break seeds.

For each row there is a unit comprising seed hopper, metering mechanism including the drive mechanism and a line of furrow openers. The planter can accomodate 5 row crop units in total. In case some rows are not used, for example for maize, the entire hopper of the not used unit (with the seed metering disk) should be removed to avoid wear. The not used furrow openers should also be removed. 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 for each row. 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 (non-used 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.

Seed metering system for row crops - precison planting

When doing the calibration for precision planting, which requires a precise number of seeds per hectare, the correct setting of the planter is of fundamental importance for obtaining an appropriate final stand for the crop to be established, considering the variety to be sown, the germination power (GP) and the energy of the seed. Another factor of utmost importance to obtain 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 center 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 (Photo 9 and 10).

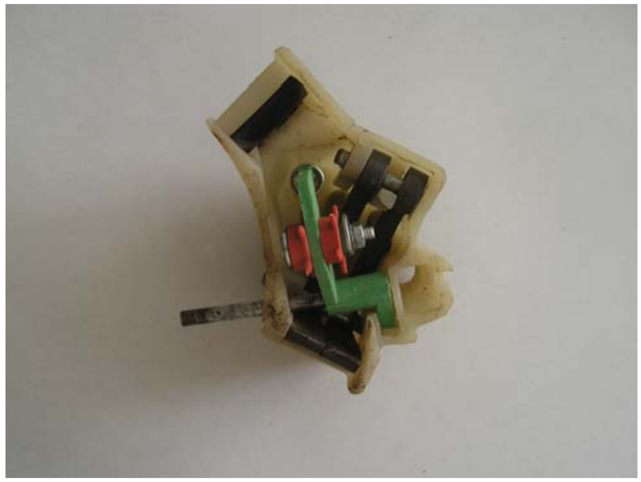

Photo 9. Seed cases assembly and wheels changing.

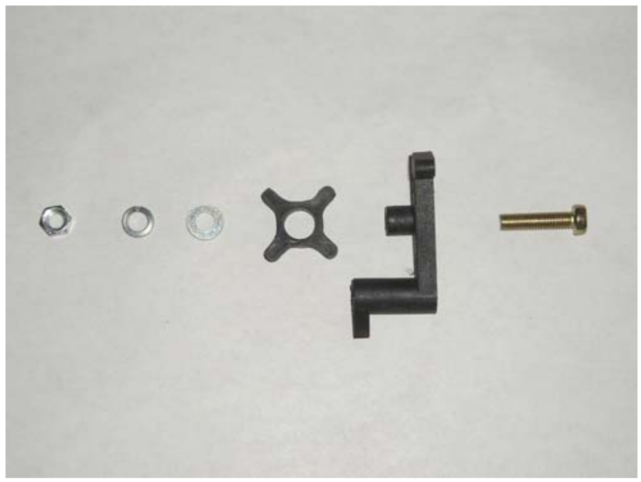

Photo 10. Wheel model to be planted corn and sunflower seeds.

The plant population or number of plants per hectare can be calculated for the planting (Table 17).

Table 17 Calibration calculation

Item	
Number of plants by linear meter	N
Final population for hectare (estimated)	50.000 plants
Spacing between lines (cm)	60 cm
1 hectare	10.000 m^2
Seed germinating power (G.P.)	96 %
Approximate skidding percentile	5%
Wheel perimeter	1.76 m

1 ha = 10.000 m^2 ________________50.000 plants
*10.56 m^2 _______________ Calibration area for 10 wheel turns in sqm

*10.56 m^2 = Spacing X wheel perimeter X number of wheel turns
*10.56 m^2 = 0.60X1.76X10

10.56m^2X50.000

10.000
N=90m=3 plants/linear meter
**17.6=wheel turns X perimeter 1.76
Germinating Power Correction (Percentage)
N=3 plants/linear meter ____________96%
N____________100%
Skidding Correction (Percentage)
N=3.125 plants/linear meter __________ 100%
Correction ___________5%
N=3.28
3.28 is the number of plants/linear meter that should be used in the sowing regulation

Sets for wheat planting

The usual range of available opener spacings is from 15 to 20 centimeters, 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 sidewards 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 18).

Table 18. Calculations to determine the amount of seeds in kg/ha (as an example)

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%

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

200X17X93/10000=0.31g/m^2

200 kg/ha ______________ 10000 m^2
X_____________ 2.99

*2.99m^2: Spacing x wheel perimeter x number of wheel turns *2.99m^2: 0.17 x1.76

X =200kg/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
Germinanating power correction (Percentage)
59.8 grams ____________93%
X____________100%
X=64.3 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.

5.2. Bed Planters

A raised-bed planter includes a planter body having three furrowers 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.

The furrow–irrigated and raised-bed technology was tested in Karakalpakstan (at Chimbay project pilot site). The seedbed was prepared conventionally and raised-beds and furrows were prepared using a machine that makes 2 beds (120 cm width) in each pass. It is possible to plant 3 rows of a crop on each bed. In this technology, the seedbed is prepared conventionally, whereas the raised-beds and furrows are prepared using a raised-bed-planting machine.

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 cultivation 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; these were found during the use of the bed planter in the farmers’ field to plant different agricultural crops. The advantages of the bed-planting practices 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
- Avoids temporary water-logging problems
- Allows subsurface basal and top dress fertiliser placement, reducing nitrogen
- Promotes rainwater conservation

The bed planter is good and suitable for mounting in the all tractors used in Karakalpakstan. 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. Taking into account the above-mentioned one Indian bed planter was provided to Karakalpak Research Institute of Farming to redesign.

5.3. Weed and Pest Control

The application of agro-chemicals is necessary to achieve higher and economical production. However, as it is a work that can bring risks to the human beings, environment and crops, a concern is always true to properly use a boom sprayer in an efficient and safe way. In CA practices, application of chemicals is critical issue because no tilled-land will tend to be weeded. Available sprayers in Uzbekistan are not suitable for use in CA because all the available sprayers are adapted for use in cotton fields. Herbicide application at the rate of 4-5 l/ha was done to control weeds before the vegetation period of wheat with the use of boom sprayer.

5.3.1. 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/cm3 (10 to 60 psi), normally used on herbicide application. The second stage is for calibration from 4.2 to 10.5 kg/cm^3 (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 sparyer can be calibrated through the formula below:

Calculating the sprayer volume

V= F x 600/S x 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= F x 600/S x A (l/ha) V= 0.68 x 600/0.5 x 4 (l/ha) V= 408/2(l/ha)= 204 l/ha

6. WATER USERS ASSOCIATION

A Water Users Association (WUA) is a self-managing group of farmers working together to operate and maintain their irrigation and drainage network, to ensure fair and equitable water distribution, and to increase crop yields. Establishment of WUA encourages greater participation of farmers in management decisions; ensures greater water-use efficiency through increased productivity per water unit, and greater participation of farmers in the operation and maintenance of irrigation systems.

Efficient irrigation is necessary to increase agricultural production in Karakalpakstan. Under the FAO-supported project a new WUA named as “Shokharik”was established to increase agricultural production. Composition, Terms of Reference and Operational Modalities of the WUA of the Shokharik canal was prepared in Russian language and was approved by 23 member farmers, who are members of the Shokharik WUA. The project implementing team believed that newly created WUA is the basis for increasing agricultural production and effectively managing water resources on irrigated lands. The project team applied a comprehensive approach to increasing efficiencies along the entire crop production and processing chain towards improving the productivity and profit margins of project demonstration pilot site farmers as members of WUA.

The main parameters of the “Shokharik” canal are presented in table 19. The linear circuit and profile structure of the canal is presented in Annex Figures 5, 6, and 7.

Table 19. The main hydraulic characteristics of the Shokarik canal and its water points

Name of the canal	Flow discharge, м3/s	Length, km	Width on top, m	Depth, m	Water intake
Shokarik	6.0	22	11	1.7	71
Maiyab	0.6	4.2	6	1.3	17

The length of Shokharik canal is 22 km and all its structures are of non-engineering type. It is poorly reinforced and overgrown with aquatic plants and weeds. There are two water distributors, which take water from two sides: both from the Shokharik main canal and from the Maiyab sub-canal. The two canals supply water for 162 ha of the farms of the project pilot. The other site of the irrigated area is taking water straight from the

Shokharik and Maiyab sub-canals by means of construction of temporary ditches (Figure 7).

A WUA should be capable of managing cost-effective irrigation services and an agricultural system capable of commercial production. Farmers also need to be able to evaluate the crops to be planted that would best reflect the quality of soil, the cost of inputs (seeds, fertilizer, labor, machinery, and pest management), and the availability of water. Learning that water delivery has a cost and deciding how to apportion that cost burden helps farmers make rational decisions that affect farm income. A business-oriented approach was taken in the project involving a number of technical and business improvement strategies to help the WUA master specific technical skills, acquire market knowledge and approach farming as a business.

7. ASSESSING THE POSSIBILITIES FOR IMPROVING CONSERVATION AGRICULTURE PRACTICES IN THE REGION

7.1 Physical Potential

The soil density is very high in the area, and, thus,plowing 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.

Because of the wide variation of conditions in sal- and drought-affected regions of the Karakalpakstan, the results of research and development in other countries need to be understood with concern. In the most common situation of existing knowledge and information being inadequate, programmes of research and development must include and bring together both the components of research within disciplines, and on-farm research on sustainable agricultural farming systems. There is little doubt for the CA practices to be adopted by the farmers in their conventional farming system.

7.2 Social possibilities

It is increasingly recognized that a complete understanding is required of all the social and economic results of the CA farming system in order to guide component research into topics and techniques which will be applicable. Collecting information and its understanding is particularly difficult in the case of farming systems in salt- and drought-affected regions of the Karakalpakstan. 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 can be no doubt that studying the whole of the CA system is fundamental to any consideration of the possibilities for sustainable agricultural development in the region.

8. WORKSHOP AND TRAINING ACTIVITIES CARRIED OUT

A two day Awareness Creating Workshop for FAO-TCP was conducted during 13-14 May 2004. It included a Meeting on 13 May in Nukus involving FAO technical officers, all stakeholders, visit to potential project sites, a Workshop at the selected site Chimbay on 14 May including plenary session and group discussions. In this Workshop twenty three officials from different organizations and 20 farmers participated.

A mid-term workshop on Sustainable agricultural practices was held from 6-7 December, 2004 in Nukus under the FAO-TCP Project and field days were conducted during 6-7 December in 2004 in Nukus. In this workshop, all National Consultants, ten scientists, and 20 farmers and members of water user associations attended to discuss the workplan and review the progress achieved.

A Formal Training Course on Conservation Agriculture Practices in Karakalpakistan was held from 23-24 February in Nukus. In total twenty nine participants from different institutions have been participated.

A formal training course for farmers on Conservation Agriculture with the presentations of the main results achieved within the framework of the Project implementation was organized in Chimbay in June 25-26, 2005. About thirty people, mostly of them were farmers, participated at the seminar.

Three Field Training courses and nine field days were organized according to project workplan to bring together participating and neighbor farmers, extension agents and researchers in the field to observe and discuss key field demonstrations.

A two day Field Training Course was conducted during 13-14 April 2005. It included a Meeting on 13 April in Nukus involving all stakeholders, visit to provide practical courses in the field of world conservation agriculture practices at the selected site Chimbay on 14 April including participatory working with no-till equipment and field day discussions. FAO experts Drs T. Friedrich, J. Benites and G. Munoz have participated in the training course and they have been given lectures world conservation agriculture practices.

Another field training course was organized from 24-25 June 2005 in Chimbay to discuss new improvement irrigation methods and the new machines of conservation agriculture practices used in the project by farmers in the project demonstration site and in the Chimbay district. In first day, national consultants of the project made presentations on the base of obtained results of conservation agriculture practices in project site and some world conservation practices. The second day of the training course was devoted to practical courses in water improvement technologies and operation, maintenance of a Brazilian boom sprayer. A total of 52 participants attended.

On 7 December 2004, field day and creation of WUA were organized in Chimbay and 35 farmers and representatives and stakeholders attended in K.Auezov farm association's office including instructors Mr. R.Koshekov, Mr. Jorge Rotermund, Drs. A.Novikova, V.Shaposhnikov and A.Nurbekov.

On 24th of March 2005, the field day was organized with participation of around 30 members of WUA. Also, around 10 mechanization specialists from the different organizations of the Chimbay district have been participated.

On 14th of April 2005, FAO experts, national consultants, project farmers and WUA members conducted a Field day in the project demonstration site in Chimbay. Participants of the field day divided into three groups: mechanization led by Dr. T. Friedrich, soil quality led by Dr. J. Benites and water management led by Dr. G. Munoz.

On 2 June 2005, a field day was conducted in Chimbay, with 42 participants including members of Shokharik WUA, pilot farmers and neighbor farmers.

A field day was conducted in 12 August 2005. The field day was devoted to improved soil leaching practices.

On 17 September 2005, a field day was organized to discuss new planting methods and new machines of conservation agriculture practices used in the project with farmers in the project demonstration pilot site. National consultants of the project made presentations on the base of obtained results on conservation agriculture practices in project site.

A one day field day was organized 11 August, 2006 in Chimbay (Karakalpakstan) under the FAO-TCP Project on conservation agriculture by the ICARDA Regional Office in Tashkent in cooperation with Ministry of Agriculture, Karakalpakstan and SANIIRI. In this field day, 42 farmers, specialists and scientists participated including representatives from ICARDA, Ministry of Agriculture and Water Resources of the Republic of Karakalpakistan, Chimbay District Farmers Association, Research Institutions, WUA. Mr. Jumanov Turdibay , Head Grain Department Ministry of Agriculture and Water Resources of the Republic of Karakalpakistan, chaired the opening session.

Field Day of TCP FAO Project "Sustainable agricultural practices in the drought-affected region of Karakalpakistan" took place in Chimbay, 12 October, 2006. A total number of 55 participants from 37 farms, agriculture research institutes participated to the field day. The participating institutions are the Chimbay district farmers, Karakalpak Research Institute of Farming, Nukus branch of Uzbek Research Institute of Rice, Central Asian Research Institute of Irrigation (SANIIRI), Nukus of SANIIRI, and Nukus Branch of Tashkent State Agrarian University. The participants were nominated by their respective institutions.

A traveling workshop to Khorezm, Bukhara and Tashkent has been organized to study experience on water saving and soil conservation technologies in farming systems. In the traveling workshop twenty participants were in attendance. They were very impressed with conservation agriculture and irrigation practices at a Tashkent UzCase Model farm.

Wrap up workshop

The wrap up workshop on conservation agriculture/no-till bed-planting technologies for crops production was conducted at the Nukus Branch of SANIIRI, Nukus, and project farm Kipchakbay, Satniyaz, Chimbay district, 4-5, September, 2007. Experts and scientists from FAO, Uzbekistan, lectured about CA (bed-planting systems, zero technologies and equipment) for crop production, demonstrated seeders for direct sowing, knife-rollers, sprayers, trained farmers on express-methods of soil quality assessment. The representatives of Chimbay, Amudarya, Ellikkala districts farms, of the Karakalpakistan Farmers' Association, the Ministry of Agriculture and Water Recourses, international centers and organizations, representatives of UNDP-Uzbekistan, GTZ and scientists and experts attended at the seminar. More than 60 people took part at the seminar.

9. BENEFITS OF CONSERVATION AGRICULTURE

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

- 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, as evidenced by the results from trials in the project demonstration pilot site.
- Reduced soil erosion, both from water and wind, due to the protection of the mulch and the absence of pulverised soil. In the results reported in this bulletin soil erosion was reduced by 45%, even with manual (hand-hoe) weeding which caused considerable movement of the soil surface. Generally, reported reductions in soil erosion with CA are much greater.

Longer-term benefits (may take 3-5 years or more to be evident)

- Increased soil organic matter (SOM) content due to the reduced rate of decomposition of crop residues and plant roots (tillage results in rapid decomposition) and the continual incorporation of organic matter into the soil by fauna and flora.
- Increased nutrient availability and soil water-holding capacity due to the increased SOM.
- Improved soil structure due to the lack of tillage, increased SOM and improved soil aggregation.
- 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.

Problems with Conservation Agriculture

- Weed control in the early years after 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 difficult for researchers and extension agents who have expounded the need for intensive tillage.
- 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. Most research and extension systems are managed on a linear knowledge flow model rather than participatory networks.

- 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. Therefore, it does not function well on poorly drained soils where it may worsen waterlogging problems.
- Ground cover with crop residues is paramount for the success of CA. It will not work where crop productivity is too low to achieve appreciable levels of ground cover.

10. CONCLUSIONS & RECOMMENDATIONS

10.1. Conclusions

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

- 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 the tillage methods, it was 8 % less in no-till than the tilled method of planting.
- There were no differences between the yields of no-tillage and conventionally-planted wheat in on-farm trials during the two years. The yields were not very high in both cases which is explained by rather high soil salinity levels.
- In both the years of 2005 and 2006, a split N application of 70-50 in March and April was a better combination than the 60-60 split. The fall N treatments were not helpful. The two-year average shows that the fall nitrogen application treatments tended to lower wheat yield.
- Wheat yields for all weed management practices exceeded 2.0 tons per hectare in 2006. The yields of plots receiving a herbicide treatment were similar and were at least 0.7 t/ha greater than the yields of no-till wheat where no herbicide treatment was used. The two-year averages for wheat yield tended to be less with Puma super applied in the spring compared to other weed management practices.
- Fungicide applications were provided for intensive production on all the treatments although no differences were observed in diseases among the treatments.
- 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.
- Both mungbean and sorghum were successfully no-tilled after the two tillage systems in which wheat was grown. The mungbeans can be double-cropped after wheat, and sorghum was planted in the next spring before wheat planting in the fall. These crops were harvested for yield to determine if the wheat tillage systems had an effect.
- A study on the protease activity of the soil in August 2005 showed that, protease activity of the soil with crop residue was higher than in the fields without crop residues
- Identified new crop rotations 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.
- The results also indicate that 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. Farmers must clearly realize that some residue retention will be essential before they attempt to adopt permanent raised-bed planting systems even though the primary goal may be to simply realize lower production costs which is common with tillage reductions.

- New machinery (3 no-till planters from Brazil) for use in sustainable agricultural practices provided by the project to the farmers which are located in the project demonstration pilot site.
- The raised-bed planter is good and suitable to be mounted on the all tractor types used in Karakalpakstan. 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.
- The WUA of Shokharik canal is established. A WUA need to be capable of managing cost-effective irrigation services and an agricultural system capable of commercial production. Farmers also need to be able to evaluate the type of crops to be planted which best reflect the quality of soil, the cost of inputs (seeds, fertilizer, labor, machinery, and pest management), and the availability of water. Learning that water delivery has a cost and deciding how to apportion that cost burden helps farmers make rational decisions that affect farm income.
- Zero tillage and raised-bed plating technologies tested in Karakalpakstn proved to be suitable for local conditions and can provide similar or higher crop yields but saving considerable resources including fuel, seeds and labor.

10.2. Recommendations

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

- In CA practices the main terms are creating of crop residue in the field with stubble stems and chopped straw, to provide full effect of mulching. 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 used to mulch the crop and help 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 some adjustments to be used for local soil and climatic conditions. Local manufacturing of conservation tillage equipment should be organized.
- Both types of crop diversification as single crops and double crops will be essential to improve sustainability of farming and income generation at the local, regional and national levels.
- It will be helpful if the Government would encourage the CA practices to enhance agricultural production of salt- and drought-affected regions, which are extremely important issues in Uzbekistan.
- Make a Special State decree on “Support the development of the zero till and direct planting practices in the Republic of Karakalpakistan” for wider adoption and increased effectiveness of CA.
- Prioritize the training programs and focus on no-till, raised-bed practices and their development and improvement, etc.

- Local agricultural research scientists should be more actively involved in developing CA technologies for different cropping systems

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ANNEX FIGURES

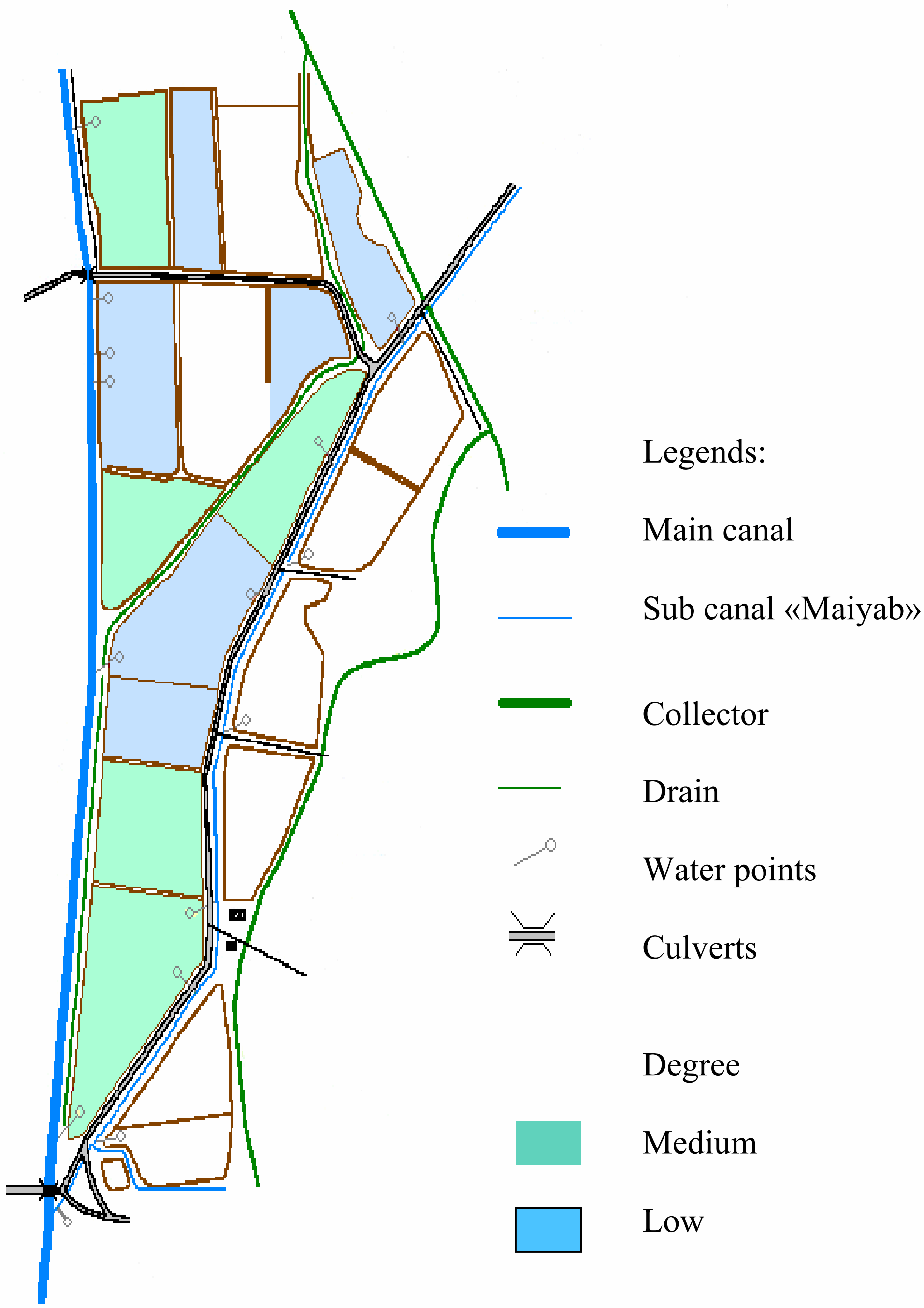

Fig. 1. Agricultural chemistry map of active forms of phosphorus in 0 – 40 cm layer of soil.

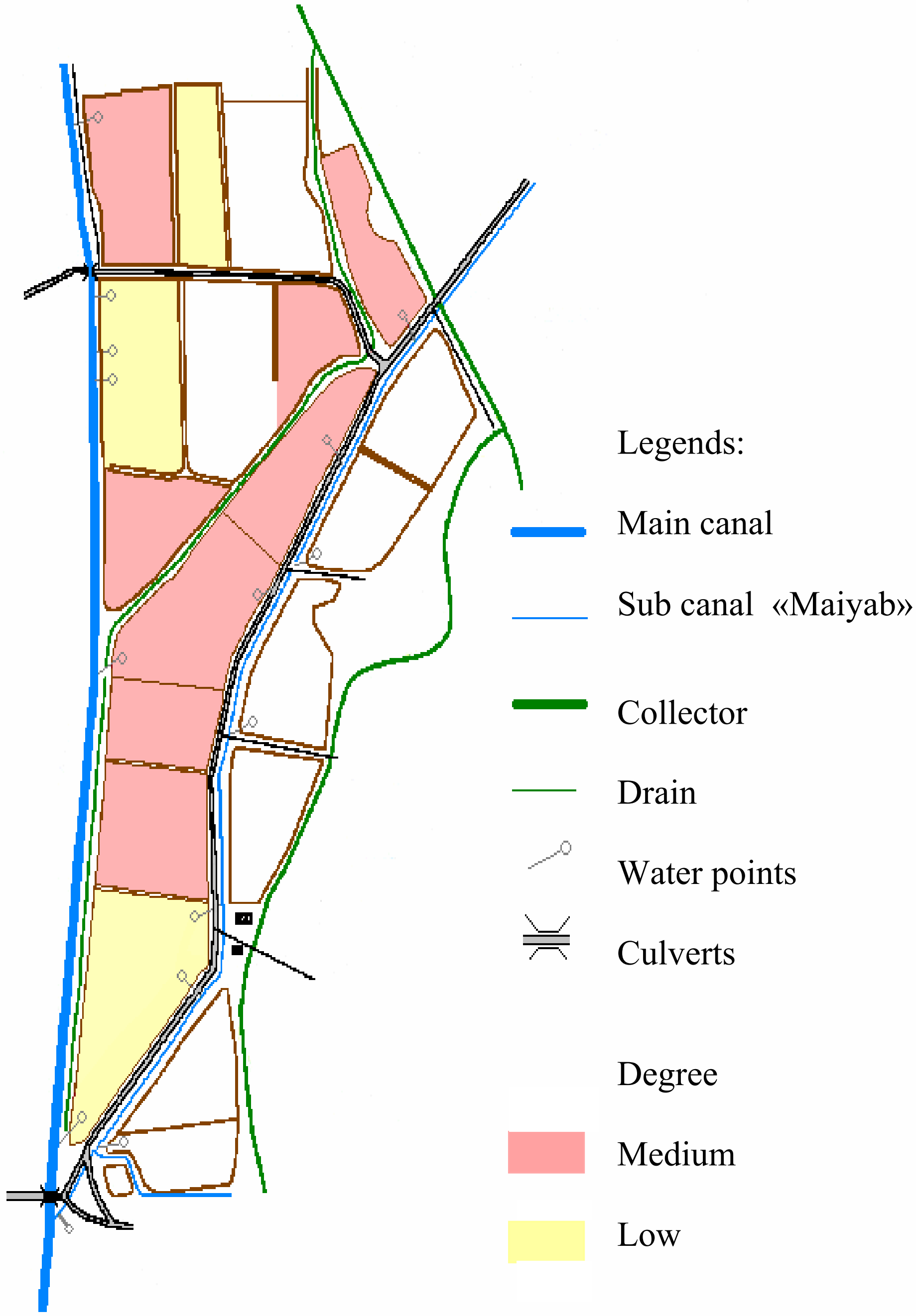

Fig. 2. Agricultural chemistry map of active forms of potassium in 0 – 40 cm of layer **of soil.**

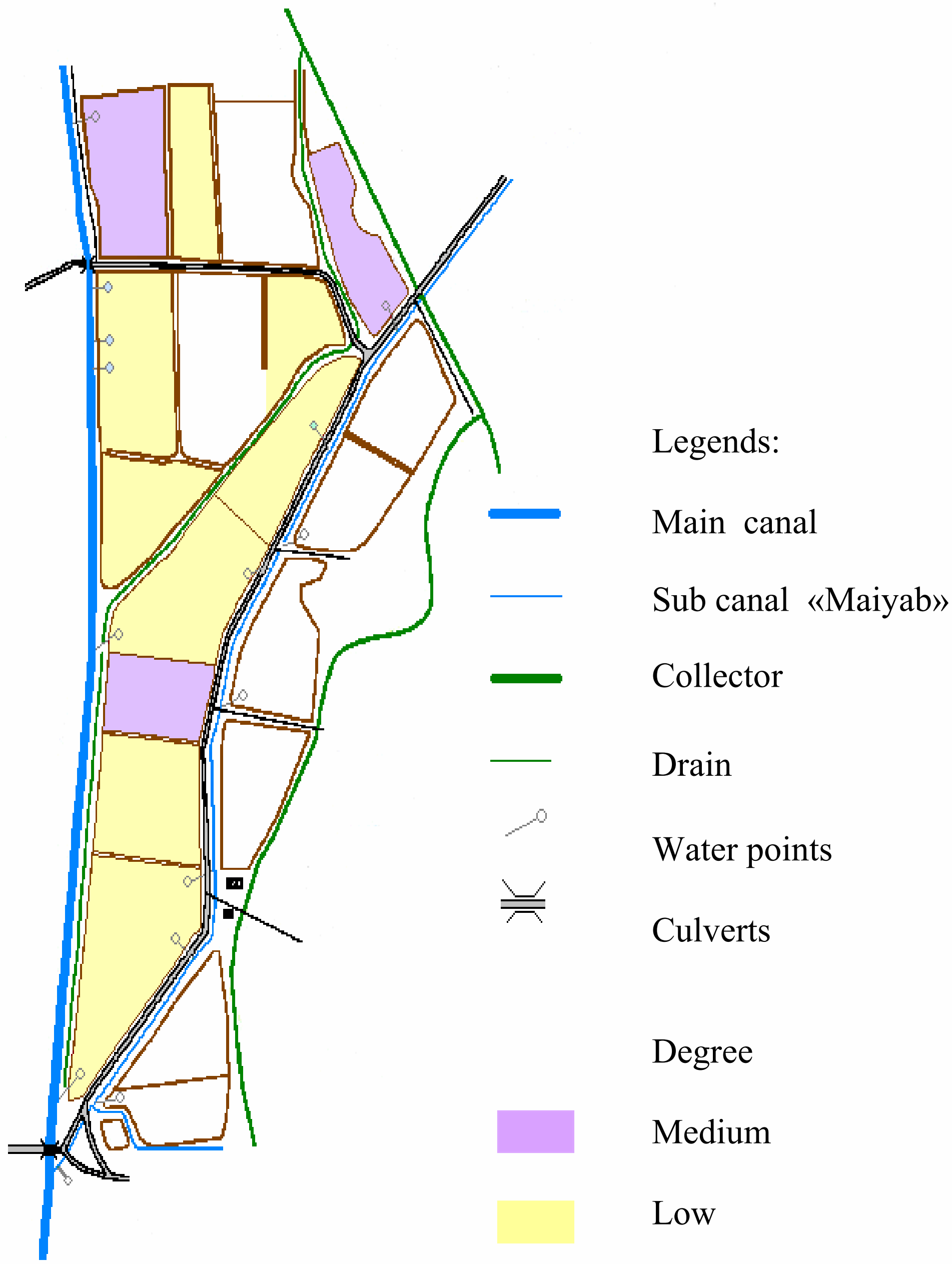

Fig. 3. Agricultural chemistry map on humus content in 0 – 40 cm layer of soil.

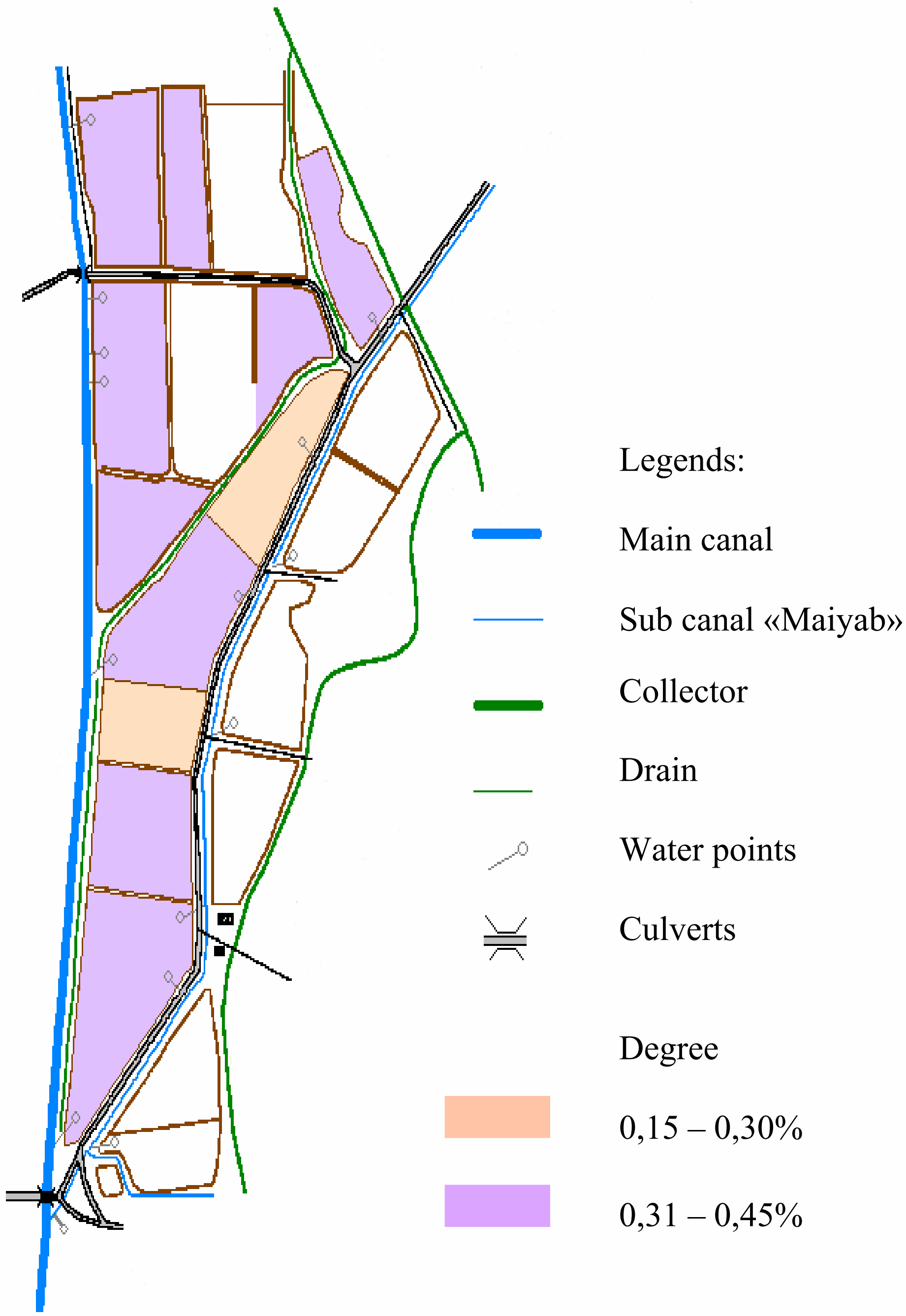

Fig. 4. Agricultural chemistry map on total nitrogen content in 0 – 40 cm layer of soil.

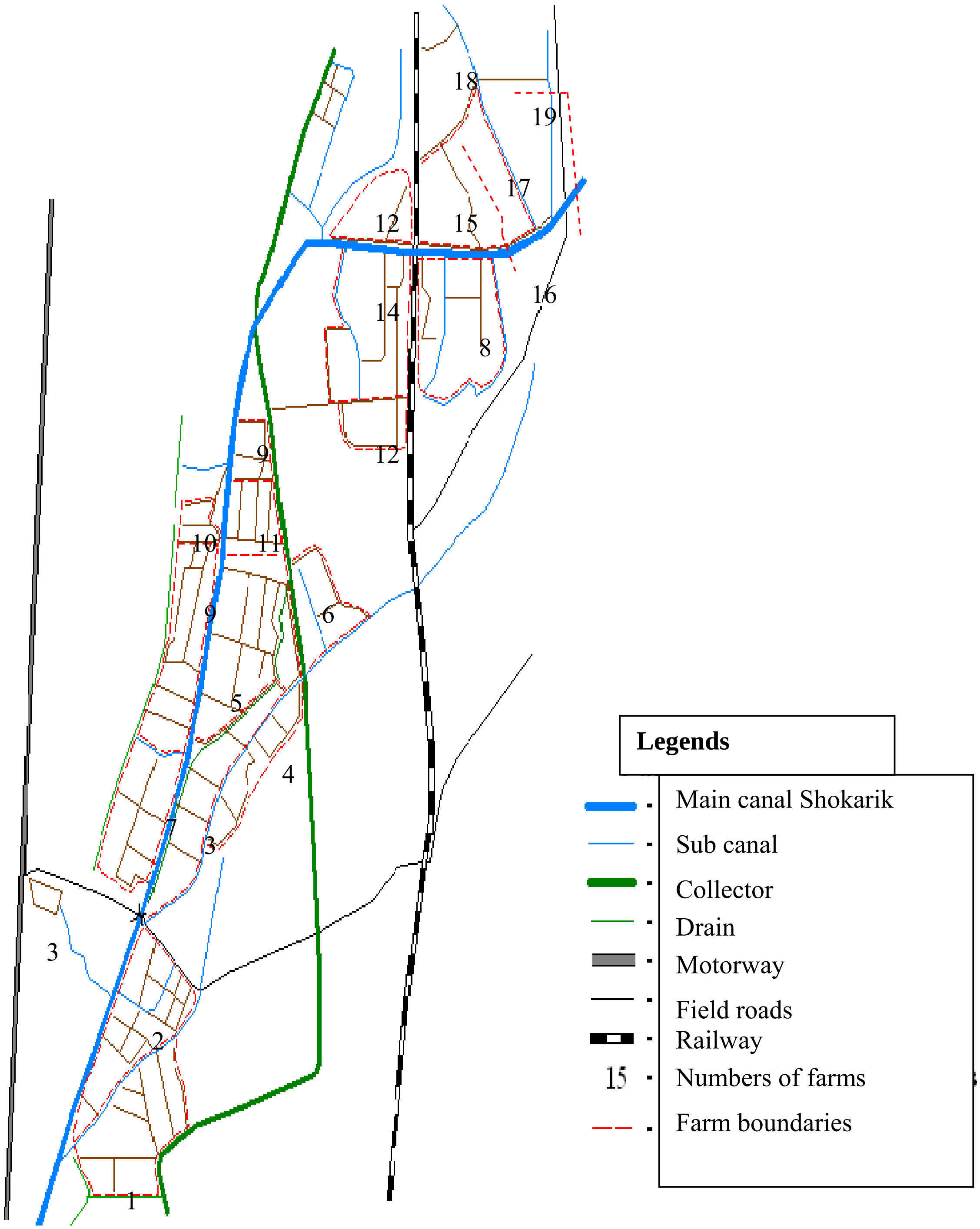

Fig. 5. Map of the demonstration farm and its location in the K. Avezov named after Farm Association of Chimbay district.

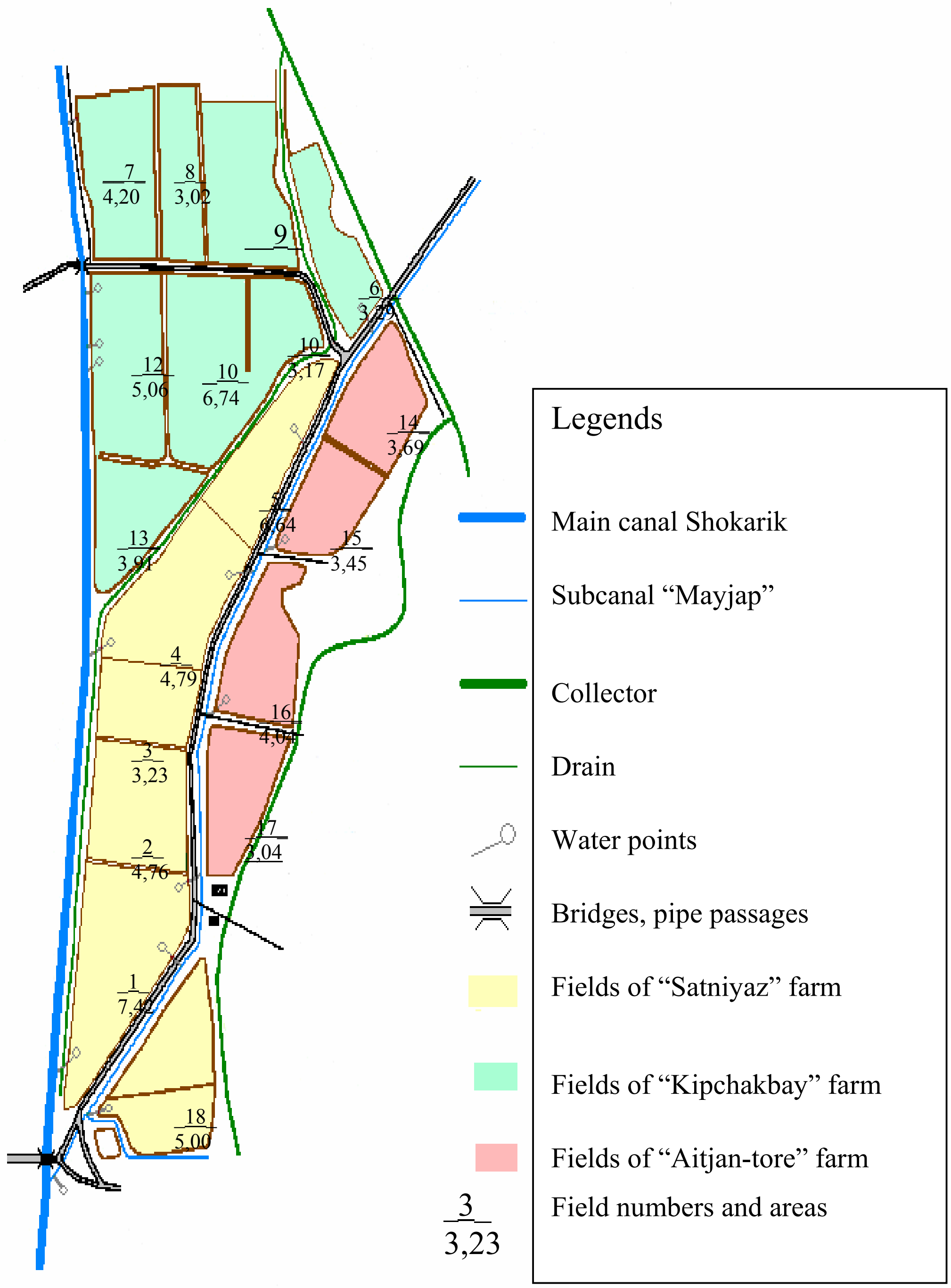

Fig. 6. Map of the demonstration site.

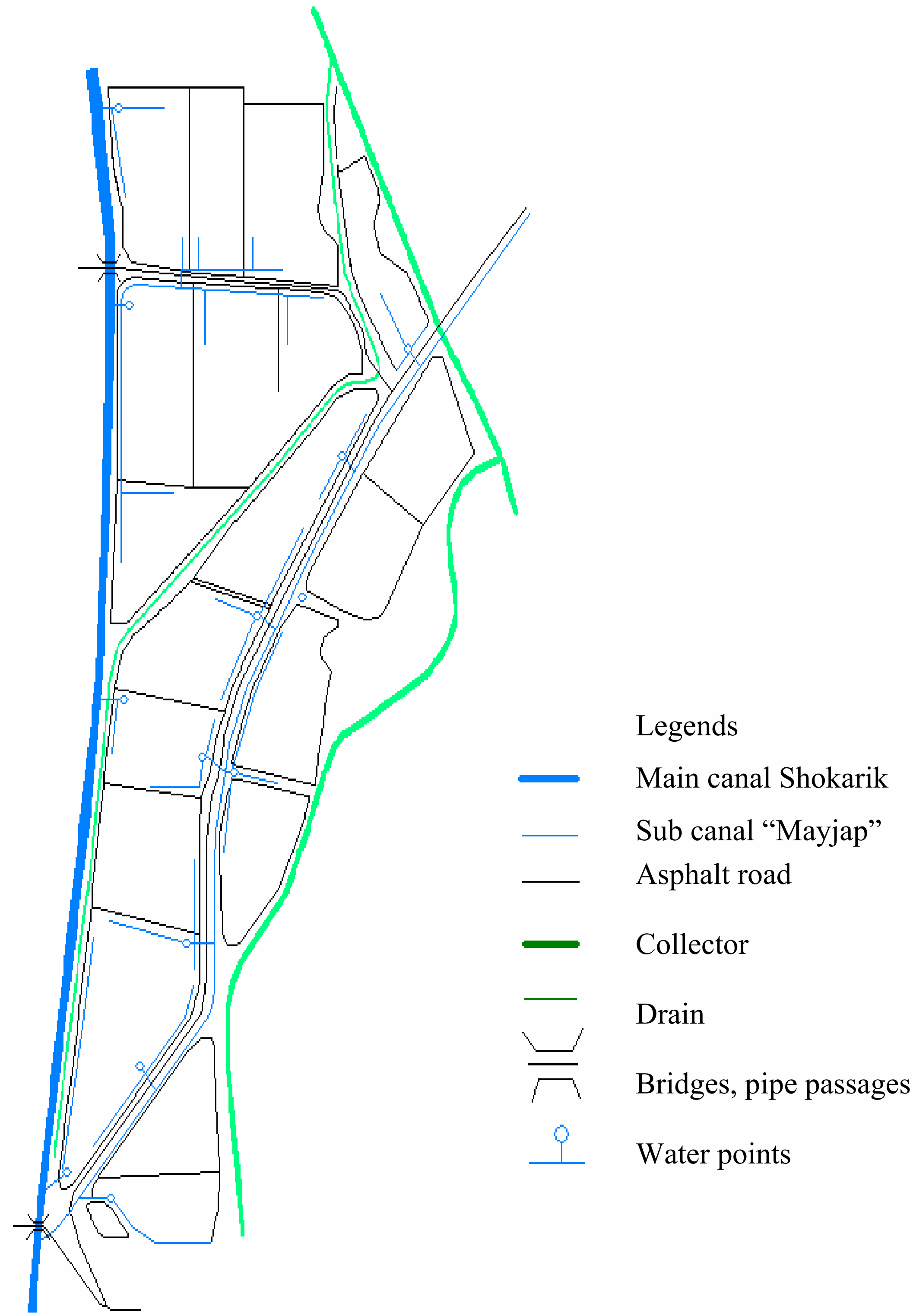

Fig. 7. Map of temporary ditches.