Chapter 2.

Management practices for improving water productivity in the Dasht-e-Azadegan

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Introduction

In the LKRB, because of the differences in factors affecting agricultural water productivity in the north and the south parts, two distinct regions can be identified. In the northern part soil and water quality is not greatly affected by external factors. In this area it seems that improving farmers' skills and application of appropriate farming systems can improve water productivity greatly. Limitations in water supply and excess irrigation water losses (mainly in earthen canals) also causes lower water productivity of crops. Therefore, demonstration of new farming systems, e.g., pressurized irrigation, land preparation methods (raised bed, double-row cropping, etc.), could be a useful method for water productivity improvement. Based on reports (Khuzestan Water and Power Authority 2004), in the next 10 years, when most of the irrigation projects will be completed, there will be more uncertainty in water supplies in the Khuzestan province (including LKRB). The report recommends that the water productivity (WP) of the province has to be increased through using pressurized irrigation systems, participation of stakeholders, and capacity buildings of water users.

Heydari 2010 concluded that for the improvement of WP in the field scale in Iran, some of the high priority issues include: enhancement of farmers' knowledge on soil-water-plant relationships, improvement of farming systems and farm mechanization, proper design and execution of water saving technologies, land leveling and consolidation, and technical and training supports. Overall, in this area, successful introduction and implementation of new farming systems and technologies in accordance with agricultural extension services can be an effective way to improve water productivity. However the problem in this area is large farm size and low-population communities. The low numbers in the communities is mainly due to migration of the people to the cities, especially during war. This has caused poor supervision and management of the farms, due to lack of effective presence of the farmers or land owners, and also shortage of the labor required for the farm and irrigation activities.

In the southern part of LKRB, mainly the Dasht-e-Azadegan plain, available data and surveys show that the problem of soil salinity is magnified due to lack of farmers' knowledge, skills and unavailability of new and improved farming practices. In general, the main cause of soil salinity in the LKRB is the high water table, often less than 2.0 m, usually 1.2-3.0 m below the soil surface (Hajrasuliha 1970). If left alone, the problem is likely to worsen with the current plans for expansion of irrigation networks (unpublished, N. Heydari 2007).

In the southern parts it seems that in addition to factors limiting water productivity (e.g. farmer skills, new farming systems, etc.) the major limiting factors are waterlogging, and soil and groundwater salinity. With the expansion of irrigation networks with no consideration to salinity management and drainage, this problem in future will worsen. At present, despite construction and operation of main drains in the area, they are not properly functioning. This is mainly due to some design problems (non-uniform slope of drain canals,) and also the problems concerning suitable outlets. Gravity drainage to outlet is not possible and pumping is needed. Environmental concerns regarding drainage to the Hawr-Al-Azim wetlands are another problem. It is thought that the government is studying a plan to construct a main drain and carry drained water to Persian Gulf by gravity (unpublished, N. Heydari 2007). However, research topics (both on-farm and experimental) related to water table management and salinity control are expected to do much to improve the productivity of agriculture in this area.

However, in the LKRB (mainly the Dasht-e-Azadegan plain) heavy soil texture and recharge from upstream areas produces natural conditions for waterlogging, and is further induced by low irrigation efficiency of irrigated agriculture in the region. Wheat is the main crop cultivated in this area. Irrigation management practices are traditional and the region suffers from poor water management. This has lead to waterlogging and soil salinity, and hence low water productivity and non-sustainable agricultural production in

Fig. 2.1. Poor irrigation management in the farmers' fields

Fig. 2.2. Poor water distribution because of improper land leveling

the Dasht-e-Azadegan plain .Therefore, sound irrigation management solutions that can be adopted and adapted by the farmers are necessary and will help to improvement agricultural WP and livelihood resilience of the communities living in this poor area.

Based on a review of 84 references on WP during the past 25 years, Zwart and Bastiaanssen (2004) found that the average WP of wheat is 1.09 kg/m^3. The range of WP is wide and varies between 0.6 and 1.7 kg/m^3. Fahong et al. (2004), by comparing basin and furrow irrigation on wheat, concluded that cultivation of wheat on a basin surface with flood irrigation causes surface sealing, irrigation efficiency reduction, and fertilizer losses. They found that furrow irrigation of wheat led to a 17% reduction in water consumption, increased irrigation efficiency (21-30%), increased fertilizer efficiency, and reduced crop disease.

Wheat is the main cultivated crop in the LKRB. Its average yield is 1500 kg/ha (Agricultural Statistics 2004). Irrigation management practices are traditional and the region suffers from poor water management, which is partly due to lack of modern irrigation infrastructure and improved on-farm activities (Figs.2.1 2.2). Therefore, sound and adoptive solutions are necessary to ameliorate this condition.

Materials and methods

Research was conducted in a farmer's field in the Dasht-e-Azadegan region during the cropping seasons of 2006-07 and 2007-08. The farm is located at 31°26'39.6''N and 48°17'45.2''E.

Soil texture was silty clay loam to silt-loam, average soil pH was 7.8, and average soil salinity at a depth of 0-30 cm was on average 15 dS/m. Table 2.1

Table 2.1. Some physical and chemical properties of the soil in the selected field (years 2006-07 2007-08 (only for EC)

Soil depth (cm)	Sampling date	Particle-size analysis (%)				EC (2006-07)	pH	OC	P	K	Fe	Zn	Cu	Mn	EC (2007-08)
		Sand	Silt	Clay	Texture	(dS/m)		(%)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(dS/m)
0-30		14	48	38		3.4	7.6	0.4	3.5	166	3.9	1.1	0.8	6.8	nm
	Aug. 06	24	48	28		18	7.7	0.4	3.4	166	3.7	1.8	0.6	5.2	nm
		18	42	40		12	7.7	0.3	8.3	166	3.9	1.1	0.5	3.6	nm
	4 Dec. 06					8.8	nm	nm	nm	nm	nm	nm	nm	nm	18.2
	21 Dec. 06					4.1	nm	nm	nm	nm	nm	nm	nm	nm	nm
	21 Dec. 06					9.9	nm	nm	nm	nm	nm	nm	nm	nm	6.2
	1 Feb. 07					3.7	nm	nm	nm	nm	nm	nm	nm	nm	3.8
	1. Feb. 07					8.9	nm	nm	nm	nm	nm	nm	nm	nm	4.9
	15 Feb. 07					4.3	nm	nm	nm	nm	nm	nm	nm	nm	5.6
	15 Feb. 07					9.4	nm	nm	nm	nm	nm	nm	nm	nm	8.4
Average		19	46	35	Silty clay loam	8.3	7.7	0.4	5.1	166	3.8	1.3	0.6	5.2	
30-60		14	50	36		3.5	7.9	0.16	2.7	115	2.4	0.15	0.5	1.6	nm
	Aug. 06	22	52	26		8.8	7.9	0.13	1.7	89	2.2	0.14	0.3	1.1	nm
		30	50	20		14.7	8	0.11	2.2	62	2.8	0.1	0.3	0.9	nm
	4 Dec. 06					5.9	nm	nm	nm	nm	nm	nm	nm	nm	nm
	21 Dec. 06					4.4	nm	nm	nm	nm	nm	nm	nm	nm	nm
	21 Dec. 06					6.7	nm	nm	nm	nm	nm	nm	nm	nm	nm
	1 Feb. 07					3.6	nm	nm	nm	nm	nm	nm	nm	nm	nm
	1. Feb. 07					6.1	nm	nm	nm	nm	nm	nm	nm	nm	nm
	15 Feb. 07					4.5	nm	nm	nm	nm	nm	nm	nm	nm	nm
	15 Feb. 07					9.5	nm	nm	nm	nm	nm	nm	nm	nm	nm
Average		22	51	27	Silty clay loam	6.8	7.9	0.13	2.2	89	2.5	0.13	0.4	1.2	
60-90		22	56	22		4.5	7.8	0.18	1.7	62	3.2	0.1	0.3	1.3	nm
	Aug. 06	28	52	20		12.6	7.9	0.1	1.3	53	2.9	0.1	0.8	1.6	nm
		28	52	20		17	8	0.12	2.3	62	3.5	0.16	0.3	1.6	nm
	4 Dec. 06					5.3	nm	nm	nm	nm	nm	nm	nm	nm	nm
	21 Dec. 06					5	nm	nm	nm	nm	nm	nm	nm	nm	nm
	21 Dec. 06					6.6	nm	nm	nm	nm	nm	nm	nm	nm	nm
	1 Feb. 07					3.5	nm	nm	nm	nm	nm	nm	nm	nm	nm
	1. Feb. 07					4.7	nm	nm	nm	nm	nm	nm	nm	nm	nm
Average		26	53	21	Silt loam	7.4	7.9	0.13	1.8	59	3.2	0.12	0.5	1.5	

nm, not measured

presents some physical and chemical properties of the soil in the selected field (years 2006-07 2007-08 (just for EC)) and Table 2.2 summarizes some of the soil's physical and chemical characteristics just prior to the first irrigation. However, the soil salinity values in the region vary greatly, both temporally and spatially, therefore different values of soil ECs were measured during different times and locations in the field, and are listed in these tables.

The source of irrigation water was the Karkheh river. The ECs of groundwater and irrigation water were 11.3 and 1.4 dS m^{-1}, respectively. Groundwater depth at the beginning of the growing season, before starting rainfall and irrigation recharges, was 237 cm. In winter, following recharge from irrigation, it increased to 3598 cm from the soil surface. In Table 2.3 and in Figs. 2.3, 2.4 and 2.5, groundwater and drainage water qualities, and variation of groundwater depth in the cropping seasons in the selected field are provided. As it can be seen from Fig. 2.3, there is a wide range of variation in water table depth. The reason is water logging, which produces increased soil salinity at certain periods in the LKRB. Wheat is planted in early November in DA, late November is the first irrigation for land preparation and harvest time is in late May. Deep percolation losses of irrigation during this period cause the water table to rise, usually in February. Therefore, depending to the recharge from irrigated areas during the peak consumption period, and due to heavy soil texture and inadequate drainage capacity of the soil, the water table fluctuates very rapidly and to a large extent.

The dimensions of the border and the basin of the treatments were selected as 160 m x 10 m (for T1, T2, T3) and 40 m x 10 m (for T4, T5, T6). These dimensions were optimal sizes and were based on Statistics and Census Sector recommendations. The traditional method of irrigation (control) was similar to a combination of basin and border irrigation. Farmers choose the borders' length according to their farm dimensions (usually 100-400 m) and then divide borders into several basins of 30-70 m length, depending on the field topography. They fill the first basin and then transfer water to the second one, and so on. The width of the borders was usually between 5 m and 14 m (Figs. 2.6, 2.7).

The Chamran wheat variety was sown in all the treatments. The seed rate was 250 kg in treatments sown by centrifugal broadcaster and managed under optimized irrigation (T1, T4). In other treatments a seed drill (TAKA) or a three-row bed seeder (Hamedani) sowed seeds at a rate of 180 kg/

Table 2.2. A summary of some soil's physical and chemical characteristics prior to the first irrigation.*

Soil depth (cm)	Year 2006-07									Year 2007-08								
	EC (dS/m)	pH	OC (%)	P (ppm)	K (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)	EC (dS/m)	pH	OC (%)	P (ppm)	K (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)
0-30	11.1	7.7	0.4	5.1	166	3.8	1.3	0.6	5.2	18.8	7.8	0.37	3.4	165	3.7	1.8	0.6	5.2
30-60	9.0	7.9	0.1	2.2	88.7	2.5	0.1	0.4	1.2	16.7	8.0	0.15	1.7	89	2.2	0.1	0.3	1.1
60-90	11.4	7.9	0.1	1.8	59.0	3.2	0.1	0.5	1.5	19.1	7.9	0.1	1.3	53	2.9	0.1	0.8	1.6

*EC_e = 15 dS/m; depth to water table = 237 cm; EC_{GW} = 11.3 dS/m; EC_{ir} = 1.4 dS/m; EC_e = 18.2 dS/m
Depth to water table = 190 cm; EC_{GW} = 38.5 dS/m; EC_{ir} = 1.5 dS/m

Table 2.3. Groundwater and drainage water quality in selected fields (2006-07; 2007-08).

Type of water*	Sampling date (2006-07)	EC (dS/m)		pH	Ions (meq/L)				
		2006-07	2007-08		Ca	Mg	Na	Cl	HCO_3
GW	4 Dec. 06	13.2	nm	7.2	22	36	82	113	12.5
GW	21 Dec. 06	11.3	nm	7.2	22	30	49	72	8
GW	26 Dec. 06	6.1	nm	7.3	26	75	22.5	20	7
GW	26 Dec. 06	44	38.5	7.1	60	130	210	400	20
GW	22 Jan. 07	39	nm	7.2	80	90	240	425	nm
GW	22 Jan. 07	0.85	nm	7	140	260	260	1150	nm
GW	22 Jan. 07	10.8	nm	7.3	32	16	56	53	nm
GW	9 Feb. 07	27.2	39.1	7.2	nm	nm	nm	nm	nm
GW	26 Feb. 07	23.4	nm	7.3	nm	nm	nm	nm	nm
GW	26 Feb. 07	62.1	nm	7.1	nm	nm	nm	nm	nm
GW	26 Feb. 07	5.2	nm	7.4	nm	nm	nm	nm	nm
GW	18 Mar. 07	20	23.3	6.6	nm	nm	nm	nm	nm
GW	18 Mar. 07	54	nm	6	nm	nm	nm	nm	nm
GW	8 April 07	36.7	nm	6.5	nm	nm	nm	nm	nm
GW	8 April 07	79	nm	6.3	nm	nm	nm	nm	nm
GW	8 April 07	10	nm	7	nm	nm	nm	nm	nm
DG	9 Feb. 07	17.3	nm	7.5	nm	nm	nm	nm	nm
DG	29 Nov 06	13.9	nm	7.8	14	36	91	123	22.5

*GW = groundwater; DG = drained water; nm = not measured.

ha. In the control treatment (Tc), which was sown by centrifugal broadcaster and managed by the farmer, the seed rate was 350 kg/ha. Other farming practices were the same for all treatments (Figs. 2.8, 2.9).

Crop yield and yield components were measured through sampling from fields before harvest. The yield samples were taken by 1 m^2 sampling frames. The amount of irrigation water applied was measured by Washington State College flumes. There was no difference between the farmer and modified management treatments in terms of interval and number of irrigation. In fact, the difference was in how to manage water flow on the land and the method of irrigation, both of which directly affected water consumption.
The research treatments were as follows:
T1 = border irrigation + sowing by centrifugal broadcaster followed by one disc pass
T2 = border irrigation + sowing by seed drill machine (Taka type)
T3 = border irrigation + sowing by three-row bed seeder (Hamedani type)
T4 = basin irrigation + sowing by centrifugal broadcaster followed by one pass of a disc
T5 = basin irrigation + sowing by seed drill machine (Taka type)
T6 = basin irrigation + sowing by three-row bed seeder (Hamedani type)
Tc = irrigation and sowing managed by traditional farming method (as control).

This research examined the reuse of drainage water for irrigation. In the first year this was done in small experimental plots. In the second year it was done in large plots beside the field. Table 2.4 shows soil salinity and pH values. Tables 2.5 and 2.6 list the soil moisture

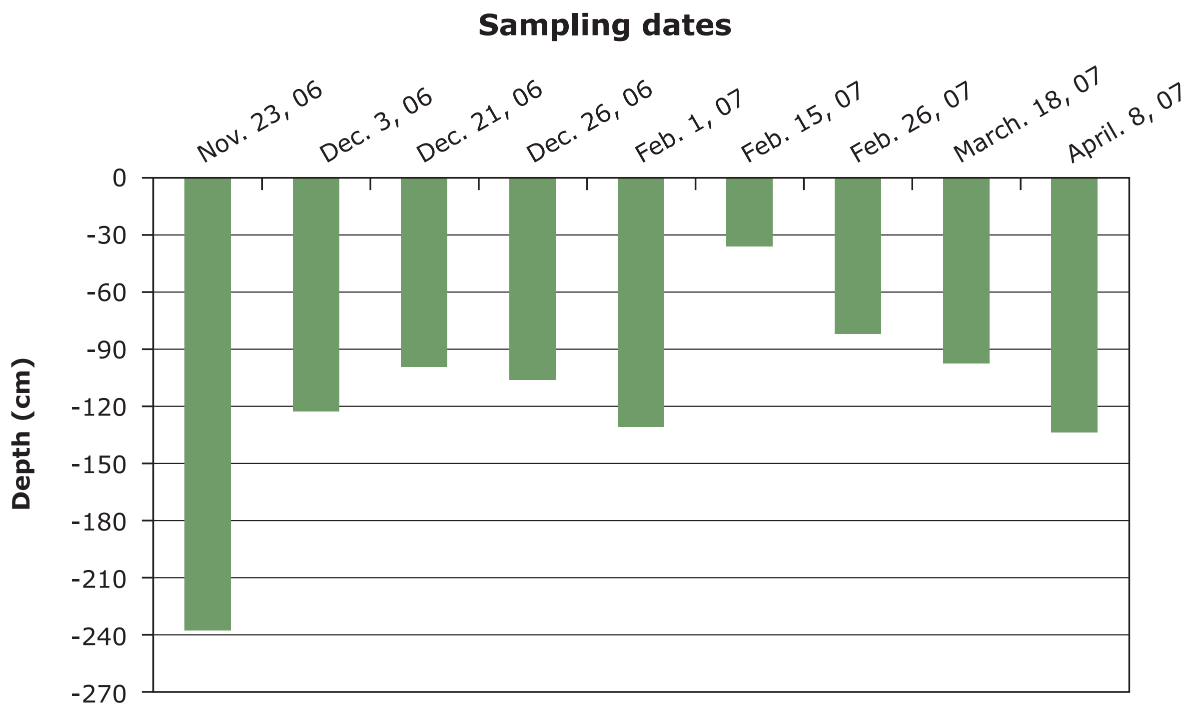

Fig. 2.3. Variation of groundwater depth (average of three points) during 2006-07

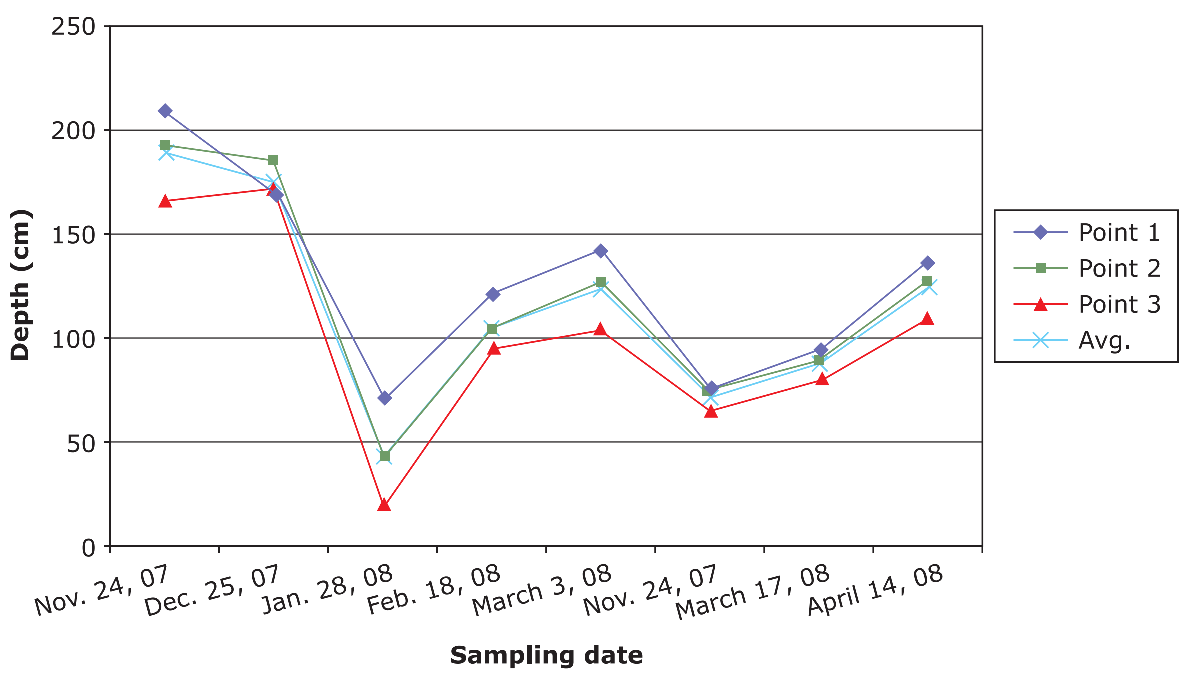

Fig. 2.4. Variation of the groundwater depth (average of three points) during 2007-08

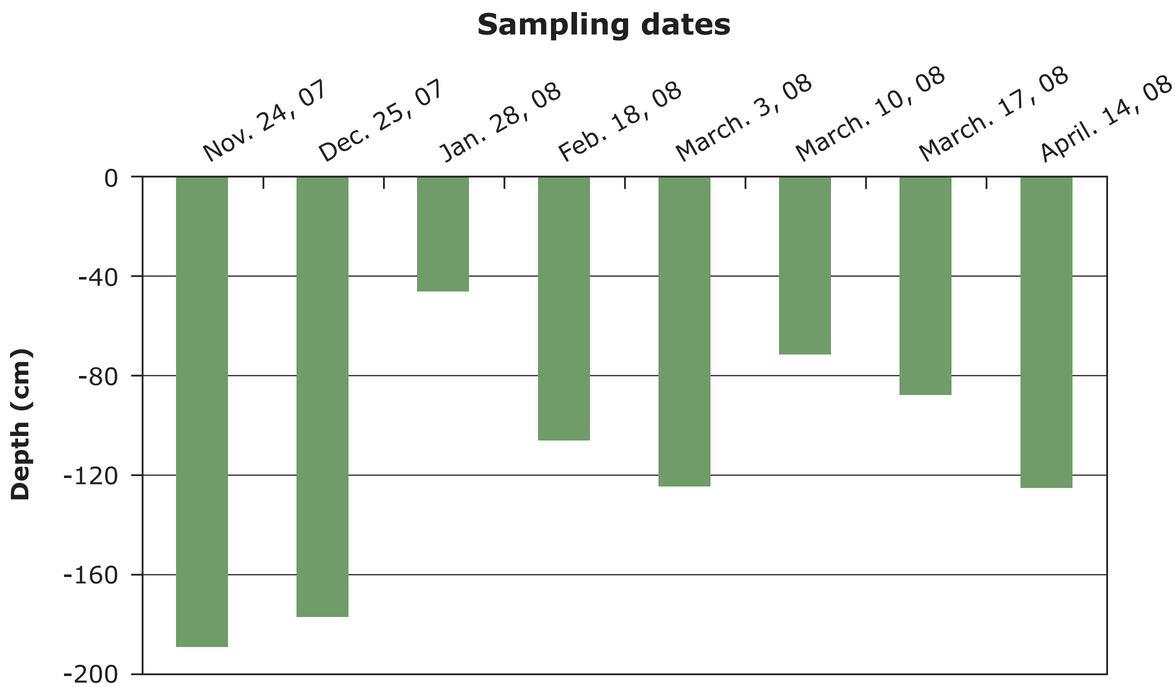

Fig. 2.5. Variation in groundwater depth (average of three points) during 2007-08

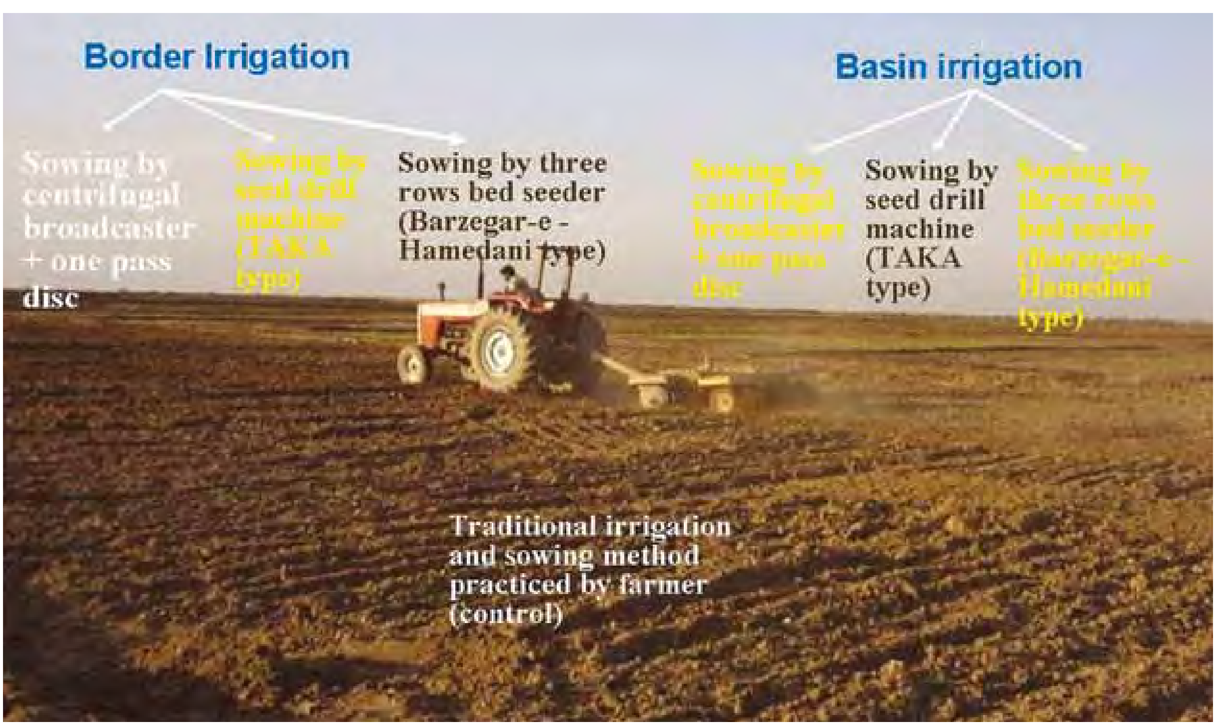

Fig. 2.6. Different combinations of the treatments and land preparation

Fig. 2.7. Measurement of flow to the irrigation border

Fig. 2.8. Barzegar-e Hamedani seed planter

Fig. 2.9. Taka type seed planter

condition, and the quality and depth of the drain water used for irrigation.

Results and discussion

The main objective was to find cost effective and short-term solutions to the salinity and waterlogging problems and hence to increase wheat water productivity in the Dasht-e-Azadegan region. The following targets were identified:

- Recognition of simple management practices for reducing soil salinity hazards and improving agricultural water productivity.
- Comparing WP under different irrigation methods i.e., traditional vs. improved border-basin irrigation method.
- Investigating the effect of different cultivation/sowing methods on wheat WP.

In this experiment, the different water quality treatments were applied in a cyclic way, i.e. drain and fresh irrigation canal water, in irrigation intervals (Figs. 2.10, 2.11). However, due to technical and logistical problems, the research

Table 2.4. Soil salinity and acidic values (year 2006-07)

Treatments	Soil layer (cm)	Sampling date	EC_e (dS/m)	pH
T1*	0-30	14 Feb. 07	4	7.9
	30-60		30	7.9
T2	0-30	3 Dec. 06	3.6	7.9
	30-60		5.7	7.9
	60-90		9.1	7.8
T2	0-30	20 Dec. 06	4.5	7.7
	30-60		4.5	7.8
	60-90		4.5	7.9
T3	0-30	3 Dec. 06	7.8	8.0
	30-60		4.1	8.0
	60-90		4.5	7.9
T3	0-30	20 Dec. 06	8.2	7.6
	30-60		4.9	7.8
	60-90		4.8	7.9

*T1 = saline-saline-fresh water;
T2 = fresh-fresh-saline water;
T3 = fresh-saline-fresh water

Table 2.5. Soil moisture in of the field during the year 2006-07

Experimental treatments	Sampling date	Soil moisture content (%) Soil layer (cm)		
		0-30	30-60	60-90
T1*	14 Feb. 07	21.58	21.86	nm
	25 Feb 07	20.2	21.2	nm
	7 April 07	16.5	17.0	nm
T2	3 Dec 06	21.89	20.22	17.30
	20 Dec 06	25.19	16.30	16.59
	14 Feb. 07	23.0	21.4	nm
	7 April 07	12.2	14.8	nm
T3	3 Dec 06	19.51	17.15	21.00
	20 Dec 06	20.09	19.16	20.34
	14 Feb. 07	22.4	24.0	nm
	7 April 07	15.3	18.6	nm
Tc	14 Feb. 07	23.72	20.61	nm
	25 Feb 07	21.2	20.8	nm
	7 April 07	13.2	13.5	nm

*T1 = saline-saline-fresh water; T2 = fresh-fresh-saline water; T3 = fresh-saline-fresh water; Tc = fresh-fresh-fresh water; nm = no measurement

Table 2.6. Quality and depth of drainage water used in the treatments as saline water

Year 2006-07		Year 2007-08		
Irrigation date	**EC of drain water (dS/m)**	**Irrigation date**	**EC of drain water (dS/m)**	**Depth of water applied (mm)**
28 Nov. 06	13.9	31 Dec. 07	18.3	61
8 Feb. 07	17.3	7 March 08	25.4	59
3 March 07	18.7	15 April 08	27.2	63

Table 2.7. The research treatments for the 2 years of the reuse experiments

2006-07		2007-08	
Treat-ment	**Explanation**	**Treat-ment**	**Explanation**
T1	Application of drain water in initial stage and after seed sowing	**T1**	Cyclic application of water (saline-saline-fresh-fresh)
T2	Application of drain water in final growth period	**T2**	Cyclic application of water (fresh-fresh-saline-saline)
T3	Cyclic application of drain water during growth period	**T3**	Cyclic application of water (fresh-saline-fresh-saline)
Tc	Control (canal fresh water)	**Tc**	Control (fresh-fresh-fresh-fresh)

Fig. 2.10. Reuse of drain water treatments

Fig. 2.11. Irrigation of reuse treatment plots by drain water

treatments for the 2 years of the experiment were different as shown in Table 2.7.

Table 2.8 shows the dates and amounts of water applied in the field under two irrigation management regimes, i.e., the traditional and the modified methods, for the 2 years of experiments are provided. There are considerable reductions in water consumption and savings in the volume of applied irrigation water.

Crop yields under different treatments were also determined. Water productivity of wheat (in kg/m^3) was calculated using yield and applied water data. Tables 2.9 and 2.10 provide the amounts of applied water, obtained yields and WP values of the different treatments for the 2 years of experiments. The WPs values were also calculated by considering the amount of effective rainfall (75% of total rain) during the growth period (Table 2.11).

Border irrigation with centrifugal and Hamedani sowing methods (T1, T3) provided the highest water productivities in years 2006-07 and 2007-08, being 1.60 and1.88 kg/m^3 respectively. Among the applied irrigation methods, the modified border irrigation had the maximum WP, 1.36 and 1.74 kg/m^3 in 2006-07 2007-08 respectively, while the farmer-managed treatment (traditional border-basin irrigation method under centrifugal sowing with 350 kg seed) provided the minimum WP of 0.61 and 0.81 kg/m^3 (Tables 2.9 2.10).

Agronomic measurements and data analysis were also conducted on the experimental treatments. Tables 2.12 and 2.13 give the measurements of some agronomics factors of the different experimental treatments.

Statistical analysis showed that the experimental treatments improved germination, yield and seed consumption in comparison to the control. Tables 2.13-17 show the results for the 2006-07 and 2007-08 seasons.

There was no significant difference (α=0.05) in yield between applied treatments and control treatment in the first year (2006-07). This indicates that the treatments were more efficient in water saving than yield improvements. However, in the second year of experiments, because of a severe drought in the area, the treatments had much

Table 2.8. The amounts and dates of irrigation under the two irrigation managements (years 2006-07, 2007-08)

Irrigation management option	**Irrigation water consumed (m^3/ha)**				**Sum (m^3/ha)**
		1^{st} irrigation	**2^{nd} irrigation**	**3^{rd} irrigation**	
Farmer management	Volume	1196	1081	928	3205
	Date	24 Nov. 06	8 Feb. 07	4 March 07	
	Volume	1196	1220	-	2416
	Date	31 Dec. 07	7 March 08	-	
Modified irrigation management (border and basin)	Volume	704	685	657	2046
	Date	24 Nov. 06	8 Feb. 07	4 March 07	
	Reduction to farmer management (%)	41.1	36.6	29.2	Avg.=35.6
	Volume	695	790	-	1485
	Date	31 Dec. 07	7 March 08	-	
	Reduction to farmer management (%)	40.4	35.2	-	Avg.=37.8

Table 2.9. Amount of applied water, yield and water productivities under different irrigation management treatments (year 2006-07)

Irrigation method	Sowing method	Water applied (m^3/ha) 1st irrig.	2nd irrig.	3rd irrig.	Sum of applied water (m^3/ha)	Yield (kg/ha)	WP (kg/m^3)	Avg. WP of irrigation method (kg/m^3)
Modified border	Centrifugal	513	547	558	1618	2590	1.60	1.36
	Taka	579	545	650	1774	2434	1.37	
	Hamedani	529	590	610	1729	1901	1.10	
Modified basin	Centrifugal	844	827	723	2394	2730	1.14	1.04
	Taka	927	795	695	2417	2521	1.04	
	Hamedani	830	808	706	2344	2198	0.94	
Average		704	685	657		2396	1.20	
Basin-border (farmer)	Centrifugal	1196	1081	928	3205	1953	0.61	0.61

more effect on water savings and hence better yields were obtained in comparison to control and the difference was significant. Although the consumption of seed used in the Taka and Hamedani sowing methods was 50% less, the seed germination percentage was higher than that with the centrifugal method.

As explained earlier, in the reuse experiments the objective was to examine the effects of using available drain water for crop production and to find out the WP in this situation. However, the main objective was to find a solution for ameliorating drainage problems by lowering the water table and at the same time to use this water for crop production and hence save more water.

Tables 2.18 and 2.19 detail the grain yield obtained under different water quality treatments (actually different cyclical applications of saline drain and fresh water) for the 2 years of the experiments.

To assess the soil salinity changes before and after irrigation with drainage water, soil samples were taken from the soil profile (Table 2.20).

Conclusions and recommendations

In the LKRB on the Dasht-e-Azadegan plain, heavy soil texture and lateral subsurface flows from upstream irrigated areas provide the conditions for waterlogging that is aggravated by the low irrigation efficiency of irrigated agriculture in the region. Waterlogging and soil salinity are the major constraints. Wheat is the main crop in the LKRB with an average yield of 1.5 t/ha. Irrigation management practices are traditional and the region suffers from poor water management, which is partly due to lack of modern irrigation infrastructure and

Table 2.10. Amount of applied water, yield and water productivities under different irrigation management treatments (year 2007-08)

Irrigation method	Sowing method	Yield (kg/ha)	Applied water (m^3/ha)	WP (kg/m^3)	WP (Avg. of irrigation treatment - kg/m^3)
Basin-border (farmer)	Centrifugal	1940	2388	0.81	0.81
Modified border	Centrifugal	2144	1348	1.59	1.74
	Taka	2471	1414	1.75	
	Hamedani	2400	1277	1.88	
Modified basin	Centrifugal	2251	1663	1.35	1.53
	Taka	2606	1633	1.60	
	Hamedani	2564	1576	1.63	

*Table 2.11. Values of water productivity of different treatments with the inclusion of rainfall**

Irrigation method	Sowing method	WP** (kg/m^3)		WP* (Avg. of irrigation treatment - kg/m^3)	
		2006-07	**2007-08**	**2006-07**	**2007-08**
Basin-border (farmer)	Centrifugal	0.40	0.65	**0.40**	**0.65**
Modified border	Centrifugal	0.80	1.10	**0.70**	**1.20**
	Taka	0.70	1.25		
	Hamedani	0.55	1.30		
Modified basin	Centrifugal	0.65	1.00	**0.60**	**1.15**
	Taka	0.60	1.20		
	Hamedani	0.55	1.20		

*Based on rainfall data, the total amounts of rainfall during the growing season for the years 2006-07 and 2007-08 were 228 mm and 72 mm respectively. Considering 75% of the total rain as effective rainfall, these values will be 1710, 540 m^3/ha respectively. The values were added to the volume of applied water to each farm for calculating the modified WPs.
**Adjusted with the amount of effective rainfall during cropping season.

on-farm improvement activities. Sound, adaptable irrigation methods that can be adopted by farmers are needed to improve agricultural WP and livelihood resilience of communities.

There is no doubt that the construction and/or completion of modern irrigation and drainage networks is the main solution. However, this is costly and time-consuming solution and may not be possible in the short term. Therefore, low-cost and short-term solutions to water management practices in the region must be developed. This could be achieved through research activities related to the water-table management, soil salinity control, irrigation water management, selection of suitable crop varieties, and improved agronomic practices. These will help to improve agricultural WP and farmers'

Table 2.12. Seed consumption, number of shrub and sprouting percentage of the treatments (year 2006-07)

Irrigation method	Sowing method	Seed consumption rate (kg/ha)	Shrubs in m^2 (No.)	Sprouting percentage (%)	Yield (kg /ha)	
					Planting treatment	Irrigation treatment
Basin-border (farmer)	Centrifugal (350 kg/ha)	350	247	34	1953	1953
Modified border	Centrifugal (250 kg/ha)	250	341	56	2590^{ns}	2308
	Taka (180 kg/ha)	180	262	60	2434^{ns}	
	Hamadani (180 kg/ha)	180	286	65	1901^{ns}	
Modified basin	Centrifugal (250 kg/ha)	250	387	63	2730^{ns}	2483
	Taka (180 kg/ ha)	180	332	75	2521^{ns}	
	Hamadani (180 kg/ ha)	180	353	80	2198^{ns}	

ns, not significant

Table 2.13. Seed consumption, number of shrubs and sprouting percentage of the treatments (year 2007-08)

Irrigation method	Sowing method	Seed consumption rate (kg/ha)	Number of shrub in m^2	Sprouting percentage (%)	Yield (kg /ha)	
					Planting treatment	Irrigation treatment
Basin-border (farmer)	Centrifugal	350	270	31	1940	1940
Modified border	Centrifugal	250	290	47	2144^{ns}	2338
	Taka	180	302	61	2471^{ns}	
	Hamadani	180	316	64	2400^{ns}	
Modified	Centrifugal	250	320	52	2251^{ns}	2474
	Taka	180	321	65	2606^{ns}	
	Hamadani	180	352	71	2564^{ns}	

ns, not significant

Table 2.14. A comparison between sowing method of the farmer (control) and the modified irrigation method regarding seed consumption rate and agronomic indexes (year 2007-08)

Irrigation method	**Sowing method**	**Seed consumption rate (kg/ha)**	**Number of shrubs (m^2)**	**Sprouting percentage (%)**	**Yield (kg /ha)**
					Planting treatment
Basin-border (farmer)	Centrifugal	350	305	35	1940
Modified border	Centrifugal	250	335^{ns}	54^{**}	2198^{ns}
	Taka	180	344^{**}	70^{**}	2538^{**}
	Hamedani	180	336^{**}	68^{**}	2482^{**}

ns, not significant; **, highly significant

Table 2.15. Results of t-test for the pair comparison of differences between grain yields of different levels of irrigation and sowing methods treatments (year 2007-08)

Basin irrigation			**Border irrigation**			**Irrigation method**	
Hamedani (2564)	Taka (2606)	Centrifugal (2251)	Hamedani (2400)	Taka (2471)	Centrifugal (2144)	**Sowing method**	
					-	Centrifugal (2144)	Border irrigation
				-	-1.5^{ns}	Taka (2471)	
			-	0.3^{ns}	-1.1^{ns}	Hamedani (2400)	
		-	0.6^{ns}	0.9^{ns}	-0.5^{ns}	Centrifugal (2251)	Basin irrigation
	-	-1.4^{ns}	-0.9^{ns}	-0.6^{ns}	-2.1^{ns}	Taka (2606)	
-	0.2^{ns}	-1.2^{ns}	-0.7^{ns}	-0.4^{ns}	-1.7^{ns}	Hamedani (2564)	
-2.8^{**}	-3.2^{**}	-1.4^{ns}	-2.3^{*}	-2.7^{**}	-1.1^{ns}	Centrifugal (Farmer) (1940)	Basin-border (farmer)

ns, not significant; *, **, significant at 5% and 1%, respectively

Table 2.16. Results of t-test for the pair comparison of differences between sprouting percentage of different levels of irrigation and sowing methods treatments (year 2007-08)

Basin irrigation			**Border irrigation**			**Irrigation method**	
Hamedani (71)	Taka (65)	Centrifugal (52)	Hamedani (64)	Taka (61)	Centrifugal (47)	**Sowing method**	
					-	Centrifugal (47)	Border irrigation
				-	-4.3**	Taka (61)	
			-	-0.7^{ns}	-4.1**	Hamedani (64)	
		-	2.8**	2.8*	-1.5^{ns}	Centrifugal (52)	Basin irrigation
	-	-3.6**	-0.2^{ns}	-1.2**	-5.1**	Taka (65)	
-	-1.2^{ns}	-3.9**	-1.3^{ns}	-2.1*	-5.0**	Hamedani (71)	
-8.3**	-10.0**	-6.3^{ns}	-8.1**	-10.0**	-5.1**	Centrifugal (Farmer) (31)	Basin-border (farmer)

ns, not significant; *, **, significant at 5% and 1%, respectively

Table 2.17: Results of t-test for the pair comparison of differences between number of shrubs/m^2 of different levels of irrigation and sowing methods treatments (year 2007-08)

Basin irrigation			**Border irrigation**			**Irrigation method**	
Hamedani (352)	Taka (321)	Centrifugal (320)	Hamedani (316)	Taka (302)	Centrifugal (290)	**Sowing method**	
					-	Centrifugal (290)	Border irrigation
				-	-0.7 ^{ns}	Taka (302)	
			-	-0.7^{ns}	-1.2 ^{ns}	Hamedani (316)	
		-	0.2^{ns}	-0.9^{ns}	-1.4 ^{ns}	Centrifugal (320)	Basin irrigation
	-	-0.1^{ns}	-0.2^{ns}	-1.1^{ns}	-1.6 ^{ns}	Taka (321)	
-	-1.2^{ns}	-1.2^{ns}	-1.3^{ns}	-2.1*	-2.4*	Hamedani (352)	
-3.0**	-2.3*	-2.1*	-1.9^{ns}	-1.6^{ns}	-0.9 ^{ns}	Centrifugal (Farmer) (270)	Basin-border (farmer)

ns, not significant; *, **, significant at 5% and 1%, respectively

Table 2.18. Grain yield (kg/ha) (2006-07)

Treatment/replication	T1*	T2	T3	Tc	Average
R1	3523	3358	3466	3963	3577.5
R2	3025	3880	3026	4088	3504.8
R3	3355	3528	3045	3839	3441.8
Average	3301	3589	3179	3963	-
Change from control (%)	16.7	9.5	19.8	-	-

*T1, saline-saline-fresh water; T2, fresh-fresh-saline water; T3, fresh-saline-fresh water, Tc: fresh-fresh-fresh water.

Table 2.19 :Grain yields under different treatments (year 2007-08)

Water treatment		Grain yield	
		kg/ha	t/ha
I1	Fresh-fresh-fresh (control)	2698.4	2.70
I2	Fresh-fresh-saline	2117.8	2.12
I3	Fresh-saline-saline	1710.1	1.71
I4	Saline-saline-saline	1501.3	1.50

Table 2.20. Soil salinity and acidity before and after drain water irrigation, 2007-08

Before irrigation		After irrigation*	
EC (dS/m)	pH	EC (dS/m)	pH
6.3	7	4	7.2
4.8	7.2	8.5	7.2
7.9	7.2	10.8	7.6
8.5	7.3	11.5	7.1

*The last irrigation was on 15 April 2008

livelihood in this region without requiring heavy investments.

The main objective of this research was to find cost effective and short-term solutions for the irrigation challenges in the area and to improve the WP of wheat in the salt-prone areas of lower KRB. Improved basin and border irrigation methods can both be recommended for this area. However, basin irrigation method is more suited to local conditions because:

- It requires less stringent land leveling and uniform slope across the irrigation plot, so requires less on-farm improvement to the existing conditions
- It is more adoptive to farm micro relief caused by common cultivation practices
- It requires less labor (considering the labor shortages in the area)
- It requires less control over flow, considering the high flow variation
- Considering the high levels of salinity

and its variation in different farms, the basin method provides pre-cultivation leaching opportunities, a common practice for reducing soil salinity prior to sowing ("Makhar" water).

Water productivity of irrigated wheat under saline-waterlogged conditions is low in the Karkheh River Basin, but it can be improved with simple irrigation management techniques. Improving traditional surface irrigation methods in the saline and waterlogged areas can help ameliorate the situation and improve crop water productivity.

It should be noted that yields under different treatments were not potential yields, but were obtained under existing farmer agronomic practices. Research treatments only focused on water-saving measures. Higher WPs could be expected under different treatments, if water management and agronomic practices were applied together.

The results of reuse experiments indicated the feasibility of the option of using drainage water as irrigation water, especially with the cyclic application of water during different growth stages without considerable yield losses. Reuse will help to improve WP levels of the wheat crop, especially in scarce water and drought conditions.

Waterlogging followed by increased soil salinity occurs in certain periods of the year. For example, under wheat cultivation, early November is the planting date in DA. Late November is the first irrigation for land preparation and harvest is in late May. Deep percolation losses of irrigation during this period cause the water table to rise. The rise peaks in February. Therefore, reuse of drainage water, considering that there are few feasible options for gravity disposal of drainage water, will also, indirectly, help to improve WP by lowering the water table and hence the salinity of the soil profile.

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