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Extent, Characterization and Causes of Soil Salinity in Central and Southern Iraq and Possible Reclamation Strategies

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Abstract
Poor irrigation practices and lack of drainage facilities have contributed to rising groundwater tables leading to soil salinization in the irrigated areas of central and southern Iraq. Salinity problems has robbed the production potential of the 70% of the total irrigated area of Iraq with up to 30% gone completely out of production. This situation has threatened the sustainability of irrigated agriculture which produces more than 70% of the total cereal production in Iraq. Most of the reclamation efforts in the past have focussed on the installation of surface drainage systems. Other management approaches such as excessive leaching, crop-based management and chemical amendments have also been used on a limited scale to enhance productivity of these soils. However success has been limited and the problems of salinity kept on increasing. Therefore there is an urgent need to develop a national strategy for the rehabilitation of these soils. This strategy should include establishment of an effective monitoring network to record spatial and temporal changes in the soil salinity and water quality. Rehabilitation of existing drainage systems and installation of new drainage systems in the needed areas should be given priority. Involvement of communities in the planning of such projects is necessary for sustainable and effective operation and maintenance of these projects.
Key words: *soil salinity, drainage systems, groundwater table, Iraq, irrigation management*

I. Introduction

The total land area of Iraq is 438,320 km^2. It consists of the Great Mesopotamian alluvial plain-the land between Tigris and the Euphrates Rivers (FAO, 2012). This plain is surrounded by mountains in the north and the east reaching altitudes of 3550 m above sea level, and by desert areas in the south and west, which account for over 40 percent of the land area (Figure 1). More than 90 percent of the country is arid and semi-arid. Summers are dry and hot with temperatures reaching as high as 53^{o}C. Winters are cool to cold, with a day temperature of about 16^{o}C dropping at night to 2^{o}C with a possibility of frost. The average annual rainfall is less than 250 mm but ranges from 1200 mm in the northeast to less than 100 mm in the south (Abbas, 2010).

The total geographic area of Iraq is 45 million hectare (mha), out of which 34 mha (78%) is not suitable for agriculture under current conditions. According to FAO estimates, the total cultivated area of Iraq is 6 mha (FAO, 2012), out of which 50 percent in the northern Iraq is in rain-fed condition while the rest is irrigated. Surface irrigation methods are widely used for irrigating crops. The total water withdrawal during 2000 was 66 km^3, of which 78 percent is used for irrigation and livestock followed by 15 percent for industry and 7 percent for domestic purposes (FAO, 2002). The productivity of irrigated lands is very low with wheat, barley and corn yields estimated at 2100, 1900 and 3159 kg ha^{-1}, respectively (FAO, 2012).

Figure 1: Map of Iraq with irrigated areas between Euphrates and Tigris Rivers.

Presence of shallow and saline groundwater is considered as one of the major reasons for increasing soil salinity problems in these regions (Pitman et al., 2004). Excessive irrigation and poor drainage conditions in irrigated areas of Iraq have contributed to rising groundwater tables leading to salinity-induced land degradation (Qureshi et al., 2013). According to recent estimates, rising groundwater tables and consequent soil salinity problems are damaging 5 percent of cultivated lands annually (USAID, 2004). Soil salinity has robbed the production potential of the 70 percent of the total irrigated area of Iraq with up to 30 percent gone completely out of production (Abrol et al., 1988; FAO, 2012). This situation has threatened the sustainability of irrigated agriculture which produces more than 70 percent of the total cereal production in Iraq (Schoup et al., 2005). Soil salinity is more prevalent in the central and southern parts of the country.

Despite heavy risks of soil salinization, no comprehensive database exists to determine the true extent and characterization of salt-prone land and water resources in Iraq. In order to develop workable strategies, it is inevitable to do in-depth review of existing information on the approaches used so far for the management and improvement of salt-prone soil and water resources. This information is also needed to develop recommendations for future research in this field. This report synthesizes the information on the extent, characterization and implications of salt-prone land and water resources in Iran. In addition, the report evaluates the management practices used for salt-affected soils and their potential for crop production systems in the foreseeable future.

II. Causes of soil salinization in Iraq

Intensive irrigation, rising groundwater table and consequent soil salinization are long-term problems for the central and southern Iraq. The genesis of soil salinity in Iraq is attributed to the salt content of the irrigation water and salt contents of groundwater. The salinity of Tigres River increases from 0.44 dS m^{-1} at the Turkish – Iraqi border to more than 3.0 dS m^{-1} at Ammarah province (south of Iraq) , and from 1.0-1.3 dS m^{-1} for Euphrates River at Syrian – Iraqi border to 2.5–4.6 dS m^{-1} by the time it reaches to Shaat Al-Arab (Wu et al., 2014). Historical data on the water salinity of Tigris Rivers at Baghdad city shows that its salinity was 0.63 dS m^{-1} in 1960 (Buringh, 1960) which has increased to 1.15 dS m^{-1} by 2011 (Qureshi et al., 2013). 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. Major sources of salts in the Iraqi soils are as follows:

Iraqi soils are rich in the naturally occurring parent materials such as limestone, sandstones, conglomerates, basalt and andesite (Al-Layla, 1978). Drainage as part of the irrigation development was non-functional in Iraq . As a result, groundwater table keeps on rising and groundwater quality deteriorating. In the central Iraq, groundwater table depth varies from 150 to 200 cm. The groundwater quality varies from 8.0 to 12.0 dS m^{-1}. In the southern Iraq, groundwater table depth varies from 100 to 200 cm whereas the salinity of groundwater is extremely high (> 30 dS m^{-1}). The presence of salts in the subsoil is partly due to high salinity of the groundwater (Qureshi et al., 2013).

Increasing salinity of the river water over time has contributed to the soil salinity in the irrigated areas of Iraq. The increase in stream salinity has been the result of industrial and urban waste discharge in the water bodies (Wu et al., 2013). In coastal areas, intrusion of sea water in the irrigated lands has compounded the salinity problems. Sea water contributes to soil salinity is more prevalent in the southern parts of Iraq.

Low rainfall and high evapotranspiration as a consequence of extreme hot and dry conditions is another major reason for soil salinity in these parts of the country. The human-induced salinization has occurred mostly in unique topographic conditions of semi-closed to closed intermountain basins where irrigation has been practices for centuries. The factors which has contributed to the occurrence of secondary salinization include (i) use of saline water for irrigation without adequate management practices in areas of extreme water scarcity; (ii) insufficient and inappropriate drainage facilities for the disposal of saline drainage water generated by irrigated agriculture. Most of the drainage projects were constructed 40-50 years ago. Due to age and poor maintenance, most of them are abandoned or non-functional. This situation is making salinity issues even more critical (Qureshi et al., 2013).

Despite water shortage, over-irrigation is a common practice in Iraq particularly in areas with no or limited drainage, resulting in rising groundwater tables and waterlogging problems. Flooding/basin method of irrigation is commonly used for irrigation. Farmers are usually ignorant of actual crop water requirements and their irrigation amounts are usually based on local experience or visual plant conditions such as dryness of soil or dryness of plant leaves, etc (Abbas, 2010). Over-grazing of pasture lands resulting in exposure of soils is also a greater risk of salinization.

III. Extent of Salt-affected Soils in Iraq

Information on the extent and characterization of salt-affected soils in Iraq is limited and widely scattered. However, limited available literature does provide insight into the extent and characteristics of salt-affected soils (Buringh, 1960; Dieleman, 1963; AlTaie, 1970; Al-Layla, 1978; (Al- Hassani, 1984; Al-Jaboory, 1987; Al-Zubaidi, 1992; FAO, 2012; Wu et al., 2014). The detailed extensive soil survey soil was conducted in Iraq from 1955 to 1958 (Buringh, 1960). The results of this survey reveal that almost all soils are saline, most of them even strongly saline and large areas are out of production. The survey estimates that even if all salts could be leached from the upper few meters of the soil, 20 percent of the Mesopotamian plain soils would be highly productive, 40 percent would be medium productive, and 40 percent would be marginal land.

Later on, an inventory of soil salinity in selected projects published in 1963 (Dieleman, 1977) shows that the three projects north of Baghdad have a soil salinity higher than 8 dS m^{-1} in 35-50 percent of the area, and higher than 16 dS m^{-1} in 15-25 percent of the area. The projects south of Baghdad show that more than 80 percent of the project area have a soil salinity larger than 8 dS m^{-1}, and 60 percent of the project area has more than 16 dS m^{-1}. The estimates of 1970s reveal that about 20 to 30 percent of the cultivated area is affected by the salinity of various levels which has resulted in the yield reductions up to 20 to 50 percent on these soils (Al-Layla, 1978).

More recently, FAO (FAO, 2012) developed a soil salinity map for Iraq which shows the extent of soil salinity (Figure 2). Where

- S1 indicates where soil salinity levels were 4-15 dS m^{-1}
- S2 indicates where soil is greater than 15 dS m^{-1}
- R1 indicates where soil salinity was increasing by 2-3 dS m^{-1}/yr.
- R2 indicates where soil salinity was increasing by 3-5 dS m^{-1}/yr.

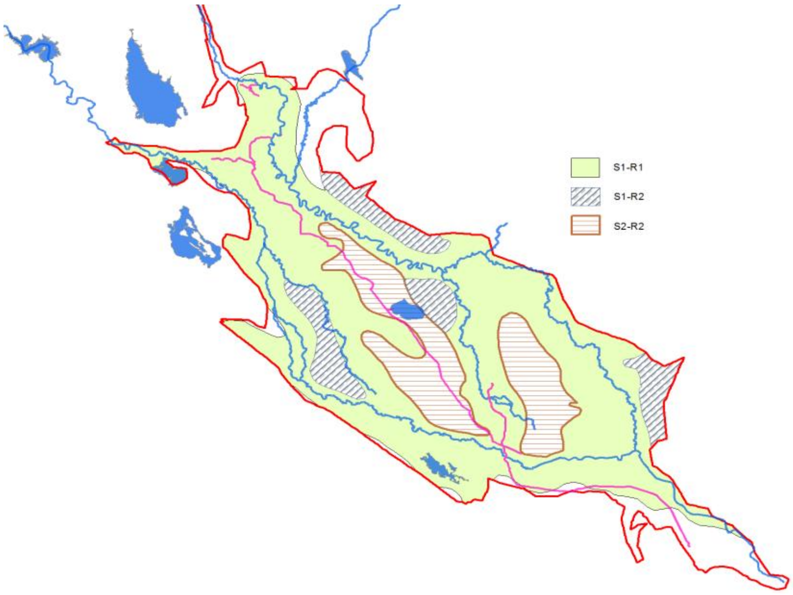

Figure 2: Degradation rate and current state of soil for the Mesopotamian plain (FAO, 2012)

These historical surveys show that soil salinity was extensive across the Mesopotamian Plain and increasing. Abrol et al. (1988) estimated that the area of salt affected soils at different levels in Iraq is about 6.7 million hectare (Mha), which constitutes 60 to 70 percent of the alluvial plain. Despite the introduction of drainage systems to control soil salinization, the estimated situation in 2002 was that 4 percent of irrigated areas were severely saline, 50 percent moderately saline and 20 percent slightly saline. This means that a total of 74 percent of irrigated land suffered from salinity of different levels. This continued high level of soil salinity is due to the degradation of the drainage and irrigation infrastructure. The salinity control efforts have so far reclaimed only 1.025 Mha (Committee of Agriculture and Water Resources Sector, 2009). The latest work by Wu et al. (2014) also confirms the previous findings and states that more than 60 percent of the soils in Iraq are saline to various degrees.

IV. Characterization of Salt-affected Soils in Iraq

Most of the soils in Iraq belong to Holocene alluvial deposits and are typically torrifluvents with a hyper-thermic soil temperature regime and a mixed (calcareous) mineralogy (Buringh, 1960). Soil characteristics differ in vertical and horizontal direction particularly in the river deposits. For this reason, occurrence of saline soil layers is irregular. Saline (-) sodic soils are very common in Iraq. In general, sodium adsorption ratio exceeded 15 percent. 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 irrigation water in addition to calcite and gypsum in the soils (Al-Zubaidi, 1992).

The most common salts present in saline soils of Iraq are sodium chloride (NaCl), calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$), potassium chloride (KCl), gypsum ($CaSO_4.2H_2O$), sodium sulphate ($Na_2SO_4.10H_2O$), and magnesium sulphate ($MgSO_4$). Presence of nitrates of sodium, magnesium, potassium and calcium in the saline soils might be attributed to the bacteriological processes of nitrification (Al-Layla, 1978). Leguminous weed plants are also common in Iraqi soils and concentrations of nitrates are more significant in uncultivated soils.

Local nomenclatures of saline soils in Iraq are Shura and Sabakh soils. Shura soils are more common in the southern Iraq. Shura soils are often with a white crust (Al-Hassani, 1984). Sabakh soils are more extensively present in central Iraq (Buringh, 1960; Al-Jaboory, 1987). 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 deposits along old and present day irrigation canals and ditches.

Al-Jaboory (1987) collected soil samples at different depths from the central Iraq. The results revealed that electrical conductivity of saturated soil paste extract (EC_e) in the uncultivated soils are extremely high in the top 20 cm of the soil profile probably due to presence of saline shallow groundwater table and very high surface temperature conditions of the area. Salts are brought to the surface through accelerated capillary rise from saline groundwater. In the area covered by the drainage system, salinity levels are relatively low but still not suitable for productive agriculture.

Table 1. Soil salinity in non-saline, saline and cultivated soils in the Euphrates area.

Depth (cm) Cultivated soils	EC_e dSm^{-1}	Depth (cm) Saline-sodic soils	EC_e dS m^{-1}	Depth (cm) Saline soils	EC_e dS m^{-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					

In a recently conducted study, soil texture of these soils is found to be silt clay loam up to the depth of 90 cm. The current soil salinity levels ranged between 2.0 to 8.0 dS m^{-1}. Table 2 shows the soil salinity and pH values of these soils (Al-Falahi and Qureshi, 2012).

The existence of soil salinity in the Euphrates River area is also the result of increasing salinity of the irrigation water. The quality of this source decreases as they flow towards south (Shaat Al-Arab). The salinity of Euphrates River has increased from 0.63 dS m^{-1} in 1960 (Buringh, 1960) to 1.56 dS m^{-1} in 2011 (Qureshi et al., 2013). Irrigation with increased salinity water has added significant amount of salts in the soils, which necessitates the need for protecting water bodies from drainage and other industrial effluents.

Table 2. Physical and chemical properties of the soils from the Euohrates River area.

Location No.	Depth Cm	Soil Texture	Particle size analysis			EC_e dS m^{-1}	pH
			Sand (%)	Silt (%)	Clay (%)		
1	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	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	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

Abbas (2010) have shown that the salinity in the areas located on the right side of the Tigris River increases as we move away from the Tigiris River. This is due to the fact that availability of fresh seepage water decreases as we move away from the river. Tables 3 and 4 show physical and chemical properties of a typical pedon located in the area (Abbas, 2010). The data shows very low presence of gypsum in the soils of both locations. The area located away from the Tigris River is not suitable for crop production due to high salinity levels.

Table 3. Physical and chemical properties of a pedon located close to Tigris River (Abbas, 2010).

Depth cm	Soil Texture	Particle size analysis			EC (dS m^{-1})	$CaCO_3$ %	Gypsum %
		Sand (%)	Silt (%)	Clay (%)			
0 -15	SiL	16.4	60.5	23.0	3.5	27.2	2.5
15- 30	SiL	5.0	60.2	33.0	4.3	25.4	1.8
30- 60	SiL	17.4	61.1	21.5	5.2	27.4	Nil
60-90	SiC	15	57.0	41.5	6.7	24.0	3.6

Table 4. Physical and chemical properties of a pedon located far from Tigris River (Abbas, 2010).

Depth cm	Soil Texture	Particle size analysis			EC (dS m^{-1})	$CaCO_3$ %	Gypsum %
		Sand (%)	Silt (%)	Clay (%)			
0 -15	SiCL	7.9	64.1	28.0	75	20.5	16.2
15- 30	SiC	5.8	53.7	40.5	50	25.8	2.0
30- 60	SiC	1.0	4.2	57.0	57	26.7	0.2
60-90	SiC	6.0	41.5	48.5	30	27.7	1.70

The data collected by Abbas (2010) from 10 pedons in the Tigris area shows that infiltration rates and hydraulic conductivity of almost all pedons is moderate to slow (Table 5). This is probably due to the presence of the high clay contents in the soil. Due to slow leaching, salts keep on accumulating in the soil profile resulting in higher salinity levels in the area.

Table 5. Infiltration rates and hydraulic conductivity of 10 pedons from the Tigris area.

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

Al-Falahi and Qureshi (2012) collected soil samples from depths of 0-15, 15-30, 30-60 and 60-90 from reclaimed, non-reclaimed and semi-reclaimed areas along the Tigris River area. These samples were analyzed for soil texture and salinity levels and the results are presented in Table 6. Due to the absence of field drains and non-functioning of main drains in the semi-reclaimed area, salinity is increasing and has gone even higher than the non-reclaimed area. Semi-reclaimed area is also extensively cultivated and addition of salts from irrigation water could also be reason for increasing salinity in this area.

Table 6. Physical and chemical properties of reclaimed, semi-reclaimed and non-reclaimed areas in the southern Iraq.

Location No.	Depth Cm	Soil Texture	Particle size analysis			EC_e (dSm^{-1})	pH
			Sand (%)	Silt (%)	Clay (%)		
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	Clay	4.8	39.6	55.6	9.30	7.85
	15- 30	Clay	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	Clay	12.4	37.2	50.4	10.56	7.71
	15- 30	Clay	20.8	31.6	47.6	12.94	7.58
	30- 60	Clay	38.8	15.6	45.6	16.44	7.82
	60-90	SiCL	16.8	52.8	36.0	15.80	7.96

V. Potential Options for the reclamation of Salt-affected Soils in Iraq

Past efforts for the reclamation of saline soils

Problems of irrigation and drainage management in Iraq are complex and no straightforward solution is available. Large tracts of irrigated lands in the southern and central Iraq are salinized and waterlogged resulting in reduced crop yields. Many other areas are under threat of being salinized in near future. Most of the reclamation efforts have been made by introducing main surface drains without any provision of field drains. The drainage effluent from these main drains is mostly discharged into Euphrates and Tigris Rivers which has considerably deteriorated surface water quality and contributed to soil salinity. Most of the drainage systems were installed 40-50 years ago. Continuous neglect, poor maintenance and war of last 10 years have made most of these systems non-functional. As a result, soil salinization is on the rise and food security for the Iraqi people is seriously threatened.

Soil salinization in the central and southern Iraq is directly linked with the depth and quality of groundwater. In the central Iraq, groundwater table depth varies from100 to 200 cm during different months of a year. In southern Iraq, groundwater table varies between 45 cm in February and 200 cm in August. The salinity of groundwater in non-reclaimed soils is extremely high with a range from 42.0-44.0 dS m^{-1}, while groundwater of semi and reclaimed soils was moderately saline (Rhoades et al. 1992) with a range between 8.2-10.0 dS m^{-1}. The salinity if groundwater in the lower Mesopotamian plain varied from 10,000 to 60,000 ppm (Qureshi et al., 2013). In many areas it may be much higher, going up to 80,000 ppm.

Despite the shortage of water, there is a general tendency of over-irrigation in Iraqi farmers. As a result, irrigation efficiencies are very low (Al-Zubaidi, 1992). Studies have shown that Improved cultural practices such as precision land leveling, zero tillage and bed and furrow-bed methods of planting can save water up to 40% without compromising on crop yields (Sarwar and Bastiaanssen, 2001; Qureshi et al., 2004; Qureshi, 2014). In the irrigated areas, absence of drainage facilities led to rise in groundwater tables in the alluvial plains bringing huge amount of salts in the root zone. The pumped irrigation which is practiced on 25 percent of the area along the banks of Euphrates and Tigris rivers further compounded the salinity problem (AlFalahi and Qureshi, 2012). Historically, soil salinity has increased from the north to the south of the Iraq. Increasing salinity of the two main rivers is contributing greatly to the salinization of soils. The salinity increase in the Euphrates River is higher than the Tigris River. It is generally believed that Euphrates get huge amount of salts as it passes through the Syrian territory. Moreover, most of the drainage effluents are discharged into the Euphrates River. The reclamation of salt-affected soils in Iraq has largely been done through the lowering of groundwater table. Before the installation of surface drainage systems, rising groundwater tables were generally controlled through crop management and restricting excessive irrigations (Qureshi et al., 2013). However, with the agricultural development, this practice became obsolete. The need for drainage as a complimentary activity to irrigation was first realized in the first quarter of the last century and the first drainage and salinity investigation was carried out in 1927 (Al-Layla, 1978). However, installation of drainage systems as part of the irrigation development projects could never be materialized.

There have been scattered efforts for the rehabilitation of salt-affected soils but no comprehensive strategic plan was ever developed for enhancing the productivity of these soils. Monitoring of spatial and temporal changes in soil salinity and water quality is done on a specific project scale and no nation-wide network exist for large scale monitoring of land and water degradation over time. Increasing soil salinity and water quality degradation problems in Iraq stresses the need to develop a national strategic plan for the management of salt-prone land and water resources in the country. Latest salinity monitoring approaches using GIS, remote sensing and satellite measurement can help a great deal in this regard. These techniques are now widely used and have proved to be accurate, less-expensive and effective in overcoming data limitation problems.

In the second half of the last century, few drainage projects were executed. However, these drainage systems were restricted to the excavation of main and lateral collector drains and no field drains were introduced. This was mainly done due to financial constraints. The drainage water from these drains was pumped and discharged into rivers. This approach partially solves the problem and the soil salinization continued to increase especially in downstream. Some tile drain projects were executed which became non-functional because of the deposition of silt and gypsum particles into the drainage pipes. Today, most of the drainage systems have abandoned or become non-functional due to poor operation and maintenance services. Over time, in many other irrigated areas, groundwater tables have gone up due to poor irrigation management practices. These areas are in urgent need of drainage systems to keep the groundwater table below the root zone for salinity control (USAID, 2004).

Recommendations for the future management of salt-affected soils

Under the current geo-political circumstances in the country, large scale investments to rehabilitate existing drainage systems and installation of new drainage systems does not seem possible in the near future. Therefore, alternate approaches have to be adopted to live the situation in order to produce food and fiber for the increasing population. For future management of salt-affected soils in Iraq, following strategies might be useful:

Introducing comprehensive monitoring program

Despite widespread salinization of land and water resources in Iraq, no comprehensive study has been undertaken to assess the extent of irrigation-induced salinity. The monitoring network to record spatial and temporal changes in soil salinity is almost non-existing. As a result, characterization of salt-affected soils in different parts of the country is not possible (Qadir et al., 2007). In the absence of scientific evidence, local knowledge of farming community such as patchy crop stand, retarded crop growth, leaf burn and changes in soil color are usually used as indicators for substantiation of salinity problems. In addition, monitoring of changes in water quality both in rivers and drainage systems over time is inadequate which is becoming a major source of secondary salinization in the irrigated lands.

In view of the complexity and scale of the problem, modern approaches for salinity monitoring such as Geographic Information Systems (GIS) and Remote Sensing (RS) would be advantageous to study the spatio-temporal changes in soil salinity. These approaches have proved highly useful in land evaluation in large countries such as Australia, China, USA and India, confronted with the problems of salinity and waterlogging (Dwivedi et al., 1999; Sharma et al., 2000). Integration of remotely sensed data, GIS and spatial statistics assists in modeling large scale variability to predict the presence and distribution pattern of plant species as well as soil characteristics. Scattered efforts are being made by different institutions in Iraq to deal with the problem of land degradation. However, more integrated efforts are needed to focus research on salinity assessment and management. This would be possible by preparing a national plan that can integrate the management of salt-affected environment into overall management of land and water resources in Iraq.

Reclamation of saline soils through land management approaches

In southern Iraq, most of the soils are rich in clay percentage and have low infiltration rates. These soils are difficult to reclaim because of the problems associated with water movement through the soil profile. These soils can be reclaimed by deep plowing which will help in breaking the hard clay pan present in the root zone (Jayawardene et al., 1994). Karimi (1997) have shown that plowing at 0.45-0.50 m depth, more than 50 percent of the salts were removed from the soil. In case of sub-soiling at a depth of 0.75-0.80 m depth, soil salinity can be reduced to a level where soil will become suitable for crop growth. The salt-affected soils having high levels of clay are equally difficult to reclaim through simple leaching because clay minerals swell rapidly and block macro pores thereby reducing the water infiltration to deeper layers. Naseri and Reycroft (2002) have shown that extensive swelling occurred when low salinity water (EC = 0.5 dS m^{-1}, SAR = 0.6) is used for irrigation. Under these conditions, increasing Ca^{++} concentration in the leaching water is useful for reducing swelling and controlling dispersion and migration of clay particles.

Fallow saline soils can also be reclaimed by surface cultivation before monsoon (Prathapar and Qureshi, 1999a; Prathapar and Qureshi, 1999b; Prathapar et al., 2005b). For fellow saline-sodic soils, gypsum application through different techniques can help in the reclamation of soils (Ardakani and Zahirinia, 2006). Prathapar et al. (2005b) have shown that gypsum slotting techniques can successfully be applied in these soils for reclamation. In this technique, slots of 15 to 30 cm wide and 60 cm deep are made in the soil. Soil is taken out and mixed with gypsum and refilled. The crops are then grown on these slots. In Iraq, this is done by applying heavy irrigation before cultivation for leaching of salts. The process is commonly known as pre-leaching in Iraq. For this purpose, good quality irrigation water is used because excessive leaching with low quality water needs extensive drainage systems to flush out salts from the system (Sarwar and Bastiaanssen, 2001). However, before deciding about options, it is important to do economic and environmental analysis to evaluate trade-offs between risks and costs. In irrigated areas, drainage should be considered as a complementary activity to irrigation. Timely installation of appropriate drainage infrastructure can help a great deal in eliminating the onset of drainage and associated soil salinity problems in the irrigated areas (Qureshi et al., 2013). Therefore it is of paramount importance that existing drainage systems are rehabilitated without any further delay to ensure food security for the Iraqi people.

Biological reclamation of salt-affected soils

In areas where salinity levels are extremely high such as in southern Iraq and installation of drainage systems is expensive or practically not possible, reclamation through different salt tolerant species could be a useful possibility. Many researchers have identified plant species that can be effectively used under these circumstances (Guiti, 1996; Djavanshir *et al*. 1996). They found *Tamarix* and *Atriplex* plantations as effective species in decreasing the salinity of surface soil. They have also recommended the use of *Haloxylon aphyllum, Haloxylon persicum, Petropyrum euphratica*, and *Tamarix aphylla* based on their experiments. Halophytes are usually considered useful for rangelands in in saline areas. Halophytes are usually used as a fodder source for grazing animals. In addition to providing fodder for animals, biological interventions also help in improving nutrient availability for soils and carbon storage in the post plantation soil (Qadir et al., 2001; Kaur et al., 2002).

In Iraq where off-farm income generation activities are very limited due to lack of industries, using abandoned soils for biomass production would be a viable option. Many tree species capable of growth and production in highly saline conditions are now available and are being used in Australia, Pakistan, India and other Central Asian and Arabian countries (ICBA, 2003). IWMI together with the national partners has also successfully tested the growth of large number of Hylophytic species in Uzbekistan and Kazakhastan (Noble et al., 2005; Noble et al., 2006).

In areas where salt-affected soils exist and drainage waters are generated on a large scale, production systems based on salt-tolerant plant species are likely to be the key of future agricultural and economic growth. While doing so, involvement of local communities and stakeholders such as industry and traders is of great importance in order to establish and strengthen markets for the products produced from salt-affected water and soils. This will be a major step forward for improving income and livelihood of the farmers of these areas. Increasing intensity of plants per unit of area is also useful in reducing surface evaporation and accumulation of salts at the surface. Maintaining soil moisture at a level that can reduce the salt stress is another way of coping with salinity. This can be done by changing the planting methods such as shifting maize from basin to furrow method of irrigation.

Problems of the disposal of saline drainage effluent can partially be solved by re-using drainage water for growing salt-tolerant crops (Stenhouse and Kijne, 2006). Drainage waters can also be used for the promotion of aquaculture especially in those areas which are abandoned for conventional agricultural production systems. In Iraq, lots of such areas exist where sources of farm income can be diversified by exploiting unutilized resources and contributing to the remediation of waterlogging problems by removing excess water from the soil. This has already been adopted in many developing countries, particularly in Nile Delta Valley. This has provided an excellent opportunity for the farming community to increase their income base.

The use of saline water in Iraq, to a large extent, is still confined to grow salt resistant grasses for fodder, bushes and trees such as Eucalyptus. Due to limited economic benefits, farmers are not very interested to adopt these practices and prefer to leave their lands and look for off-farm income employment. Stenhouse and Kijne (2006) have shown technical feasibility of using saline water and land for irrigated agricultural production into the mixed farming systems of West Asia and North Africa (WANA) region. With practical examples from Egypt, Syria and Tunisia, they have shown the efficacy of using saline and drainage water for conventional crops (Qadir and Oster, 2004). The agro-climatic conditions in Iraq are very similar to these countries therefore there is a good potential for adopting these practices. This will increase economic benefits to farmers and help in keeping their spirits high to work on these troubled lands.

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