

# Soil Salinity Assessment and Characterization in Abandoned Farmlands of Metouia Oasis, South Tunisia <sup>†</sup>

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**Abstract:** In Tunisia, the phenomenon of abandonment of agricultural fields due to soil salinization is becoming common in oasis systems. However, little is known about the salinity level and the geochemical composition of abandoned oasis soils. A total of 156 soil samples were collected from abandoned plots in the Metouia Oasis, south-east of Tunisia, and characterized for electrical conductivity and cation and anion composition. In addition, a spatial analysis using spatial data and field verification was carried out. The results can be used to establish a management plan to address the problem of farmland abandonment associated with soil salinization and ensure the viability and sustainability of oasis systems.

**Keywords:** soil salinity; farmland abandonment; spatial analysis; anions; cations; oasis system



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## 1. Introduction

In recent years, agricultural land abandonment has become a serious problem in many countries worldwide. Land abandonment due to soil salinization has been reported in China [1], Saudi Arabia [2], and most European countries [3]. This phenomenon is leading to the loss of agricultural soils and threatening food security and local livelihoods. In Tunisia, the phenomenon of abandonment of agricultural fields is becoming a common occurrence in oasis systems where it is usually associated with soil salinization. However, little is known about the salinity level and the geochemical composition of abandoned oasis soils. Such information would enable a better understanding of salinization sources, which is crucial for amelioration and for the development of sustainable management of salt-affected soils. Therefore, the objectives of our study were: (1) to assess the salinity of abandoned soils in a coastal oasis of south Tunisia, (2) to characterize the salt profiles of the abandoned soils.

## 2. Materials and Methods

The Metouia Oasis is part of the coastal oases located in the south-east of Tunisia. It covers an area of about 270 ha divided into 2132 plots distributed among 1450 farmers. The average sized are 0.1862 ha/owner and 0.1266 ha/plot. The oasis of Metouia is characterized by an arid climate where precipitation is rare (164.86 mm/year on average over the 10-year period) and irregular. The maximum annual average temperature is 31.5 °C, while the minimum annual average temperature is 11.23 °C. The average monthly evaporation varies from 62.65 mm in January to 210.45 mm in August, which shows a water deficit over the whole year of about 1000 mm, given an average rainfall of 164.86 mm.

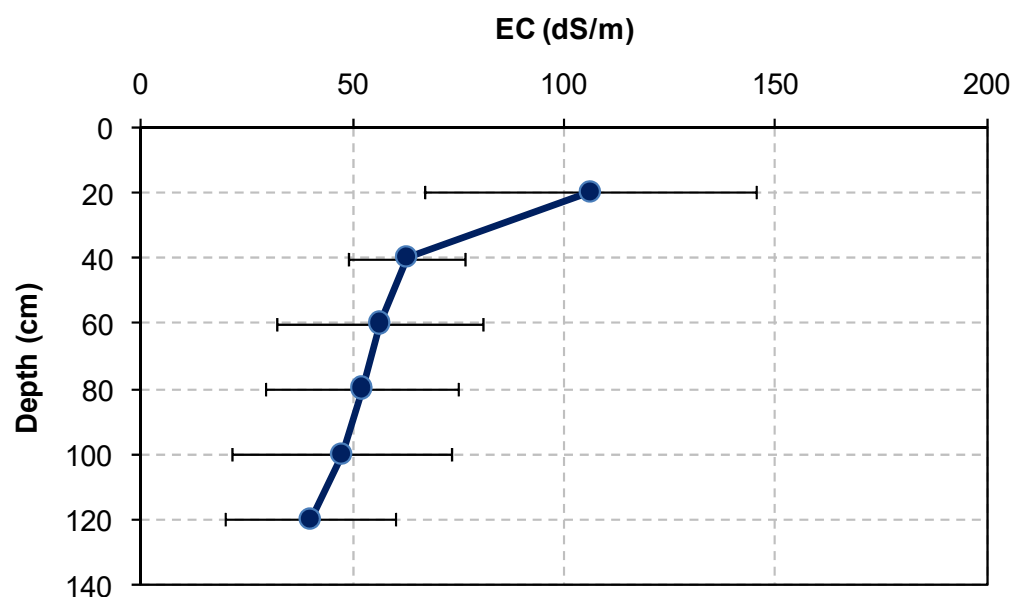
In order to characterize soil salinity in the abandoned farmlands, soil samples were collected from 26 locations from six depths. A total of 156 soil samples were collected from abandoned plots. The electrical conductivity (EC) of the soil extracts was determined

using a conductivity meter. The cations ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ) and anions ( $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$ ,  $\text{Br}^-$ ) were determined by the simultaneous determination of anions and cations using ion chromatography [4]. In order to characterize the chemical properties of the saturated paste extracts of the abandoned soils, a Piper diagram was used for presenting their anionic and cationic compositions. Additionally, spatial analysis using spatial data and field investigation was carried out to identify and characterize abandoned farmlands in the Metouia Oasis. In this study, high resolution Google Earth satellite images of the year 2020 covering the study area were utilized to identify the abandoned farmlands through onscreen digitizing, using ArcGIS software. The outcomes of this image-based identification were then verified and corrected through several field visits. The plot boundaries were set based on the plot map of the Metouia Oasis.

### 3. Results

#### 3.1. Salinity Status of Abandoned Soils

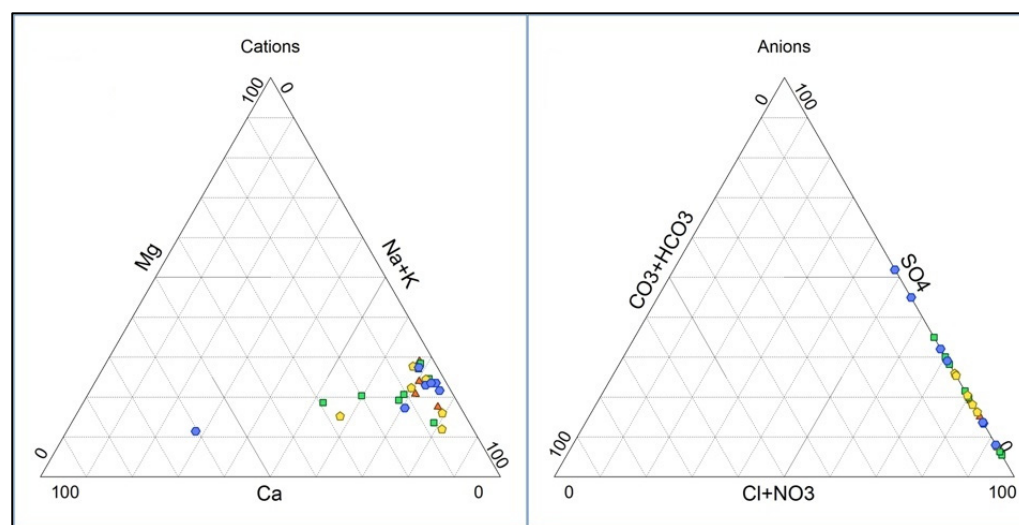
The soil surface salinity of the abandoned plots showed a very high salinity value, exceeding  $60 \text{ dS m}^{-1}$  in all sampled soils. The mean EC values of abandoned soils varied between a maximum of  $76 \text{ dS m}^{-1}$  at the soil surface (0–20 cm) to a minimum of  $27 \text{ dS m}^{-1}$  in the bottom layer (100–120 cm). In most of the locations, the EC values showed a decreasing trend from the surface to the bottom of the soil profile (Figure 1). Additionally, the correlation analysis showed high and positive correlation coefficients of soil salinity between all soil layers ( $p < 0.05$ ).



**Figure 1.** Soil salinity profile at abandoned farmlands in Metouia Oasis.

#### 3.2. Chemical Properties of Abandoned Soils

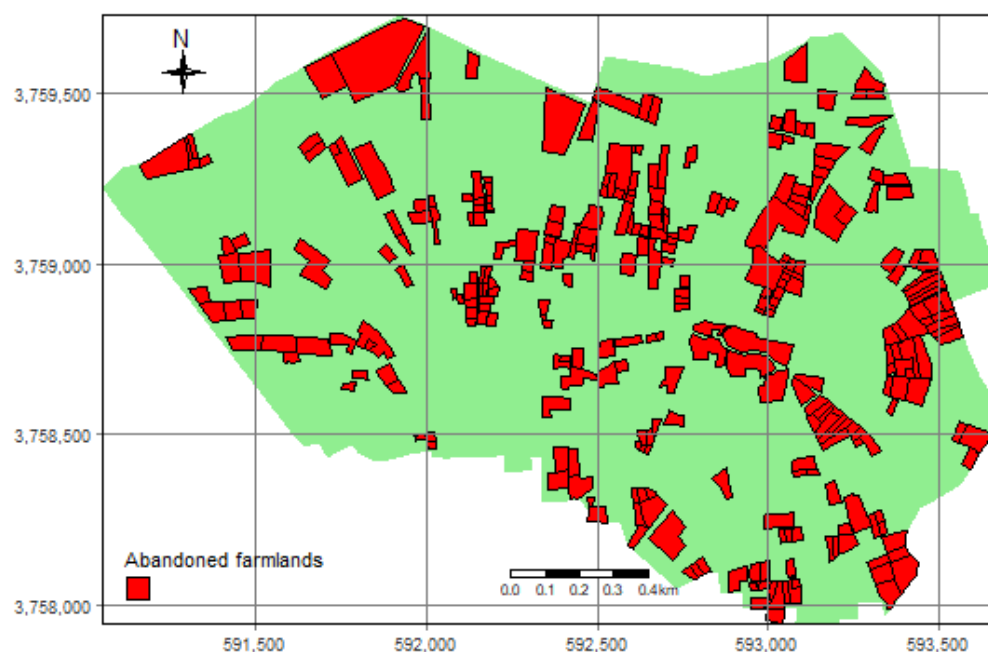
At the surface layer, cation concentrations were in the order  $\text{Na}^+ > \text{Mg}^{2+} > \text{Ca}^{2+} > \text{K}^+$  while anions were in the order  $\text{Cl}^- > \text{SO}_4^{2-} > \text{NO}_3^- > \text{Br}^-$ . At the deepest sampled layer (100–120 cm) cation concentrations were in the decreasing order of  $\text{Na}^+ > \text{Ca}^{2+} > \text{Mg}^{2+} > \text{K}^+$  and anions had similar patterns as the surface layer. From a cationic point of view, saturation extracts have dominant sodium content at the surface and bottom layers. As for the anionic composition, in most of the studied profiles, the saturation extracts were chlorine dominant (Figure 2).



**Figure 2.** Piper diagram presenting anionic and cationic compositions of the saturated paste extracts of abandoned soils.

### 3.3. Spatial Distribution of Abandoned Farmlands

The spatial distribution of abandoned farmlands in Metouia Oasis is shown in Figure 3. We found that there are more abandoned farmlands throughout the oasis area. In total, there are 312 abandoned farmlands occupying 66 ha, which represent 24% of the total oasis area.



**Figure 3.** Spatial distribution of abandoned farmlands in Metouia Oasis.

## 4. Discussion

The EC data showed that soils of abandoned plots in the Metouia Oasis were characterized as highly saline. Our results are consistent with those of Costa et al. [5], who reported extremely high values of salinity in abandoned soils of the oasis of Masafi in the United Arab Emirates. Gopalakrishnan and Kumar [6] also reported extremely saline soils in permanently abandoned paddy lands in the semi-arid region of the Jaffna Peninsula, Sri Lanka. In our study area, it was observed that soil salinity gradually decreased with increasing depth. This pattern of salt profiles in the abandoned plots can be attributed to

the effect of evaporation, leading to continuous and significant salt accumulation in the soil surface layer [7]. In our study site, the aridity of the climate and the absence of leaching of salts have favored the existence of this upward salinity gradient of the abandoned soils. Previous studies carried out by Ibrahim et al. [8] in the Metouia Oasis showed that ground-water depth and salinity are the major factors affecting soil salinization. Considering the soil profile, the adjacent layers were better correlated in terms of EC levels than distant ones, suggesting the more pronounced mutual effect of soil salinity between soil layers which are close to each other. Similarly, Wang et al. [9] reported higher correlation coefficients of soil salinity between two adjacent soil layers than between non-adjacent ones. Moreover, in our study area, geochemical analysis showed that abandoned soils appear enriched in Na and Cl, suggesting that the main sources of soil salinity in the abandoned plots of Metouia Oasis were sodium and chloride.

## 5. Conclusions

Abandoned farmlands are spread throughout Metouia Oasis. Soils at these plots were characterized by very high salinity rates. The salt profiles in these soils showed salt accumulation at the surface layer with an upward gradient of salinity. Saturation extracts of abandoned soils showed dominant sodium and chloride ions at surface and bottom layers of the soil profile. The results of this study can be used to establish a management plan to address the problem of farmland abandonment and associated soil salinization in order to ensure the viability and the sustainability of oasis systems.

**Author Contributions:** Methodology, K.I. and N.K.; software, N.K. and L.A.; formal analysis, K.I., N.K. and L.A.; data curation, K.I.; writing—original draft preparation, K.I.; writing—review and editing, K.I. All authors have read and agreed to the published version of the manuscript.

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## References

- Li, Y.; Shan, Y.; Chen, Y. Analysis of Farmland Abandonment and Government Supervision Traps in China. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1815. [\[CrossRef\]](#) [\[PubMed\]](#)
- Al-Rowaily, S.L.; Al-Dosari, D.H.; Assaeed, A.M.; Abd-ElGawad, A.M.; El-Sheikh, M.A.; El-Bana, M.I.; Al-Taisan, W.A. Native Perennial Plants Colonizing Abandoned Arable Fields in a Desert Area: Population Structure and Community Assembly. *Agriculture* **2020**, *10*, 550. [\[CrossRef\]](#)
- Kozak, M.; Pudetko, R. Impact Assessment of the Long-Term Fallowed Land on Agricultural Soils and the Possibility of Their Return to Agriculture. *Agriculture* **2021**, *11*, 148. [\[CrossRef\]](#)
- Nesterenko, P.N. Simultaneous separation and detection of anions and cations in ion chromatography. *Trends Anal. Chem.* **2001**, *20*, 311–319. [\[CrossRef\]](#)
- Costa, S.; Purdue, L.; Dufour, A.; Charbonnier, J. An oasis soil reference collection for the identification and study of ancient cultivated soils in arid environments (Oasis of Masafi, United Arab Emirates). *Geoarchaeology* **2021**, *36*, 404–428. [\[CrossRef\]](#)
- Gopalakrishnan, T.; Kumar, L. Linking Long-Term Changes in Soil Salinity to Paddy Land Abandonment in Jaffna Peninsula, Sri Lanka. *Agriculture* **2021**, *11*, 211. [\[CrossRef\]](#)
- Liu, S.; Huang, Q.; Ren, D.; Xu, X.; Xiong, Y.; Huang, G. Soil evaporation and its impact on salt accumulation in different landscapes under freeze–thaw conditions in an arid seasonal frozen region. *Vadose Zone J.* **2021**, *20*, e20098. [\[CrossRef\]](#)
- Ibrahimi, K.; Miyazaki, T.; Nishimura, T.; Imoto, H. Contribution of shallow groundwater rapid fluctuation to soil salinization under arid and semiarid climate. *Arab. J. Geosci.* **2014**, *7*, 3901–3911. [\[CrossRef\]](#)
- Wang, Z.; Zhao, G.; Gao, M.; Chang, C. Spatial variability of soil salinity in coastal saline soil at different scales in the Yellow River Delta, China. *Environ. Monit. Assess.* **2017**, *189*, 80. [\[CrossRef\]](#) [\[PubMed\]](#)