沙漠研究 **19**-1, 323- 326 (2009)
Journal of Arid Land Studies

"Desert Technology IX "
Refereed Paper

Water Management and Salinisation in Irrigated Areas
-A Case Study of Sidi Sallem Oasis in the Southeast of Tunisia-

Cherifa FDHIL[1], Abdessatar HATIRA[2], Tahar GALLALI[2], Houcine TAAMALLAH[1]

Abstract: This research aims to study soil salinisation in irrigated lands of Sidi Sallem oasis (Southeast Tunisia). This zone covers about 146 ha, irrigated by an artesian drill exploiting the deep water of Djeffara (Q = 75 l/s and Total Dissolved Salts = 3.5 g/l).

In this study, morphological and chemical characteristics of 10 soil profiles samples were identified. The oasis has an alluvial soil dominated by fine sand with a particular structure and gypsum crusts and crusting at groundwater levels. The salt accumulation in the soil was recorded in the first layer of the majority of soil profiles and essentially near the water table level. Because of the topography, we identify that the highest salinity was recorded in northern sector. Also we studied the hydrological and chemical characteristics of 29 piezometers. The ground water level was very close to the soil surface in northern part of the oasis (Z < 1 m), whereas in the Southern and Western part, it was further than 2 m. The highly mineralized water table located at shallow depth increased the risk of salinisation. The high soil salinity was attributed to the poor quality of irrigation water and saline ground water very close to the soil surface mainly during the summer period when evaporative demand was high.

The soil and groundwater properties, coupled with the data related to irrigation and drainage water, can facilitate the comprehension of the soil salinity in this oasis in order to minimize by consequence the severe climatic conditions in this region. Also they help to estimate the necessary leaching fraction of the soil and control the network of drainage for better evacuation of salts.

Key words: Drainage, Groundwater, Irrigation, Oasis, Soil salinity

1. Introduction

The problem of salinity and water shortage in agricultural areas is of increasing concern in the arid regions of southern Tunisia which has a wide variation in the climatic conditions, salinity and crops types and where there is little scientific information on the occurrence of this problem. Indeed, climate in this region is characterised by a low yearly precipitation (150-200 mm), yearly evaporation exceeding 1300 mm and diurnal evapotranspiration higher than 8 mm during the summer. Capillary rise under these conditions can be extremely important which increase the salinity problem in the soil because of the low salts leaching especially in dry years (Ould Ahmed, 2006). In addition, the level of salinity in the water or the accumulation of soluble salts in the soil is transient conditions since it varies during the growing seasons and may also aggravate in dry years and impairing traditional systems of cultivation in the oasis with consequent risks of soil degradation (Brahim, 2002). Thus, permanent care and proper control actions are required. Adequate soil and water conservation practices based on a comprehensive soil or land degradation assessment can provide an "early warning system" as a tool for efficient salinity control.

2. Materials and methods

2.1. Study area description

The oasis of Sidi Sallem is approximately 25 km southwest of the city of Gabes (Southern Tunisia - Northern Africa) (**Fig. 1**). It covers about 146 ha, distributed in 70 plots (4.58 to 23 ha).

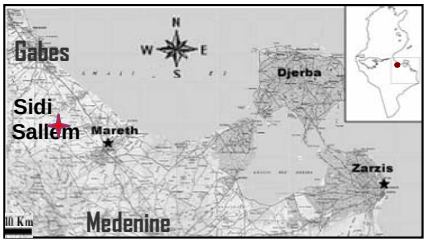

Fig. 1. Location of the study area.

2.2. Soil study Thirty soil profiles covering the whole area of the oasis were identified. The morphological and chemical characteristics of the soil profiles were studied from the surface layer until groundwater levels (98-300 cm). The description of the profiles was conducted during the summer.

[1] Eremology and Combating Desertification Laboratory, Institute of Arid Area 4119 Medenine - Tunisia).
[2] UR. Pedology. Department of Geology. FST. Universities Campus 2092. Manar II. Tunisia.

2.3. Water study

The irrigation water of the oasis was pumped from artesian drilling water exploiting the deep groundwater of Djeffara. The water which has a Total Dissolved Salts (TDS) about 3.44 g/l was stored in tank upstream of the oasis and distributed by irrigation network (seguias and PVC pipes) with the flow rate of 75 l/s and a time pump operation of 10 h/day. The net area of the oasis is about 146 ha. The applied irrigation water supply was about 54 mm which was under the estimation of the Agriculture Department of Gabes (88mm). The saline groundwater very close to the surface (>1m), imposed a soil drainage either by natural or artificial drainage. Sampling and analysing of drainage and irrigation water have been carried out in January 2006. To monitor ground water depth and salinity, a network of 29 piezometers (D=8 cm, L=3 m) was installed (**Fig. 2**). To ensure better water percolation into the piezometers, holes were drilled each 10cm along the first 100 cm. The ground water Salinity and depth were measured in August and January.

3. Results and discussion

3.1. Soil study

The oasis of Sidi Sallem has an alluvial soil dominated by fine sand (**Table 1**). All profiles were filled of gypsum (Gy=1-69%) with an increasing gradient top-down profiles (Fig. 2). Generally, the rate of limestone (TL) was low and almost invariant along the soil profiles but in some profile correlate with the rate of gypsum such as the profile P8 where they were inversely proportional with (Gy=0.59%, TL=16% or Gy=27.3%, TL=0.8%).

The P4 profile had high proportions of gypsum (Gy = 69.91%). Its situation near the water channel (Wadi El Maleh) where the water circulates especially in rainy periods inhibited the formation of gypsum crusts (**Fig. 3**). The salt accumulation in the soil surface was recorded in the first centimetres of the majority of soil profiles «salt efflorescence» and near the water table levels. The P1 profile (centre of the oasis) had a moderate saline profile (EC = 3.47 - 4.4 dS/m). In addition P5 profile was not very concentrated in salt (EC = 8.91 dS/m), only near water table level (EC= 61.2 dS/m) whereas the P4 profile

Table l. Morphological characteristics of the four representative soil profiles in the oasis of Sidi Sallem.

	P1	P4	P5	P8
Location	Eastern sector	Northern sector	Western sector	Southern sector
Surface state	Wind recovery	Thin layer of salt	Anthropogenic surface.	Sand + Manure residue
Current use	Cultivated plot	Abandoned plot	Cultivated plot	Cultivated plot
Corps	-Fodder (alfalfa) - Shrub (pomegranates) - Vegetables (peppers)	Natural Halophytes species	-Trees (peaches, figs and pomegranates) - Forage	Trees (pomegranates and apricots)
Soil structure	- Particular - Massive (105-150 cm)	- Particular - Slightly massive (75- 35 cm)	Particular, gradually Massive along the profile, rich in pink sand	Particular + gypsum crust at the intermediate layers
Soil texture	Sandy clay soil (FS =52%, Gy =24%), rich in gypsum nodules and in pink sand in low profile (130-150 cm)	- Fine sandy soil (77%) at surface - Sandy clay soil Gy = 14%) + coarse and gravel (1m)	Fine sandy soil (FS = 82%) at surface gradually sandy clay soil at 3 m (FS = 68%, Gy = 18%)	- Fine sandy soil (FS = 68%) - Gypsum crust

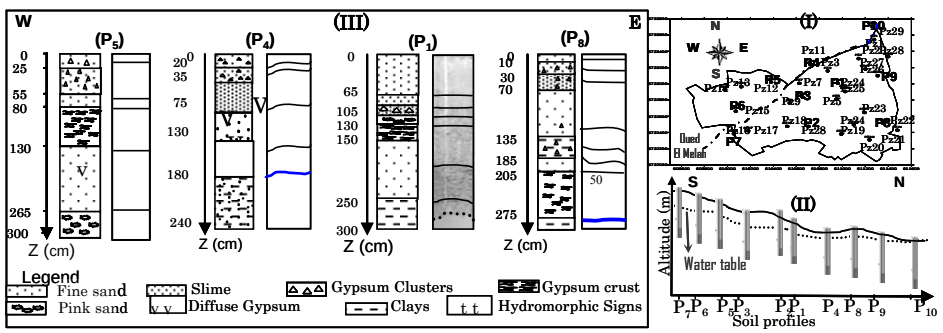

Fig. 2. Location of the soil profiles (P) and piezometers (Pz) on the oasis map (I); Location of soil profiles based on topography (II); 4 representatives soil profiles of the oasis (III).

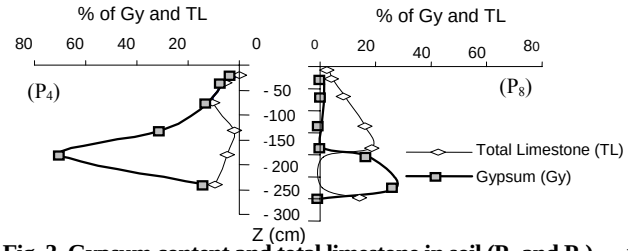

Fig. 3. Gypsum content and total limestone in soil (P_4 and P_8).

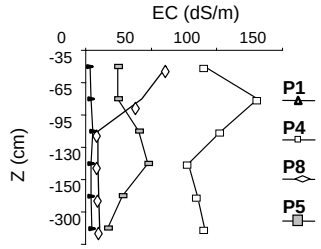

Fig. 4. 4 representative Saline Profiles of the oasis.

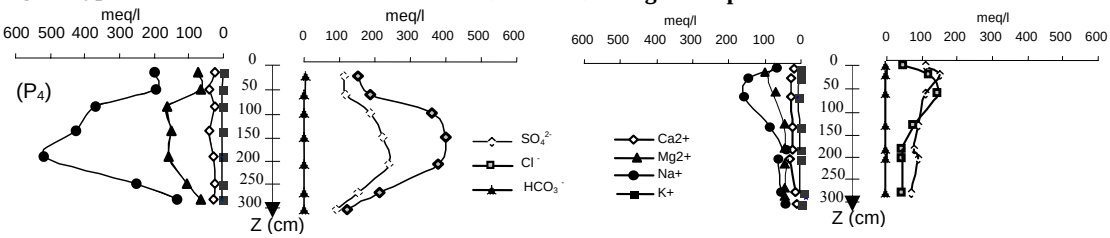

Fig. 5. Ionic profiles of two representative soil profiles of the study area (P4 and P8).

Table 2. chemical analysis of irrigation and drainage water (January).

Chemical analyses (meq/l)	Ca^{2+}	Mg^{2+}	K^+	Na^+	SO_4^{2-}	Cl^-	HCO_3^-	SAR	EC (dS/m)	TDS (mg/l)	pH
Irrigation water	17.6	18.4	0.37	16.6	24.5	23	3.4	3.91	3.44	3000	7.4
Drainage water	29.2	86	2.18	150	109	166	8.85	19.76	23.6	17000	8.27

(northern oasis) had a very high salinity in all layers (EC = 85 -130.9 dS/m) and it was very affected by hydromorphy which could be explained by its location at the downstream near the principal drain of the oasis (**Fig. 4**). The salt accumulation in surface soil layer could be explained by irrigation with saline water and the high evaporative demand.

The ionic profiles in P8 (eastern oasis) showed that the ion concentration was greater in the soil surface layer (**Fig. 5**). The sodium adsorption ratio ($SAR=Na^+/\sqrt{(Ca^{2+}+Mg^{2+})/2}$) is an index quantifying the proportion of sodium (Na^+) to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in a sample. It was lower and invariable along the profile (6.68 to 9.58). The major cations are very similar; Na^+/Mg^{2+} and Ca^{2+}/Mg^{2+} ratios are close to 1. Cl^-/SO_4^{2-} was somewhat variable along the profile and the proportions of these two major anions were very close. The P4 profile (northern oasis) was the most concentrated in ions. Its ions concentration increases, mainly in the intermediates layers. The SAR ranged from 8.62 to 21.77; the highest was recorded in the intermediate levels where the Na^+ concentration was maximum. SO_4^{2-} dominated for most levels.

3.2. Water study

3.2.1. The irrigation water (drilling of Sidi Sallem)

Its chemical analysis showed an electrical conductivity of 3.44 dS/m, neutral pH (7.4) and a Joint sulphated facies with a very high salinity risk and a medium risk of alkalinity (C4-S2) because its high contents on sodium and chloride (**Table 2**).

3.2.2. The drainage water

It had a chloride sulphated sodium facies. These waters eliminated especially sodium, chlorides and sulphate (Table 2). Its drainage flow was about 1.6 l/s which eliminated only 31.8% of all salts provided by irrigation water (CRDA Gabes). The salinity of drainage water was closely related to the injected water volume from rainfall.

3.2.3. The groundwater

The Chemical analysis was carried out during August and rainy period (January). The groundwater had chloride sodium sulphated facies**.** The maximum of ions has been recorded in the piezometer Pz11 with high concentration in Cl^- and Na^+. Only some piezometers showed a variation in their chemical composition (Pz2: Σcations = 179-1097 meq/l and Σanions = 185-1061 meq/l). This seasonal and spatial

variation is closely linked to rainfall, irrigation supply and soil topography (**Fig. 6**). The oasis includes two major sectors: an up sector (altitude: 50 m) composed by the centre and the west of the oasis and a down sector of Oued El Maleh. The depth Changed between the dry season "August" when the minimum was about 97 cm in Pz3 (N) and the maximum was 3.2 m in Pz16 (SE) and the wet season "January"(Zmin = 45 cm in Pz3). Salinity changed. In the summer, two main axes of the highest water salinity were N-S and E-W. The maximum salinity was recorded in the northern oasis at Pz11 (EC = 152.5 dS/m). The high salinity could be explained by an increase of the irrigation water supply to compensate the loss of water by evapotranspiration and the gathering of drainage waters in these areas. In rainy period, the minimum salinity was observed along E-W axis (ECmin = 25 dS/m). The downstream areas kept high salinity (Pz11: EC = 110 dS/m) (**Fig. 7**). As irrigation was insignificant during this period only storm water had flowed in and diluted the ground water.

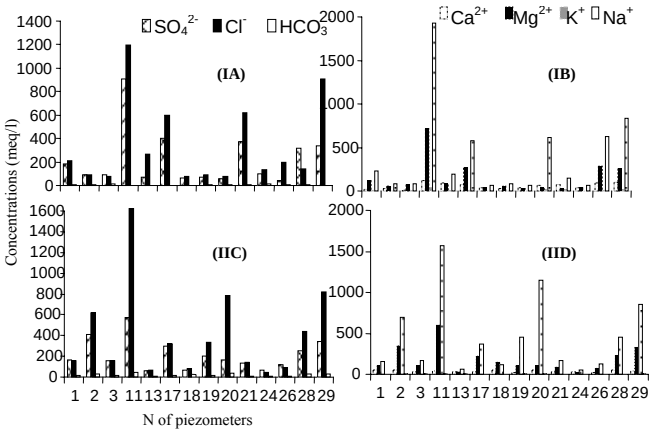

Fig. 6. Anions (A and C) and cations (C and D) Concentrations of the water table in August (I) and January (II).

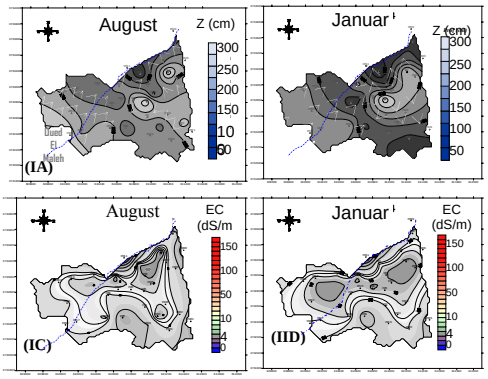

Fig. 7. The groundwater depth (A and B) and salinity (C and D), in August (I) and in January (II).

4. Conclusion

The oasis of Sidi Sallem has an alluvial soil dominated by fine sand. This texture is favourable for an active dynamic of water in the unsaturated zone which was manifested by water capillary rise to the surface during the dry season causing salt accumulation in the soil surface (Ben Hassine and Mtimet, 1999). The northern sectors were the most affected by salinisation. Thus, hydromorphy affect most of soils in these sectors and becomes permanent in some places. The analysis of the soil saturation extracts shows a high proportion of sodium and chloride. The salt accumulation was recorded in the first cm of the majority of soil profiles. Gypsum was concentrated in the form of gypsum crust and crusting in the middle of soil profiles, close to water table level. In the northern sector of the oasis, the highly mineralized water table located at shallow depth increased the risk of salinisation. The high soil salinity was attributed to the poor irrigation water quality and the saline groundwater very close to the soil surface mainly during the summer period where evaporative demand is high. Under these conditions, the excessive use of irrigation water by farmers causes to the increasing level of the groundwater that in some places. The results of our studies confirm the existence of an outstanding salinisation in the soil surface layers, particularly in northern oasis. The intensity of salinisation process is not depended only on water quality but also on the type and properties of soils. In order to avoid soil salinisation by capillary rise, it is necessary to check the installation of the drainage system and ensure regular maintenance.

References

Ould Ahmed B. (2007): The impact of saline water irrigation management options in a dunes and on available soil water and its salinity. *Agricultural water management Journal*, **88**: 63–72.

Brahim A. (2002): *Contribution à la compréhension du processus de salinisation des sols irrigués en zones arides cas de l'oasis Segdoud. Thèse 3ème* ENIT. 168p.

Ben Hassine H., Mtimet A. (1999): *Suivi de l'évolution de la salinité des sols dans les périmètres irrigués de Tunisie - Distribution géographique et approche adoptée*. Es n°309,9p.