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Research article

The impact of the slope on the organic and minerals amendments in the salinity of soil in the south Tunisian

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Abstract

In the arid regions of southern Tunisia, the date palm is the main source of income for farmers. However, soil degradation through salinization has a significant influence on soil fertility in this Oasis system. Thus, in order to mitigate the consequences of soil degradation in the old oases and to find solutions to this problem, we will consider the amendment as an effective action for degraded soils restoration and a means for improving the production and preservation of agricultural activity. In effect, this study analyzes the potential effects of mixed organic-mineral amendments on the evolution of marginal soil salinity properties along a downstream upstream transect that ends in the natural outfall (Chott) of surface water and irrigation. Two amended plots since two years have been selected in Om Rouss oasis in southwestern Tunisia: (i) Soil upstream at high slop with an area of 8 hectares; (ii) Soil downstream at low slop with an area of 7 hectares in comparison with (iii) no amended control soil. The physicochemical characterization of these soils revealed that their functional properties materialized mainly by particle size, salinity are closely related to the topographic position, the overall texture and closeness to the Chott. Upstream sandy-loam soil characterized by a good infiltration was slightly desalinized and leached soluble salts in the lower levels while the heavily impacted area was scattered sporadically in the downstream zone.

Key words: Amendments, Salinity, High/Low slop, Soil texture, Tunisia.

1. Introduction

All over the world, public concerns are related to aquifer depletion and subsequent problems that induce desertification: poor agricultural management, water salinization and soil degradation (Feng et al., 2008; OSS, 2008; Saiko and Zonn, 2000; Zammouri et al., 2007; Huang and Pang, 2000). In Tunisia, salt-affected 1.5 million of hectares of soils which represent 10 % of the country's land area. These soils are found throughout the territory but concentrated in the center and south where climatic aridity causes their extension. The areas most influenced by soil salinization are the regions suffer from water deficit like the oases region in the south Tunisia (Hachicha, 2002). The Nefzaoua region (22 900 km^2) in southern Tunisia covers 48% of the total area of all Tunisian oases with nearly 15 600 ha of traditional and modern palm plantations (Rurales 2016). The unfavorable location of Nefzaoua oasis around chatt el Garsa and chatt djerid Oasis accent the problem of salinization (Kadri and Van Ranst, 2002). Since the earliest times of history, the exploitation of artesian springs has allowed the establishment of a suitable agriculture in the oases (Ghazouani et al., 2007). This oasis is the first source of income of the rural population (Lasram, 1990). The variability of soil salinity is mainly the result of the hydrological process in relation to the topography (Marlet, 2013). Nearly 100,000 ha of irrigated perimeters are deeply affected by salinization. 75% of soils are moderately to highly sensitive to salinization (Litifi, 2008). Flood irrigation of these oases with saline groundwater can lead to soil degradation (Moussa et al., 2000). These problems can get worse in the presence of a gypsum crust that prevents deep drainage and represents a mechanical

barrier to root penetration (Hatira et al., 2005). In addition, the location of the Nefzaoua Oasis surrounded by Chott Jerid and Chott El-Gharsa can aggravate the problems of soil degradation (Marlet et al., 2009). The mixed amendment soil (organic/mineral) appeared as a means to mitigate the effects of degradation and especially the decline of soil fertility in the ancient oasis (Wichern et al., 2004). Amendment operations usually take place after harvesting, usually in winter, although they do not occur in a unified way for all farmers. The sandy soil of the dunes has been used as an amendment for oasis soils to improve water dynamics, soil aggregation and cations exchange capacity. While for the organic amendment, the inhabitants of Tunisian oasis use manure from their farms livestock as a common practice to maintain soil fertility (Ayuke et al., 2011). The amendment is an old application that has been used since ancient times to restore marginal lands, but due to the climatic change and lack of drainage arrangements the problem of salinity become more and more dangerous.

We try in this study to understand scientifically the conditions necessary for the success of this application. The main objective of our study is to examine the viability of the amendment (it is about mixtures of organic matter (compost) with minerals (sand) since two years (2015) on the salinity soil of the different horizons of soil (de 0 à 120 cm). The aim also of this work is to see the effect of the slope on the studied plots: parcel located upstream (north part) with high slope and the other plot closer to the Chott located downstream (southern part) at low slope.

2. Material and methods

2.1. Study area

The Oasis of Om Rouss is located in the Northeast of Douz (Southwest of Tunisia). It is cover a surface area of 15 ha (Fig 1). It is part of the continental oasis of Nefzaoua in the Governorate of Kebili and is located to 33.33° and 33, 32° latitude North and 8.54° and 8.55° east longitude. This region is characterized by a Mediterranean arid climate with a high temperature up to 55°C and irregular precipitation with an average of 80 mm/year (Sghaier, 2010). The evapotranspiration is important and estimated at 1680 mm/year in the oasis of Kebili. The annual needs for irrigation water are estimated at 1578 mm, with a maximum of 272 mm in the month of August. The region of Nefzaoua undergoes the influence of the hot winds (sirocco) of the western sector in summer, cold and dry winds of the West and Northwest sector in winter and the winds of sand of the sector is and the North is for spring. These spring winds are the most frequent (120 d / year). The average speed of the wind in this region is 1, 45 m/s. The plant cover is low (Mtimet, 2001).

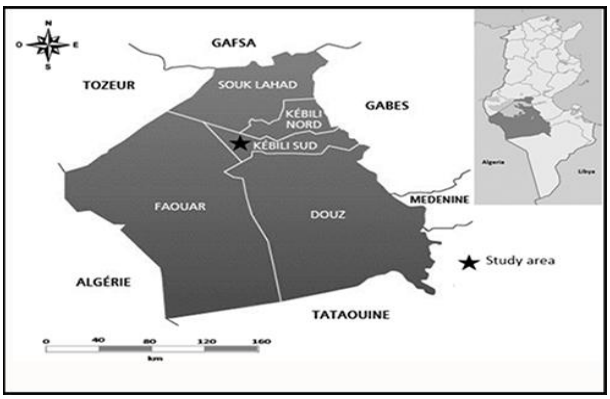


Fig. 1: Location map of the studied oases in the governorate of Kebili

2.2 Collect and Preparation of Soil Samples

Soil samples were collected from upstream to downstream, to ward sebkha in six depths (0-20, 20-40, 40-60, 60-80, 80-100 and 100-120 cm deep). They were collected on 16 March 2017 from two amended parcels of the Om Rouss oasis. This treatment amendment is applied on 05 January 2015: (i) Parcel upstream with an area of 8 hectare (i = i1, i2, i3, i4, i5), (ii) Plot to downstream with an area of 7 hectare (ii = ii1, ii2, ii3, ii4, ii5) by comparing with untreated control (iii).

2.3. Physicchemical analyzes

The approach adopted for the soil survey includes two steps:

- The first step is concerned with the temporal and spatial monitoring of soil salinity by measuring the electrical apparent conductivity of the soil (EAC). Currently, the device is most commonly used is the Geonics EM-38 (1.5 m of investigation). The latter is particularly adapted to the agricultural problems because of its depth of investigation which corresponds approximately to the root zone (Corwin and Lesch, 2005). We configured a mesh which is based on the date palm implantation area according to a regular structure by an approach of targeted sampling and systematic to facilitate the data mapping.
- The second stage is characterized by an approach of targeted sampling. It is an analytical study in the laboratory on samples taken at the level of each horizon. In effect, we collected samples of the soil to a specific location by choosing the points where the data

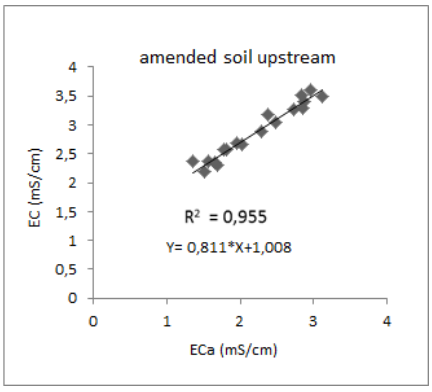
of the probe recorded in the datasheet of survey showed a large variability between series of data. Using a manual auger which drills the soil of low depth (zero to 1.20 meter). We collected samples of the soil to prepare the saturated paste in the laboratory and measure the electrical conductivity. The particle size analysis was performed to determine the overall texture of soils horizons using a series of sieves for sandy fraction and sedimentation in water with Robinson eyedropper (Yoka et al., 2010) for the fine fractions.

The electrical conductivity has been determined according to the method recommended by the Riverside Laboratory (US Salinity Laboratory staff), USSL, 1954. It has been measured on the extract of the saturated paste and corrected to a temperature of 25°C.

ECa: The apparent electrical conductivity measured by the Geonics.

EC: The actual electrical conductivity of medium depth 0-200 cm of wet paste. The affine equation of the linear regression is written: Yi (x) = a Xi + b; L and Xi = ECa (S/m à 25°C) and Yi = EC (S/m à 25°C)

- For the upstream-amended soil, we have the following equation: ECa= 0,811 × EC +1.08
- For the downstream-amended soil, we have the following equation: ECa= 0, 87 × EC + 1,545



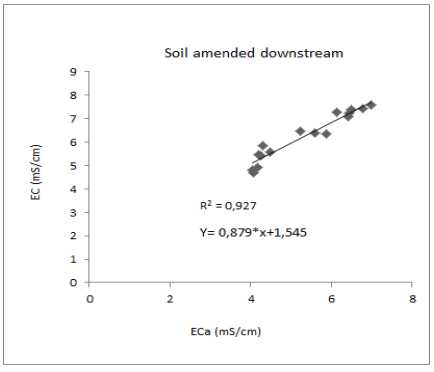


Fig. 2: Correlation between CEa and EC

The correlation is positively significant with a correlation coefficient equal to 0,972 for the amended upstream soil and to 0, 95 for the amended downstream soil. These coefficients are very close to 1 and therefore the correlation is almost perfect between the real electrical conductivity and the apparent electrical conductivity to the two parcels concerned.

3. Results and discussion

3.1 Soil texture

In the oasis area of Om Rouss, the soil distribution (table1) is closely linked to the topography:

- The upstream northern part has a sandy-silty texture. This soil is, therefore, characterized by a good infiltration of water and a low water retention capacity which are favorable characteristics of the soluble salts transfer and their accumulation towards the deepest layers by vertical leaching.
- The southern part downstream is characterized by a sandy-loamy surface texture at a depth ranging from 0 to 40 cm while the texture is sandy loam to loam-clay in deep horizons (40-120 cm). This part ends with the salt depression of the Chott.

3.2 Soil salinity: EC

The mapping of the salinity at the level of our oasis reveals a large spatial variation for the two plots concerned.

- Upstream parcel amended: The salinity varies between 1.5 and 3.9 mS/cm. The spatial variability of the salinity observed seems to be linked to the topographical parcel context and the oasis location in relation to the natural flow network. This parcel is characterized by a surface with a slope greater than 3%. The salinity could also be explained by the occupation of the ground and by the farmers managing mode of their parcels. In effect, the irrigation has contributed to the decrease of the soil salinity at this parcel level.
- Downstream parcel amended: The salinity observed is higher than that observed at high slope ground level. It varies between 4 and 6 mS/cm. The latter presents a distribution as a function of the virtually flat topography, which affects water dynamics and salts transfer. The Om Rouss oasis development is toward the low-lying areas and is only stopped by a hypersalty and a hyromorph depression composed by fine alluvium (Sebkha).

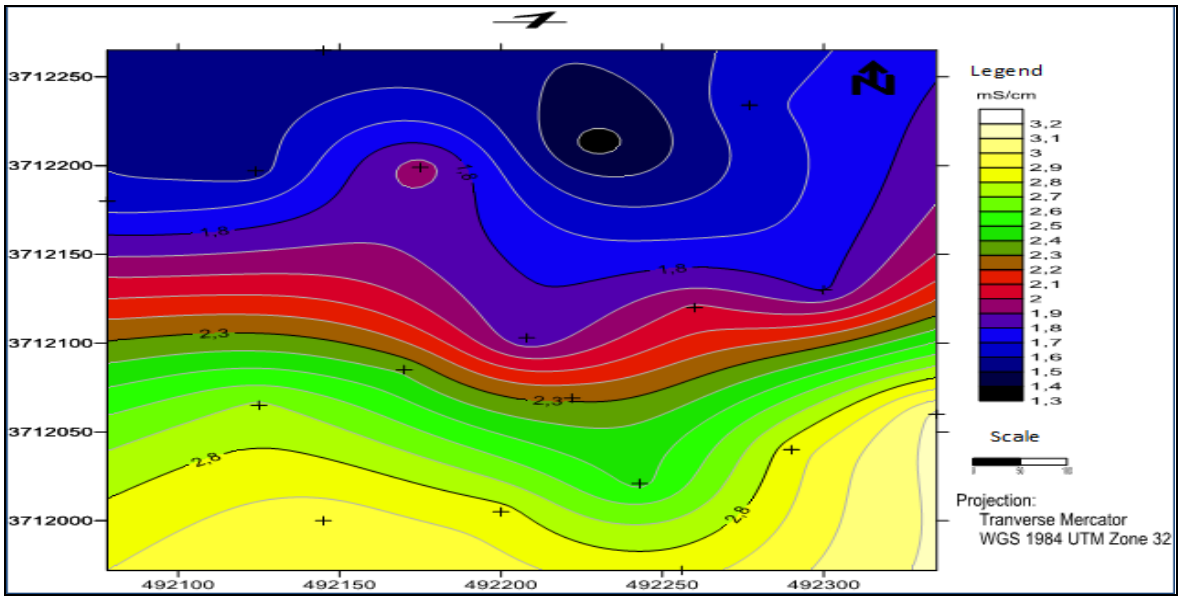


Fig. 3: Amended soil upstream

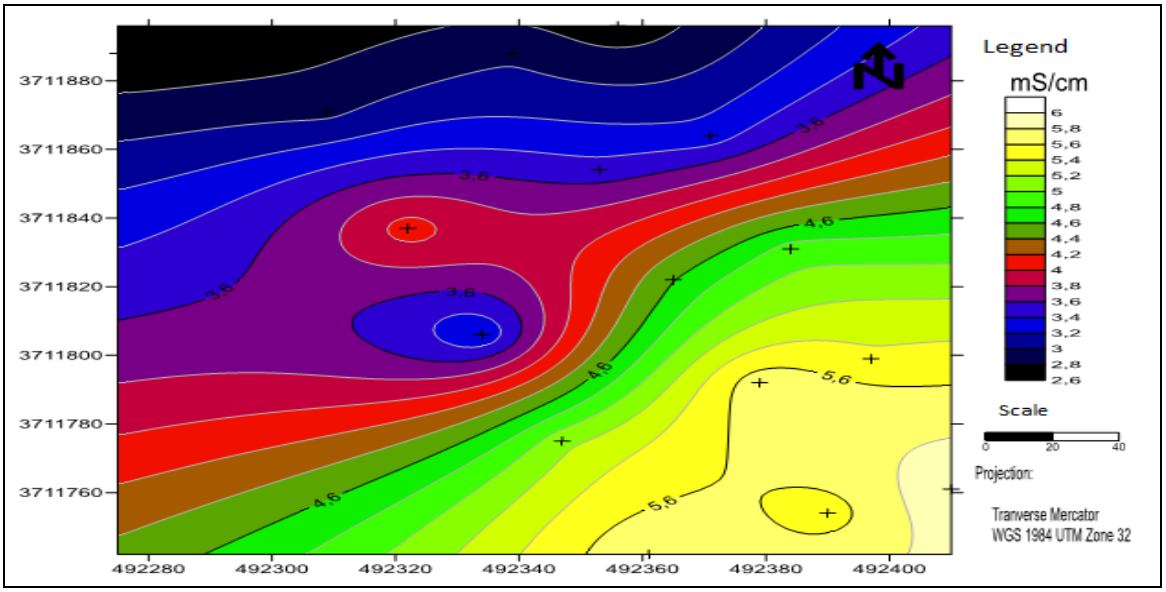


Fig. 4: Amended soil downstream

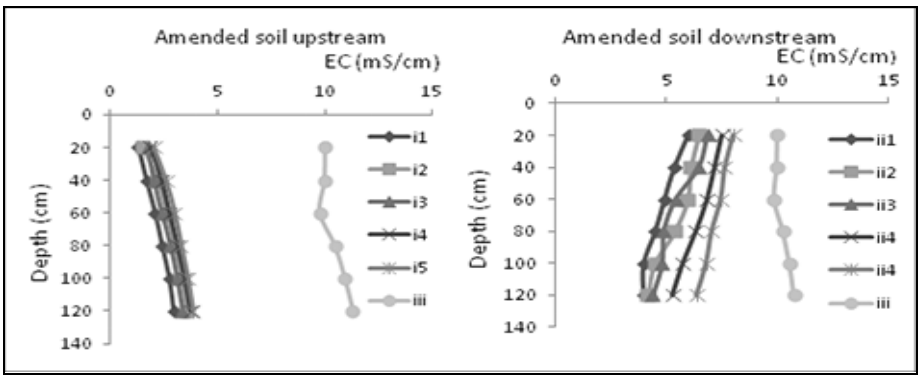


Fig. 5: Effect of the slope on the variation of EC

In the upstream amended parcel, the salinity varies between 1.29 and 3.84 mS/ cm. The monitoring of the salinity variation was significantly influenced by increasing depth. In Figure 5, the salt gradient is increasing from the surface to the deeper layers. This gradient may be expressed by salts leaching at depth following the irrigation and infiltration of rainwater. This result is in agreement with (Louati 2015) study which showed that the superficial layer of the soil, characterized by a sandy-silty texture, a good permeability and a low cationic exchange capacity, underwent a slight desalination and an infiltration of soluble salts. In addition, having soil salinity higher at depth than at the surface shows that salt leaching is real and that these are partly retained in the lower levels. While for the amended plot downstream, the observed salinity varied between 4 mS / cm and 8 mS / cm, the salinity decreases with depth due to the presence of a saline water table. Close to the surface and also due to the sandy-loam soil texture, this favors the mobilization of salts by capillary rise. It is therefore, a moderately saline soil with a decreasing salinity gradient from the surface to the depth. The unamended soil electrical conductivity has a high grade (between 10,541 mS/cm and 11.09 mS/cm) all along the profile with values higher than those observed in the amended plots, which explains that the spreading of the geological materials (sand spreading) reduces the salinity of soils.

4. Discussion

Referring to recent studies on traditional oasis soil (Boulbaba et al., 2012, Askri and Bouhlila, 2014) and data collected (APIA, 2008); some degradation phenomena that have affected some oasis and their exploitation have been noticed. These include hydromorphic soils, soil salinization, declining fertility, and lower yields. Thus, to remedy the lack of fertility of these soils, to deal with the degradation of their structure due to the effects of excessive salts, hydromorphic soils, and to improve the performance of palm groves, the farmer-led among other things with often limited. The study of soils amended in the oasis of Om Rouss in southern Tunisia has shown that the soils restoration from the homogeneous contribution of the sandy-muddy wind on the marginal lands near the chott type closed depression has had a beneficial effect on improving soil properties. In fact, the results of soil analysis and diagnosis revealed the presence of a very permeable level at the surface from of upstream to downstream and a level rich in fine particles with low permeability at depth, especially downstream near chott. The salinity of the soil at the Oasis level shows a strong spatial variability related to the topography and the drainage efficiency in the studied perimeter. As a result, the northern upstream part of the oasis is well drained and less salty than the downstream area near the natural Sebkha irrigation and drainage outfall. These results confirm the role of sandy amendments as an effective action to combat soil degradation, improve production and especially the preservation of agricultural activity, especially in the old oasis. The study of soils in the root zone of palmier in Om Rouss oasis which covers 15 ha shows that the soils consist of a homogeneous sandy silty apline highly permeable upstream and heterogeneous soils (finer in depth) downstream. The preferential drainage of water is always from an elevated area north of the oasis to a large depression in the south and large drainage ditches. Soil salinity, at the oasis level, has a high spatial variability (Askri, 2002).

5. Conclusion

Their spatial distributions seem to be related to the geomorphology of the perimeter. The northern parts of the oasis (high slope) are well drained. On the contrary, downstream zones (low slope) are zones of salt accumulation located in the southern part of the oasis, where the nappe is outcropping and the salinity is very high. According to the intensity of these phenomena, this sequence of processes has repercussions on the palms that are less productive or completely absent in slight slope soils. In addition, the low salinity observed in the north of the oasis (soil with a steep slope) compared to the southern part (sloping soil) could be explained by the fact that the latter is closer to the Chott. Zidi and Hachicha, (1977) confirmed that the decline in production is accompanied by an increase in soil salinity.

Our study provided the first field study in oasis systems in southern Tunisia, which shows that the topographic position, the overall texture and the closeness of the Sebkha (natural outlet of surface water and irrigation) can modify the functional parameters of the soil and that it plays an important role in the functioning of organic and mineral amendment. The results show that after two years of amendment, the upstream part of the oasis shows a more lasting change compared to the downstream field closer to the Sebkha. Thus, after the application, the upstream soil with sandy-silty texture characterized by a good infiltration of water and a low water retention capacity, a good permeability and a low

cation exchange capacity, favorable characteristics to soluble salts transfer and their accumulation to the deepest layers by vertical leaching. This soil has undergone a slight desalinization and an infiltration of the soluble salts. In addition, having soil salinity that is higher at depth than at the surface shows, that salt leaching is real and that these are partly retained in the lower levels. In contrast to the soil that has been amended downstream, the salinity decreases with depth due to the presence of a saline water table close to the surface, which favors the mobilization of salts by capillary rise. It is therefore a moderately saline soil with a decreasing salinity gradient from the surface to the depth. Thus, this combined organic amendment (compost or manure) with a cheap mineral amendment (sand) should be considered, as an intelligent alternative for the sustainable management of Tunisian oasis systems as a solution but still it is necessary to the intervention of government before practicing this application.

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