Soil salinity management on raised bed with different furrow irrigation methods in salt-affected lands in Aral Sea Basin (CRP DS, Russian Funding)

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About the Project

Implemented by:
Karakalpak Crop Husbandry Research Institute (KKCHRI)
ICARDA

Funded by:
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Report compiled by:
Dr. Bogachan Benli, ICARDA Project Coordinator, Senior Irrigation and Water Management Specialist, IWLMP, Egypt
Mr. Tulkun Yuldashev, ICARDA-CAC, Soil and Water Specialist, IWLMP
Dr. Ram Sharma (ICARDA) - Head, PFU-CGIAR / Regional Coordinator, ICARDA-Tashkent / Senior Scientist / Breeder
Dr. Esbosin Sadikov, Director of Karakalpak Crop Husbandry Research Institute

Mr. Bahytbay Aybergenov, Researcher of Crop Husbandry Research Institute

Dr. Genjebay Sayipnazarov, PhD, Researcher of Crop Husbandry Research Institute

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About ICARDA

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International Center for Agricultural Research in the Dry Areas (ICARDA)
PO Box 114/5055,
Beirut, Lebanon (*temporary headquarters*)
www.icarda.org

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CRP-DS Aral Sea Action Site (Chimbay, Karakalpakstan)

Activity title: Soil salinity management on raised bed with different furrow irrigation methods in salt-affected lands in Aral Sea Basin.

Integrated Land and Water Productivity Improvement in Aral Sea Basin

Collaborator: Karakalpak Research Institute of Crop Husbandry (KRICH), Karakalpakstan

IARC Project Team:	Dr. Bogachan Benli (ICARDA) - Senior Irrigation and Water Management Specialist, IWLMP Tulkun Yuldashev (ICARDA-CAC), Soil and Water Specialist, IWLMP Dr. Ram Sharma (ICARDA) – Senior Scientist (Breeder)
Implementing Country:	Uzbekistan
Research Team (National):	Dr. Esbosin Sadikov, Director of Karakalpak Crop Husbandry Research Institute, Mr. Bahytbay Aybergenov, Researcher of Crop Husbandry Research Institute, Dr. Genjebay Sayipnazarov, PhD, Researcher of Crop Husbandry Research Institute
Data collection site:	Experimental station of Crop Husbandry Research Institute, (2015-2016), Chimbay district, Republic of Karakalpakstan, Uzbekistan

Rationale

Agriculture in the Aral Sea Basin is concentrated on cultivation of cotton, cereals, rice, vegetables and fruits, and it relies entirely on irrigation water supply. However, the farmers of the basin are challenged by low crop yields, water scarcity and salinity problems. However, farmers are intended to apply excessive volume of irrigation water and the overall irrigation efficiency is measured as only 26%. This inefficiency in irrigation causes widespread salty flood plains. A United Nations report in 2001 estimated that 46 percent of Uzbekistan's irrigated lands have been damaged by salinity, that causes low crop yields and desertification. In Karakalpakstan, 45-47% of irrigated lands are affected by medium to high salinity levels. Excessive levels of salts in the soil solution have a negative impact on the growth of main crops (winter wheat and cotton).

Average cotton yield for Karakalpakstan (1.68 t/ha) and winter wheat (3.0 t/ha) are lower by 33% and 25% over average crop yields for all provinces.

The permanent raised-bed/furrow system, a water-wise conservation agriculture-based practice, is gaining importance in irrigated areas of Uzbekistan. Because of additional surface exposure and elevation, raised beds may be more prone to salt accumulation especially under shallow water table conditions.

Objectives of the experiment

A field study are being carried out on experimental station in Experimental Station of Crop Husbandry Research Institute, in Chimbay District of Karakalpakstan to investigate the performance of three furrow irrigation methods on salt dynamics of the soil and wheat agriculture. The irrigation methods include (i) Conventional furrow irrigation where irrigation will be applied in every furrow (EFI) at each irrigation event; (ii) Alternate skip furrow irrigation (ASFI where one of two neighboring furrows will be alternately irrigated during consecutive irrigations events; and (iii) Permanent skip furrow irrigation (PSFI) during which irrigation will be permanently skipped in one of the two neighboring furrows during all irrigation events.

Location and climate

Experimental station of Crop Husbandry Research Institute (42^{o}57'07'', 59^{o}46'37'') is located around 60 km north-east of Nukus city (capital of Karakalpakstan) in Chimbay district of Karakalpakstan, Uzbekistan.

The climate in the study area is continental and arid, with an annual rainfall of about 120 mm. The climate of Karakalpakstan falls into the BWwk Köppen-Geiger climate class (Peel et al., 2007). According to the ICARDA map of Agroclimatic Zones (De Pauw, 2010) the site belongs to zone 310, which is arid climates with cool or cold winters, and warm or very warm summers. The ICARDA Land Use/Land Cover map (Celis et al., 2007) indicates 'Other irrigated field crops' as main land use/land cover class.

The area is characterized by sharply continental and dry climate (with hot summers and cold winters) with strong fluctuations of temperatures both daily and seasonally, with an annual rainfall of about 120 mm. Desert winds are common. Following the cold winter, spring is notoriously short and immediately followed by hot, dry and long summers (Glazirin *et al.*, 1999). The maximum temperature in the region is in July-August with an average of between +24.6 and +27.4° C and with a minimum of – 9.6° C in January (**Figure 1**). The mean annual precipitation (MAP) in the form of snow and rain varies from 60 up to 180 mm. Precipitation occurs predominantly during the cold period with roughly 28% of the annual precipitation falling as snow in winter and about 61% in spring and autumn as rain. The number of frost days varies from 90 to 110.

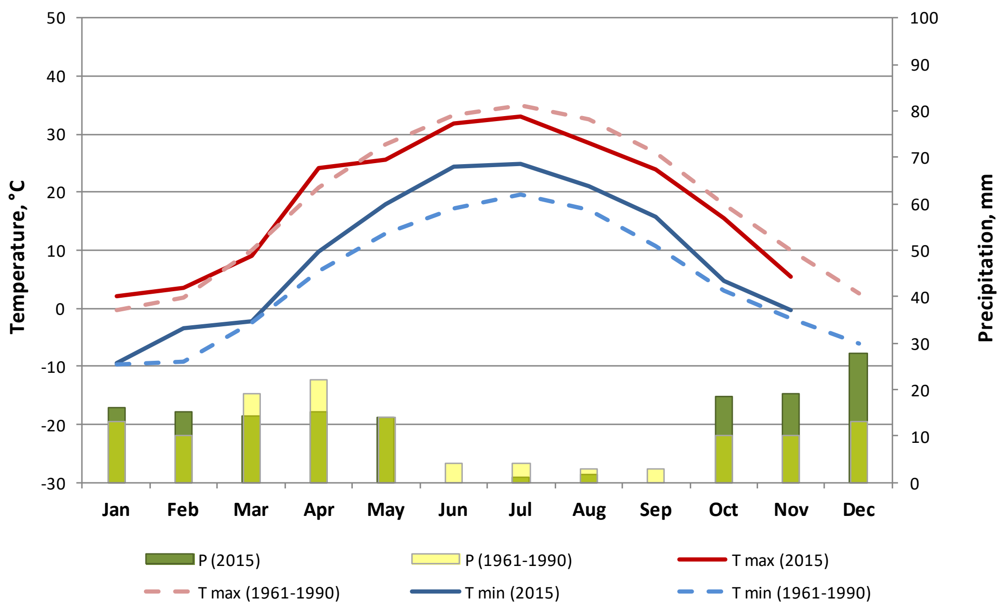


Figure 1: Monthly precipitation and monthly mean air temperature in Chimbay (weather station: Chimbay) comparing long-term data and observations made during the study period.

Soil

Soils were classified as Yermosols (very poorly developed soils of (semi-) deserts) and Xerosols (poorly developed soils of (semi-) deserts) (FAO-1995). Both types of soils are alternatively known in Central Asia as *Sierozems* or *'grey-brown soils*, which cover a wide range of soils with different morphology and physical characteristics. According to the FAO map (Kunzer *et al.*, 2010) the soil was described as a Meadow-oasis Saline and irrigated meadow-desert (takir-like) Soils of the desert zone. Soil texture is sandy loam in the top 0-17 cm followed by light loam at the depth of 17-91 cm and medium loam at the depth of 91-150 cm. Soil is slightly and moderately saline (3-9 dS/m). The salinity type is chloride - sulphate and sulphate. Ground water is 1.0-1.8 m deep during winter season and raises up to 0.6-1.0 m during summer. Ground water salinity varies from 3 to 6 g/l. The amount of totally dissolved solids in irrigation water stands at 1.5-2.0 g/l with the prevalence of sodium-ion among cations and sulphate-ion among anions.

In mid November 2015 one pit (1.5 m depth and 2 m length) were established in the middle of the experimental site to describe the soil by genetic layers (Appendix 2). 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 1**). In 2015-2016 the soil at the Chimbay study site had a loam texture at top 0-17 cm and Silt loam at 17-150 cm soil depth (USDA classification; **Table 1**). 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.

Table 1: Soil physical and chemical properties of Chimbay, Karakalpak site (2015-2016 experiment)

Soil characteristics	**Soil layer**					
Depth, m	**0-0.17**	**0.17-0.42**	**0.42-0.68**	**0.68-0.91**	**0.91-1.17**	**1.17-1.50**
Sand (0.05-2.0 mm), %	45.2	28.92	42.37	31.37	33.69	14.23
Silt (0.002-0.05 mm), %	45.25	61.78	50.36	63.26	60.68	71.39
Clay (<0.002 mm), %	9.56	9.31	7.28	5.37	5.63	14.38
Soil texture (USDA classification)	Loam	Silt loam	Silt loam	Silt loam	Silt loam	Silt loam
Field capacity, $m^3\ m^{-3}$	0.28	0.26	0.30	0.43	0.44	0.44
Infiltration rate, mm day^{-1}	320					
Soil bulk density, g cm^{-3}	1.51	1.66	1.61	1.50	1.41	1.48
ph	8.14	8.13	8.23	8.27	8.31	8.29
Organic matter, %	0.83	0.66	0.50	0.27	0.13	0.13

Experimental management and start-up conditions

The experiment was initiated in fall 2015. To evaluate the performance of three furrow irrigation methods on salt dynamics of the soil and wheat agriculture; two cultivars of winter wheat (Yaksart and Krasnodar-99 (local check)) have been planted in raised bed furrow irrigation system in randomized complete block design with three replications. Yaksart is a new, high yielding, improved quality winter wheat variety identified as tolerant to medium level soil salinity, and frost under Karakalpakstan condition. Krasnoddar-99 is a widely grown variety by the farmers in Karakalpakstan. These two varieties were included in the study to evaluate their comparative performance.

These wheat entries were planted manually on October 30 at the experimental site of the Karakalpak Crop Husbandry Research Institute. Each plot has four rows with a length of 10 m and a width of 4.8 m. Distance between rows is 20 cm. Sowing of each variety was done in 6 beds, 1 block is 12 beds (90 cm inter-row space length of furrow 20 m). The experimental layout is presented in **Figure 2** and **Figure 3**. Moldboard tillage was applied using tractor (Model: MTZ-80) on 28th of October 2015. Nitrogen in the form of Ammonium Nitrate, phosphorus in the form of superphosphate and potassium in the form of potassium chloride were applied at the rate of 40, 90 and 60 kg ha^{-1}, respectively just before sowing. Afterwards harrowing was implemented.

The following initial conditions have been determined: Nmin, P and K available forms, soil moisture and soil salinity (TDS) before land preparation (tillage) (**Appendix 3**). The sampling was done at 4 soil depths (0-20, 20-40, 40-70 and 70-100 cm) and 6 sampling points located as per "envelop" scheme. Number of reps (sub-samples) per depth is 3 merged to one sample. The soil moisture content in mid-September 2015 in 0-1 m was in the range of 0.122 to 0.339 m^3 m^{-3} . 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.

At tillering and heading stage (20 March 2016 and 26 April 2016) Nitrogen in the form of Ammonium Nitrate was applied at the same rate of 70 kg ha^{-1}. 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. The Thomson (or triangle) weirs used to measure the irrigation rates before each irrigation event.

Table 2: Experimental management of Chimbay site (2015-2016)

Farming practices	Dates
Tillage (Moldboard)	10/28/2015
Harrowing	10/29/2015
Land leveling	10/29/2015
Planting date	10/30/2015
Seeding rate, kg ha^{-1}	200
Harvest	06/26-29/2016

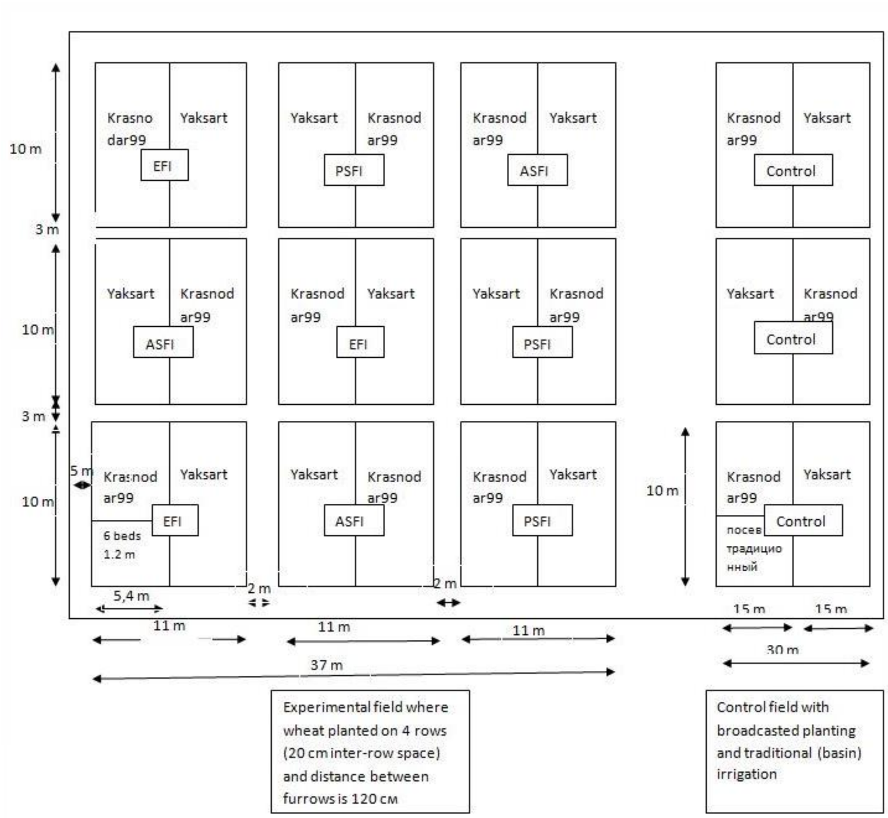
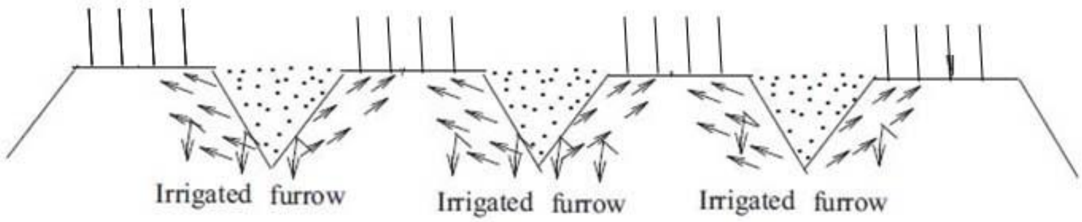
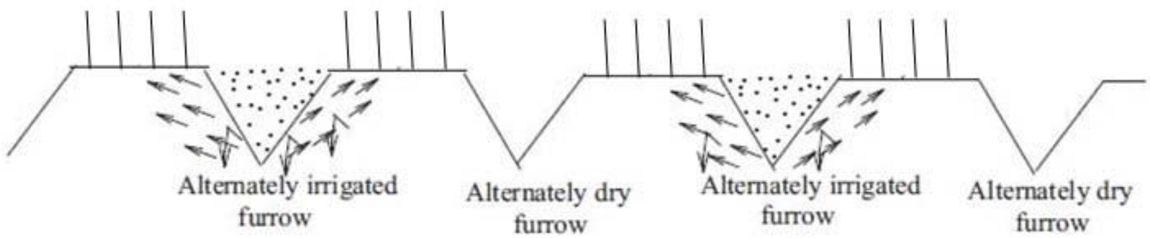


Figure 2 Experimental layout of sowing of 2 winter wheat varieties at experimental site of KRIGBSPCC (2015- 2016) ***(EFI = every furrow irrigation-conventional irrigation, ASFI =alternate skip furrow irrigation, PSFI = Permanent skip furrow irrigation)***

A. Every-furrow irrigation.



B. Alternating skip furrow irrigation.



C. Permanent skip furrow irrigation

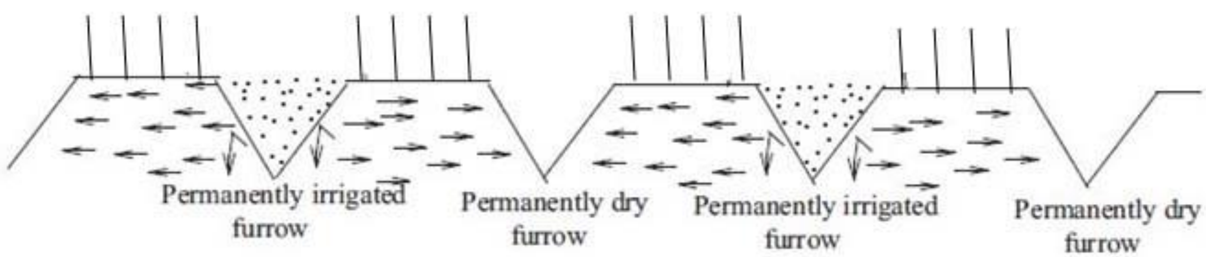


Figure 3 Experimental layout of Irrigation treatments allocated in each replication in raised beds.

Wheat was harvested in late June 2016 from each subplots and yield crop parameters were estimated.

The pre-experiment soil salinity levels in terms of ECe values were determined at different soil depths (7.5, 22, 45 cm) using EC meter (Direct Soil EC meter) and at depths of 75 cm and 150 cm using EM38 instruments (Table 3). Corresponding ECe values at the 7.5, 22 and 45 cm soil depth were 3.9, 3.1 and 3.1 dS m^{-1}, respectively. The correlation between the soil salinity measured at depth of 7.5 cm by EC meter and that measured at depth of 75 cm by EM38 is high (R^2=0.77) (**Figure 4**). The salinity data measured by EM-38 instrument was plotted using ArcMap 10.1 software (**Appendix 3**). As shown from the Maps the salinity of around 70-80 % of area was in the range of 4.1-8.0 dS m^{-1}, i.e. could be classified as medium saline (**Appendix 4**). Groundwater is shallow (1.0-1.4 m).

Table 3 Soil salinity data (dS m^{-1}) measured at experimental site of KRICH (Fall 2015)

Plot/TDR	EC, dS/m, Direct EC meter			EC, dS/m, EM38 measurements	
	7.5	22	45	75	150
1	2.0	2.3	1.4	2.69	3.50
2	1.9	1.8	1.6	3.16	4.40
3	2.0	2.6	3.1	4.00	5.35
4	5.4	5.6	3.0	4.88	6.55
5	2.4	4.1	5.0	5.58	7.18
6	2.0	1.7	1.3	3.49	4.92
7	8.3	6.5	4.8	12.46	11.67
8	11.3	11.2	8.8	12.29	11.58
9	6.3	4.3	5.0	10.41	10.21
10	6.4	3.6	3.5	8.59	10.22
11	6.6	4.0	6.6	8.99	9.79
12	10.3	2.9	3.0	8.63	6.26
13	1.5	1.7	1.3	2.77	3.91
14	2.7	1.7	1.7	3.44	5.79
15	2.7	1.7	1.1	3.45	4.74
16	2.1	2.6	2.0	5.45	7.36
17	2.7	3.9	5.0	6.27	7.41
18	2.3	3.3	3.7	5.23	6.47
19	1.4	1.5	2.0	2.81	4.27
20	3.3	1.5	4.3	2.64	3.70
21	2.3	1.6	2.0	3.44	4.76
22	2.9	1.4	1.0	3.23	4.72
23	2.4	1.4	1.2	2.56	3.78

24	1.8	1.7	1.2	2.80	4.34
Mean	**3.9**	**3.1**	**3.1**	**5.4**	**6.4**

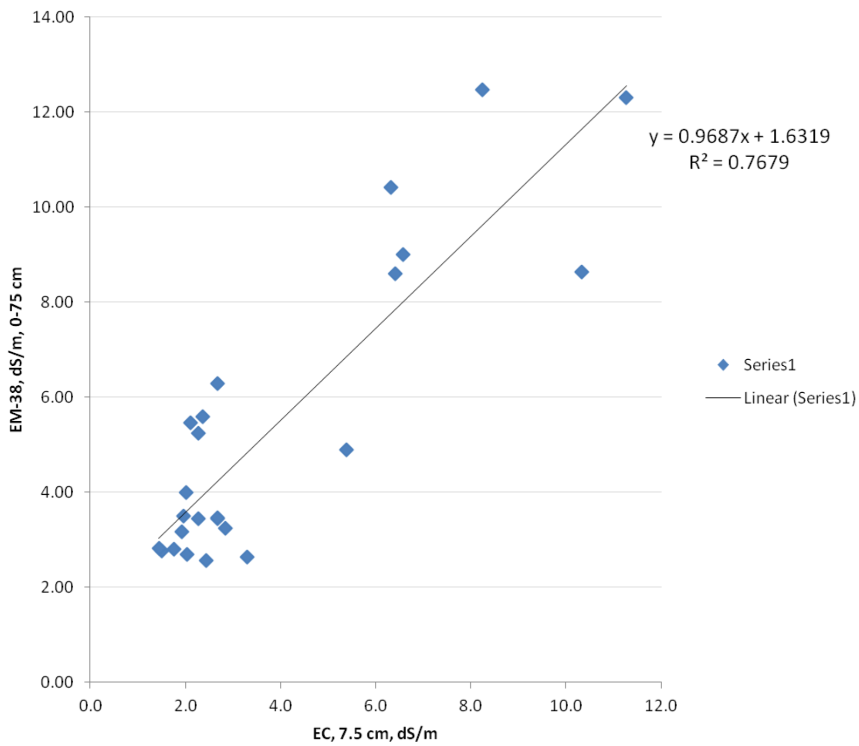


Figure 4. Correlation between the soil moisture measured by EM38 and EC meter instruments

Soils were sampled from seven points to determine the initial soil salinity at raised beds (centre of the bed, two sides of the bed, slope of both furrows and centre of the furrows) with three replications in each treatment. Samples were taken at every 15 cm soil depth down to 90 cm using a tube auger. The collected soil samples were air dried and analyzed for electrical conductivity (ECp) The ECp was converted to an international standard EC value of the saturated soil extract, ECe using following equation:

$$ECe(dS\ m^{-1})=(2.7\times ECp+ 0.8) \qquad (1)$$

Initial values of soil salinity in raised beds for first replication of each irrigation treatment are provided in Appendix 5.

As seen from the data initial soil salinity level at different plots were not homogeneous and pattern of soil salinity was heterogeneous which could be explained by different soil salinity level at different locations. 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 22 October 2012 every 60 minutes by IMKO data logger system (**Appendix 4**). Data from the PDA of data loggers (soil moisture) from 24 TDR access tubes were imported to computer.

Irrigation and groundwater characteristics

Irrigation water salinity in the region was 0.75-1.88 g L^{-1}, i.e. with each cubic irrigation water 0.75-1.88 kg soil is entered. The groundwater table depth (**Figure 4**) was measured in weekly basis at twelve locations across the field in 2015-2016. The ground water table was also considerably higher and varied along the length of the field at the range of 0.2-1.7 m, with an average depth of 1.17 m. Groundwater salinity was in the range of 2.5-8.4 dS/m in Nov 2015-June 2016

(**Table 5**) .

Table 4: Irrigation water salinity in Karakalpakstan, Chimbay site, g L^{-1}

Date	TDS, ds/m	Cations			Anions		
		Ca	Mg	Na +K	HCO_3	Cl	SO_4
24.11.2015	1.09	0.05	0.033	0.124	0.055	0.07	0.37
28.03.2016	1.82	0.14	0.048	0.364	0.177	0.266	0.79
28.05.2015	1.85	0.13	0.09	0.119	0.14	0.224	0.50

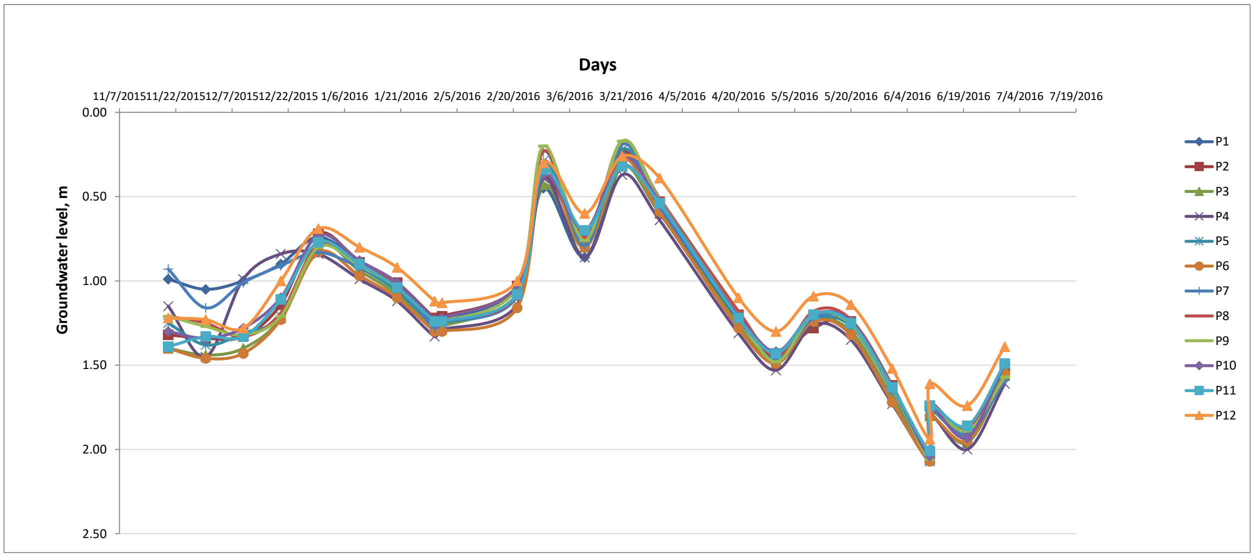


Figure 5 Groundwater level at experimental site in Karakalpakstan during wheat crop season (Nov 2015- June 2016)

Table 5: Groundwater table and salinity in Karakalpakstan, wheat trials, 2015-2016

wells	24.11.15		29.12.15		30.01.16		28.02.16		30.04.16		31.05.16		30.06.16	
	Ground-water level, m	EC, dS/m	Ground-water level, m	EC, dS/m	Ground-water level, m	EC, dS/m	Ground-water level, m	EC, dS/m	Ground-water level, m	EC, dS/m	Ground-water level, m	EC, dS/m	Ground-water level, m	EC, dS/m
P1	0.99	4.06	0.74	3.99	1.26	4.34	0.45	4.46	1.45	3.99	1.65	3.96	1.57	4.74
P2	1.32	4.54	0.70	4.73	1.22	4.88	0.37	4.54	1.43	6.75	1.62	8.38	1.51	7.50
P3	1.4	4.15	0.8	4.92	1.28	5.27	0.43	5.09	1.49	5.50	1.69	6.24	1.56	5.33
P4	1.2	4.35	0.84	3.66	1.33	4.81	0.39	2.84	1.53	4.60	1.73	5.23	1.61	6.52
P5	1.25	5.86	0.79	4.75	1.27	5.78	0.29	5.25	1.45	5.70	1.65	7.14	1.53	6.34
P6	1.4	5.91	0.83	5.72	1.30	7.27	0.33	5.91	1.49	6.15	1.72	6.57	1.55	5.16
P7	0.93	2.56	0.83	2.80	1.28	3.35	0.23	3.17	1.47	3.80	1.65	4.31	1.59	5.12
P8	1.21	4.74	0.79	4.42	1.24	5.28	0.23	4.35	1.45	5.42	1.63	6.87	1.50	6.40
P9	1.21	4.65	0.80	4.22	1.24	5.10	0.20	4.96	1.47	5.13	1.64	8.40	1.57	6.00
P10	1.30	3.84	0.73	4.04	1.23	4.36	0.37	4.41	1.42	4.23	1.63	3.74	1.49	4.70
P11	1.40	3.77	0.77	3.80	1.24	4.55	0.34	4.40	1.43	3.93	1.63	3.64	1.49	3.85
P12	1.20	4.11	0.69	4.01	1.12	4.45	0.30	4.13	1.30	4.02	1.52	4.16	1.39	4.64

Crop data (winter wheat)

Germination of winter wheat started in early December 2015, the highest average plant density was observed for entry Yaksart (221-237 plants m^{-2}). The lowest plant density (152-209 plants m^{-2}) was observed for Krasnodar-99.

The winter wheat was at stem elongation stage on 26 April 2016, heading stage on10 may 2016 flowering stage on 21 May 2016 and full maturity on 18 June 2016. Plant height dynamics during winter wheat crop season presented in **Table 6 and Figure 6**:

Table 6. Mean plant height in a study of evaluation of wheat varieties, management options and crop rotation in Chimbay, Karakalpakstan in 2015-2016 wheat growing season

Irrigation Treatment	Date					
	10/03/16	16/04/16	26/04/16	10/05/16	21/05/16	02/06/16
Krasnodar 99						
Every Furrow	18.7	20.1	23.6	32.2	49.3	54.2
Alternate Skip Furrow	15.3	16.1	23.0	27.9	42.9	48.7
Permanent Skip Furrow	18.0	19.4	20.0	30.1	40.4	49.8
Traditional	19.6	21.8	24.4	32.9	51.1	54.6
Yaksart						
Every Furrow	15.9	18.2	20.7	27.0	47.9	55.6
Alternate Skip Furrow	17.7	18.4	19.4	24.0	54.3	55.7
Permanent Skip Furrow	17.9	19.8	20.4	23.5	43.2	55.10
Traditional I	19.3	20.2	25.7	31.1	52.9	58.9

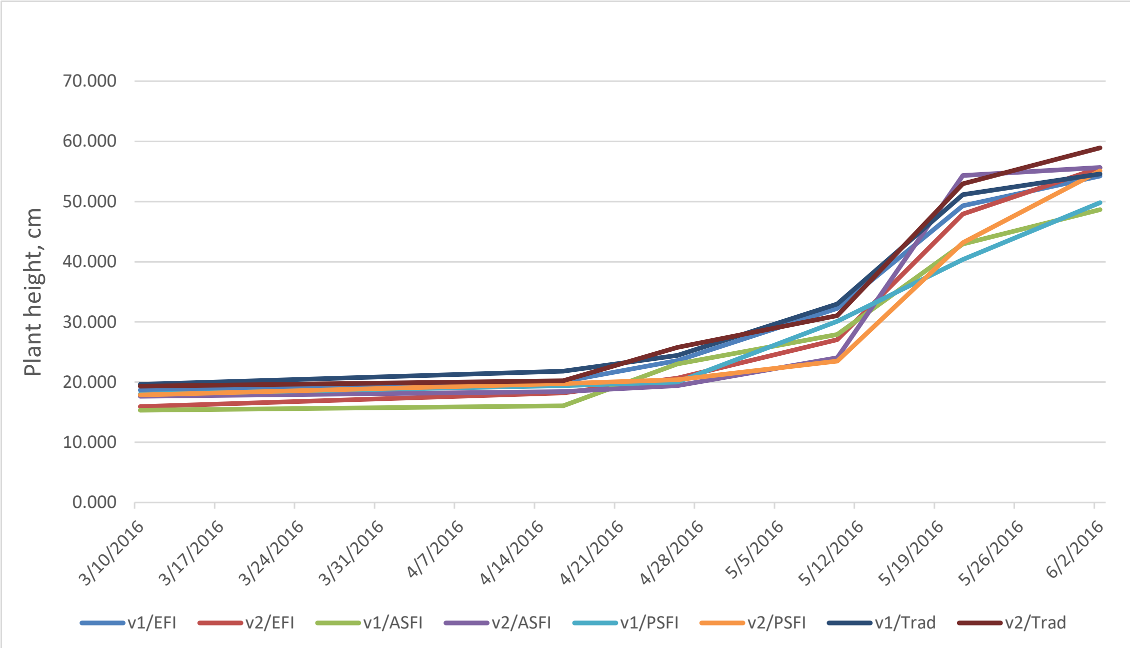


Figure 6 Winter wheat plant height dynamics at experimental site in Karakalpakstan during wheat crop season (Nov 2015- June 2016) (v1-Karsnodar-99, v2-Yaksart)

As seen from above table Yaksart had demonstrated higher plant height in comparison with Krasnodar-99. Effect of irrigation treatments on wheat yield parameters is presented in **Figure 7.**

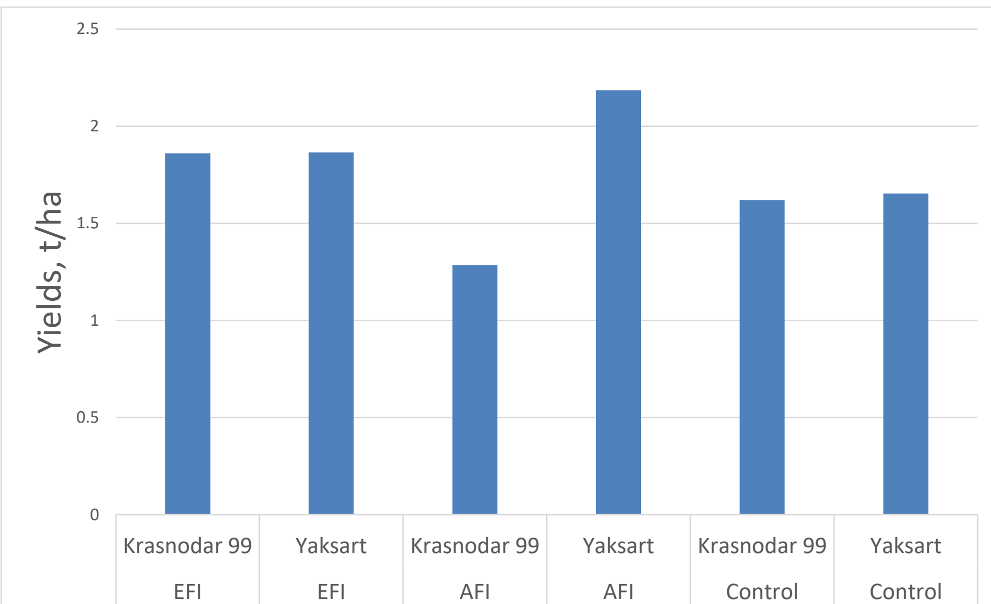


Figure 7. Grain yield of 2 winter wheat varieties (Yaksart and Krasnodar 99) under different Irrigation practices.

Analyses of yield data revealed that yields of wheat entries ranged from 1.12 to 2.18 t/ha with its maximum observed for Yaksart entry under Alternate Skip Furrow irrigation and raised bed planting. Minimum yields were observed for Krasnodar-99 variety under Control and Alternate skip furrow irrigation. However, *Yaksart* variety provided better performance, regardless of irrigation regime or cropping pattern .

Irrigation scheduling and crop water productivity

Irrigation rates for raised bed and traditional irrigation regimes were measured by Tomson (or triangle) weirs installed before each irrigation event (**Table 7**). Irrigations under optimum irrigation treatments were applied through raised bed furrows when the root zone water deficit equaled them maximum allowable depletion of the available soil water. The control treatment was irrigated in traditional way as basin irrigation. We can conclude that raised bed irrigation resulted in higher water productivity 1.4-1.8 kg/m^3 in comparison with traditional irrigation which had water productivity 1.2 kg/m^3 (**Figure 8**).

Table 7: Irrigation regime of winter wheat at Karakalpakstan site (2016)

Irrigation treatment	Irrigation date	Irrigation rate, m^3/ha	Total irrigation rate, m^3/ha
Traditional (control)	13.05.2016	583	1369
	01.06.2016	333	
	2.06.2016	453	
Alternate Skip furrow irrigation	13.05.2016	276	926
	01.06.2016	221	
	2.06.2016	423	
Every furrow irrigation	13.05.2016	291	1071
	01.06.2016	323	
	2.06.2016	505	

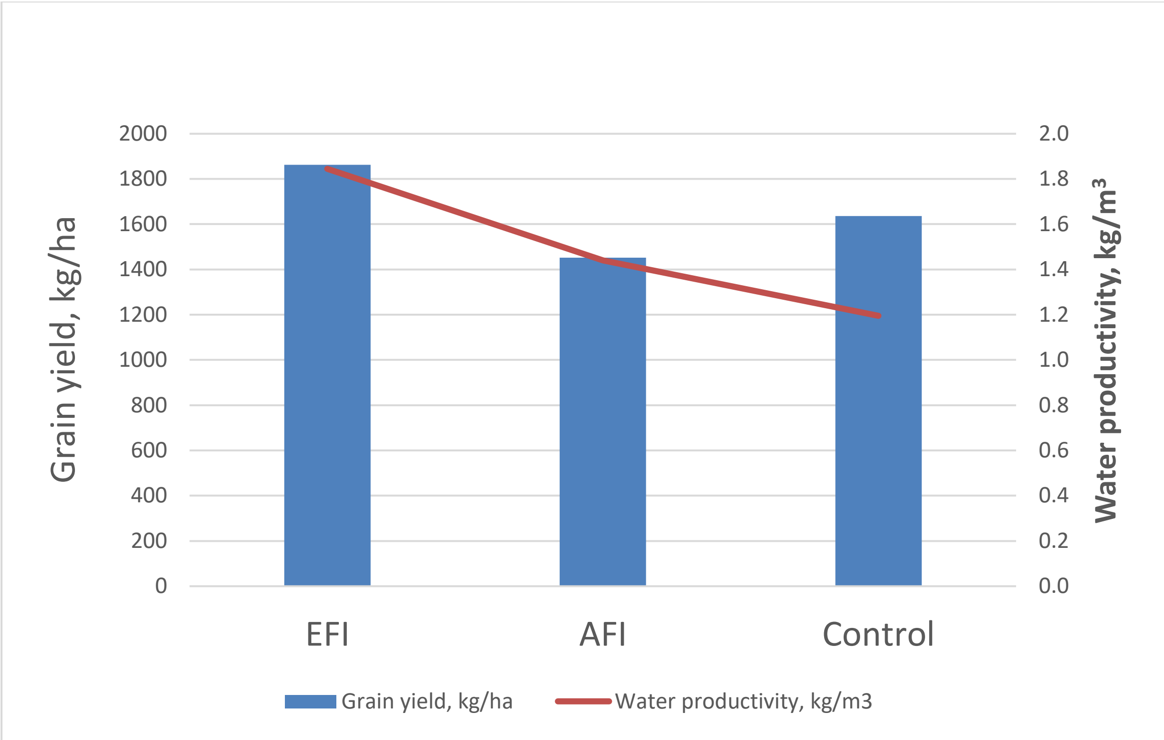


Figure 8. Grain yield and crop productivity under different Irrigation practices in Chimbay, Karakalpakstan.

Conclusions

Prior to this demonstration, experiment comprehensive investigation on efficiency of conventional irrigation scheduling against widely used ET-based irrigation scheduling in Karakalpakstan region had been limited. This experiment while demonstrating the efficacy of ET-based irrigation scheduling services 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 could 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 raised bed planting in wheat crop rotation showed positive impact of the technology in terms of additional source of income to farmers. Optimum irrigation scheduling applied for wheat increased not only yield and water productivity but also ensured getting additional income to the farmers at the project site.

Outputs

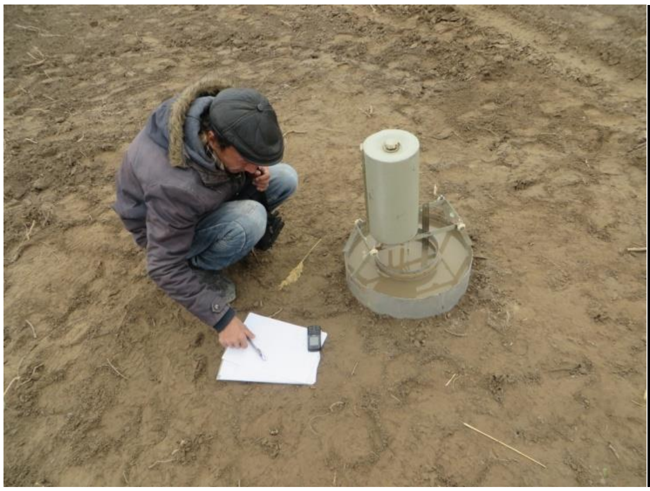
1. Partnership was established with Karakalpakstan Crop Husbandry Research Institute and Uzbek State Soil Scientific Research Institute.
2. Field trials with different raised bed furrow irrigation and with two wheat varieties implemented in Chimbay District, at experimental site of Karakalpakstan Crop Husbandry Research Institute.
3. Research data including soil characterization, crop yields, water use etc. had been collected from the site
4. Raised bed technology demonstrated 20-54% higher Water Productivity
5.
6. WUAs and farmers' capacity development were enhanced through organizing observation field days of on-farm demonstration of package of improved crop management practice

Outcomes

1. Capacity building for farmers, using the field trials were conducted in the farm fields in KaraOzek District. (40 Farmers)
2. Experimental design and Raised bed furrow irrigation was presented to stakeholders during the Conservation Agriculture workshop in KaraOzek.

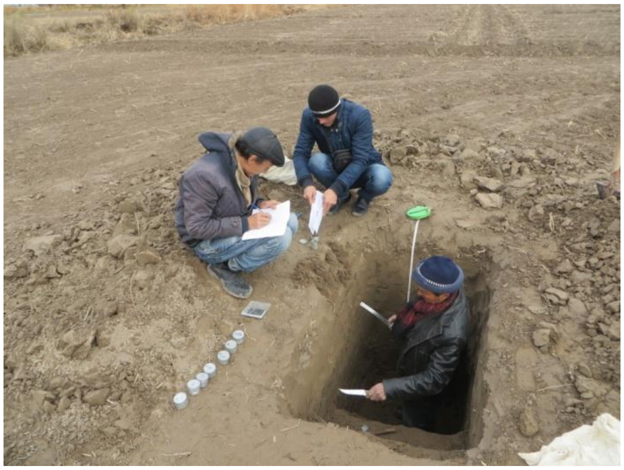
Appendix 1

Soil physical parameters collection (infiltration rates and Field Capacity) and morphological description of soil horizons at Chimbay experimental site (2015-2016)



Appendix 1 (Continued)

Genetic horizons, cm	Soil morphologic description
Ap 0-17 cm	Light gray, fresh, loose, granular structure, loamy sand, plant residues are met, changes are clear
A2 17-42 cm	Very pale brown, moist, more dense than previous layer, blocky (sub angular) structure, sandy loam, along the profile inclusion of half decayed roots, worm-holes, clear wavy horizon changes
B1 42-68 cm	Pale-brown, moist, less dense than previous layer, sandy loam, along the profile inclusion of half decayed roots
B2 68-91 cm	Pale-brown, moist, less dense than previous layer, sandy loam, few decayed roots are met, gradual density and color changes
B3 91-117 cm	Grayish-brown, moist, friable, loam, gradual density and color changes
B4 117-150 cm	Yellowish-brown, moist, more dense than previous layer, structure less massive, loam



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

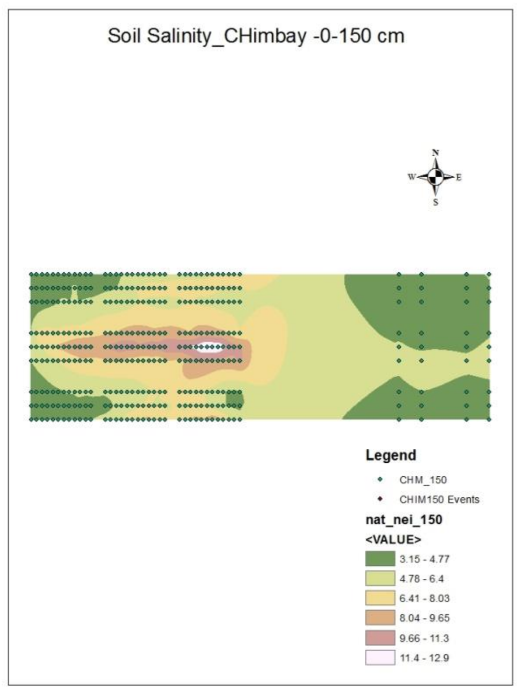
Date	Horizon (cm)	mg kg^{-1}				TDS	Soil moisture
		NO_3	NH_4	P_2O_5	K_2O	%	g g^{-1}
20/09/2015	0-20	5.4	15.0	21.7	141	0.66	0.122
	20-40	3.2	12.2	18.8	99	0.67	0.198
	40-70	2.6	9.0	13.0	93	0.54	0.261
	70-100	1.9	4.3	6.3	84	0.47	0.339

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 0-20 cm and very low in 20-80 cm. Average salinity is medium in all horizons.

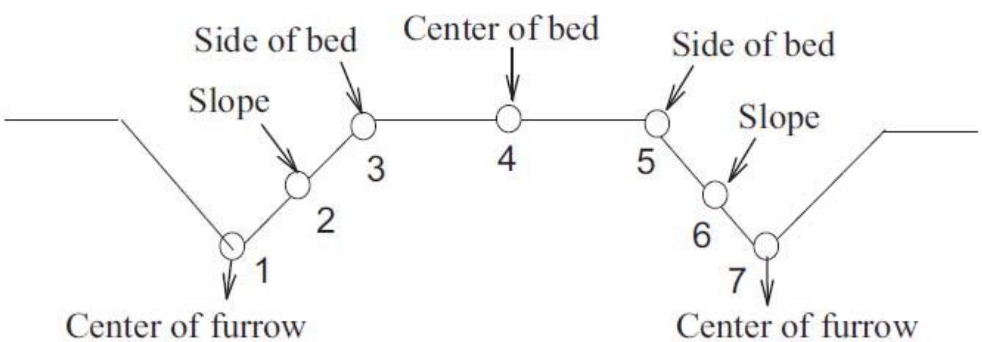
Appendix 3 Measurements of soil salinity using EM-38 instrument and EC meter and soil moisture by TDR access tubes in experimental site in Kashkadarya province.

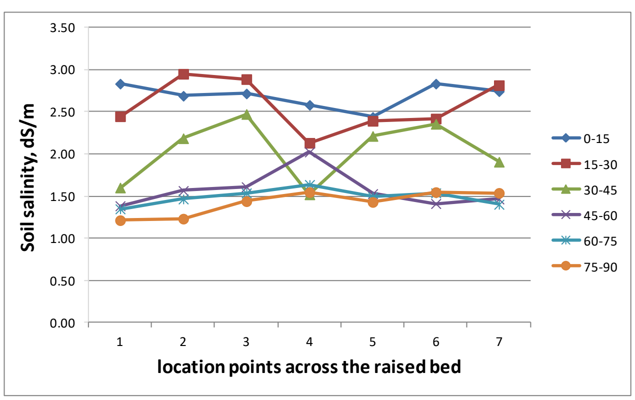
Appendix 4 Soil salinity (dS m^{-1}) measured by EM38 instrument in Chimbay site, 2015



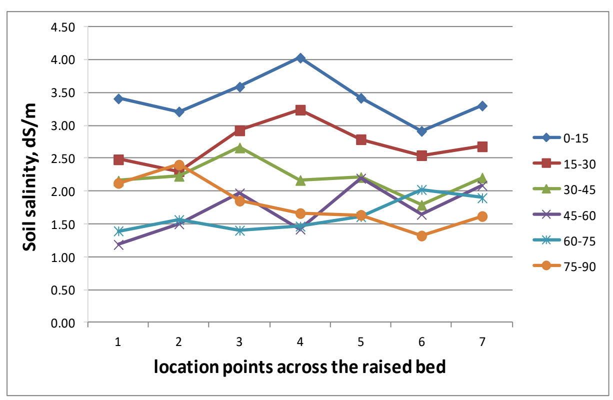
Appendix 5 Measurements of soil salinity using Direct Soil EC meter in experimental site in Karakalpakstan, Chimbay District.

Vertical cut through a bed flanked by 2 furrows. Soil sampling points, the circle represents the position of sampling points in bed and furrow

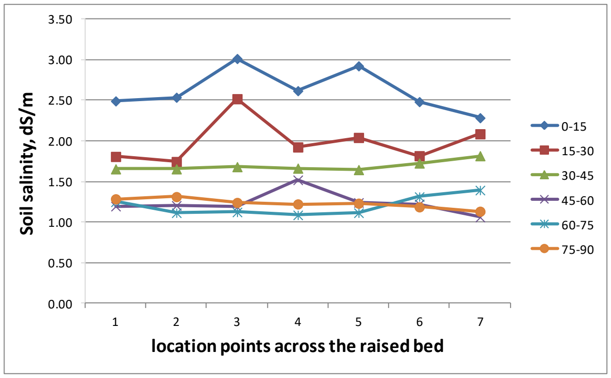




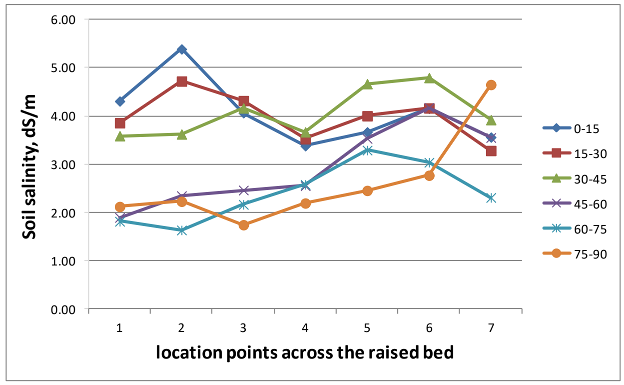
Plot 1



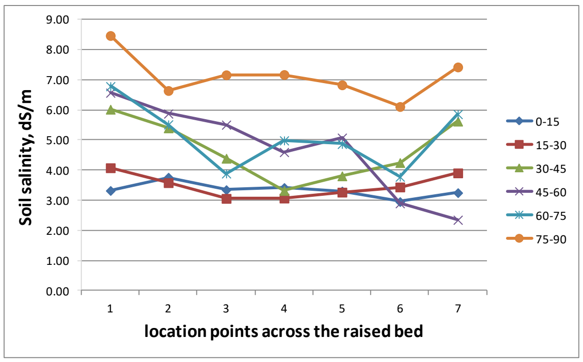
Plot 2



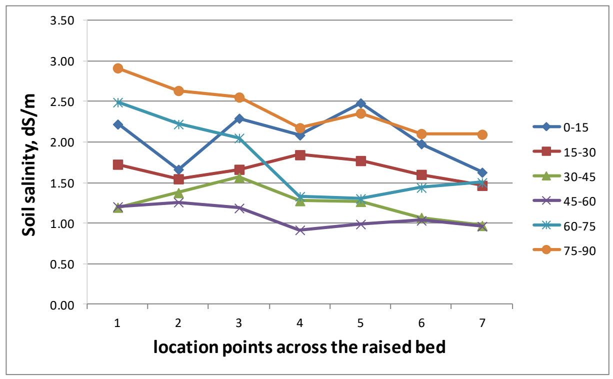
Plot 3



Plot 4



Plot 5



Plot 6