2015-2016

CRP-DS Action site: Aral Sea (Urgench, Khorezm province, Uzbekistan)

Activity title: Integrated Land and Water Productivity Improvement in Aral Sea Basin within CGIAR Research Program on Dryland System (CRP DS)

Collaborator: Khorezm Rural Advisory Support Service (KRASS), Urgench, Uzbekistan

IARC Project Team:	Dr. Bogachan Benli (ICARDA) - Senior Irrigation and Water Management Specialist, IWLMP Mr. Tulkun Yuldashev (ICARDA-CAC), Soil and Water Specialist, IWLMP Dr. Ram Sharma (ICARDA) -Senior Wheat Breeder
Implementing Country:	Uzbekistan
Research Team (National):	Dr. Jumanazar Ruzimov - Senior Researcher KRASS, Dr. Yulduz Jumaniyazova -researcher of KRASS, Mr. Izzatbek Kuryazov - researcher of KRASS.
Data collection site:	Experimental station of Khorezm branch of Uzbekistan Cotton Research Institute, (2015-2016), Urgench district, Republic of Uzbekistan

Rationale

In Uzbekistan, agriculture is still the key sector of the economy with a share in the GDP of over 30%, whereas over 50% of the labor force is employed in this sector. Cotton cultivation was continued after independence from the Soviet Union. However, as part of the government's policy to achieve national food sufficiency, nowadays also staple crops such as wheat and rice make up for a large share of the agricultural land (Martius and Wehrheim 2008). Current agricultural production systems are characterized by crop rotations of cotton-wheat-rice under heavy inputs of water and fertilizers. Water is delivered via extensive irrigation systems that were created during Soviet times from 1925-1985. High amounts of irrigation water are applied to the fields via rather inefficient surface furrow irrigation, while the water management is poor and efficient drainage lacking. As a result, rising groundwater tables have led to severe problems of waterlogging, salinization and land degradation, in Uzbekistan.

The irrigated wheat production in Khorezm, started after getting Uzbekistan independency from 1991 and it has reached to 1.1 million hectares of cultivation area, with an average yield of 4.5 t ha^{-1}. There are a number of biophysical and socio-economic constraints to successful and sustainable intensification of wheat agriculture in Khorezm province. Cultivation of disease susceptible varieties, lack of an organized seed system, excess volumes of irrigation, lack of proper crop rotations to sustain soil health, little application resource conservation agricultural practices and lack of advisory services on precision and profitable agricultural practices are important issues that need to be addressed. Irrigated management of yellow rust susceptible varieties of wheat disease control through fungicide increases production cost and is hazardous to environment and human health. A number of high yielding yellow rust resistant wheat varieties have been developed however, farmers in Khorezm province have limited access to the information. Field observations show that, farmers are intended to apply 300-500 mm irrigation at each irrigation events - and that contributes to water logging, low soil fertility, low yield, high cost and aggravate water scarcity problems in the basin. Improved water and land productivity are required, mainly through efficient seed varieties, crop rotation.

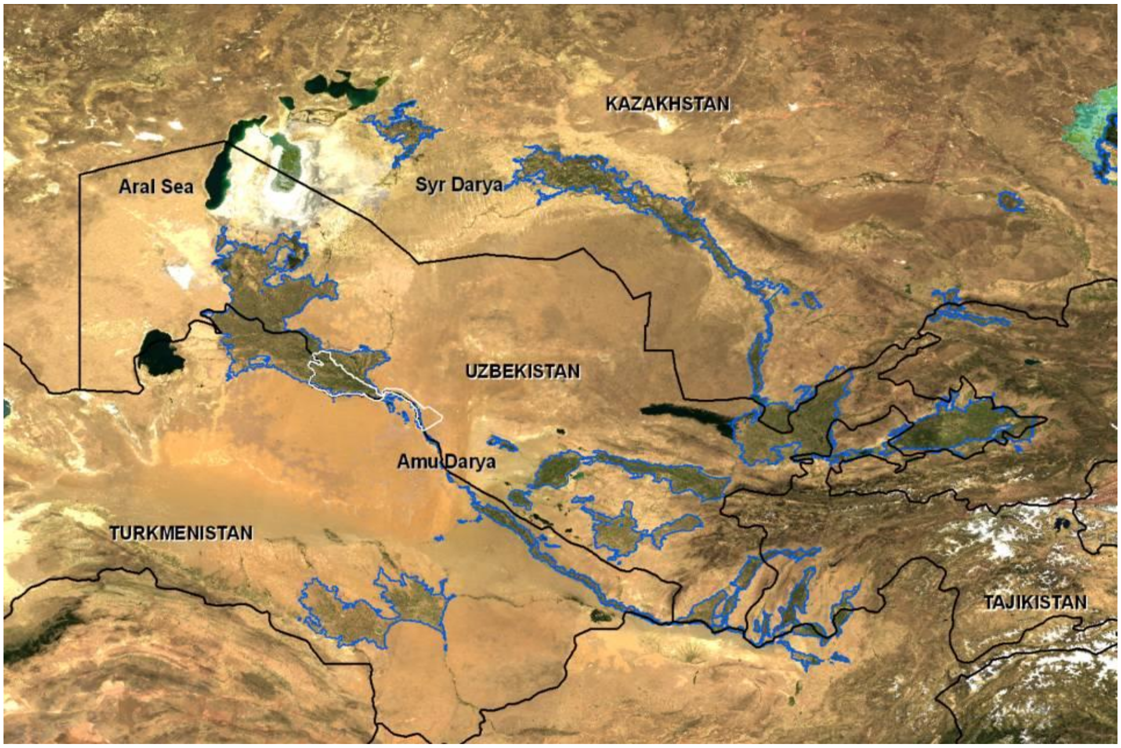
Objectives of the experiment

The main objective of the study is to develop an integrated and sustainable crop production system, for improved land and water productivity in the Khorezm province.

Location and climate

This research work was carried out within the framework of the ICARDA project in 2015 in the Khorezm region of Uzbekistan. The Khorezm region (60.05°-61.39°N latitude, 41.13°-42.02°E longitude) covers about 6,200 km² and is situated in the northwest of Uzbekistan on the lower left and right bank of the Amu-Darya river; the largest part of the region is on the left bank (**Figure 1**). It is part of the northern Turan lowlands of Central Asia and surrounded by deserts: to the north and east by the Kyzylkum desert, while in the south it borders on the Karakum desert (Yagodin and Betts 2006). The topography of the region is characterized by flat slopes (Djumaniyazov 2006) with a slight inclination from north-west towards south-east (Mukhammadiev 1982) and an elevation of 90-138 m above sea level (Katz 1976). Administratively, the region borders on the Amu Darya district of the autonomous Republic of

Karakalpakstan in the north and east, while in the west and south the Dashauz region of the Republic of Turkmenistan is located. With a total population of 2.0 million in 2015 (OblStat 2015).



Study site

Figure 1: Central Asia, the Aral Sea and the Project Region

Experimental station of Khorezm experimental Station of Cotton Breeding, Seed Production and Agrotechnologies Research Institute (41°32'12'', 60°41'11'') is located around 7 km south-east of Urgench city (capital of Khorezm province) in Urgench district of Khorezm province, Uzbekistan. The climate in the Khorezm region is dry continental with very hot summers and cold winters. Table 1 demonstrates the average monthly temperature, relative humidity and precipitation values, measured at the Urgench Meteorological Station during the period 1990 and 2000. Figure 2 demonstrates the measured data during the field trials and with comparison to long term data between 1961 -1990.

Table 1: Average annual meteorological indicators at the "Urgench" station in 1990 – 2000

Measurement period	Average Air T (°C)			Average		Precipitation (mm)
	Mean	Max	Min	Soil T (°C)	Rel. humidity (%)	
January	-2.2	2.6	-5.9	-1.6	80.0	13.7
February	0.3	6.1	-4.1	1.1	73.3	9.2
March	5.6	12.0	0.4	7.1	63.9	12.3
April	15.6	22.8	8.9	18.3	52.1	14.0
May	21.1	28.6	13.8	25.5	49.3	6.6
June	27.2	34.5	19.5	32.8	44.5	4.3
July	28.2	35.6	20.5	34.9	47.2	1.1
August	25.8	33.8	17.9	31.4	50.3	2.1
September	19.2	28.0	11.5	22.7	53.0	1.7
October	11.9	20.6	4.8	13.4	58.2	7.9
November	4.4	10.2	-0.6	4.4	71.6	10.2
December	-0.3	4.7	-4.3	0	80.2	8.3

Source: Glavgidromet 1999

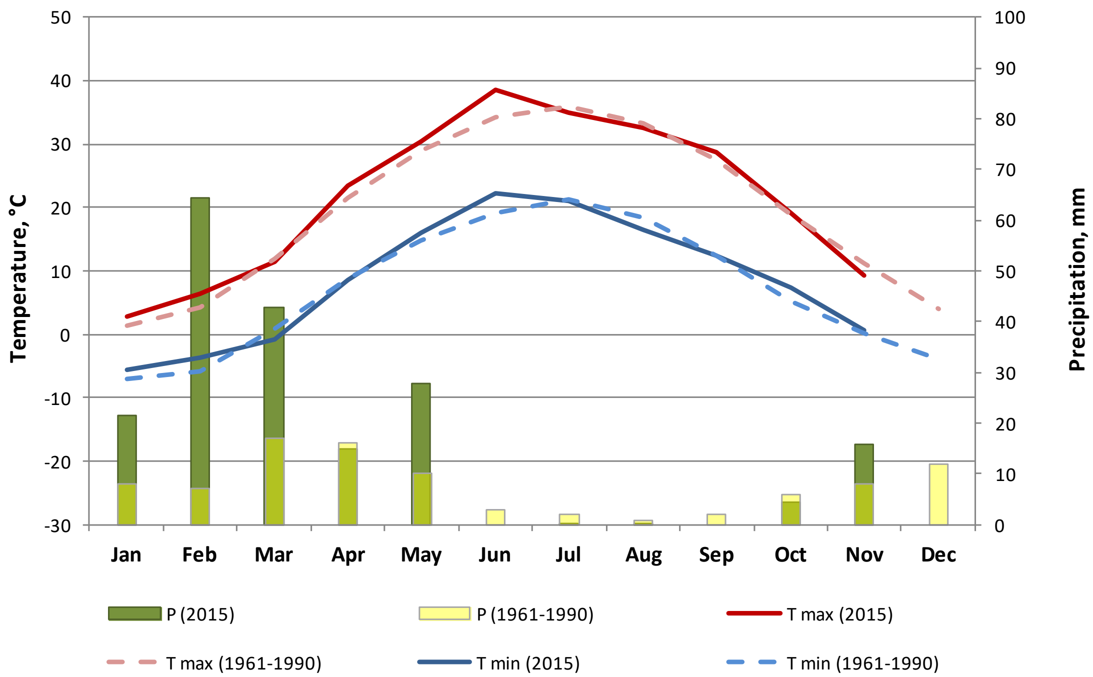


Figure 2: Monthly precipitation and monthly mean air temperature in Urgench (weather station: Urgench) comparing long-term data and observations made during the study period.

Soil

In mid-July 2015 one pit (1.5 m depth and 2 m length) was established in the middle of the experimental site to describe the soil by genetic layers. Three replicates of undisturbed soil cores were sampled with sampling rings (Eijkelkamp) at each genetic horizon for determination of soil bulk density. Soil sub-samples were sampled in three replications from the soil pit according to each morphological horizon to determine soil texture, pH and organic matter content (**Table 2**). Soil texture is moderate loam at the depth of 0-62 cm followed by sand at the depth of 62-200 cm. The soil salinity levels (July, 2015); in terms of TDS at the different soil depths extending up to 2 m were in the range of 2350 mg L^{-1} to 31400 mg L^{-1} (**Table 3**). Among the anions, SO_4^{2-} was dominant having concentration of 10-27 me L^{-1} in the upper 0.40 m depth. Ratio of chloride (Cl^-) to sulphate concentration ranged from 0.1 to 0.8 in the soil profile. Considering content of dissoluble inorganic species, soil was assessed as moderate/highly saline with mostly chloride-sulphate and sulphate type of salinity. Addition to the abundant salts as ($Ca(HCO_3)_2$, $CaSO_4$, Mg SO_4, Na_2SO_4, NaCl) toxic salts such as $CaCl_2$ и $MgCl_2$ were also met.

Field capacity was determined in 2 x 2 m plot by measuring water content after wetting a soil profile, covering it (to prevent evaporation) and monitoring the change soil moisture in the profile. Infiltration rate was determined by standard double metallic ring infiltrometers (**Figure 3**).

Table 2 Soil physical and chemical properties at Khorezm Experimental Station of Cotton Breeding, Seed Production and Agro technologies Research Institute

Soil characteristics	Soil layer					
Depth,m	**0-0.25**	**0.25-0.35**	**0.35-0.50**	**0.50-0.62**	**0.62-1.20**	**1.20-2.00**
Sand (0.05-2.0 mm), %	47	47	43	47	47	50
Silt (0.002-0.05 mm), %	37	37	43	36	36	35
Clay (<0.002 mm), %	16	16	14	17	17	15
Soil texture (USDA classification)	loam	loam	loam	loam	sand	sand
Field capacity, $m^3 m^{-3}$	0.315	0.292	0.305	0.323	0.310	0.310
Infiltration rate, mm day^{-1}	301					
Soil bulk density, g cm^{-3}	1.41	1.65	1.56	1.40	1.40	1.40
ph	8.43	8.65	8.58	8.86	8.61	8.68
Organic matter, %	0.89	0.86	0.83	0.64	0.59	0.61

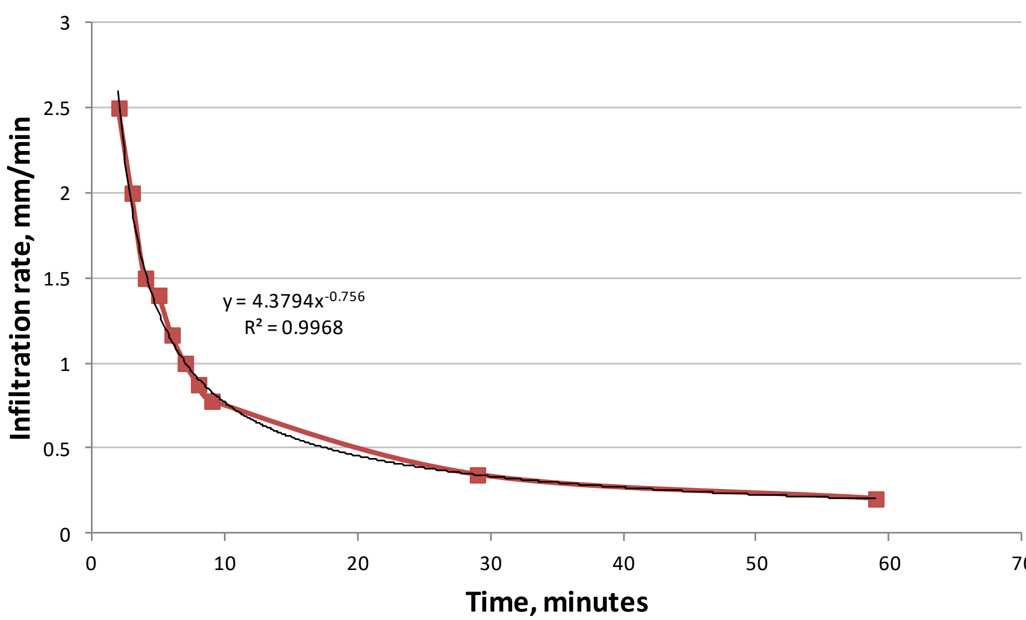


Figure 3. Infiltration rate of Khorezm site before establishment of mungbean trials (2015)

Table 3: Initial soil salinity level at experimental site on 01.07.2015

№ profile	Soil depth, cm	TDS, mg L^{-1}	HCO 3	Cl	SO_4	Ca	Mg	Na	Salinity type	$CaSO_4 \cdot 2H_2O$	CO_2
1	0-31	8500	0.033	0.021	0.494	0.100	0.060	0.034	SO4-Mg-Ca	1.550	6.56
	31-40	15100	0.027	0.022	0.963	0.290	0.060	0.038	SO4-Mg-Ca	0.500	6.666
	40-52	15650	0.021	0.035	0.950	0.260	0.069	0.056	SO4-Mg-Ca	0.590	6.88
	52-68	6050	0.018	0.024	0.385	0.125	0.032	0.003	SO4-Mg-Ca	0.710	6.88
	68-210	6020	0.024	0.031	0.278	0.055	0.018	0.065	SO4-Ca-Na	0.250	6.74
2	0-25	31400	0.015	0.662	1.310	0.215	0.098	0.591	Cl- SO4-Ca-Na	1.167	6.63
	25-35	14200	0.015	0.077	0.840	0.230	0.030	0.136	Cl- Na-Mg-Ca	0.667	6.70
	35-50	2350	0.027	0.045	0.080	0.025	0.012	0.026	Cl-SO4--Na- Ca	0.500	6.77
	50-62	2700	0.021	0.052	0.105	0.030	0.012	0.034	Cl-SO4--Na- Ca	0.250	6.77
	62-120	11600	0.024	0.056	0.665	0.155	0.030	0.128	SO4- Na-Mg-Ca	0.361	6.98
	120-200	2050	0.018	0.049	0.070	0.040	0.012	0.003	Cl-SO4--Mg-Ca	0.584	6.63

Cation and anions expressed in %

Irrigation, drainage and groundwater characteristics

Irrigation water salinity in the region was 0.89-0.91 g L^{-1}, i.e. with each cubic irrigation water 0.89-0.91 kg soil is entered. Drainage and collector water salinity was 3.03 - 3.37 g L^{-1} (**Table 4**).

The groundwater table depth (**Figure 4**) was measured in weekly basis at ten locations across the field in 2015. The ground water table was also considerably higher and varied along the length of the field at the range of 0.6-1.6 m, with an average depth of 0.93 m. Groundwater salinity was in the range of 1-3 dS/m in July-September 2015 and was 0.37-0.4 in late November 2015 and ph ranged from 7.2 to 8.0 (**Table 5, Table 6**) .

Table 4: Irrigation, drainage, groundwater salinity in Khorezm region, g L^{-1}

Type of water	Number of samples	Ranges			Mean		
		TDS, %	Cl	SO_4	TDS, %	Cl	SO_4
Irrigation	6	0.78-1.24	0.17-0.22	0.24-0.41	0.911	0.190	0.293
Drainage	5	1.87-4.23	0.24-1.13	0.72-1.43	3.114	0.694	1.123
Collector	5	2.71-4.04	0.39-1.04	1.21-1.73	3.375	0.581	1.413
groundwater	56	1.03-24.80	0.17-6.13	0.34-7.72	4.73	1.01	1.76

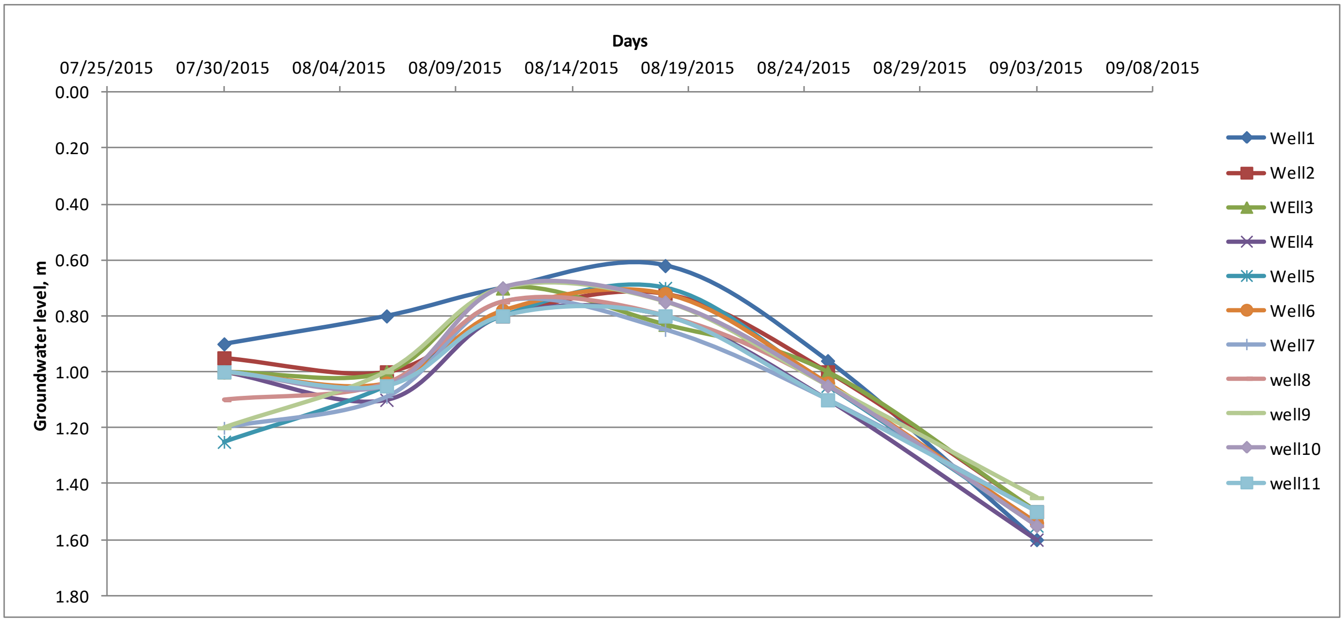


Figure 4 Groundwater level at experimental site in Khorezm during mungean crop season (July-Sep 2015)

Table 5: Groundwater table and salinity in Khorezm region, mungbean trials, 2015

№ Pizometr	30.07.15			06.08.15			11.08.15			18.08.15			25.08.15			03.09.15		
	Ground-water level, m	EC, dS/m	pH	Ground-water level, m	EC, dS/m	pH	Ground-water level, m	EC, dS/m	pH	Ground-water level, m	EC, dS/m	pH	Ground-water level, m	EC, dS/m	pH	Ground-water level, m	EC, dS/m	pH
P1	0.90	1.54	7.23	0.80	1.26	7.37	0.70	1.40	7.26	0.62	2.01	7.23	0.96	1.64	8.07	1.60	2.64	8.07
P2	0.95	1.19	7.52	1.0	1.33	7.30	0.80	1.17	7.42	0.72	1.37	7.52	1.0	1.31	7.75	1.50	2.31	7.75
P3	1.0	1.52	7.37	1.0	1.39	7.24	0.70	1.47	7.31	0.83	2.39	7.37	1.0	2.07	7.51	1.50	2.47	7.51
P4	1.0	1.59	7.30	1.10	1.94	7.75	0.80	1.74	7.30	0.80	2.94	7.30	1.10	3.0	7.51	1.60	3.0	7.51
P5	1.25	1.41	7.24	1.05	1.29	7.51	0.80	2.98	7.24	0.70	3.64	7.24	1.05	2.95	7.33	1.55	2.95	7.33
P6	1.0	1.04	7.21	1.04	1.98	7.51	0.78	1.98	7.21	0.72	3.25	7.21	1.04	2.48	7.31	1.54	2.78	7.31
P7	1.20	1.11	7.32	1.09	2.17	7.33	0.75	2.07	7.32	0.85	2.22	7.32	1.10	1.86	7.35	1.50	2.86	7.35
P8	1.10	1.77	7.20	1.04	1.38	7.31	0.75	2.91	7.20	0.80	2.96	7.20	1.05	2.31	7.35	1.55	2.81	7.35
P9	1.20	1.15	7.21	1.0	1.41	7.35	0.70	2.47	7.21	0.75	2.48	7.21	1.05	2.45	7.28	1.45	2.85	7.28
P10	1.0	1.09	7.26	1.05	1.31	7.33	0.70	2.37	7.26	0.75	2.36	7.26	1.05	2.26	7.3	1.55	2.76	7.3
P11	1.0	1.50	7.26	1.05	1.39	7.31	0.80	3.32	7.26	0.80	3.37	7.26	1.10	3.14	7.28	1.50	3.44	7.28

Table 6: Groundwater level and EC of groundwater on 25.11.2015

№	Observation well	Groundwater level (cm)	Ec, dS/m
1	GW1	205	0.37
2	GW2	205	0.39
3	GW3	214	0.39
4	GW4	208	0.38
5	GW5	213	0.38
6	GW6	212	0.38
7	GW7	200	0.36
8	GW8	211	0.4
9	GW9	207	0.39
10	GW10	203	0.38
11	GW11	202	0.38
12	GW12	200	0.37
13	GW13	208	0.37
14	GW14	211	0.38

Experimental management and start-up conditions

The experiment was initiated in July 2015. In order to evaluate the performance of optimum irrigation scheduling under raised bed furrow irrigation methods and effect of introducing of mungbean-wheat rotation mungbean Durdona variety was planted in raised bed furrow irrigation system in a Split-Plot design with management practices (traditional and optimal) as main-plot and three varieties as subplot treatments. The experiment was conducted under W-M-W (Wheat-mungbean-Wheat) and W-F-W (Wheat-fallow-wheat) rotations side-by-side on the same field. One more treatment as farmer's management practice under the two crop rotation was included in the experiment. Individual plot size was 300 m^2.

This mungbean entry was planted manually on July 13 at the experimental site of the Khorezm Experimental Station of Cotton Breeding, Seed Production and Agro technologies Research Institute. Each plot had 2 rows (for mungbean) and 4 rows (for winter wheat) with a length of 50 m and a width of 13.5 m and 90 cm inter-row space. The experimental layout is presented in **Figure 5.**

Moldboard tillage was applied using tractor (Model: MTZ-80) on 06 of July 2015 (**Table 7**). Nitrogen and Phosphorus in the form of Ammophos (282 kg/ha) N30 P130, and potassium in the form of potassium chloride were applied at the rate of 100 kg ha^{-1}, respectively just before sowing. At flowering stage (11 August 2015) the second Nitrogen application (Urea) was implemented at the rate of 30 kg/ha. The cropping history consisted of cotton the previous year followed by winter wheat which was harvested in early July. Pest and weed control were conducted as required. After harvesting of mungbean at the end of September, 3 winter wheat varieties, Yaksart and Elomon, new wheat variety with local variety Tanya (variety used by farmers around the experimental site) were planted at the experimental site. Nitrogen and Phosphorous (Ammophos) in the form of Amophos (282 kg/ha) and Potassium (Potassium Cloride) were applied at the rate of 30 kg/ha, 130 kg/ha and 100 kg/ha in active matter.

Table 7: Experimental management of Khorezm site (2015-2016)

Farming practices	Dates (mungbean)	Dates (winter wheat)
Tillage (Moldboard)	07/06/2015	09/26/2015
Harrowing	07/07/2015	09/26/2015
Grinding	07/09/2015	09/27/2015
Land leveling	07/10/2015	09/27-28/2015
Planting date	07/13/2015	09/29/2015
Seeding rate, kg ha^{-1}	30	200
Harvest	09/24/2015	

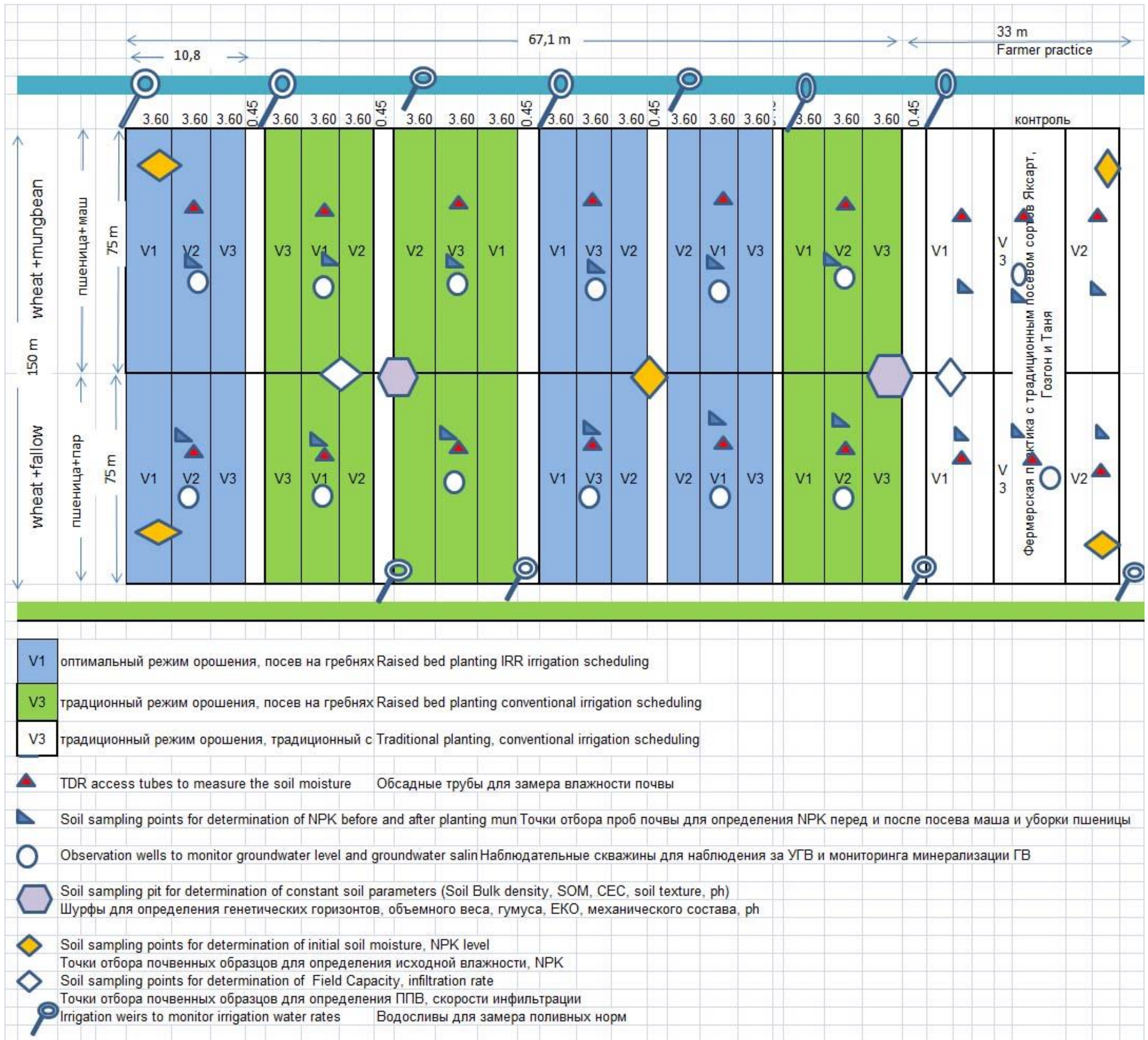


Figure 5 Experimental layout of sowing of mungbean Durdona variety and 3 winter wheat varieties at experimental site of KES CBSPARI (2015-2016)

The following initial conditions have been determined: Nmin, P and K available forms, soil moisture and soil salinity (TDS) before land preparation (tillage) (**Appendix 2**). The sampling was done at 4 soil depths (0-20, 20-40, 40-70 and 70-100 cm) and 5 sampling points located as per "envelop" scheme. The soil moisture content in mid-July 2015 in 0-1 m was in the range of 0.128 to 0.299 m^3 m^{-3} (**Table 8**). The mineral N content, i.e. the sum of soluble NO_3 and NH_4 in the top 1 m of soil was measured to amount to 188 kg N ha^{-1}. Soil organic matter content decreased from 0.89 % in the top (0-20 cm) to 0.61 % in 0.70-1.00 m depth.

Table 8: Initial soil conditions of Khorezm site for 2015-2016 (15.07.2015)

Soil characteristics	**Soil layer**			
Depth, m	**0-0.20**	**0.20-0.40**	**0.40-0.70**	**0.70-1.00**
Soil moisture, $m^3\ m^{-3}$	0.128	0.208	0.261	0.299
Soil organic matter, %	0.89	0.83	0.58	0.61
NH_4-N, kg ha^{-1}	15.6	10.3	11.6	8.4
NO_3-N, kg ha^{-1}	43.0	40.1	40.4	18.9

NPK data

Soil analysis on the available and gross forms of mineral Nitrogen content (Nmin (NO_3, NH_4) and Phosphorus and Potassium had been taken 2 times (before mungbean planting and after harvest of mungbean), at the following depths: 0-0.15 m, 0.15-0.30 m, 0.30-0.60 m, and 0.60-0.90 m from experimental site. As per collected data NPK level has increased under mungbean-wheat crop rotation in comparison with fallow-wheat crop rotation.

Performance of Irrigation Methods

Crop data (mungbean)

The mungbean was at first-three leaves (V2-V3) stage on July 21, sprouting stage (V3) on August 10, budding stage (R1-R2) on September 1, and flowering stage (R3-R5) on September 10, 2015 (**Table 9**). Plant height at traditional planting was 8.4, 12.2 and 21.3 cm and that under optimum irrigation was 10.9, 13.0 and 26.9 cm at first three leaves development stage, sprouting and budding stages, respectively.

Number of leaves and number of pods were also higher under optimal irrigation regimes.

Table 9: Plant height, number of leaves and number of pods at Khorezm site for 2015

Treatments	Plants height (cm)			Number of leaves			Number of pods
	V2-V3	V3	R1-R2	V2-V3	V3	R1-R2	
	21.07.15	10.08.15	01.09.15	21.07.15	10.08.15	01.09.15	
Tradition	8.4	12.2	21.3	10.7	21.0	22.3	34.9
Optimal	10.9	13.0	26.9	12.7	24.9	24.9	39.9

V2-V3 = first three leaves developed, V3 =sprouting, R1-R2=budding, R3-R5 =Flowering

Aboveground biomass dynamics are presented in **Figure 6**.

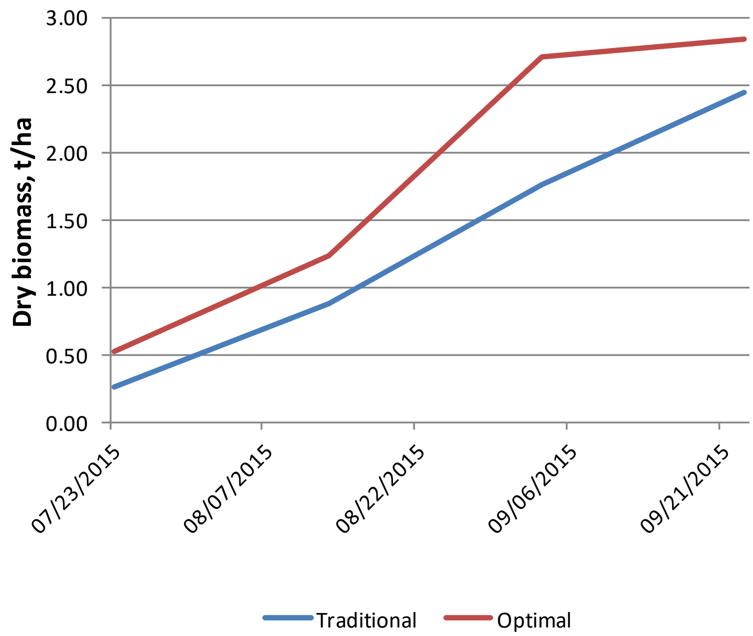


Figure 6 Dynamics of aboveground biomass accumulation during mungbean crop season (2015)

Crop yield parameters including grain yield data for each of the treatments are presented in **Table 10**. Optimum irrigation significantly influenced the number of pods per plant, number of seeds per pod and 1000 -Seed yield which all together significantly increased yield by 17% as compared to control (**Table 10**)

Table 10: Effect of irrigation on yield contributing characters and yield of mungbean

Treatments	Plant height, cm	No. of pods/plant	No. of seeds/pod	1000-seed weight (g)	Seed yield (t/ha)
Traditional irrigation	40	27	9	61.6	1.92
Optimum irrigation	42	32	10	63.2	2.25
LSD (0.05)	3.06 (NS)	2.67	0.87	1.16	0.23

Statistical analyses were implemented using GenStat 17th Edition software. Number of days from emergence till maturity for optimal irrigation was 70-75 days while that for traditional irrigation was 74-78, i.e. difference in maturity days was 3-4. At maturity AGB was maximum (6.22 t/ha) under optimum irrigation treatment while that was minimum (5.33 t/ha) under traditional irrigation treatment. Difference was 0.89 t/ha. Maximum Photosynthetic potential was observed under optimum irrigation treatment while that was minimum under traditional irrigation. Net Photosynthetic productivity was in the range of 4.2-4.4 g/m2 × days (**Table 11**). Leaves work productivity was not much differ between treatments and ranged from 1.03-1.08 kg grain per 1000 units of Photosynthetic potential. Leaves fruit loads was in the range of 60.6-56.3 g/m^2.

Table 11: Effect of irrigation regime on photometrical characters of mungbean

Treatments	Parameters					
	AGB, t/ha	Maximum Leaf Area, thous. m^2/ha	Photosynthetic potential, Mln. units	Net Photosynthetic productivity, g/m^2 × days	Leaves work productivity, kg/1000 units Photosynthetic potential	Leaves fruit loads, g/m^2
Optimal	6.22	34.3	2.02	4.4	1.03	60.6
Tradition	5.33	32.7	1.69	4.2	1.08	56.3

In fruit production stage (23.09.2015) LAI was 3.47-5.63 and 3.47-4.93 under optimum and traditional irrigation treatments, respectively with maximum observed under optimum irrigation (**Table 13, Figure 7**).

Table 13: Effect of irrigation regime on LAI dynamics

№	Treatments	23.07.15	13.08.15	03.09.15	23.09.15
1	Trad V1R1	1.80	2.51	2.79	3.79
2	Trad V1R2	1.65	1.93	2.47	3.47
3	Trad V1R3	1.76	2.25	2.93	4.93
4	Trad V2R1	1.50	1.80	1.99	3.99
5	Trad V2R2	1.35	2.30	2.53	3.53
6	Trad V2R3	1.24	1.80	2.47	3.47
7	Trad V3R1	2.50	2.71	3.38	4.38
8	Trad V3R2	2.99	2.72	3.31	4.31
9	Trad V3R3	2.30	3.25	3.35	4.35
10	OPT V1R1	1.83	3.31	3.64	5.64
11	OPT V1R2	2.42	2.60	4.18	4.18
12	OPT V1R3	2.42	2.90	3.66	3.66
13	OPT V2R1	2.00	2.66	2.88	3.88
14	OPTV2R2	1.93	2.50	2.90	3.90
15	OPT V2R3	1.88	2.17	2.48	3.48
16	OPT V3R1	2.63	3.13	3.67	3.67
17	OPT V3R2	2.31	3.31	4.69	4.69
18	OPT V3R3	2.49	3.69	4.68	4.68
	Traditional	1.90	2.36	2.80	4.02
	Optimum	2.21	2.92	3.64	4.20

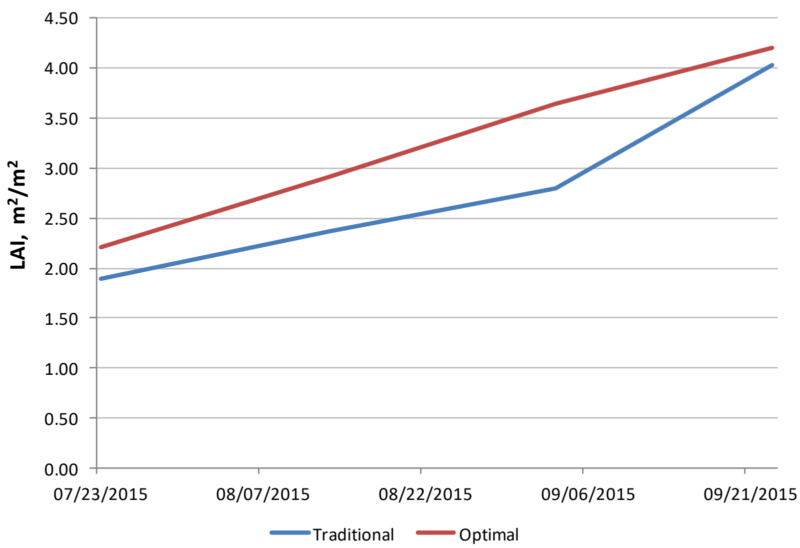


Figure 7 Dynamics of aboveground biomass accumulation during mungbean crop season (2015)

Crop data (winter wheat)

Analysis of variance showed that mean effect of various factors (rotation, management practice, and variety) as well interactions among these factors were non-significant at *P*=0.05 for plant stand and NDVI value (**Table 14**). The mean plant stand was higher for two new varieties (Yaksart and Elomon) compared to the variety (Tanya) commercially grown by the farmers (**Table 14**). The results are as expected because difference in management level and crop rotation will be more critical as crop will develop towards advanced growth stages and water and nutrient requirements will increase. Under that condition, a more efficient crop management system will sustain crop growth better than the less efficiecient system.

The experiment was planted in the end of September 2015 and initial data were collected on crop stand and NDVI (normalized difference vegetative index) (**Table 15**). It has been suggested that NDVI could be used to predict grain yield in cereals (Raun et al. 1999; Wang et al. 2010; Hazratkulova et al., 2014).

Table 14. Analysis of variance table for plant stand and NDVI value at seeding stage in a study of evaluation of wheat varieties, management options and crop rotation in Urgench, Uzbekistan in 2015-2016 wheat growing season

Source of variation	df	Plant stand at seedling stage		NDVI value at seedling stage	
		Mean square	F-Probability	Mean square	F-Probability
Rotation (Rot)	1	1312	>0.10	0.114582	>0.10
Replication/Rot	4	4367		0.050965	
Practice (Prc)	2	3663	>0.10	0.004579	
Prc x Rot	2	581		0.040246	
Error (a)	4	2606		0.002676	
Variety (Var)	2	6212	0.10	0.006414	>0.10
Var x Prc	4	4602	>0.10	0.001002	>0.10
Var x Rot	2	82	>0.10	0.000637	>0.10
Var x Prc x Rot	4	273	>0.10	0.002249	>0.10
Error (b)	16	2377		0.002623	

Table 15. Mean values for plant stand and NDVI value at seedling stage in a study of evaluation of wheat varieties, management options and crop rotation in Urgench, Uzbekistan in 2015-2016 wheat growing season

Variety	Predicted mean	
	Crop stand (m^{-2})	NDVI value
Yaksart	294 a†	0.374
Elomon	288 ab	0.336
Tanya	255 b	0.375
$LSD_{0.05}$	39	0.042

†Means within a column followed by different letters are significantly different based on $LSD_{0.05}$.

Performance of Irrigation scheduling and management

Irrigation rates for optimum and traditional irrigation regimes were measured by Tomson (or triangle) weirs installed before each irrigation event (**Table 16**). Irrigations under optimum irrigation treatments were applied when the root zone water deficit equaled them maximum allowable depletion of the available soil water. The non-stressed ET was estimated using the FAO Penman–Monteith equation. For the FAO recommended irrigation schedule, or no stress condition, with optimal irrigation scheduling the plots were irrigated when 40-45% of the available water was depleted. We can conclude that optimum irrigation scheduling in spite had one irrigation more but resulted in higher water productivity 5.26 kg/mm x ha in comparison with traditional irrigation which had water productivity 3.83 kg/mm x ha (**Table 17**).

Table 16: Irrigation regime of mungbean at Khorezm site (2015)

Irrigation treatment	Irrigation date	Irrigation rate, m^3/ha	Total irrigation rate, m^3/ha
Traditional	13.07.2015	586	1568
	30.07.2015	490	
	18.08.2015	492	
Optimum	13.07.2015	513	1985
	21.07.2015	488	
	30.07.2015	502	
	18.08.2015	482	

Table 17: Amount of irrigation water applied, number of irrigation events, seed yield and water productivity

Treatments	TDR	Replication	Yield, kg/ha	Number irrigation	Irrigation rate, mm	ET, mm	Water productivity , kg/mm x ha
Optimum irrigation	4	1	2339	4	200	453	5.16
Optimum irrigation	7	2	2180	4	189	410	5.32
Optimum irrigation	8	3	2219	4	207	418	5.31
Optimum irrigation	average		2246	4	199	427	5.26
Traditional irrigation	5	1	2043	3	153	477	4.28
Traditional irrigation	6	2	1828	3	159	582	3.14
Traditional irrigation	9	3	1884	3	159	462	4.08
Traditional irrigation	average		1918	3	157	507	3.83

Soil moisture, soil temperature and soil salinity were recorded at 0-10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70-80 and 80-90 cm depths from 20 July 2015 by IMKO data logger system (**Appendix 1**). Data from the PDA of data loggers (soil moisture) from 24 TDR access tubes were imported to computer.

Post-sowing irrigation for winter wheat were applied twice on 30 Sep 2015 and 16 Oct 2015 at the rate of 55 and 49 mm, respectively.

Crop coefficients

For implementing ET based irrigation scheduling, field capacity (FC) of soils in the experiment plots were measured. Irrigation was scheduled when soil-water content in the root zone is depleted by the crop to 80% of FC. Amount of irrigation applied is measured using Tomson triangle irrigation weirs at both supply and tail end of the furrow. The weather data (daily air temperature, relative humidity, wind speed, solar radiation) required for calculating ET_o is being obtained from iMETOS®ag weather station (Pessl Instruments GmbH, Austria) (**Figure 8**) installed in middle of the cotton planted field and open area close to the experimental site (around 500 m).

Figure 8. Establishment of automatic weather station at Khorezm Station of Cotton Breeding, Seed Production and Agro-technologies

Crop water demand or ET calculated using grass reference ET and crop coefficients was compared with ET derived using the soil water balance equation (Ibragimov et al., 2007):

$$ET_c = P + I + F - R - \Delta S$$

where ET is the crop water use, P is the precipitation, I is the irrigation, F is flux across the lower boundary of the root zone, R is the sum of runoff and run-on, and ΔS is the change in soil water content in the soil profile. Precipitation data is obtained from a weather station installed specifically for this experiment.

Single day values of mungbean Kc were determined by taking a ratio of ETc measured by water balance equation to ETo estimated by Penman-Monteith equation as described in FAO-56 Irrigation and Drainage paper (Allen et al. 1998). The Kc values were determined until mungbean plants were harvested on September 24 2015 (**Table 18**).

Table 18 Average Kc values for different growth stages and their duration.

Growth stages	Duration of stage (number of days)		Average Kc values	
	Measured	FAO-56	Measured	FAO-56
Initial	15	20	0.60	0.50
Development	20	30	0.90	0.80
Mid season	23	30	1.02	1.05

The growth stages including initial, developmental, and midseason were identified by visual observations of crop data on growth and development during the season. In general, Kc values for mungbean followed the same pattern as described in FAO-56 Irrigation and Drainage paper (Allen et al. 1998) (**Figure 9**).

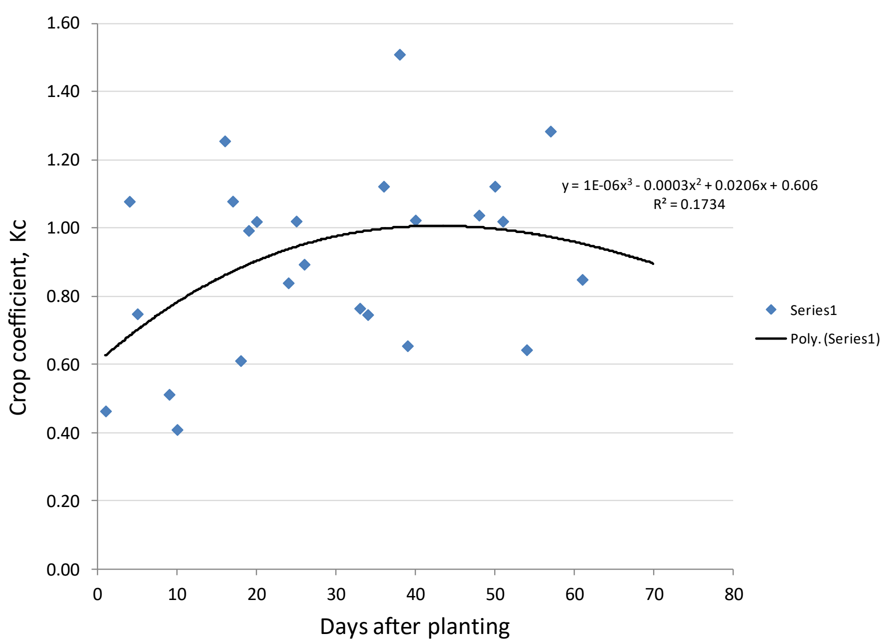


Figure 9. Crop coefficients estimated for mungbean trials during crop season in 2015

Productive and profitable agricultural systems identification

Revenue values calculated on the base of input data incurred in optimum and traditional irrigations revealed that optimum irrigation produced maximum 4007 USD revenue while that was 3423 USD (**Figure 10**) i.e. less by 17 %, which additionally proves higher economical benefit to farmers from introducing new advanced irrigation technology.

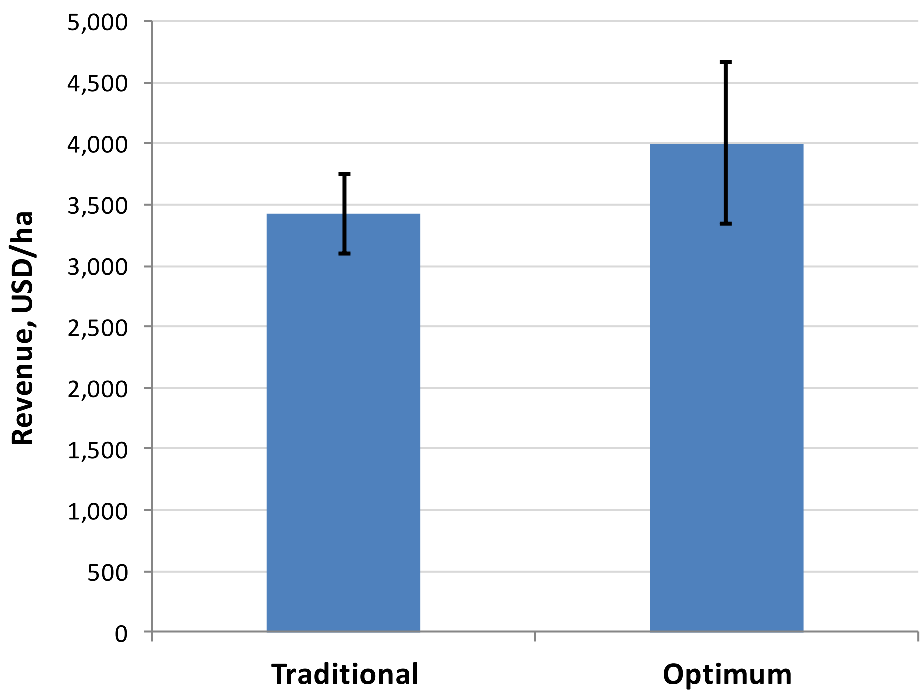


Figure 10. Revenue values estimated for mungbean trials during crop season in 2015 (Traditional irrigation -3 irrigation events, optimum irrigation -4 irrigation)

Conclusions

Prior to this demonstration experiment, comprehensive investigation on efficiency of conventional irrigation scheduling against widely used ET-based irrigation scheduling in Khorezm region had been limited. This experiment, while demonstrating the efficacy of ET-based irrigation scheduling services, provides crop coefficients for mungbean and winter wheat grown in predominant HMZs. In addition, the data collected as part of this experiment can be used to conduct crop modeling to evaluate the effects of climate change on water availability and water demand in the Aral Sea Basin. Irrigation and water use efficiencies calculated using this experiment can be used to compare their relative performance with other cotton and winter wheat producing nations in Central Asia and around the world.

First year trial with introducing mungean in wheat crop rotation showed positive impact of the technology in terms of additional source of income to farmers with soil nutrient enhancement potential. Optimum irrigation scheduling increased not only yield and water productivity but also ensured getting additional income to the farmers at the project site.

Outputs

1. Partnership was established with Khorezm Rural Advisory Support Service (KRASS) and Khorezm branch of Uzbekistan Cotton Research Institute
2. Field trials with different raised bed furrow irrigation, with two crop rotation and three wheat varieties implemented in Urgench district, at experimental site of Khorezm branch of Uzbekistan Cotton Research Institute
3. Mungbean yield values improved 17%. Water Productivity enhanced 20%
4. Kc values for mungbean determined as 0.60 , 0.90 and 1.02
5. Revenue has increased around 16% in mungbean cultivation.

Outcomes

1. Capacity building for farmers (10 female, 20 male), using the field trials were conducted in the experimental site in Urgench District.
2. Experimental design and Raised bed furrow irrigation was presented to stakeholders (40) during the Conservation Agriculture workshop in KaraOzek.
3. NARS partner's (KRASS) staff (4 Female and 2 Male) capacity enhanced on integrated land and water management, conservation agriculture, wheat varieties, irrigation scheduling, raised bed furrow irrigation applications and economic evaluation of water saving technologies.

Appendix 1

Field data collection at Khorezm experimental site (2015-2016)

Appendix 1 (Continued)

Genetic horizons, cm	Soil morphologic description
Ap 0-25 cm	Gray, from dry at top to fresh down, moderate loam, moderate dense, homogeneous, coarse soil, worm-holes, plant roots residues are met, changes are gradual
A2 25-35 cm	Gray with pale-yellow tinge, fresh moderate loam, more dense than previous layer, dusty, cloddy structure, along the profile inclusion of half decayed roots, worm-holes, changes are gradual
B1 35-50 cm	Pale-brown, fresh, density is same as previous layer, homogeneous, cloddy-nut structure, worm-holes, moderate loam, changes are clear
B2 50-62 cm	Pale-brown, fresh, moderate dense, homogeneous, cloddy structure, moderate loam, changes are clear
B3 62-120 cm	Grayish-brown, from moist to wet, homogeneous sand, moist, friable, gradual density and color changes, worm-holes, Fe inclusions
B4 120-200 cm	Grayish -brown, wet sand, water at down layers

Appendix 2 Initial nutrient content of soil, soil salinity and soil moisture in the study area (2015) (Khorezm)

Date	Horizon (cm)	mg kg^{-1}				TDS	Soil moisture
		NO_3	NH_4	P_2O_5	K_2O	%	g g^{-1}
10/11/2015	0-20	5.2	1.6	20.6	200	0.15	0.068
	20-40	3.9	1.4	15.9	200	0.13	0.103
	40-70	4.1	2.1	12.6	192	0.13	0.131
	70-100	2.6	1.9	9.0	180	0.16	0.152

Nmin content is low in all horizons. P_2O_5 content is low in 0-40 cm horizons and very low in 40-100 cm,
K_2O content is low in all horizons. Salinity is low in all horizons.

References

Abdullaev S. 1995. Agro-physical basis of saline soils amelioration in the lower reaches of Amu-Darya (in Russian). Tashkent State University, Tashkent, pp. 1-44.

Abdullaev C (2003) Republic of Uzbekistan. Land degradation assessment in dry lands (LADA). State Design and Research Institute (UzGip), Tashkent. http://www.fao.org/nr/lada/. Cited 02 June 2009

Ablyazov A. 1973. Agro-physical soil properties, processes of salt accumulation and desalinization in the Khorezm region (in Russian). Tashkent Institute of Agriculture, Tashkent, pp. 1-21.

Academy of Sciences of Uzbek SSR, 1982. Atlas of Uzbek SSR. Volume 1. Central Administrative Board of Geodesy and Cartography under Council of Ministers of USSR, Moscow-Tashkent, 1982

Allen, R.G., M. Smith, A. Perrier and L.S. Pereira, 1994: An update for the definition of reference evapotranspiration. ICID Bulletin 43 (2): 1-34.

Allen, R.G., L.S. Pereira, D. Raes and M. Smith, 1998: Crop evapotranspiration: guidelines for computing crop water requirements (FAO irrigation and drainage paper 56) Food and Agriculture Organization, Rome, Italy. Available at http://www.kimberly.uidaho.edu/refet/fao56.pdf Last Accessed: March 8, 2011.

Allen, R.G., I.A. Walter, R. Elliot, T. Howell, D. Itenfisu and M. Jensen, 2005: The ASCE standardized reference evapotranspiration equation. American Society of Civil Engineers. Reston, Virginia.

Berdjansky, V. and Zaks, I. 1996. Environmental benefits of reducing collector-drain runoff and ways to improve irrigation water quality in the rivers of the Aral Sea basin. In: M. G. Bos (ed). Kluwer Academic Pub.

Bremen Cotton Exchange (2004) Cotton varieties by origin. Bremen, Bremen Cotton Exchange, p 25

Chaudhry MR and Guitchonouts A (*2003*) Cotton facts. Technical Paper No. 25 of the Common Fund for Commodities, International Cotton Advisory Committee, p 158

Chub, V. E., 2000: Climate Change and its Impact on the Natural Resources Potential of the Republik of Uzbekistan. (available from Hydrometeorological Service, Makhsumov Street 72, Tashkent 700052, Uzbekistan).

Celis, D., De Pauw, E., Geerken, R., 2007. Assessment of land cover and land usein central and west Asia and north Africa. Part 1. In: Land Cover/Land Use–BaseYear, 1993. International Center for Agricultural Research in Dry Areas (ICARDA),Aleppo, Syria, p. vi+54.

Chembarisov, E. I. 1996. The problem of water resources management in Central Asia with regard to the Aral Sea situation. In: P.P.Micklin and W.D. Williams (Ed) The Aral Sea Basin. NATO ASI Series, Vol. 12. 115-121.

Chembarisov, E. I. and Bakhritdinov, B. A. 1989. Hydrochemistry of river and drainage waters in the Central Asia. Ukituvchi, Tashkent

De Pauw, E., 2010. Agro-ecological zoning of the CWANA region. In: El-Beltagy, A.,Saxena, M.C. (Eds.), Sustainable Development in Drylands – Meeting the Chal-lenge of Global Climate Change. Proceedings. , pp. 335–348.

GME (Hydrogeologic Melioration Expedition) 2001. Information about ameliorative conditions of the irrigated lands in the Khorezm region, Uzbekistan. Ministry of Agriculture and Water Resources, Tashkent, Uzbekistan

DAWR (Khorezm Department of Agriculture and Water Resources) 2002. Annual report. Uzbekistan, Tashkent

Dukhovny, V. A. and V. Sokolov. 2000. Lessons on cooperation building to manage water conflicts in the Aral Sea Basin. UNESCO http://www.siwi.org/downloads/Reports/Report%209%20Aral%20Sea%20Seminar%202000.pdf.

Dukhovny, V. A. and V. Sokolov. 2001. Diagnostic Study. Rational and Effective Use of Water Resources in Central Asia. UN-Special Program For Economics of Central Asia. Tashkent, Uzbekistan and –Bishkek, Kyrkyzstan

Glazirin, G.E., Chanishev, S.G. and Chub, V.E. (1999). Kratkie polojeniya klimata Uzbekistana. Chinor ENK – Galaba, Tashkent, 29 pp. (in Russian)

Dzhabarov, H. 1990. The analysis of the indicators of ameliorative conditions in irrigated areas of Khorezm region. PhD Thesis, NPO SANIIRI, Tashkent Uzbekistan

Djumaniyazov A (2004) Literature review of field experiments on use of mineral fertilizers for cotton, conducted at the Khorezm branch of the Uzbek Cotton Research Institute (1927-2003). ZEF Internal Report. Center for Development Research (ZEF), Urgench, Uzbekistan, pp43

Djumaniyazov A (2006) Literature review of soils in Khorezm. Internal report. ZEF, Urgench, Uzbekistan, pp34

Faizullaev B.F. 1980. Water-salt regime of the soils developed on the different alluvial deposits of Amu-Darya River (in Khorezm oasis) (in Russian). SANIIRI, Tashkent, pp. 1-25.

FAO-UNESCO 1995. The digital soil map of the world and derived soil properties. Land and Water Digital Media Series 1. FAO, Rome. CD-ROM

FAO and IFA (2000) Fertilizers and their use. A pocket guide for extension officers. 4th edition. Rome, FAO and IFA, p 34

Hazratkulova, S., R.C. Sharma, S. Alikulov, S. Islomov, T. Yuldashev, Z. Ziyaev, Z. Khalikulov, Z. Ziyadullaev and J. Turok 2012. Analysis of genotypic variation for normalized difference vegetation Index and its relationship with grain yield in winter wheat under terminal heat stress. Plant Breeding, 131:716-721.

Ibragimov NM (2007) Ways of increasing the nitrogen fertilizer efficiency on cotton in the belt with irrigated sierozem soils. (Habilitation, in Russian). Dissertation,Uzbekistan Cotton Research Institute. p 348

Katz DM (1976) The influence of irrigation on the groundwater (in Russian). Moscow,Kolos Pub, p 271

Keyser, D. 1996. The ecological restoration of delta areas of the Aral Sea. Review of the scientific and environmental issues of the Aral Sea basin. NATO ASI series. Partnership Sub-Series, 2. Environment – Vol.12 The Aral Sea Basin. Berlin, Springer-Verlag.

Kovda, V.A, 1973.The principles of pedology. General theory of soil formation. Second Book. Pubslishing house “Nauka”. Moscow

Kunzer, M., Kelgenbaeva, K., Khasankhanova G. 2010. ADB CACILM SLMIS Regional GIS Datasets for Central Asia: Soils. Bishkek, Kyrgyzstan.

McGiffen ME, Lebron I, Ngouajio M and Hutchinson CM (2004) Soil organic amendments change low organic matter agroecosystems. Acta Hort (ISHS) 638:249-254

Miller W (1970) Inter-regional predictability of cation-exchange capacity by multiple regression. Plant and Soil 33(1):721-725

Mukhammadiev UK (1982) Water resources use (in Russian). Tashkent, Uzbekistan,FAN Publishing House

Mickin PP (1988) Desiccation of the Aral Sea: A water-management disaster in the Soviet Union. Science 241:1170-1176

Micklin, P 2007. The Aral Sea Disaster. Annual Review of Earth and Planetary Sciences 35.

OblStat (2015) Annual report for crop production in the Khorezm region. Regional Department of Statistics, Urgench, Khorezm, Uzbekistan

Peel, M.C., Finlayson, B.L., McMahon, T.A. 2007. Updated world map of the Köppen-Geiger climate classification. Hydrology and Earth System Sciences Discussions 4, 439-473.

Popov VG, Sektimenko VE and Tursunov AA (1992) Soil cover change in the contemporary Amu-Darya River delta under the influence of anthropogenic desertification (in Russian). Tashkent, Uzbekistan, FAN Publishing House

Raun, W. R., G. V. Johnson, M. L. Stone, J. B. Solie, W. E. Thomason, and E. V. Lukina, 1999: In-season prediction of yield potential in winter wheat. Better Crops 83, 24-25.

Riskieva HT (1989) Nitrogen in soils in the cotton belt of Uzbekistan (in Russian). Tashkent, FAN Publishing House, p 148

Rizayev FR (2004) Soil texture of irrigated soils of the Khorezm region (in Russian).Conference Proceedings "Soil Science and Agrochemistry in the XXI Century", Tashkent, 9.-10.10.2003, Uzbekistan State Committee of Land Resources, State Scientific Institute of Soil Science and Agrochemistry

Syers J, Campbell A and Walker T (1970) Contribution of organic carbon and clay to cation exchange capacity in a chronosequence of sandy soils. Plant and Soil 33(1):104-112

Soil Science Institute (2003) Soils of the Khorezm region (in Uzbek). Tashkent, Uzbekistan Soil Science Research Institute, p 188

Sommer R, Djanibekov N, Salaev O and Rücker G (2008a) Integrated bio-economic optimization of water and resource allocation on farm-aggregated level in Khorezm, Uzbekistan – model description and scenario analysis. ZEF Discussion paper.

Sommer R, Kienzler K, Conrad C, Ibragimov N, Lamers JP, Martius C et al. (2008b) Evaluation of the CropSyst model for simulating the potential yield of cotton. J. Agron.Sustain.Dev. 28(2):345-354. DOI: 10.1051/agro:2008008

Tursunov LT and Abdullaev C (1987) Soil-physical characteristics of soils in the lower Amu-Darya region (in Russian). Tashkent, Uzbekistan, FAN Publishing House, p 224

Vinogradov S and Langford VPE (2001) Managing transboundary water resources in the Aral Sea Basin: in search of a solution. Int. J. Global Environmental Issues 1(3-4):345-362

Vlek PLG, Fillery I and Burford J (1981) Accession, transformation, and loss of nitrogen in soils of the arid region. Plant and Soil 58(1):133-175

Wang, S., C. Huang, Z. Y. Sun, L. G. Li, and Z. H. Ma, 2010: Yield estimate of wheat cultivar mixtures with stripe rust by hyperspectral remote sensing. Transactions of the Chinese Society of Agricultural Engineering 26, 199-204.

Wehrheim P and Martius C (2008) Farmers, cotton, water, and models - Introduction and overview. In: Wehrheim P, Schoeller-Schletter A and Martius C (eds) Continuity and Change: Land and Water Use Reforms in Rural Uzbekistan. Socio-economic and Legal Analyses for the Region Khorezm. IAMO,Halle/Saale, pp1-16

Yagodin VN and Betts AVG (2006) Ancient Khorezm. Tashkent, UNESCO, p 32

Yuan TL, Gammon N, Jr. and Leighty RG (1967) Relative contribution of organic and clay fractions to cation-exchange capacity of sandy soils from several soil groups. Soil Science 104(2):123-128

WARMAP and EC-IFAS (1998) Water use and farm management survey (WUFMAS) - Agricultural Year 1998 - Annual Report. Water Resources Management and Agricultural Production in the Central Asian Republics (WARMAP-2); Executive Committee Interstate Fund for the Aral Sea (EC-IFAS); TACIS Project

WBGU 1999. World in Transition: Ways towards sustainable management of freshwater resources. Springer Verlag, Berlin.