Iraq Salinity Project **Technical Report 12**

Understanding the linkages between groundwater table depth, groundwater quality, soil salinity and crop production in Al-Musaib and Al-Dujaila Project areas of Iraq

Reporters:

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Key words: southern Iraq, central Iraq, spatial distribution, remote sensing, irrigation, salinity mapping.

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INTRODUCTION

Soil and groundwater salinization are major problems for irrigated agriculture in many arid and semi-arid areas of the world. In addition to the enormous financial cost of production there are other serious impacts of salinity on infrastructure, water supplies, and social structure and stability of the communities (Pitman et al. 2004).

Saline soils occupy 60 to 70 percent of the alluvial plain. It is estimated that 4 percent of irrigated areas were severely saline, 50 percent moderately saline and 20 percent slightly saline (Al- Taie, 1970). Other estimates indicate that the area of salt affected soils in Iraq is about 6.7 million hectare (Mha) (Abrol et al., 1988), however only 1.025 Mha are partially or totally reclaimed (Committee of Agriculture and water Resources Sector, 2009).

Salinity problems are very pronounced in the central and southern Iraq unlike the northern Iraq while the alluvial plain in central and south Iraq became a discharge area for saline ground water. As a consequence, annual loss of cultivated lands in Iraq is about 5% due to salinization and water logging (Committee of Agriculture and water Resources Sector, 2009).

Soil salinization is a long-term problem for the central and southern Iraq. The first salinity records encountered in 2400 B.C. are related to the present area of Gharraf in East Iraq. This salinity may well have been caused by intensive irrigation and rising groundwater table. The area did not recover from this onset of salinity and this phenomenon may well have contributed to the decay of the Sumerian Empire, coinciding with this onset. There was a salinity onset in Northern Babylonia around 100 B.C. but it was much less severe and the area recovered. The recovery was probably due to a deeper groundwater table (Dieleman, 1963).

Salinity occurs through natural and\or human-induced processes that results in the accumulation of dissolved salts in the soil. The genesis of soil salinity in Iraq as a whole must be attributed to the salt content of the irrigation water. The elevated groundwater tables in irrigated areas are a consequence of high seepage losses from canals and irrigated fields. Large scale salt accumulation is the result of soil evaporation caused by the arid climate. However, the situation has become more severe due to rising groundwater tables because capillary action continues causing evaporation even after the actual irrigation has ceased. Soils have been irrigated since early Babylonian times. Owing to the very slight slope of the river plains

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and the low rainfall, natural drainage or leaching was very limited. As a result, the salts from the irrigation water of some millennia have accumulated in the topsoil.

Salinity in shallow groundwater and the root zone are closely correlated (Schoups et al., 2005). The coincidence of irrigation and salinization threatens the sustainability of high agricultural productivity (Flowers and Yeo, 1995). Yields of Wheat, Barley and corn yield in Iraq are estimated at 1700, 1288 and 3159 kg ha^{-1}, respectively. Use of marginal quality soils and irrigation water and lake of innovative production technologies are considered responsible for these low productivities (Committee of Agriculture and water Resources Sector, 2009).

The main objective of this study is to assess the current state of groundwater levels, groundwater and soil salinity, irrigation and drainage practices and their combined impact on crop production and soil salinization under and the ‘do nothing’ scenario in central and southern Iraq.

Study area

This study is being carried out in two project areas located in the central and northern Iraq i.e. Musaib project area and the Dujaila project area. The Musaib project area is located 90 km south of Baghdad in Babil Province on both the east and west banks of the Euphrates river, which splits into the Hindiya and Hilla branches. The Musaib project area consists of 83500 ha, out of which large part is severely affected by salinity due to the occurrence of highly saline groundwater (18-12 mmhose\cm) (Al-Zubaidi 1992). The groundwater depth in uncultivated soils is 200 cm and 90-160 cm in state and farmer fields due to seepage from irrigation fields and inefficient drainage. In order to solve the salinity problems of this project area, a large scale project was initiated in 1954.

The Dujaila area is the largest and oldest settlement project in Iraq, which was started in 1946 (Dieleman, 1963). The project is located in Wasit province, on the right side of the Tigris River and on the left side of al-Garraf River. The total area of the project is 99000 ha (land irrigated and non-irrigated). The project is divided into three areas i.e. reclaimed, semi-reclaimed and non-reclaimed. Reclamation of soils was stopped in 1983.

Climatically, both Al-Musaib and Dujaila areas represent a hot sub-desertic climate. It is characterized by short cool winters and long hot summer with almost no spring or autumn season. Rainfall is very seasonal and occurs in winter from December to February. Average annual rainfall is estimated at (133mm and 137mm) for Al- Musaib and Al-Dujaila project areas, respectively. Winter are cool to cold and short, with a day temperature of about (18.3°C , 19.7 °C) dropping at night to 7.3°C and 8.5°C during November to February for Al- Musaib and Al-Dujaila project areas, respectively. Summers are dry and hot to extremely hot and long season with shaded temperature of over 44°C during July and August and dropping at night to 26.4°C. The crops cultivated in both project areas are wheat, barley, corn, millet, sorgham and sunflower in summer and mostly vegetables in winter. Cotton and sunflower is also grown on a limited area in summer.

RESULTS AND DISCUSSION

(a) Cropping patterns, crop yields and fertilizer use

For this study, secondary data regarding climate, cropping patterns, crop calendars, consumptive use of main crops, volume of irrigation water applied to each crop, fertilizer use and soil fertility, quality of Euphrates and Tigris River water, permeability and infiltration rates of soils, soil salinity, groundwater table and quality, chemical and physical and hydrological properties of soils was collected from different national organizations and institutions. These data were used to evaluate the trends in soil salinization over time in two project areas.

Three piezometers were installed in a sub-project area (50 ha) of the Al-Musiab project area to monitor the groundwater table and salinity on monthly basis. Similarly three locations in Al-Dujaila Project were selected (Reclaimed area, Semi reclaimed area and Non-reclaimed area with total area of 62 ha for each) to monitor the behavior of groundwater table and salinity. In May 2011, field data was collected to determine the physical and chemical properties of soil profile at various points located in the two study areas of Al-Musaib and Al-Dujail.

Table 1 Illustrate the crop calendar and average yields of major crops in both project areas. The lower yields of these crops are attributed to traditional farming methods, in-sufficient extension services about modern farming techniques, soil salinity and limited availability of fresh irrigation water.

Table 1. Crop calendar and yield of main crop

Crops	**Sowing and Harvesting dates**	**Yields kg/ha**
Wheat	01/Dec. – 30/Apr.	1200 - 3000
Barely	01/Dec. – 30/Apr.	1000 - 2800
Corn	15/Jul. – 01/Nov. 15/Mar. – 01/Jun.	1000 - 2800
Cotton	15/Mar. – 15Aug.	2000 - 2400
Sun flower	15/Feb. – 01/Jul. 01/Jul. – Nov.	1000 - 2000

Table 2 shows the consumptive use of water for different crops cultivated in Al-Musaib and Al-Dujaila Project areas. Consumptive use is affected by many factors (soil, climate, topography, length of growing season...etc.). The data of consumptive use for main crops in Al- Musaib and Al- Dujaila Projects which listed in this table seem that winter crops (wheat and Barley) use less amount of irrigation water when compared with summer crops (corn, sorghum and cotton). The water applied to field crops From other side the consumptive use of vegetable crops is more than in field crops is well within the world averages however keeping in view the high soil salinity levels, this much water application might not be sufficient for leaching salts. However, non-functional nature of drainage facilities restrict further application of irrigation water as this will help in the rise of saline groundwater tables which can exacerbate the salinity problems.

Table 2: Irrigation water applied to different crops

Crops	Water applied (m^3/ha)	No. of irrigations
Wheat	5140	6
Barely	5140	6
Corn	8332	10
Cotton	10952	16
Sorghum	9760	10
Tomato	10000	10

Table 3 shows that the Iraqi farmers in Al- Musaib and Al-Dujaila project areas use two kind of fertilizers i.e. Urea and DAP or Urea with NP. DAP fertilizer is newly introduced to Iraqi farmers in the last two decade. The use of micronutrients and potassium is not common. It seems that the farmers in these project areas use extra quantity of fertilizers.

Table 3. Rate of application of fertilizers in Al- Musaib and Al-Dujaila project areas.

Crop	**Urea Kg/ha/season**	**Applied**	**DAP Kg/ha/season**	**Applied**	**NP 18:18 Kg/ha/season**
Wheat	500 divided into 3 portion	With	240	OR	600
Barely	400 divided into 2 portion	With	Not applied	OR	400
Corn	500 divided into 3 portion	With	400	OR	No Applied

(b) Physical and chemical soil properties and water quality

All soils in the Al-Musaib and Al-Dujaila project areas belong to Holocene alluvial deposits and are typically torrifluvents with a hyperthemic soil temperature regime and a mixed (calcareous) mineralogy, according to US Taxonomy (soil survey, 1999). Table 4 gives the characterization of different pedons in Al-Mussiab project area.

Table 4. Characterization of different Pedons of the Al-Musaib project area.

Pedon No.	**Soil drainage : well**
Location : AlMussaib Project (Selected Area)	Water table depth : 160 cm
Mapping unit	Vegetation : prosopis
Parent material : alluvium	Elevation (m) : 24 m
Soil Classification : Typic Torrifluvents	Surface stoniness : None
Physiographic : levee	Remarks : irrigated
Topography : flat	Date of description : 1977

Tables 5 and 6 shows a typical pedon located in the north of Wasit governorate close to Al-Dujaila project on the right side of the Tigris Rivers, which has been selected to characterize several soil properties (Abbas, 2010). These two tables show the chemical and physical properties of two profiles of levee and Basin area.

Table 5. Physical and chemical properties of soils North of Wasit governorate close to Al-Dujaila project area (Abbas, 2010) (Close to Tigris River).

Depth cm	Soil Texture	Particle size analysis			EC dS m^{-1}	CaCO3 %	Gypsum %
		Sand (%)	Silt (%)	Clay (%)			
0 -30	SiL	16.4	60.5	23.0	3.5	27.2	2.5
30- 70	SiL	5.0	60.2	33.0	4.3	25.4	1.8
70- 110	SiL	17.4	61.1	21.5	5.2	27.4	Nil
110-130	SiC	15	57.0	41.5	6.7	24.0	3.6

Table 6. Physical and chemical properties of soil from North of Wasit governorate close to Al-Dujaila project area (Abbas, 2010) (far from Tigris Rivers).

Depth cm	Soil Texture	Particle size analysis			EC dS m^{-1}	CaCO3 %	Gypsum %
		Sand (%)	Silt (%)	Clay (%)			
0 -10	SiCL	7.9	64.1	28.0	210	20.5	16.2
10- 40	SiC	5.8	53.7	40.5	50	25.8	2.0
40- 95	SiC	1.0	4.2	57.0	57	26.7	0.2
95-125	SiC	6.0	41.5	48.5	30	27.7	1.70

Depth Cm	**Soil Texture**			**Soil Tex.**	**pH**	**EC dS m^{-1}**	**Lime %**	**Gypsum %**	**CEC Cmol (+) kg^{-1}**	**ESP**	**O.M %**
	Sand %	**Silt %**	**Clay %**								
0-15	5	64	31	SiCL	7.6	24.0	23.6	1.5	16.2	29.4	1.4
15-35	7	66	27	SiCL	7.6	9	25.2	0.9	18.5	14	0.7
35-65	7	63	30	SiCL	7.7	5.9	26.6	1.1	18.0	10.5	0.4
65-105	8	61	31	SiCL	7.7	5.3	23.8	0.9	17.0	12.5	0.4
105-130	11	62	27	SiCL	7.7	5.3	28.7	1.3	16.2	12.0	0.3
130-160	10	66	24	SiCL	7.7	6.2	27.1	2.0	18.0	13.3	0.2

Table 7 shows the physical and chemical properties of the soils of the area selected by the component C in the Al- Musaib project. The texture of these soils is silt clay loam up to the depth of 90 cm. This shows that this area was true representative of the Al-Musaib project.

Table 7. Physical and chemical properties of the study area soils in Al-Musaib project.

Location No.	Depth Cm	Soil Texture	Particle size analysis			EC dS m^{-1}	pH
			Sand (%)	Silt (%)	Clay (%)		
1 (a)	0 -15	SiCL	9.0	61.0	30.0	7.03	7.68
	15- 30	SiCL	8.0	62.8	29.2	8.10	7.69
	30- 60	SiCL	5.0	66.4	28.6	4.00	7.81
	60-90	SiCL	11.0	66.0	23.0	7.4	7.73
2 (b)	0 -15	SiCL	11.0	62.0	27.0	8.08	7.51
	15- 30	SiCL	12.4	66.0	21.6	5.50	7.71
	30- 60	SiCL	5.0	64.0	31.0	6.00	7.71
	60-90	SiCL	10.8	63.0	26.2	8.00	7.70
3 (c)	0 -15	SiCL	9.8	60.0	30.2	4.4	7.71
	15- 30	SiCL	12.8	65.4	21.8	2.50	7.86
	30- 60	SiCL	8.5	61.2	30.3	2.50	7.82
	60-90	SL	62.8	36.4	0.8	2.00	7.96

(a) N:324504, E:443840; (b) N:324504, E: 443853; (c) N: 324457, E: 443917

Table 8 shows chemical and physical properties of soils from three study areas in the Al-Dujaila project. Table 9 shows different soil properties of the study area located north of Wasit governorate (Abbas , 2010).

Table 8. Physical and chemical properties of study area in Al-Dujaila project.

Location No.	Depth Cm	Soil Texture	Particle size analysis			EC dS m^{-1}	pH
			Sand (%)	Sand (%)	Sand (%)		
Semi-reclaimed area	0 -15	SiL	20.3	61.6	17.6	37.80	7.68
	15- 30	SiL	20.3	61.6	17.6	24.94	7.75
	30- 60	SiCL	10.8	51.6	37.6	33.44	7.59
	60-90	SiC	9.2	48.4	42.4	24.62	7.73
Reclaimed area	0 -15	C	4.8	39.6	55.6	9.30	7.85
	15- 30	C	8.8	35.6	55.6	9.60	7.85
	30- 60	SiC	4.8	42.0	53.2	11.06	7.68
	60-90	SiC	6.4	40.0	53.6	9.32	7.85
Non-reclaimed area	0 -15	C	12.4	37.2	50.4	10.56	7.71
	15- 30	C	20.8	31.6	47.6	12.94	7.58
	30- 60	C	38.8	15.6	45.6	16.44	7.82
	60-90	SiCL	16.8	52.8	36.0	15.80	7.96

Table 9. Infiltration rate and hydraulic conductivity (Abbas, 2010).

Pedon no.	Infiltration rate (cm/hr)	Class of infiltration	Soil texture	Hyd. Cond. (m d^{-1})	Hyd. Con. Class
1	0.87	Moderate to slow	SiL	1.54	Moderate
2	3.35	Moderate	SiC	2.08	Moderate
3	0.05	Very Slow	SiCL	1.04	Moderate
4	0.36	Slow	SiL	0.70	Moderate
5	0.22	Slow	SiC	1.23	Moderate
6	0.09	Very Slow	SiCL	0.54	Moderate
7	6.00	Moderate	SiL	1.78	Moderate
8	24.00	Fast	SCL	1.44	Moderate
9	1.70	Moderate to slow	SiCL	4.20	Fast
10	0.21	Slow	SiC	0.51	Moderate

Comparison of secondary data presented in tables 4, 5 and 6 for Al-Musaib and Al-Dujaila projects and the actual field data presented in tables 7 and 8 for above two sites shows a close proximity. This shows that secondary data of infiltration rate and permeability of these two study sites can also be used for analysis.

(c) Groundwater quality, soil salinization and drainage

For thousands of years, Iraq has been the home of perennial irrigation, just as Egypt has been the home of the ancient basin irrigation with a single cereal crop per year. The principle sources of irrigation water in Iraq are the Tigris and Euphrates Rivers. The quality of these two sources decreases as they flow towards south (Shaat Al-Arab). The water salinity of Tigres River increases from 0.44 dS/m at the Turkish – Iraqi border to more than 3 dS/m at Ammarah province (south of Iraq) , and from 1.0-1.3 dS/m at Syrian – Iraqi border to 2.5–4.6 dS/m by the time it reaches to Euphrates River. Historical data on the water salinity of Tigris Rivers at Baghdad city shows that its salinity was 0.63 dS/m in 1960 (Buringh, 1960) which has increased to 1.15 dS/m at Al-Dujaila project (200 Km south of Baghdad) by 2011. The same is the situation for Euphrates River where salinity has increased to 1.56 dS/m over the same period of time.

Salinization of soils is a major problem in saline shallow water table areas. This is influenced by climate, soil type, crop, irrigation water quality, management practice, groundwater table depth and quality. There is a close relationship between groundwater table depth and capillary rise. In irrigated areas like Al-Musaib and Al-Dujaila, groundwater table depths vary significantly depending on the location of the fields. Table 10 shows historical data regarding groundwater table depth in the Al-Dujaila project area (Dieleman, 1963).

Table 10: Groundwater table depth (cm) below soil surface (Dieleman, 1963).

Year and crop	1956-Green gram				1958- Barley			
Month	June	July	Aug	Sept	Jan	Feb	Mar	Apr
Gen. avarage	65	82	82	100	70	80	100	103
Average minimum	25	45	60	72	40	55	75	85
Average maximum	70	105	102	118	100	110	105	120

The concentration of salts in the groundwater varied in the lower Mesopotamian plain from 10,000 to 60,000 ppm (Buringh, 1960). In many areas it may be much higher, up to 80,000 ppm. Al–Zubaidi (1992) illustrated that salinity of groundwater in Al- Musaib before reclamation was 12-18 dSm^{-1}. The chemical composition of Al- Musaib groundwater is sodium chloride as the dominant salt whereas magnesium and sodium sulphates are equally important.

Table 11 shows that in Al- Dujaila project area, groundwater table varies between 45cm in February and 200cm in August. Groundwater salinity at the measured points was extremely high reaching up to 30 dSm^{-1} (point 5), fluctuating from month to month based on irrigation activity and drainage efficiency. This feature seem to be common in many Iraqi soils and as a result of that soil profiles are wet to partially wet especially in the winter season.

Table 11. Groundwater table depth and quality of the Al-Dujaila project area in 2007.

Location	GPS Readings		Months						
			February			March		April	
	N	E	Levels (m)	Depth (cm)	EC (dSm^{-1})	Depth (cm)	EC (dSm^{-1})	Depth (cm)	EC (dSm^{-1})
Point 1	3222693	4620238	11.38	45	16.5	45	16.6	90	17.0
Point 2	3222681	4620343	11.24	60	26.6	61	26.6	45	20.8
Point 3	3222632	4620254	11.14	60	12.0	60	12.0	100	10.1
Point 4	3222575	4620227	10.90	85	22.3	85	22.3	90	23.6
Point 5	3222571	4620114	11.17	50	20.4	50	20.3	85	30.5
Point 6	3222393	4620604	11.02	60	21.3	60	21.3	45	19.8
Point 7	3222434	4620438	10.74	62	8.8	62	8.8	45	5.2
Point 8	3222317	4620112	10.94	50	11.7	62	11.7	90	11.7
Point 9	3222283	4619918	11.01	62	9.3	62	9.3	65	9.6
Point 10	3222063	4619871	10.63	62	9.4	64	9.4	65	9.9

Table 11 *(Continued)*

Location	May		June		July		August	
	Depth (cm)	EC (dSm^{-1})	Depth (cm)	EC (dSm^{-1})	Depth (cm)	EC (dSm^{-1})	Depth (cm)	EC (dSm^{-1})
Point 1	100	17.5	180	-	>200	-	>200	-
Point 2	75	21.2	185	-	>200	-	>200	-
Point 3	110	13.8	180	-	>200	-	>200	-
Point 4	110	24.0	190	-	>200	-	>200	-
Point 5	105	31.1	190	-	>200	-	>200	-
Point 6	95	22.0	190	-	>200	-	>200	-
Point 7	95	9.8	200	-	>200	-	>200	-
Point 8	120	12.6	200	-	>200	-	>200	-
Point 9	110	10.1	200	-	>200	-	>200	-
Point 10	110	11.0	200	-	>200	-	>200	-

Al-Musaib project is irrigated from the left side of Euphrates River through a 50 km long main non-piped canal (except for the first 500 m) with a discharge capacity of 40 m^3/sec. Total length of main branches and tertiary branches of this canal is 122 km. Drainage system consists of collective and open field drains with total a length of 520 and 1600 km, respectively. The sub-drains discharge their drainage water into northern and southern main drains. These drains are 47.5 km and 59.5 km with a discharge capacity of 15m^3/sec and 3m^3/sec, respectively. There are seven pumping stations to regulate drainage water.

Soil reclamation is done with the help of covered field drains with a total length of 611 km (http://www.mowr.gov.iq:81/mosoa/FOR4.htm#). The project suffers from re-salinization due to drainage water seepage from the general drain (Al- Zubaidi 1992). Currently, Al-Musaib project have only one drainage outlet called as Al-Musaib southern drain (pump station No. 4), which discharges drainage water from Al-Musaib project area to Al-Musab Al-Am river. The salinity of drainage water varies between 3.4-4.7 dSm^{-1} (TDS 2315-3045) during different months.

Al-Dujaila project is irrigated from the Tigris River by a main canal with a maximum design discharge of 42m^3/sec and with an operational discharge of 15m^3/sec. The total length of this canal is 57km and has 13 branch canals in addition to distribution canals. Al-Dujaila project has four padded canals into reclaimed area with a total length of 40.7 km, in addition to 12 km unpadded canal. Irrigation is done by flooding method. The number of lateral padded canal in reclaimed area is 23 with a total length of 72 km.

Semi-reclaimed area is irrigated by five lateral canals consists of irregular traditional canals. Main drains of the project area are discharging drainage water to Al-Msandk lake. The total length of main and sub collected drains is 1121 km. Al-Duajila project had 3 drainage outlets and four pumping stations with a discharge capacity of 3.0 m^3/sec each. According to 1996 estimates, the salinity of Al-Dujaila southern drain varies between 6.7-16.0 dSm^{-1} (TDS 4635–11090 ppm) along different months. Al-Dujaila eastern drain discharges into Al-Msandk lack and salinity of drainage water varies between 8.0 -13.0 dSm^{-1} (TDS between 5550–9162 ppm) along different months. Currently, there are three pumping stations with 11 pumps with a total discharge of 6.5 m^3/sec.

Local nomenclatures of saline soils in Iraq are Shura and Sabakh soils. Shura soils are often with a white crust. Sabakh soils have the dark brown color and high content of deliquescent salts and occur in irregular patterns generally in silt or loamy textured soils in areas where the surface is still in contact with the ground water by the capillary rise at least during the greater part of the year. They are common in the silt irrigation deposits along old and present day irrigation canals and ditches. Extensive areas covered with Sabakh soils were recognized by Buringh (1960) in Al- Musaib. Al-Hassani (1984) reported the analysis of Shura and Sabkha soils in Al-Dujaila area . He found different ionic compositions of the two profiles due to difference in ground water composition. The depths of the saline layer above ground water depend on soil texture, structure, bulk density, porosity and consistency.

Table 12. Soil salinity in non-saline, uncultivated and Al-Musaib project soils.

Depth (cm) Non-saline soils	EC dSm^{-1}	Depth (cm) Uncultivated soils	EC dSm^{-1}	Depth (cm) Al-Musaib project	EC dSm^{-1}
0-30	3.10	0-20	40.11	0-40	19.57
30-60	2.60	20-40	19.61	40-60	13.00
60-95	2.80	40-75	13.00	60-80	14.61
95-120	3.80	75-90	7.59	80-100	11.82
120-140	4.40	-	-	100-20	13.10
140-GW	10.96	90-GW	40.80	200-GW	17.90
Source : Al-Jeboory, 1987					

Soil characteristics differ in vertical and horizontal direction particularly in the river deposits. For this reason, occurrence of saline soil layers is irregular. Al-Jaboory (1987) found drastic changes in salinity patterns in the Al-Musaib area. In Al- Musaib area cultivated soils varies between non-saline to saline sodic soils with shallow and very high saline ground water. The uncultivated soils also classified as saline sodic soil with saline ground water at 200cm depth. In general, sodium adsorption ratio exceeded 15%. Saline sodic soils are very common in Iraq. Although the pH of the soil paste does not exceed 8.5, exchangeable sodium percentages of over 50 are quite common. The average exchangeable sodium percentage for all saline soils is estimated to be somewhere between 20 and 25 (Dieleman, 1963). The resistance of Iraqi soils to sodification is very high due to the presence of high quantity of soluble exchangeable calcium and magnesium in addition to calcite and gypsum (Al-Zubaidi, 1992).

Analysis of secondary data revealed that 60% of Al-Dujaila surface soils have an electrical conductivity of higher than 16 dSm^{-1} (Dielman, 1963). Table 13 gives a typical example of the salt content of the soil under the conditions prevailing in the Dujaila area. Comparison of field data presented in table 8, secondary data listed in table 13 and from the field observations of the last year, we can conclude that there is a decrease in soil salinity which might be the result of land use for agriculture and reclamation practices adopted by farmers in the project area.

Table 13. Soil salinity in the Al-Dujaila project

Depth (cm)	EC dSm^{-1}	Depth (cm)	EC dSm^{-1}	Depth (cm)	EC dSm^{-1}
0-30	65	0-30	64.0	0-31	3.5
30-60	36	30-65	42.0	31-72	4.3
60-100	35	65-105	44.5	72-109	5.2
100-150	34	105-140	57.0	109-131	6.7
150-200	35	-	-	131-150	7.1
Source : Dieleman, 1963; Abbas, 2010					

(d) Field observations made during 2011

The results of the monitoring data on groundwater table depth and groundwater quality from Al- Musaib and Al- Dujaila project area by the team of component C are shown in Figure 1. In general, groundwater salinity was higher in Al-Dujaila project area than Al-Musaib project area. In two observed locations, groundwater salinity remained up to 5.0 dSm^{-1}, while at the third location it went up to 8.0 dSm^{-1}. In contrast, groundwater salinity at both locations in the Al-Dujaila project area remained above 10 dSm^{-1} during the monitoring period. Groundwater salinity at location 3 went up to 45 dSm^{-1}, which is even above Sea water salinity.

The groundwater table depth at all locations of the Al-Musaib area remained between 1-2 m with minor fluctuations within months depending upon the irrigation and evapotranspiration activity. This fluctuating behavior is similar to what was found from the historical data of 2007 (Table 11) and 1956-1958 (Table 10) although current data showed a declining trend in groundwater table depth comparing to historical data. The groundwater table depth at Al-Musaib project virtually remained stable which shows that recharge was equal to discharge and a state of hydrological equilibrium exist. The field data showed that relatively shallow groundwater table depths and high salinity of groundwater temporarily or constantly causing a serious threat of soil salinization.

Salinity of groundwater of non-reclaimed soil in Al- Dujaila ranged between 42-43.8 dSm^{-1}, while groundwater of semi and reclaimed soils was moderately saline (Rhoades et al. 1992) with a range between 8.2-10 dSm^{-1} during May-September. This groundwater salinity reflects a serious problem and deserves careful consideration. It is also observed that groundwater salinity of semi-reclaimed soil rose in November and reached to 20 dSm^{-1}. This rise in groundwater salinity was partly due to closing of pumping station. Al- Musaib groundwater salinity ranged between 3.5 dSm^{-1} for location 1 and 8.0 dSm^{-1} for location 2. Groundwater salinity for all locations of the Al-Musaib project area were classified as moderately saline (Rhoades et al. 1992). Lower groundwater salinity in Al Musaib project area represents a trend of desalinization when compared with historical data (Table 12).

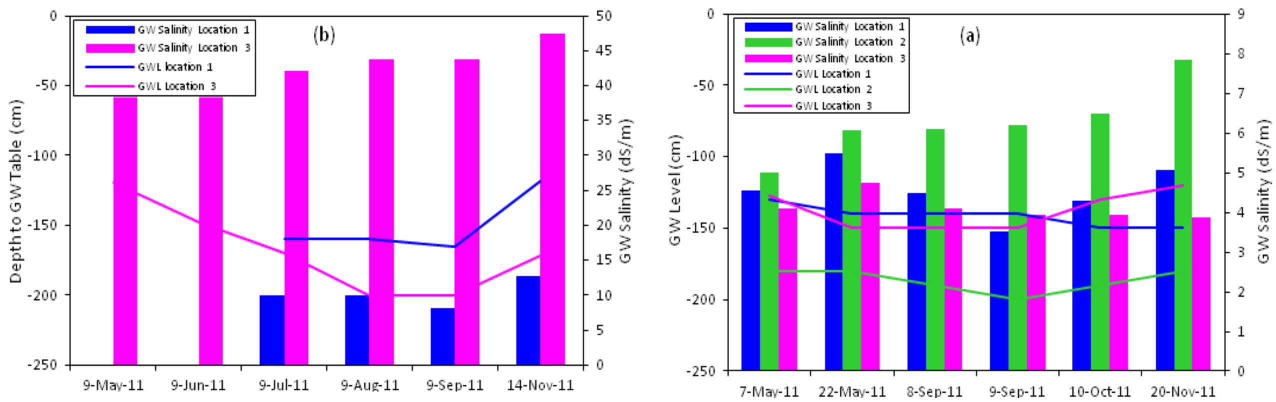

Figure 1. Existing groundwater table depth and quality in (a) Al-Mussaib and (b) Al-Dujail project areas.

It was further observed that all studied soils in Al–Dujaila project area were saline – classified as solonchak. Soil EC was increasing in the order: Reclaimed < non- reclaimed< semi-reclaimed. It is obvious that fluctuation of hydromorphic conditions (groundwater table depth and salinity) coupled with lack of drainage led to increased salinization in these soils. However, salt balance is found to be more stable compared with the historical data.

Conclusions

Historically, problems of salinity started between 2,000 and 3,000 B.C. in the southern part of Iraq and then spread over other parts of the country. Drainage was never a part of the irrigation development, which led to increased groundwater tables in the alluvial plains in the southern and central Iraq where main irrigated agriculture is practiced. This rise in saline groundwater tables brought salts in the root zone. The pumped irrigation which is practiced on 25% of the area along the banks of two rivers further compounded the salinity problem.

Large tracts of irrigated lands in the southern and central Iraq are now salinized which has reduced the crop yields significantly threatening the food security of the Iraqi people. Areas adversely affected by irrigation return flows are located in the lower basin of the Euphrates River. These areas cannot be irrigated without providing adequate drainage facilities. In the absence of drainage, large areas have and will go out of production. Poor quality of groundwater is not only creating problems for irrigators but also affecting human beings as they are using this water for domestic needs. Many villages and small towns in this area have become desolate due to deterioration of the Euphrates River water quality.

For Iraq it seems necessary to intensify the study of groundwater issues due to increasing soil salinity and drainage problems. Equally important is the study of soil solutions because they are more directly related to crop production. The findings show that the soil solution is much higher (2 to 3 times) than in the groundwater as a consequence of higher temperature in the upper parts of the soil. Iraq has to invest and invest soon in improving its drainage facilities in order to ensure future food security for the country.

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