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Conservation Agriculture in Irrigated Areas of Azerbaijan, Kazakhstan and Uzbekistan

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Executive Summary

This project, implemented by ICARDA and funded by FAO-Turkey Partnership Program, provides convincing evidence for farmers and policymakers to adopt conservation agriculture (CA) in Central Asia. For instance, as a result of this project, irrigated areas under conservation agriculture reached 1,800 ha in Azerbaijan, 1,100 ha in Kazakhstan and 2,050 ha in Uzbekistan in 2013.

The following conclusions and recommendations resulted from this project:

- No-till maize, sunflower, winter wheat in Azerbaijan and Kazakhstan, and no-till mung bean and winter wheat in Uzbekistan under irrigation provided yields comparable to those obtained through conventional and reduced tillage.
- Permanent bed planting technologies proved to be suitable under irrigated conditions and provided similar or higher crop yields. The main benefit of bed planting is water saving. Improving water use efficiency is an important contribution towards achieving food security in this region.
- The economic assessment of technologies was based both in quantitative and qualitative methods of analysis. Among those technologies, the application of no-till practices and bed planting of winter wheat, new crop rotation options with inclusion of legumes in cropping systems, etc. were found to be useful for increasing farmers' income and improving their livelihoods.
- Local no-till drill development is absolutely essential for up-scaling of conservation agriculture practices in the region and manufacturing of no-till drill should be organized. It is recommended that a project proposal on the development of no-till drill in the region be formulated and implemented.
- The availability of affordable and appropriate CA equipment for the specific farming conditions is critical.
- Both types of crop diversification as single crops and double cropping systems will be essential to improve the sustainability of farming and income generation at the local, regional and national levels.

The most important recommendation stemming from this project was that the Governments of the Central Asian countries need to be assisted in the formulation and implementation of national strategies for the adoption and promotion of CA.

1. Introduction

In Azerbaijan, Kazakhstan, and Uzbekistan there have been enormous changes in the agricultural sector since the break-up of the Soviet Union in 1991. The economic transformation has led to the conversion of large state and collective farms into small private farms. This transformation has resulted in numerous challenges for the farmers, including the reduced availability of affordable agricultural machinery and other production inputs. Ongoing efforts for economic and agricultural development are striving to overcome these obstacles and achieve national food security by intensively investing in strategic crops.

However, poor agricultural land management has resulted in the degradation of soil resources throughout Central Asia, which is a threat to the sustainability of agricultural production. Conservation agriculture (CA) presents options to counter this threat of degradation and rehabilitate agricultural land so that productivity and ecosystem services can be sustainably enhanced. CA can help address a broad variety of challenges, including food insecurity, poverty alleviation, rural livelihoods, rising costs of energy and production inputs, natural resource management, resource scarcity, and climate change.

With the goal of improving rural livelihoods and food security through increasing the productivity of irrigated farming systems in Azerbaijan, Kazakhstan and Uzbekistan by using the principles and practices of CA, the Government of Turkey and FAO signed an agreement setting up an FAO/Turkey Partnership Program (FTPP) in mid-2006. The FTPP had an annual trust fund contribution of US$2 million over an initial period of five years (2007– 2011).

The results of these experiments provide valuable examples, data, and economic assessments. The dissemination of this information will not only help the farmers involved in these studies, but also benefit the communities. This knowledge can also be adapted and used by other countries with similar agroecosystems.

2. Selection criteria and analysis of the project demonstration sites

2.1. Selection criteria of project sites

Based on local agricultural conditions, the selection criteria were developed for each country during national seminars held during February-March 2011. These selection criteria included area of farms, knowledge level of farmers about conservation agriculture, interest of farmers to work in the project, access to market, etc.,. During the national seminars, the project was briefly introduced to the local stakeholders. This was followed by discussions on project sites, selection criteria, crop rotations and equipment to be purchased. Sometimes these discussions turned controversial, but overall they were constructive. Specific project farms were agreed upon by the regional coordinator, project team, and local counterparts.

2.2. Analysis of the project sites

2.2.1 Characterization of selected project demonstration sites in Azerbaijan

When Azerbaijan achieved independence, agricultural land was given to individuals who are now allowed to own small private farms and sell their farm products in the local markets. Some are even allowed to export them abroad. There are also a few state owned farms. Agriculture in this country is traditionally based on high water consuming crops. Water shortages are recorded during the summer in many regions, including the Tartar and Barda districts that were selected for the project field demonstration.

Project sites were selected in Tartar and Barda districts of Azerbaijan. The Tartar and Barda sites are located in the Karabakh steppe in the southern subzone of the Ganja region. Long term mean rainfall ranges between 300-400 mm and occurs mostly in November-December (winter) and March-April (spring). There is almost no rain between July and September. The climate is continental with an average annual temperature of 13.4^{0}C. Summer temperatures sometimes surpass 35°C and the average temperature in January is around 3°C.

One of the main constraints to increasing agricultural production is limited irrigation water. The irrigation and drainage infrastructure have been deteriorating since the country's independence in 1991. Before independence, overall maintenance of the canals occurred approximately every three years. Since independence, canal maintenance has been erratic and insufficient. Irrigation water flows constantly into most canals up to the medium level during the irrigation season. This results in high water losses. Water is provided to farmers for free and they do not participate in the management of the irrigation scheme.

In the late 1980s, Ganja region was one of the leading regions in Azerbaijan that produced cotton, wheat and canned fruits. After independence, the crop rotation system has changed. Currently, main crops in the production system are cereals, cotton, vegetables, potatoes, fruit trees and forage.

2.2.2 Characterization of selected project demonstration sites in Kazakhstan

Project demonstration sites were selected in South Kazakhstan (SK) province. Agriculture has long been a major contributor to Kazakhstan's economy. Most of the farmland is privatized prior to independence in 1991. Farms are owned by agricultural enterprises/individual farmers, several agricultural co-operatives, joint-stock companies and limited partnerships and a few are owned by state-owned enterprises.

Climatic conditions of SK are very diverse, comprising steppes, hot and dry semi-deserts. The climate is continental, with hot temperatures and low air humidity in summer and cold winters with low snow fall. Average frost-free period lasts for about 225 days. The average daily temperature is 16.9°C. June through August are the hottest months with temperatures rising to 40°C. January and February are the coldest months when temperature dips to -35°C. The long term annual precipitation level is around 350 mm, but rainfall can strongly vary each year. Precipitation starts during the end of September and early October. The highest precipitation is observed in winter and spring seasons (78 percent) followed by autumn (18 percent) and summer (4 percent). Low precipitation level permits only irrigated crop production.

Water scarcity has remained one of the most important issues in the irrigated crop sector of the South Kazakhstan province. With its shallow groundwater level and saline soils, the province is in need of water-saving technologies and efficient irrigation systems for diversified cropping systems. Currently, grain crops such as winter wheat are grown continuously after wheat or winter barley, which is not a sustainable crop rotation system. In most cases, wheat and barley are irrigated by flood irrigation resulting in crop loss due to rise of highly mineralized ground water and soil crusting.

The crop production sector is dominated by cereal crops, mostly wheat, which accounts for 66 percent of the total crop output. Other important crops in this region are fodder crops, potatoes and vegetables.

2.2.3 Characterization of selected project demonstration sites in Uzbekistan

After achieving independence in the year 1991, Uzbekistan placed great emphasis on agricultural growth and efforts to develop its own market economy. During this transition, large inefficient *shirkat*[1] farms were disintegrated and a number of small farms were established. Therefore, technologies that use high inputs may not be suitable for these small farms.

Kashkadarya province, where the project demonstration sites were selected, is located in southeast of the country, in the Kashkadarya River Basin and on the western edges of the Pamir-Alai Mountain Range. Continental, partly subtropical and dry are the three types of climates in this province. Winters are warm followed by long, hot summers. Average long term precipitation ranges widely between 100 and 450 mm in the foothill, mountain and desert zones. The main river is the Kashkadarya River with its numerous streams originating from the mountains. The average annual air temperature is 16.8°C. During the year, temperatures can vary from 1.2°C in January to 31.7°C in July.

The main agricultural crop is cotton followed by wheat, barley, rice, maize and potatoes. Fruits and vegetables are also important crops. The agricultural output of the province makes slightly more than 10 percent of Uzbekistan's total agricultural production.

3. Field Activities within each country

3.1. Field activities in Azerbaijan

3.1.1 Effects of planting methods on productivity of winter wheat (Triticum aestivum) varieties in the irrigated conditions of Karabakh lowlands

Effects of planting methods were observed on the productivity of winter wheat (*Triticum aestivum*) varieties in the irrigated conditions of Karabakh lowlands. The objectives of this experiment were to test at least two methods of planting on three winter wheat varieties in irrigated conditions, and adopt the bed planting systems to irrigated conditions of Karabakh lowlands in order to intensify wheat production in the Republic of Azerbaijan.

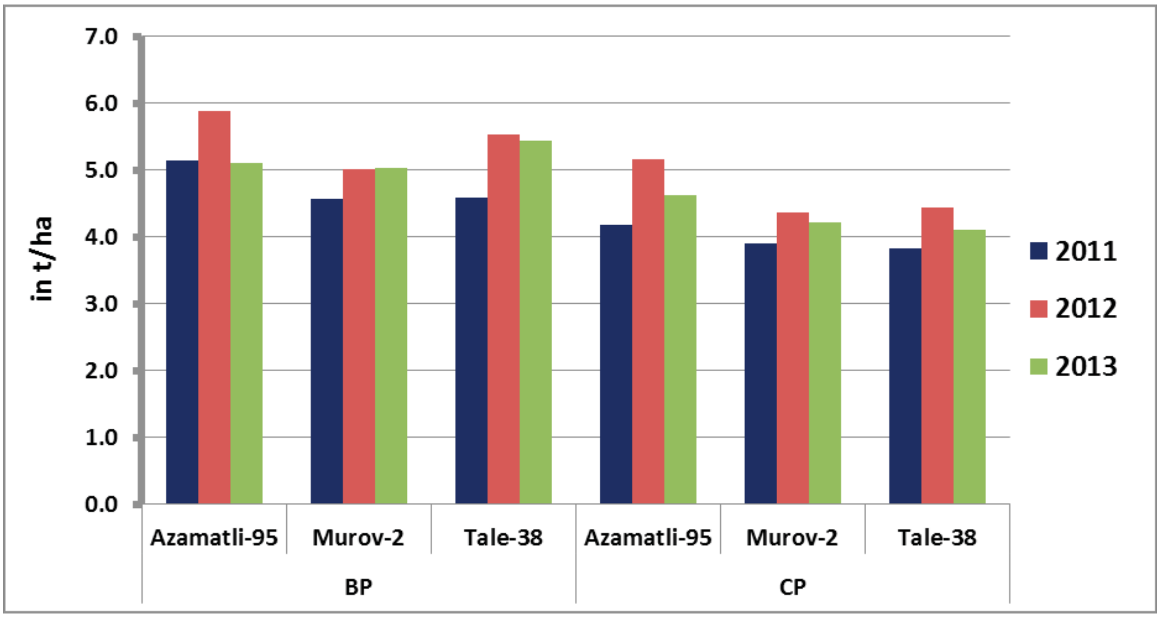
[1] Shirkat farms are agricultural cooperatives

Results of bed planted winter wheat (*Triticum aestivum*) were compared to conventional planting in this research. Soil bulk density at the demonstration site was lower and more adequate on raised beds: 1.18, 1.21 and 1.22 g cm^{-3} as compared to more compacted soil: 1.28, 1.26 and 1.30 g cm^{-3}, respectively. Crop growth was much better and advanced by 5-6 days on bed planting. Water used for irrigation was reduced on raised bed planting by 13 percent – 1780 m^3 ha^{-1} on control site as compared to 1550 m^3 ha^{-1} on bed planting. Water use efficiency was 25 percent higher at raised bed planting amounting to 2.90 kg m^{-3} as compared to 2.32 kg m^{-3} on control site.

The high tillering winter wheat variety Azamatli-95 had maximum grain yield (5.88 t ha^{-1}) in 2012 in bed planting, while variety Tale-38 had the lowest grain yield (3.82 t ha^{-1}) in 2012 in conventional planting (Figure 1).

Photo 1: Bed planted winter wheat variety Azamatli-95 at tillering and flowering stages in Azerbaijan

Figure 1: Productivity of Bed planted (BP) compared to conventional planted (CP) winter wheat varieties



Bed planting was found to be more profitable than conventional planting for growing winter wheat due to higher yields and savings in planting costs obtained under raised bed planting; bed planting generated 13.33, 38.22, and 73.37 percent more revenues than conventional planting in all the three varieties, respectively.

Table 1: Cost benefit analysis of winter wheat varieties under conventional and bed planting methods 2013 (US$ ha^{-1})

	Winter wheat varieties					
	Azamatly-95		Murov-2		Tale-38	
	Conventional planting	Bed planting	Conventional planting	Bed planting	Conventional planting	Bed planting
Yield (t ha^{-1})	4.6	5.1	4.2	5.0	4.1	5.4
Total production value (US$ ha^{-1})	1018.6	1124.2	926.2	1108.8	904.2	1196.8
Total production cost (US$ ha^{-1})	567.3	612.7	567.3	612.7	567.3	612.7
Net benefits (US$ ha^{-1})	451.3	511.5	358.9	496.1	336.9	584.1
Profitability rate (%)	100.0	113.3		138.2		173.4

It was concluded that bed planted winter wheat variety Azamatli-95 had maximum grain yield as compared to other winter wheat varieties in this research because this variety had highest tillering capacity than others. It shows that high tillering winter wheat varieties can be suitable for bed planting practices. Economic assessment of this research showed that bed planting is more profitable than conventional planting for growing winter wheat.

3.1.2 Short term crop rotation system in irrigated conditions through the application of conservation agriculture technologies in Karabakh lowlands

An experiment was carried out to study short term crop rotation system when using CA practices. The three different treatments included: continuous winter wheat (Ww), winter wheat + soybean + winter wheat + soybean (WwSbWwSb), and winter wheat + corn + wheat + corn (WwCWwC). All treatments involved direct seeding of second crops after winter wheat harvest under stubble mulch.

It was found that wheat yields were higher with the WwSbWwSb treatment than with the Ww and WwCWwC rotations (Photo 2). Moisture content for growing winter wheat in irrigated conditions depends a great deal on the preceding crop or if the land was left fallow (Table 2). Water storage before sowing winter wheat was found to be very low when it was in continuation with wheat. It improved after cereals, but after legume crops soil moisture accumulation was the highest (almost one and a half times more than control).

Table 2: Soil moisture content as affected by preceding crop to wheat (in %) (2012)

Soil layer, cm	Wheat after wheat		Wheat after corn		Wheat after soybean	
	Seeding	Harvest	Seeding	Harvest	Seeding	Harvest
0-10	9.2	7.5	11.2	11.8	14.1	12.1
10-20	9.7	7.8	12.8	12.5	15.5	13.5
20-30	11.5	10.2	14.5	13.1	17.1	14.1
30-40	10.2	9.5	16.8	13.2	20.3	18.3
40-50	10.0	9.1	17.2	14.1	17.8	16.9

Weed infestation is not only common in CA, but CA also causes a change in the dynamics of weed growth that are already present in the traditional production systems. Crop rotation helps to suppress weeds, but development of an appropriate strategy is needed for CA. The findings of this experiment showed that weed infestation was remarkably lower when wheat was grown after cereals. This was because of efficient weed control during cereal growing period, and also because wheat tillering capacity and plant growth was high due to better moisture availability. Breaking the cycle of continuous wheat growth and interspersing it with legumes cultivation has changed the weed growth situation dramatically. Weed numbers after legumes crops were almost three times lower as compared to the wheat-after-wheat cycle (Table 3).

Table 3: Weed numbers in winter wheat stand as affected by preceding crop (pieces per m^2)

Preceding crops	Wheat stage	
	Tillering	Full maturity
Wheat	120	43
Corn	84	21
Soybean	63	16

The wheat–legume rotation resulted in the highest winter wheat yield and better yield components compared to Ww and WwCWwC rotations (Table 4). The winter wheat grown on the legume rotation yielded 25.1 percent more than winter wheat grown on the cereal rotation. Winter wheat grown on cereal rotation yielded 10.8 percent more than winter wheat growing on wheat stubble. Wheat yielded more on legume than stubble with significant effects of crop rotation. Higher winter wheat yield was achieved when legume crops were used as second crops. It can be explained by the fact that legume crops can fix nitrogen and improve soil fertility. More information is needed concerning the effects of diversification of cropping systems to choose the right legume crops to be included in crop rotation.

Photo 2: No-till corn at V8 and R1 stages[2] in Azerbaijan

Table 4: Effect of rotation on winter wheat yield

Crop rotations	Land use efficiency, %	Plant height, cm	Height difference, %	Winter wheat yield, t ha^{-1}	Yield differences, %
WW	50%	110	100.00	4.50	100.0
WCWC	100%	105	95.79	4.99	110.8
WSBWSB	100%	101	91.99	5.88	125.1

Grain yield in continuous wheat cycle (4.50 t ha^{-1}) was the lowest because plants had the least amount of soil moisture and were competing with large number of weeds. Winter wheat grain yield following other cereal was 10.8 percent higher compared to continuous wheat yield (4.99 t ha^{-1}). However, when wheat was rotated with legumes its yield was the highest: 5.88 t ha^{-1} or 25.1 percent more as compared to wheat after wheat. Weed control seemed to be an important factor in support of replacing cereals with legumes in the rotation cycle. The wheat–legume rotation in this experiment seemed to be the best practice in the irrigated conditions of Azerbaijan. Also, short term crop rotation can improve land use efficiency in the irrigated areas that are extremely important in this country. Short term wheat-legume crop rotation under no-till practices can

[2] Corn stages determined according to the method developed by Abendroth et al., 2011

be recommended for farms in Azerbaijan. Many aspects of crop rotation and second cropping are compatible with current crop rotation practices in the country and could become more accessible to farmers if government policies are restructured to reflect the true environmental costs of agricultural production.

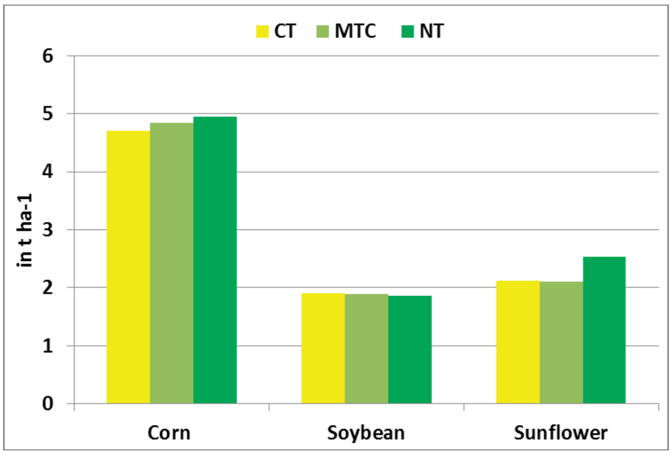
3.1.3 Effects of tillage on productivity of corn, sunflower and soybean in the irrigated conditions of Azerbaijan

Impacts of tillage on the productivity of corn, sunflower and soybean were studied in the irrigated conditions of Karabakh lowlands. Tillage treatments include conventional tillage or plough (CT) as control, minimum tillage with chiseling (MTC) and no-till (NT) respectively.

Photo 3: No-till sunflower (L) and minimum till sunflower (R) Azerbaijan

It was found that tillage systems had a significant effect on the yields of corn, soybean and sunflower grown on stubble (Figure 2). Some crops better adapted to no-till practices than others. For instance, in the case of sunflower, yield with no-till increased by 19.33 percent as compared to conventional till and minimum till with chiseling. In comparison, soybean yield remained similar in all the cases of tillage treatments but saved up to 70 percent fuel for planting of all crops. In the case of corn, yield was not greatly affected by tillage systems. With no-till treatment, yield of corn was recorded to be 4.95 t ha^{-1}, whereas with conventional till it was 4.71 t ha^{-1}. Similar trends were observed for both corn and sunflower (Photo 3), however tillage methods did not seem to have any significant effect on the grain yield of soybean (Figure 2).

Figure 2: Effect of tillage on corn, soybean and sunflower yields in Azerbaijan, 2011-2013



From the study results, it can be concluded that corn, soybean and sunflower yields are less affected by the different tillage methods; the obtained yields were similar across treatments.

3.1.4 Effects of traditional and bed planting technologies on winter wheat yield and water use efficiency

To identify the best planting method for increasing winter wheat yield while decreasing water consumption in the irrigated conditions of Karabakh lowlands, impacts of traditional and bed planting technologies were studied. Treatments included traditional and bed planting practices with two irrigation rates.

It was observed that the main benefit of bed planting is water savings. Almost all farmers reported 30-35 percent less irrigation time. Therefore, under high production situations, bed planting exceeds the yields possible on the flat bed (Nurbekov, 2008). Results of the current study were in accordance with the results of Fahong et al. (2004) in China, where results displayed an improvement in the water use efficiency by 21–30 percent combined with an approximate 17 percent savings in applied irrigation. Water use efficiency was significantly higher with bed planting (2.36 and 2.11 kg m^{-3}) as compared to conventional planting (1.67 and 1.85 kg m^{-3}) (Table 5). The grain yields were less conclusive; on farm 1 a significantly higher grain yield was observed with the bed planting method during both the years, while on farm 2 not much difference was observed.

Table 5: Effect of traditional and bed planting on winter wheat yield and water use efficiency

Farmers	Treatments	Yield, t ha^{-1}		Water rate, m^3 ha^{-1}	Water use efficiency, kg m^{-3}
		2011	2012		
Farm 1	Traditional planting	3.76	3.54	1900	1.67
	Bed planting	5.23	5.10	1600	2.36
Farm 2	Traditional planting	2.57	2.23	1900	1.85
	Bed planting	3.42	3.52	1600	2.11

Net benefit with bed planting was higher (745 US$ ha^{-1}) than with conventional method (Table 6). Furthermore, net benefit also depends heavily on the market price of wheat grain that can decrease considerably in good rainfall years when grain becomes more abundantly available in the markets.

Table 6: Economics of planting methods on winter wheat productivity in Azerbaijan

Planting methods and seeding rates	Grain yield, t ha^{-1}	Production cost, US$ ha^{-1}	Production value, US$ ha^{-1}	Net benefits, US$	Profitability rate, %
Traditional – 220 kg ha^{-1}	3.02	465	960	495	106
Bed planting – 130 kg ha^{-1}	4.29	535	1280	745	139

Water use efficiency is an important consideration in Azerbaijan in view of the country's limited water resources. As indicated by the results of this experiment, water use efficiency was significantly higher with bed planting. Results also showed that significant economic benefits were achieved in the winter wheat productivity through increased yields and less production cost while using bed planting practices as compared to traditional planting. Using these preliminary results, further studies can be carried out to get detailed information on factors influencing farmers' choices and preferences and identifying suitable varieties for bed planting method in Azerbaijan.

3.2 Field activities in Kazakhstan

3.2.1 Effects of planting date on productivity of no-till maize in South Kazakhstan province

Maize seeds begin to germinate when the seed contains at least 25-30 percent moisture. Adequate soil moisture is the most important factor for rapid and uniform germination and it helps set the stage for maximum grain yield at the end of the season. This study tried to determine optimum planting date for maize in the irrigated conditions of South Kazakhstan province under no-till technology. Four planting dates (April 15, repeated every 15 days until May 30) were evaluated in this experiment.

Observations were made for four planting dates and it was found that seed germination ranged from 64.9 to 82.6 percent across treatments, farms, and years. For example, for the planting date of 30 May, the average seed germination increased up to 27 percent during the vegetation period.

Number of plants per m^2, which is the most important agronomic trait to determine maize biomass and grain yield, was significantly affected by planting dates. The highest number of plants per m^2 was 9.35 in farm 1 in the treatment where maize was sown on 30 April, 2012. The lowest number of plants was recorded (6.55) in farm 2 where maize was planted on 30 May, 2013 (Photo 4).

Photo 4: No-till maize planted on April 30 (L) and May 30 (R) in Kazakhstan

This experiment also found that the average height of maize crop was the tallest (291 cm) and had a high biomass yield when planted on 15 May (Table 7). The results revealed that plant height, which is an important trait, was reduced by late sowing date.

Table 7: Seed germination, plant density and height of maize at the experimental in South Kazakhstan

Farm	Planting date	Seed germination, %			Number of plants, per m^2			Plant height, cm		
		2012	2013	Average	2012	2013	Average	2012	2013	Average
F1	15-April	77.8	64.9	71.3	8.60	7.58	8.09	230.0	283.8	257
	30-April	72.8	69.5	71.2	9.35	8.25	8.80	238.5	284.2	261
	15-May	74.3	66.6	70.5	8.75	7.72	8.24	257.1	325.5	291
	30-May	78.5	65.5	72.0	7.07	7.08	7.08	242.5	237.8	240
F2	15-April	74.8	74.8	74.8	8.19	8.20	8.20	210.7	260.5	236
	30-April	70.0	78.6	74.3	8.90	8.92	8.91	218.4	269.8	244
	15-May	71.5	71.7	71.6	8.33	8.34	8.34	235.4	311.3	273
	30-May	75.5	82.6	79.1	7.43	6.55	6.99	222.1	244.5	233

Grain yield is one of the most important factors to determine total production of maize. Mean results on grain yield (Table 8) revealed that planting date of 30 April on both the farms gave the highest grain yield. Average grain yield was lowest for planting date of 30 May. Thus, a clear association was observed between grain yield and planting date.

Decrease of 8 and 40 percent in the grain yield during early and late sowing respectively, might be due to lower nutrient uptake and reduced photosynthetic translocation in the developing grain. It is therefore evident that 30 April is the optimum planting time for maize grain production in South Kazakhstan province. (Table 8).

Table 8: Grain yield of maize (2012-2013)

Farms	Planting date	Grain Yield, t ha^{-1}		
		2012	2013	Mean
Farm 1	15-April	4.4	3.9	4.2
	30-April	7.4	4.9	6.2
	15-May	6.0	5.0	5.5
	30-May	5.7	4.8	5.2
Farm 2	15-April	4.7	3.6	4.1
	30-April	6.8	4.6	5.7
	15-May	5.1	4.7	4.9
	30-May	4.1	3.3	3.7

The results of this study thus prove that planting dates have a significant effect on number of plants, plant height, and grain yield in maize.

3.2.2 Effects of no-till practices on the productivity of crops under short-term cereal crop rotation in the irrigated conditions of South Kazakhstan

Through this experiment it was explored how short-term crop rotation increases cereal-legume production through the implementation of no-till practice and improves soil fertility. Two crop rotations were used that included four different crops: 1) winter wheat (Ww); 2) maize (M); 3) winter field pea (Wfp) and 4) mung bean (Mb).

Photo 5: No-till winter wheat (L) and no-till mungbean (R) after winter wheat in Kazakhstan

Crop rotation effects were observed for winter wheat and maize (Table 9). The winter wheat grown on the WwMbWwMb (Photo 5) rotation yielded 9.2 percent more than winter wheat grown on the WwMWwMb rotation. Maize grown on winter field pea stubble yielded 22.4 percent more than maize grown on winter wheat stubble. Winter wheat yielded more on fallow than stubble with no other significant effects of crop rotation.

Table 9: Effects of crop rotation on the yield of winter wheat and maize from 2012 to 2013 in South Kazakhstan province

Crop rotation	Yield t ha^{-1}
	Winter wheat
WwMbWwMb	4.12
WwMWwM	3.77
	Maize
WwMWwM	4.23
WfpMWfpM	5.18

The introduction of cereal-legume (WwMbWwMb) crop rotation in the no-till practices was seen to improve soil fertility and increase crop productivity. This beneficial aspect of crop rotation needs to be further investigated not only in South Kazakhstan province but also in the Central Asian region.

3.2.3 Effects of planting methods and seeding rates on productivity of winter wheat in the irrigated conditions of South Kazakhstan province

In this experiment two planting methods and four seeding rates were tested for bed planted winter wheat in irrigated conditions of South Kazakhstan to study the effects on productivity.

Photo 6: Bed planted winter wheat (L) and winter wheat planted on flat surface (R) in Kazakhstan.-

The Bed Planting System (Photo 6) was compared to Flat Planting System (Photo 6) based on conventional and seedbed preparation for seeding winter wheat. Studies showed that the planting method has a significant impact on the grain yield of winter wheat (Table 10).

Overall, the winter wheat grain yield ranged between 3.91-4.74 t ha^{-1}. The two year average data showed that bed planted winter wheat with seed rate 120 kg ha^{-1} treatment led to higher winter wheat yield as compared to control where winter wheat was planted on flat surface with seeding rate 200 kg ha^{-1}. This technology not only reduces the cost of production by using lower seed rate but also provides higher grain yield, thereby increasing the net income of the farmers. The reasons for higher yields of bed planted winter grown wheat also included improved water management because irrigated water can be distributed evenly across the beds and also keeps soil moisture longer than flood watering. There are a number of changes that take place in the soil with a permanent bed system in the long run.

Table 10: Effects of different planting methods on the productivity of winter wheat in South Kazakhstan province (2012-2013)

Planting methods	Seed rate kg ha^{-1}	Yield, t ha^{-1}	Yield, difference, %	Saved water, %
Winter wheat planting on flat surface	200	3.91	0.00	0
Winter wheat planting on beds	100	4.65	118.9	35%
Winter wheat planting on beds	120	4.74	121.2	35%
Winter wheat planting on beds	140	4.68	119.7	35%

Bed planting system tested in South Kazakhstan reduced the seed rates by almost half and provided higher winter wheat yields. At the same time, effective weed management appeared to be critical for the success of this technology.

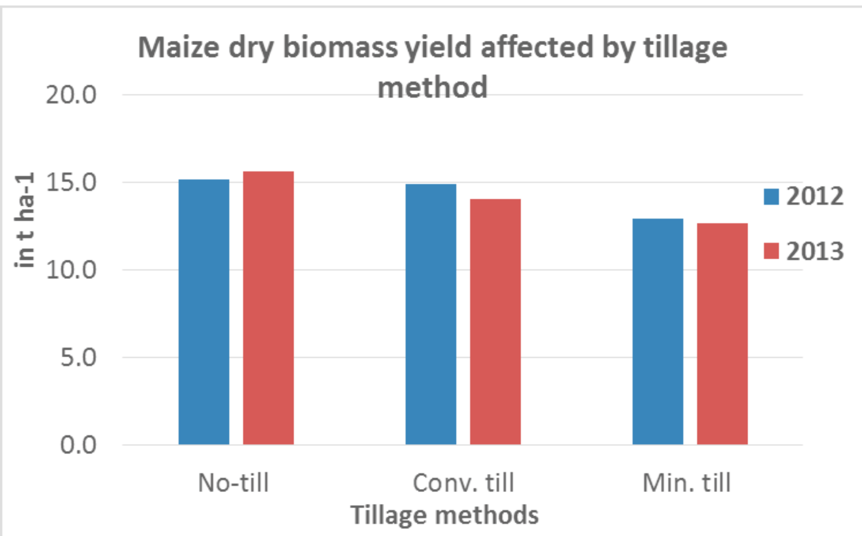
Benefits of planting winter wheat on beds in irrigated systems in terms of water savings on project demonstration site were significant and ranged around 35 percent. Irrigation farmers must realize that seed rate decrease will be essential if they attempt to adopt permanent bed planting systems even though their primary goal may be simply to reduce production costs.

3.2.4 Effects of tillage on productivity of maize in irrigated conditions of South Kazakhstan province

Recent introduction of new technology such as the no-till system offers an opportunity to increase farmers' income. The objective of this experiment was to evaluate the impact of different tillage on productivity of winter wheat in South Kazakhstan province. The treatments included were no-till (NT), conventional till (CT) and minimum till (MT).

According to the results, no-till improves green forage yields and saves agricultural inputs. Agricultural input savings were significant across treatments, which is a critical issue in the irrigated conditions of South Kazakhstan. Dry biomass yields of maize ranged from 12.7 t ha^{-1} to 15.6 t ha^{-1}. The yields for no-till and conventional till were significantly higher than for minimum till in both the years (Figure 3). These results also emphasized the necessity of taking into account the no-till method in the cultivation of maize in the irrigated conditions of South Kazakhstan to stabilize maize production. The results showed that no-till practices are feasible for the production of maize green biomass yield.

Figure 3: Maize dry biomass yield affected by tillage method, (Kazakhstan) 2012-2013



No-till is significantly more profitable and efficient than conventional till practices for growing maize in South Kazakhstan. With the expected continuation in the rise of fuel prices, the relative profitability of direct seeding as compared to traditional practice will only increase over time. No-till cultivation of maize has provided savings for the producer, with a greater benefit also recorded for minimum till due to the less total production cost. Consultations with the farmers involved in these trials showed that farmers would be willing to introduce no-till practices in their fields. The net benefit from no-till and minimum till was US$ 736.5 ha^{-1} and US$ 641.9 ha^{-1} respectively, higher than conventional till (US$ 595.3 ha^{-1}). The benefit-cost ratio varied from 45.9 percent in conventional till to 57.3 percent in no-till (Table 11).

Table 11: Benefit-cost ratio for forage production from no-till and conventional maize in Kazakhstan

Treatments	Dry mass yield, t ha^{-1}	Total production cost, US$ ha^{-1}	Total income	Net benefit US$ ha^{-1}	Benefit-cost ratio
NT	15.6	548.6	1285.1	736.5	57.3
CT	14.1	701.4	1296.6	595.3	45.9
MT	12.7	647.3	1289.2	641.9	49.7

Maize dry forage yield was higher in the treatment involving no-till method as compared to the other treatments. Further investigation of the effect of no-till are needed to assess its longer term impacts.

These results show that introduction of conservation agriculture as a no-till maize forage crop will help livestock producers to have access to low-cost forage resources and thus improve the efficiency of livestock production in Kazakhstan, and perhaps in other Central Asian countries as well.

3.2.5 Effects of different irrigation rates on the productivity of winter wheat in the irrigated conditions of South Kazakhstan

The most crucial period in ensuring the availability of water for maize plant is the period beginning 10-15 days before panicle initiation and ending 20 days after flowering, just prior to the milk stage of maturity. Water consumption usually reaches its maximum value in this period and amounts to nearly 50 percent of the water requirement for the entire growing season. Therefore, irrigation during the vegetative growth must be timed to this vital and critical period of maize development. This study looked at the effects of different irrigation rates on the winter wheat yield in the irrigated conditions of South Kazakhstan province through conservation agriculture technologies. There were six treatments in this experiment and these were as follows: Float irrigation (1200 m^3 ha^{-1}), Furrow irrigation (800 m^3 ha^{-1}), Float irrigation (1600 m^3 ha^{-1}), Furrow irrigation (1200 m^3 ha^{-1}), Float irrigation (2000 m^3 ha^{-1}) and Furrow irrigation (1600 m^3 ha^{-1}).

The highest grain and green mass yields with irrigated agriculture were obtained by ensuring persistently high soil moisture levels. The moisture in the root zone (0.6-0.8 m) should not fall below 70 percent of field capacity in the period from planting to emergence and formation of 13-14 leaves, and below 80 percent in the period from 13-14 leaves to grain filling.

The experiments in 2013 at the project site in Sayram district confirmed that furrow irrigation at 1800 m^3 ha^{-1}, is more profitable than conventional flood irrigation for planting maize on raised beds as observed in 2012, because under furrow irrigation the yields of maize were on an average 35.11 percent higher than under flood irrigation and also saved considerable water, up to 75 percent, while the input costs were basically the same. To sum it up, the experiments conducted in 2012 and 2013 left no doubt that the furrow irrigation at 1800 and 2200 m^3 ha^{-1} with raised bed planting is more efficient than conventional furrow irrigation with bed planting because they allow getting more output using less input (Table 12). Table 12 also highlights that one of the main advantages of furrow irrigation as compared to conventional flood irrigation, is its higher water productivity.

Table 12: Yield difference of flood and furrow irrigation in Sayram site in South Kazakhstan (2012-2013)

Yield	Irrigation rate	2012	2013	Mean
Yield, t ha^{-1}	FI* 2400 m^3 ha^{-1}	3.22	4.84	4.03
	FuI** 1800 m^3 ha^{-1}	5.66	5.23	5.44
Yield +- %		175.78	108.06	35.11
Yield, t ha^{-1}	FI 2600 m^3 ha^{-1}	5.59	4.97	5.28
	FuI 2200 m^3 ha^{-1}	5.91	6.14	6.03
Yield +- %		105.72	123.54	14.11
Yield, t ha^{-1}	FI 3000 m^3 ha^{-1}	4.82	5.11	4.97
	FuI 2600 m^3 ha^{-1}	4.21	5.78	4.99
Yield +- %		87.34	99.41	0.60

*FI - Flood irrigation
** FuI - Furrow irrigation

The experiments conducted in 2012 and 2013 left no doubt that the furrow irrigation at 1800 and 2200 m^3 ha^{-1} with raised bed planting is more efficient than conventional flood irrigation without bed planting. This experiment confirmed the relationship between grain yield of maize and the irrigation rate. Best irrigate rate and improved water management technology were identified but further investigations are needed for wider adoption of the practices.

3.3 Field activities in Uzbekistan

3.3.1 Effects of seeding rate on the productivity of bed planted maize in the irrigated conditions of Kashkadarya province

The effects of seeding rate on productivity of permanent bed planted maize were studied in this experiment in the irrigated conditions of Kashkadarya province. Maize usually is a tall, warm season, annual plant. Seven different seeding rates of permanent bed planted maize after winter wheat as double cropping were tested in this study. The seeding rates are as follows 40000 through 100000 live seeds ha^{-1} (Photo 7).

Plant height varied between 222 and 280 cm. Some significant differences were observed in plant height across the treatments of this experiment (Table 13). The highest (280 cm) plant height of maize was observed with the treatment of 60000 seeds per hectare followed by the treatment of 70000 seeds per hectare (plant height 267 cm) in 2012. Plant height was minimum (222 cm) with the treatment of 40000 seeds per hectare in 2013. Treatments with 60000 and 70000 seeds per hectare gave taller plants than other treatments and there was excellent grain yield.

Photo 7: Permanent bed planted maize in Uzbekistan.

Significant yield (7.83 t ha^{-1}) was obtained with the seeding rate of 60000 seeds per hectare. Next best yield was observed at the seeding rate of 70000 seeds per hectare (7.78 t ha^{-1}), followed by 80000 seeds per hectare (7.13 t ha^{-1}). Plant height was best at these seeding rates too. The treatment of 40000 seeds per hectare produced the lowest yield (3.92 t ha^{-1}).

Table 13: Effect of seeding rate on plant height and productivity on permanent bed planted in Qarshi, Uzbekistan (2012-2013)

Seeding rate, seed ha^{-1}	Plant height, cm			Grain yield, t ha^{-1}		
	2012	2013	Mean	2012	2013	Mean
40000	253	222	237	3.95	3.89	3.92
50000	238	267	252	4.72	7.14	5.93
60000	280	273	276	6.96	8.71	7.83
70000	267	258	262	6.81	8.76	7.78
80000	261	258	259	6.22	8.05	7.13
90000	259	239	249	5.75	7.41	6.58
100000	250	231	240	4.31	4.13	4.22

On the basis of this performance, seeding rates of 60000 and 70000 seeds per hectare can be considered as the best for permanent bed planted maize cultivation in the irrigated conditions of Uzbekistan. For the first time permanent bed planting practices with different seeding rate of maize tested in the irrigated conditions of Kashkadarya province. There are other crop management issues should be tested in this site.

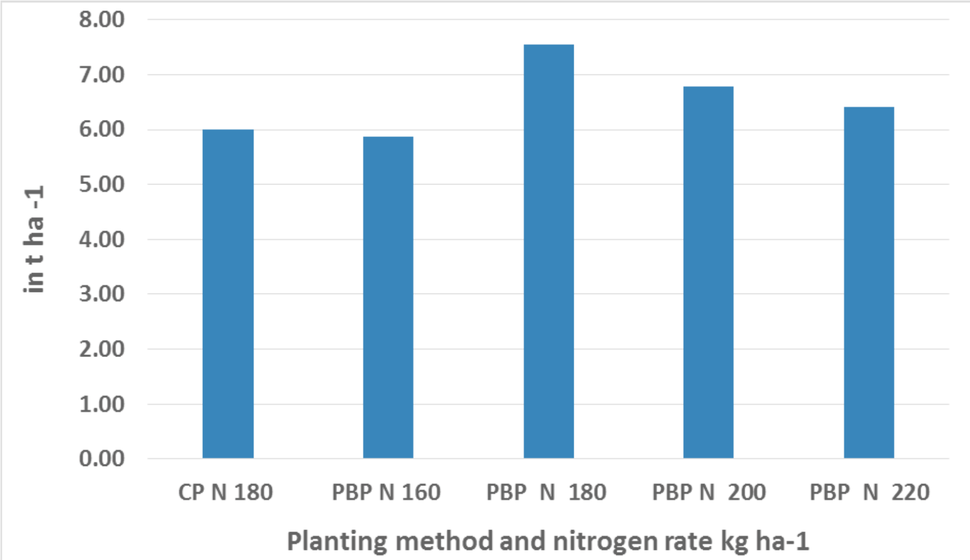
3.3.2 Effects of planting methods and nitrogen rates on winter wheat yield

Nutrient deficiency at any time during a wheat plant's life reduces yield, but if the nitrogen deficiency occurs during its rapid vegetative growth phase and at the beginning of the booting stage, yield losses may be severe. Thus, the primary goal of timing fertilizer application is to ensure that fertilizer is sufficient at the time of application. Therefore this study was carried out to investigate the optimal timing for fertilizer application (Photo 8). Five nitrogen rates were evaluated in this experiment and these were as follows: 1. Conventional planting with N 120; 2. Bed planting N 160; 3. Bed planting N 180; 4. Bed planting N 220; 5. Bed planting N 220. Nitrogen was managed for intensive production with 1/3 of the N applied at tillering stage and the remainder at jointing stage.

Photo 8: Bed planted winter wheat in Uzbekistan

It was found that the increased fertilizer rates produced the greatest yield response. Highest grain yield was in response to the treatment bed planting+nitrogen (BP N) 180 kg ha^{-1} which produced an additional yield increase that was statistically significant across the two years. The highest yield (7.54 t ha^{-1}) was recorded in the treatment where nitrogen rate was 180 kg ha^{-1} while the lowest yield was recorded (5.88 t ha^{-1}) in the treatment where nitrogen rate was 160 kg ha^{-1} (Figure 4) while in the conventional planting (CP N) 180 kg ha^{-1} winter wheat yield was 6.0 t ha^{-1}.

Figure 4: Winter wheat yield as affected by planting method and nitrogen rates (2012-2013)



It was thus evident from these findings that fertilizer use efficiency can be increased by using bed planting in the region. Application of N at the rate of 180 kg ha^{-1} and bed planting performed better than other treatments. There is a future need to cultivate wheat on beds to increase wheat N use efficiency and grain yield in the irrigated conditions of Uzbekistan.

3.3.3 Effects of rhizobial inoculation on the productivity of bed planted soybean in Kashkadarya province

A study was conducted to note the effects of *Rhizobium* with a combination of Potassium and Phosphorus on the productivity of bed planted soybean in the irrigated conditions of Kashkadarya province (Photo 9).

Maximum plant height of 104.8 cm was observed in the treatment when *Rizobium*+K60+P120 was applied. Lowest plant height of 82.3 cm was observed in the control treatment. Soybean grain yield varied among the treatments. The same trend was observed in grain yield. Soybean grain yield increased with *Rizobium*+Fertilizer applications throughout the experiment (Table 14).

Photo 9: Bed planted soybean in Uzbekistan

Thus, *Rizobium* application has a significant effect in increasing the grain yield. *Rizobium* application rate of enhancement was stable and increased the yield difference steadily across the treatments from 0.20 to 0.66 t ha^{-1} with and without *Rizobium* application. The eighth treatment (Control + *Rizobium* K60+P120) gave the highest grain yield (2.23 t ha^{-1}) and the control treatment gave the lowest grain yield (1.62 t ha^{-1}).

Table 14: Plant height and Grain yield of bed planted soybean affected by different fertilization rate and Rhizobium (2011-2012)

Treatments	Plant height, cm	Grain yield, t ha^{-1}	Yield difference, t ha^{-1}
Control	82.3	1.67	0
Control+K60	88.8	1.97	0.20
Control+P120	92.9	1.99	0.32
Control+K60+P120	95.6	2.09	0.42
Control+ Rizobium	91.5	1.95	0.28
Control+ Rizobium +K60	95.5	2.11	0.44
Control+ Rizobium +P120	99.2	2.21	0.54
Control+ Rizobium+ K60+P120	104.8	2.33	0.66

Thus, it was concluded that soybean has a high response to *Rizobium* application in all treatments, especially Control+*Rizobium*+ K60+P120. The response was lowest in the treatments where *Rizobium* was not applied.

3.3.4 Effects of tillage and seed rate on the productivity of winter wheat in the irrigated conditions of Kashkadarya province

Conservation Agriculture systems have a great potential for increasing agricultural production in the project countries while maintaining soil health and fertility. Wheat is the easiest crop to initiate CA, because after wheat harvest succeeding crops can be grown under the no-till system. An experiment was carried out to investigate the impacts of different tillage and seed rate on the productivity of winter wheat growth and development in Kashkadarya province.

Unfortunately, the winter of 2012 was unfavorable for the growth and development of winter wheat. It was colder than usual with heavy snow cover and the temperatures plummeting down to – 25°C. This negatively affected the productivity of winter wheat in the entire experiment and, as a result, yield was lower as compared to that observed in 2013 (Table 15). Winter wheat productivity was higher in the treatment with no-till method as compared to the other treatments. Absolute highest grain yield of 6.71 t ha^{-1} was recorded in the no-till treatment in 2013 with 5 mln seeds per ha^{-1} while in conventional tillage the maximum yield was 6.54 t ha^{-1} also with 5 mln seeds per ha^{-1}. No-till (NT) winter wheat resulted in an increase in the crop production (Photo 10) and higher grain yield as compared to conventional (CT) and minimum till (MT).

Winter wheat yield under no-till system was higher than conventional till practice (Table 15). This can be explained by the fact that evaporative losses of water from no-till plots are lower than that of conventional till and with reduced evaporation the accumulation of salts in root zone decreases. This facilitates in proliferation of roots and in turn gives greater yields. In the long-run, no-till practice with retention of crop residues helps in lowering the salinity levels due to combined effects of reduced evaporation and recycling of organic matter.

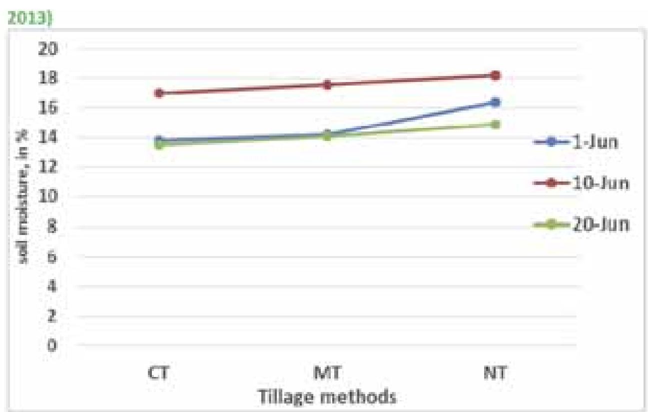
Photo 10: No-till winter wheat planted into standing cotton in Uzbekistan

Table 15: Effect of different tillage methods and seed rate on winter wheat yield, t ha^{-1}

Tillage method	Yield, t ha^{-1}					
	4 mln seeds		5 mln seeds		6 mln seeds	
	2012	2013	2012	2013	2012	2013
CT	6.04	6.08	6.36	6.54	6.20	6.13
MT	4.19	4.69	4.46	4.90	4.73	5.45
NT	5.85	5.40	6.30	6.71	6.65	6.41

The reason for higher yields of no-till wheat is not clear at this stage. There are a number of changes which take place in the soil with no-till system. 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 wheat during the late-vegetative stages of growth. The results presented in the following figure showed that more water was found at each date of sampling in the no-till treatment. 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 (Figure 5).

Figure 5: Soil moisture in the top soil with no-till wheat in the late-vegetative stage of growth (2012-2013)



No-till winter wheat results in an increase in crop production and higher grain yield as compared to conventional and minimum till. 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. It will be helpful for farmers to 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 lower the production costs which are common with tillage reductions.

3.3.5 The effects of short-term cereal crop rotation on the productivity of crops under no-till practices in the irrigated conditions of Kashkadarya

An experiment was conducted to explore the possibilities of short-term crop rotation increases in cereal-legume production through the implementation of no-till practice. Three crop rotations where used that included six different crops: 1) winter wheat (Ww); 2) Soybean (SB); 3) Mungbean (Mb); 4) Corn (Cr); 5) Sunflower (Sf); 6) Sesame (Ss).

Photo 11: No-till winter wheat planted after corn in Uzbekistan

The highest grain yield of winter wheat was obtained on cereal-legume (WwSBWwMb) crop rotation (Table 16), where no-till practice was used. This was normal as the field provided more moisture and nitrogen for crop. It was 34 percent higher than cereal-cereal (WwCrWw) crop rotation in winter wheat after corn (Photo 11). The same trend was seen in cereal-oil (WwSfWwSs) rotation or winter wheat after oil crops. Grain yield was 26 percent higher than cereal-cereal rotation since oil crops provided quite good moisture supply and crop was as clean as after oil crops. In addition, cereal-oil rotation provided grain yield as high as cereal-legume. The response of wheat yield to crop rotation provides an example of the typical response to crop rotation that is possible. The greatest benefit from crop rotation comes when crops grown in sequence belong to totally different families. In response to crop rotation, it is common to get 15 percent higher yield in the case of soybean and 10 percent for wheat. Crop rotations can also decrease the cost of crop production.

Table 16: Wheat Yield Response to Rotation

Rotation	Yield, t ha^{-1}	Yield difference, %
Winter wheat-corn-winter wheat	5.18	100
Winter wheat- Soybean-Winter wheat-Mung bean	6.94	134
Winter wheat-sunflower-Winter wheat-sesame	6.55	126

The results presented in this study have shown that adopting cereal-legume rotation can increase winter wheat crop productivity. Crop rotations play an important role in the success of most crop production enterprises, but rotations are important for no-till crop production. With carefully planned crop rotations, the advantages of no-till crop production can be extended to soils or situations where success is difficult. This should be further studied in no-till system.

3.3.6 Effects of tillage methods on the productivity of double-cropped mung bean

A two year experiment and a demonstration module were conducted at farmers' fields in Qarshi district, Uzbekistan, to investigate the impact of tillage methods on the productivity of double cropped mung bean. There were three different treatments that included CT - conventional till, NTC – No-till one cultivation and NT – no-till. No-till mung bean was successfully grown as a catch crop after winter wheat in the irrigated conditions and provided 3.3 percent higher yield advantage as compared to traditional tillage practice.

Photo 12: No-till mungbean planted after winter wheat harvest in Uzbekistan

Results of this experiment (Table 17) showed that there was little difference on organic matter content between the treatments. This is to be expected since all the plant residue is placed on the soil surface and the plant residue positively affects soil fertility. The tilled plots mixed and diluted this effect.

Table 17: Soil chemical parameters in the different tillage systems (2012-2013)

Soil characteristics	2012			2013		
	CT	NTC	NT	CT	NTC	NT
Humus (%)	0.612	0.612	0.612	0.612	0.618	0.627
Nitrogen (%)	0.045	0.045	0.045	0.045	0.049	0.059
Phosphorus (%)	0.141	0.141	0.141	0.141	0.152	0.161
N-NO3, mg kg^{-1}	12.87	12.87	12.87	12.87	13.22	13.93
P_2O_3, mg kg^{-1}	27.84	27.84	27.84	27.84	28.25	29.14
K_2O, mg kg^{-1}	291	291	291	291	299	303

Plant's root length is one of the key yield components in legume cultivation. According to Table 18, root length did not significantly change; therefore, tillage method does not have a significant impact on root length. The same trend was observed with plant height across the treatments.

No-till was also advantageous to crop yields; it demonstrated advantages in terms of conservation of energy and labour resources. Fuel for producing agricultural products has become expensive; therefore, farmers have started looking for ways to decrease fuel consumption. The lowest fuel consumption (5.9 l ha^{-1}) was obtained with no till mung bean, which was 47.7 l ha^{-1} lower than conventional mung bean. Fuel consumption per ha was 53.6, 13.6 and 5.9 litres under full tillage, no-till one cultivation and no-till, respectively (Table 18).

Table 18: Effects of tillage method on the productivity of double cropped mung bean (2012-2013)

Planting method	Spent fuel for planting, l ha^{-1}	Root length, cm	Plant height, cm	Yield, t ha^{-1}	Yield difference, %
Conventional till	53.6	25.4	67.2	1.61	
No-till with 1 cultivation	13.6	23.5	68.8	1.78	9.9
No-till	5.9	23.8	65.4	1.94	20.5

It appears that mung bean tends to yield more where wheat was grown in no-till situation. Grain yield was significantly affected by tillage method across both the years. Maximum grain yield of 1.94 t ha^{-1} was recorded with no-till mung bean while minimum grain yield (1.61 t ha^{-1}) was recorded when conventional mung bean was grown. The no-till mung bean provided 330 kg ha^{-1} (20.5 percent) yield advantage as compared to the conventional mung bean, which was significantly different. The average yield advantage in no-till mung bean with one cultivation was 160 kg ha^{-1} (9.9 percent) more than control treatment (Table 18).

To estimate the economic returns of tested tillage methods, cost benefit analysis was done. The highest profit was recorded with no-till mung bean with 1,113 US$ ha^{-1} while lowest profit was obtained with conventional till mung bean which was 825 US$ ha^{-1} (Table 19).

Table 19: Cost-benefits of double cropped mung bean under different tillage methods

Tillage method	CT	MT	NT
Yield, t ha^{-1}	1.61	1.78	1.94
Crop price, t US$	800	800	800
Total income, t US$	1,288	1,416	1,552
Total costs, t US$	463	443	439
Profit	825	973	1,113

The results presented in this experiment indicate that tillage reduction for surface irrigated production systems reverberate in the same positive way in terms of production profitability and sustainability of total grain production. The retention of crop residues will be essential to ensure that the required enrichment of critical levels of the chemical, physical and biological soil parameters can be achieved, which is crucial to ensure long-term production sustainability. Land use efficiency can be increased with double cropping of no-till mung bean.

3.3.7 Effects of different irrigation rates on the productivity of winter wheat in Kashkadarya province

Effects of irrigation rates on winter wheat yield were studied in the irrigated conditions of Kashkadarya province.

Furrow irrigation increased uniformity of water distribution and helped adjust irrigation rates and timing according to the available soil moisture content. Consequently, furrow irrigation increased crops yields as compared to flood irrigation. Application of furrow irrigation for winter wheat increased grain yield by 27 percent in 2012 and 21 percent in 2013, as compared to the traditional flood irrigation. The maximum grain yield (7.45 t ha^{-1}) was obtained from furrow irrigation where irrigation rate was 2550 m^3 ha^{-1} (Table 20).

Water use efficiency (WUE) of the irrigation technologies during 2012 and 2013 as compared to controls were, on an average, 30 percent higher for winter wheat. This is extremely important for winter wheat cultivation in Kashkadarya province of Uzbekistan where water shortage is common.

Table 20: Irrigation and productivity of winter wheat at Kashkadarya, Uzbekistan

Field Capacity, %	Irrigation		Grain Yield	
	m^3 ha^{-1}	m^3 ha^{-1}	t ha^{-1}	t ha^{-1}
	2012	2013	2012	2013
Flood irrigation 60-70-60	1800	2250	5.11	5.89
Furrow irrigation 60-70-60	1200	1600	6.54	7.18
Flood irrigation 70-70-70	2000	2450	6.74	7.28
Furrow irrigation 70-70-70	1900	2350	6.86	7.35
Flood irrigation 70-80-80	2200	2690	6.34	6.32
Furrow irrigation 70-80-80	2100	2550	6.66	7.45

Improved furrow irrigation technologies (raised bed planting) provide significant increase in WUE and good net returns due to increased crop yields. On the basis of this study the best irrigation rate and improved water management technologies were identified and were adopted by the neighboring farmers around project the demonstration sites.

4. Field activities across project countries

4.1 Laser Land-leveling

In order to have effective CA under furrow irrigation, the land first needs to be laser leveled. Laser leveling involves using laser-equipped drag buckets to create a constant slope of 0 to 0.2 percent. This practice requires the use of tractors and soil movers equipped with receivers and laser-guided instrumentation. The soil is moved by either cutting or filling to create the desired slope/level. The technique is well known for its high level of accuracy in land leveling and the process itself offers great potential for water savings and increased grain yields. While the concept of moving soil to level land is old, laser land-leveling is an improvement in the process, such that the actual surface finish can be controlled to very tight tolerance levels.

A laser-controlled land-leveling system consists of a rotating laser light source located somewhere in the field. As the laser rotates rapidly, a virtual "plane" of light is produced in the field. A "receiver" is mounted on the leveling equipment and connected hydraulically to the earthmoving blade. When activated, the receiver (and thus, the blade) will "lock on" to the laser source, thus, adjusting in relation to the height and distance from the laser, and providing a smooth flat surface with the program slope. As the earthmover moves over a high spot in the field, the blade will penetrate deeper. If the earthmover moves across low spot, the blade will lift up, dumping soil into the low spot. By tilting the rotating laser source to the desired angle/grade, the slope can be created in the field to provide for the optimal flow rate of irrigation water through a furrow system.

Prior to starting the laser land-leveling, the soil should be loosened with a tillage equipment (Photo 13) to make leveling process easier, a topographic survey (Photo 14) should be carried out to determine the optimal slope and slope direction for the site. An example of a topographic survey is provided in Table 21. For more information please visit the web site www.krass.uz and refer to the manual on laser land-leveling prepared by Ibragimov et al. (2011).

Photo 13: Ploughed Field

Photo 14: Topographic Survey

Table 21: Measurements of uneven field areas within 1 ha obtained using laser device with a 20x20 meter measurement points[3]

	Distance between measurements	100 м					Mean, cm
		20 m	20 m	20 m	20 m	20 m	
100 м	20 m	322	325	316	316	318	319
	20 m	323	326	317	316	318	320
	20 m	321	327	315	320	320	320
	20 m	325	327	316	317	310	319
	20 m	326	327	310	320	320	320
	Mean, cm	323	326	315	317	318	320

Using the topographic survey, a topographic map was developed for the project demonstration site at Karshi. Based on the map the tractor operator was able to accurately level the field (Table 22).

[3] Red – cut, blue – fill, and green – equal to average.

Table 22: Map and calculated depth and volume of cut and fill for each cell

2 cm ($8m^3$)	5 cm (20 m^3)	-4 cm ($16m^3$)	-4 cm ($16m^3$)	-2 cm (8 m^3)
3 cm (12 m^3)	6 cm (24 m^3)	-3 cm (12 m^3)	-4 cm ($16m^3$)	-2 cm (8 m^3)
1 cm (4 m^3)	7 cm (28 m^3)	-5 cm (20 m^3)	0 cm	0 cm
5 cm (20 m^3)	7 cm (28 m^3)	-4 cm ($16m^3$)	-3 cm (12 m^3)	-10 cm (40 m^3)
6 cm (24 m^3)	7 cm (28 m^3)	-10 cm (40 m^3)	0 cm	0 cm

Fill up to 2 cm	Fill from 3-5 cm	Cut up to 5 cм
Fill >6 cm	Cut > 5 cm	± projected

The on-farm project showed that laser leveling operations lead to increased water use efficiency at the project demonstration sites. Even distribution of water throughout the furrow system led to uniform seed germination, resulting in a more optimal plant density. Effective land-leveling resulted in improved crop establishment in general and the ability to manage the crops, thereby increasing both yield and quality. In addition, it improved water use efficiency by reducing high spots in the fields that blocked water movement across the field, and by reducing low spots that resulted in flooded areas and poor crop production.

It was also observed that by improving water coverage, weed population could be reduced by up to 40 percent, which resulted in less time spent on weeding operations; from 21 down to 5 labor-days per hectare. This represented a reduction of up to 16 person-days per hectare, a 75 percent decrease in the traditional labor requirement for weeding.

4.2 Seeding date and rate

Optimal seeding dates and timely pre-sowing irrigation pre-define the yield potential of agricultural crop in bed planting. Timely planting also stimulates plants' rapid growth with effective use of precipitations in the early spring. In the spring, raised beds warm up faster and growth of winter wheat occurs earlier than with conventional seeding practice.

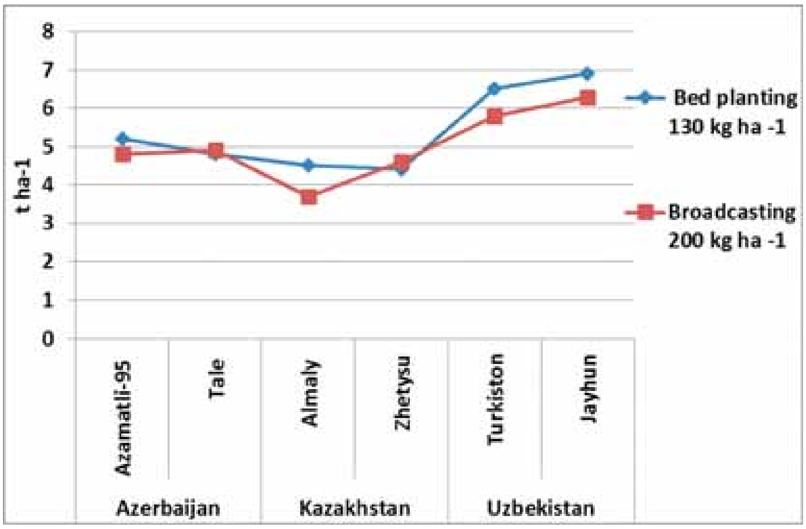
The following winter wheat varieties were sown at a rate of 130 kg ha^{-1} on raised beds while the same varieties were planted by using broadcasting method at a seeding rate of 200 kg ha^{-1}: Azamatli-95 and Tale in Azerbaijan; Almaly and Zhetysu in Kazakhstan; and Turkiston and Jayhun in Uzbekistan. Grain yield was significantly affected by planting method (Figure 6).

Optimal Planting Dates for Bed Planted Winter Wheat

- Southern Kazakhstan: September 25 until October 15-20
- Kashkadarya province of Uzbekistan: Mid-October
- Azerbaijan: End of October through beginning of November

Depending on seeding methods, high rates do not always facilitate crop yield. In contrast, the following increase and facilitate higher yields: lower seeding rate, productive tillering factor, spike sizes, number of grains per spike and weight of 1,000 kernels.

Figure 6: Effects of planting method and seeding rate on the productivity of winter wheat 2012-2013



The benefits of planting wheat on beds in irrigated systems in terms of yield and water savings on various farms of the project demonstration site are provided in Table 23. Bed planting improves yields and saves seed. In test sites across the three project countries, a maximum grain yield of 7.51 t ha^{-1} was recorded in Uzbekistan with bed planting while the lowest yield of 4.45 t ha^{-1} was recorded in South Kazakhstan. Water savings, as indicated, are significant and range from 27 to 36 percent, which is a critical issue in the irrigated conditions of Azerbaijan, South Kazakhstan and Uzbekistan.

Table 23: Wheat Yield Response to planting method (2011-2013)[4]

Planting method	Wheat grain yields (t ha^{-1})			Saved water, %		
	Azerbaijan	Uzbekistan	Kazakhstan	Azerbaijan	Uzbekistan	Kazakhstan
Bed planted	5.42	7.51	4.73	27 %	36%	30%
Broadcasted	5.02	6.32	4.45	0 %	0 %	0 %

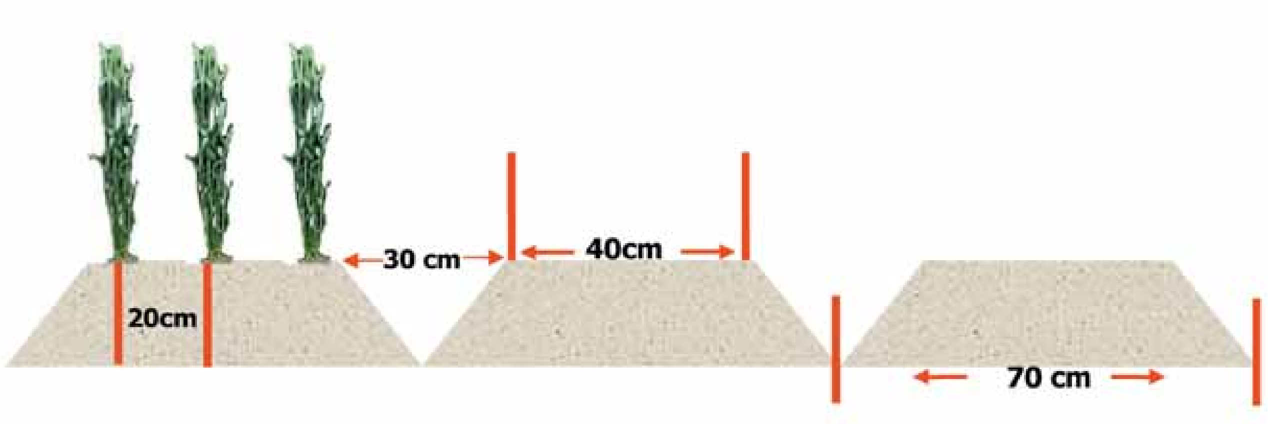
In Azerbaijan and South Kazakhstan province, the winter wheat crop yield under irrigation is still low, in the range 1.8-2.7 t ha^{-1}. One of the reasons for this low productivity is the failure to observe the set of crop management activities in the course of its production, e.g., delay in planting dates, poor irrigation, failure to fulfill seeding rates, incorrect selection of varieties and others.

With raised bed technology, the land is prepared conventionally prior to preparing raised beds and furrows using a bed maker and a furrow opener on the laser leveled field. The raised beds and furrows are prepared using a machine that makes 4 beds (70 cm width) in each pass. It is possible to plant 2 or 3 rows of a crop on each raised bed (Figure 7). The width of the beds can vary according from 40 cm to 90 cm, depending on the crop and on the soil type. Beds are wider in lighter soils and narrower in heavier soils.

Three rows of wheat were tested by the project. Two rows resulted in equal yields to that of three rows. Two rows have an additional advantage because the weeds between the two rows of wheat can be managed mechanically, fertilizer can be placed as a top dress application between the rows (increasing efficiency) and there is less lodging due to larger plants. Bed planting also has the advantage of lowering seed rates, and produces bolder seeds with greater panicle length, which is an important issue for hybrid seed multiplication programs. In this test, planting was done using a new no-till drill adjusted to bed planting.

[4] All wheat treatments were fertilized with 90 kg ha^{-1} of N and 60 kg ha^{-1} P.

Figure 7: Configuration of raised beds and planting arrangements for irrigated wheat



5. Conclusion

This project provides convincing evidence for farmers and policy makers to adopt conservation agriculture techniques in all of the project countries.

One of the most notable outcomes was that permanent bed planting technologies tested in Azerbaijan, Kazakhstan and Uzbekistan proved to be suitable for irrigated conditions, provided similar or higher crop yields, and saved a considerable amount of resources, including fuel, seeds and labor. Therefore, under high production situations, bed planting exceeds the yields possible on the flat bed. An improvement in the water use efficiency by 21-36 percent combined with an approximate 17 percent savings in applied irrigation was observed.

No-till maize, sunflower, winter wheat in Azerbaijan and Kazakhstan, and no-till mung bean and winter wheat in Uzbekistan under irrigation provided yields comparable to those obtained through conventional and reduced tillage. The analysis of cost-effectiveness of no-till winter wheat, no-till maize, alfalfa, mung bean and soybean showed feasibility of this technology in the respective project countries.

The project also identified new crop rotations and studied their potential impacts for use in conservation agriculture. Sorghum and pearl millet in Azerbaijan, pearl millet in Uzbekistan, as well as, kidney bean and mung bean in Kazakhstan were introduced as new crops. Laser leveling operations proved to increase water use efficiency.

Additionally, soil analysis was carried-out in each country according to the work plan. Organic matter content was higher in the soil under no-till wheat than conventional tilled wheat in the 0-10 cm depth. Preservation of crop residues in the soil surface and slower mineralization of these residues building up the soil organic matter contributes to the success of conservation agriculture system.

Cost-benefit analyses of improved technologies to assess the economic viability of useful options for better livelihood of farming communities in the three participating countries under this project were completed. The analyses revealed that many of the technologies developed and disseminated under the project have considerable advantage than those currently being practiced by the farmers in Central Asian countries. The economic assessment of technologies was based both in quantitative and qualitative methods of analysis. Among those technologies, the application of no-till practices and bed planting of winter wheat, new crop rotation options with inclusion of legumes in cropping systems, etc. were found to be significantly useful for increasing farmers' income and improving their livelihoods.

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Appendixes

Appendix 1: Machinery for Conservation Agriculture

The project made new machinery for CA practices available to the farmers at the demonstration pilot sites.

No-till Planter (Photo 1)

The project provided three no-till planters. The planter can accommodate 5 row crop units in total. Good seed placement and soil contact is important to achieve healthy crop development and even germination. The sets are comprised of a support in which plastic reservoirs are fixed with the horizontal seeds distributing mechanism and motor system of the set. Weight of the no-till seeder is 1800 kg. Box capacity for wheat is 190 kg and box capacity for fertilizer is 505 kg. Working width for wheat is 2380 mm while for row crops it is 2400 mm. Traction is pull type that is very easy to transport from one place to another. The Fankhauser 2115 no-till seeder, which is universal, can be converted to plant either field or row crops.

Photo 1: Four row no-till planter

Row unit for large grains (Photo 2)

A precision planter for large grains is a four or five row planter spaced at 40-90 cm. For each row there is a unit comprising seed hopper, metering mechanism including the drive mechanism and a line of furrow openers. Each row is independently metering the seed for accurate seed spacing in the row and has also independent furrow opener units allowing accurate depth placement of the seed. The operating depth adjustment of the coulter is obtained with adjustments on the frame leveler of the machine.

Photo 2: Disc opener, gauge wheel, double disc closing wheels

Each disc on the planter 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 seed discs are specified by the size of the holes, the number of holes and their thickness. An example of the discs for soybean will be, size of the holes: 7.5 mm, number of holes: 90, and thickness of the disc: 5.5 mm. The seed discs follow a universal standard and can be easily found in the market.

In this planter, number of seeds per meter can range between 2.2 and 63.1 depending on the crops. For row crops, the speed should be maintained at a maximum of 6 km h^{-1} to avoid seed breakage. With high and hard residues, high speed aids in cutting the residues, but more than 6 km h^{-1} could break seeds. When doing the calibration for precision planting that requires a precise number of seeds per hectare, the correct setting of the planter is of utmost importance for obtaining an appropriate final stand for the crop to be established, considering the variety to be sown and the germination percentage. Another important factor for obtaining good stands is the correct choice of the seed distributing disks that should be determined according to the form and size of the seeds.

Fertilizer metering

The fertilizer transmission is located on the left side of the planter. After choosing the fertilizer application rate, the necessary sprockets should be installed. Prior to putting the planter into motion, the user should observe the correct alignment of the idler, chain and sprockets. There are two augers for fertilizer metering: low-rate application auger and high rate application auger.

Seeds distribution system for field crops (Photo 3)
The issue with the seeder is that the conversion between field and row crop use is quite technical and time-consuming and may present a problem in regions with limited technical expertise. Roughly 1.5 days are required to convert row crop seeder into field crop seeder.

The usual range of available opener spacing is from 15 to 20 centimeters, which is the conventional spacing for wheat. Some farmers double-drill forages in two directions for a closer and effective spacing. A few drills are available with spacing down to 10 cm for high-yielding 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. Wheat seed metering is done by a gouged rotor, which can be moved sideways allowing a larger or smaller amount of seeds to be distributed. Each row has one metering roller.

Photo 3: Field crop seeder from back and right side

Regulation procedure is done by the displacement of axis increasing or decreasing the opening work of the rotors inside the distribution box, through the lever. After obtaining the desired seeds outlet, the regulator lever is fastened through the fastening nut.

The sowing depth of seeds is very important, and it is one of the factors that interferes in the emergence and germination of plants. The limiting wheels copy the soil unevenness, which allows keeping 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.

Boom sprayers (Photo 4)
The project also provided three boom sprayers for project countries. 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.

Photo 4: Boom sprayer for broad field

These factors include the ideal time for spraying, which should be chosen according to the chemical product characteristics as well the field conditions. Also, 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 that is properly calibrated. There are four steps in calibration: (1) check driving speed; (2) calculate required nozzle flow and choose nozzle size; (3) check liquid system; and (4) check nozzle output.

Appendix 2: Development of no-till seeder in Uzbekistan

On tilled soils in rainfed areas of Uzbekistan, most of the farmers use conventional seeder model SZ-3.6. This commercially produced seeder is intended for sowing wheat, barley and other cereals. Use of this seeder requires preparation of fields for sowing, i.e. cleaning of field from residues, plowing, levelling, and harrowing. The sowing of winter wheat in rainfed areas requires number of field operations. To avoid the many field operations which are necessary for sowing winter cereals on rainfed areas, farmers have modified existing SZ-3.6 seeder by adding a chisel. This allows farmers to sow winter wheat or other cereals right after first the rainfall, which is very important in rainfed agriculture. Currently, total area under conservation tillage has reached up to 30,000 ha in rainfed areas.

World experience on adoption conservation agriculture shows that only countries with local production of no-till is adopting CA practices fastest compared to other countries where no-till manufacturer is not in place. The leading countries in the world with the biggest area under no-till are the Brazil, USA, Canada, Argentina, Australia, China and etc. All countries are having different kind of manufacturers with development of CA equipments. As a good example Brazilian no-till drills delivered to the project countries. The Brazilian no-till drill is expensive and total cost is about 38,000 USD including transportation. Not all farmers can afford to buy such expensive equipment. But, there is a need to ensure availability of more raised bed planters and no-till drills for covering large areas under conservation agriculture in the project countries. In general, a suitable chisel can be mounted to front line of seeder to plant winter wheat. But this is not enough to properly manage seeding of any cereal crop. Taking this into account National consultants from Uzbekistan modified existing conventional planter into no-till drill. A signal variant of this planter has been produced in a factory located in Karshi, near the Uzbekistan project site (please see photo 5).

The newly developed no-till drill in this case is an own development, modifying a disc type seeder to a no-till drill, with the advantage over the models from Turkey seen in other parts of the project, that the tine type can handle residues and that they follow the contour for each row independently and are not fixed. Weight of the no-till seeder is 1500 kg. Box capacity for seed is 300 kg and box capacity for fertilizer is 400 kg. Working wide width for wheat is 3600 mm and distance between row is 15 cm.

Photo 5: Newly developed no-till planter in Uzbekistan

Appendix 3: Capacity building activities

Inception workshop

A two-day inception workshop was conducted from January 31 – February 1, 2011. The objectives of the workshop were to (1) discuss the detailed national and regional work plans of the project; (2) obtain valuable inputs and suggestions from the participants related to conservation agriculture in the project countries; and (3) review proposals and options for the expendable equipment.

It was attended by experts from the Food and Agriculture Organization (FAO), ICARDA, the Japan International Research Center for Agricultural Sciences, ZEF-project, and others. A total of 40 participants from three countries participated in the workshop.

The workshop was highly successful because regional and national work plans of the project were introduced and discussed. It also allowed participants to understand the importance of conservation agriculture in the region.

Field days

ICARDA scientists continued their capacity-building efforts in Central Asia and the Caucasus in 2013. Efforts focused on conservation agriculture practices, like no-till, bed planting, crop residue retention, and crop rotation. During these field days, CA technologies, improved water management and crop diversification methods were demonstrated by ICARDA staff and project national consultants.

List of Field Days organized in the project countries (2011-2013)

#	Title	Date	Number of attendees	Country
1	Introduction of bed planting technologies in the project demo site in Azerbaijan	21 May, 2011	33	Azerbaijan
2	Bed planting technologies for agricultural crops in the South Kazakhstan province	16 June, 2011	35	Kazakhstan
3	Improving current conservation agriculture practices in the project demo site	24 August, 2011	40	Uzbekistan
4	Demonstration of no-till winter wheat cultivation in Azerbaijan	13 March, 2012	40	Azerbaijan
5	Introduction of no-till drill in Uzbekistan	27 March, 2012	52	Uzbekistan
6	No-till alfalfa and winter wheat planting under irrigated conditions of South Kazakhstan province	06 April, 2012	55	Kazakhstan
7	Demonstration of the capability of no-till seeder to seed maize directly after the harvesting of wheat	04 June, 2012	70	Azerbaijan
8	Installation of no-till drill in Kazakhstan	12 June, 2012	50	Kazakhstan
9	Mung bean planting after winter harvest in Uzbekistan	08 June, 2012	70	Uzbekistan
10	Bed planting and its environmental impact	27 March, 2013	44	Azerbaijan
11	The system of crop rotation under conservation agriculture	16 March, 2013	43	Kazakhstan
12	No-till practice and succeeding crops (multi-cropping)	25-Apr, 2013	46	Uzbekistan

Field training courses

A series of training courses on CA practices were conducted in Azerbaijan, Kazakhstan and Uzbekistan. In all, 540 participants (Azerbaijan 170, Kazakhstan 172 and Uzbekistan 198) attended the course, including policy makers, delegates from the Ministry of Agriculture, researchers, national consultants of the project, and farmers. The main objectives of the courses were to train the scientists and farmers on the required skills and tools to be used in better targeting of conservation agricultural research in order to increase adoption of conservation agriculture technologies in the respective countries.

List of Trainings courses organized in Azerbaijan, Kazakhstan and Uzbekistan (2012-2013)

#	Title	Date	Number of trainees	Country
1	Promotion of conservation agriculture in South Kazakhstan province	01 March, 2012	47	Kazakhstan
2	Soil fertility improvement training course in Azerbaijan	12-13 March, 2012	40	Azerbaijan
3	Bed planting and no-till practices in Uzbekistan	26-27 March, 2012	52	Uzbekistan
4	Exploitation of boom sprayer and herbicide application in conservation agriculture	19-20 July, 2012	40	Azerbaijan
5	A training course on conservation agriculture in South Kazakhstan province	11-12 July, 2012	35	Kazakhstan
6	Concepts of practices of no-till and the technical aspects of double cropping in Uzbekistan	July 27-28, 2012	52	Uzbekistan
7	Laser land-leveling reintroduced in Azerbaijan under Conservation Agriculture project	03 October, 2012	45	Azerbaijan
8	Adoption of Conservation Agriculture started in the irrigated areas of Kazakhstan	10-11 October 2012	47	Kazakhstan
9	Conservation agriculture awareness comes to the farmers through field training course in Uzbekistan	24-25 October 2012	45	Uzbekistan
10	Training course on soil fertility improvement in Uzbekistan	18-19 February 2013	49	Uzbekistan
11	Soil fertility Management under conservation agriculture	01-02 February 2013	45	Azerbaijan
12	Training course on soil fertility improvement in Kazakhstan	07-08 February 2013	43	Kazakhstan

Closing workshop

The final workshop of the project was held from December 10-11, 2013. The objective was to highlight and review the most important technical results that were generated. About 30 participants attended this regional event. During the workshop, participants shared their impressions about the project and provided critical and valuable inputs on the recommendations of the workshop. There are a number of challenges that CA faces throughout the largely agricultural region of Central Asia and the Caucasus, including lack of crop diversification on small-size farming areas, knowledge about CA practices among extension and technical staff, knowledge about CA at decision-making levels, farmers' ability to decide on diversified crop rotations, and CA equipment.

Appendix 4: Field activity pictures

Topographic survey in Kazakhstan

Laser land-leveling in Azerbaijan

Bed planted soybean in Uzbekistan

Bed planted winter wheat in Azerbaijan

No-till triticale in Kazakhstan

Herbicide application into no-till corn in Azerbaijan


Direct planting of corn in Azerbaijan


No-till mung bean in Uzbekistan


Field day in Uzbekistan, 08 June 2012


Formal training course in Kazakhstan, 12 June 2012


National Coordinator Dr. Asad Musaev being interviewed by local media in Azerbaijan


FAO team visited project demo site in Azerbaijan

About ICARDA and the CGIAR

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is one of 15 centers supported by the CGIAR. ICARDA's mission is to contribute to the improvement of livelihoods of the resource-poor in dry areas by enhancing food security and alleviating poverty through research and partnerships to achieve sustainable increases in agricultural productivity and income, while ensuring the efficient and more equitable use and conservation of natural resources.

ICARDA has a global mandate for the improvement of barley, lentil and faba bean, and serves the non-tropical dry areas for the improvement of on-farm water use efficiency, rangeland and small-ruminant production. In the Central and West Asia and North Africa region, ICARDA contributes to the improvement of bread and durum wheats, kabuli chickpea, pasture and forage legumes, and associated farming systems. It also works on improved land management, diversification of production systems, and value-added crop and livestock products. Social, economic and policy research is an integral component of ICARDA's research to better target poverty and to enhance the uptake and maximize impact of research outputs.

CGIAR is a global research partnership that unites organizations engaged in research for sustainable development. CGIAR research is dedicated to reducing rural poverty, increasing food security, improving human health and nutrition, and ensuring more sustainable management of natural resources. It is carried out by the 15 centers who are members of the CGIAR Consortium in close collaboration with hundreds of partner organizations, including national and regional research institutes, civil society organizations, academia, and the private sector.

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