Modeling of soil salinity in Rheris Oasis (Southeastern of Morocco) using satellite spectral indices

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Abstract. The Rheris oases in Southeastern Morocco are an essential ecosystem. It presents enormous ecological and natural values. Water scarcity coupled with agricultural intensification results in soil salinization and its degradation. This work aims to propose a spatiotemporal monitoring method of soil salinization in the Rheris oasis using spectral indices derived from Thematic Mapper (TM) and Operational Land Imager (OLI) data. The most used indices in the literature were (14 indices) tested and correlated with the results obtained from 50 samples taken from the first soil horizon at a constant depth of 0.20 m from the November 2022 campaign. The findings confirm that this method is highly effective and reliable for the modeling and spatial mapping of soil salinity in this region. The state of the hydroclimate is an aspect that influences soil salinization. An increase in salinized surfaces is observed during the periods of 1990–1996, 2000–2005, and 2017-2022. The spatio-temporal distribution of saline soils in Rheris Oasis is very variable. The monthly variations are more important than the annual ones.

Keywords : Rheris Oasis, soil salinity, modeling, remote sensing.

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1 Introduction

Multiple recent studies show that Geographic Information System (GIS) and Remote Sensing (RS) have the potential to be more effective than traditional methods such as field measurement and laboratory analysis for soil salinity assessment and monitoring over large areas. This is due to the high cost of traditional methods, which require large surfaces [1]. Such information is already available for some arid and semi-arid regions in Morocco, such as the Tadla Plain [2] and Tafilalet Plain [3, 4], and other areas outside of Morocco [5, 6, 7]. For the Rheris region, the extent of land that is threatened by this degradation process has yet to be determined.

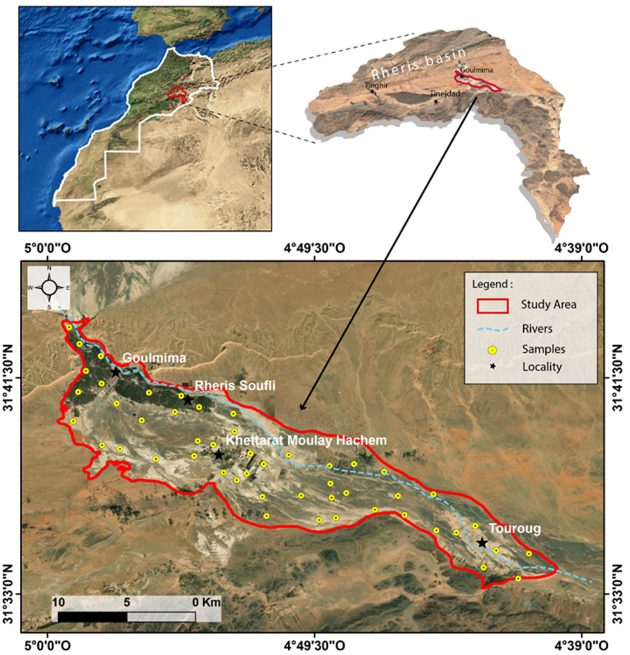

Fig. 1. Localization of the study area

2 Methodology

The satellite image data used for the geospatial analysis was obtained from Land-sat, provided by the US Geological Survey (USGS) Earth Explorer (https://earthexplorer.usgs.gov/) and the Copernicus Open Access Hub of the Euro-pean Space Agency (ESA). Soil sampling was carried out in the Rheris Oasis. The 50 sampling sites are distributed to cover the entire study area and represent the different soil types of the region (Fig. 3). At each location, three samples were taken from the upper soil horizon (0 – 20 cm) and mixed to give a representative probe. Afterwards samples were taken to the laboratory for the measurement of Electrical Conductivity (EC) according to [8].

The main goal of the present step is to confirm the validity of these spectral indices. To determine the most suitable indices and models for monitoring soil salinity in an area with a high water stress index, regression models were used with soil samples. For each SSSI, five regression models were calibrated on the soil salinity data from the research area in order to find the best correlation between the EC of the soil as observed and as predicted by the satellite image analysis.

- Step 1. Choose & calculate SSSI and its normalization.
- Step 2. Find best regression model for each SSSI salinity prediction based on R squared from cross validation
- Step 3. Fit chosen regression model for each SSSI on whole dataset
- Step 4. Choose best SSI based on multiple model fit accuracy measures
- Step 5. Use the best regression model of best performing SSI for salinity mapping

3 Results and discussion

3.1 The spatial variation between the different normalized salinity indices

To identify which of the 14 indices was most appropriate in this particular setting, it was necessary to comprehend the process and variability of soil salinization in the Rhers Oasis. The suitability of these indicators for salinity mapping may vary significantly depending on the type of soil, the climate, and the availability of water (Fig. 2).

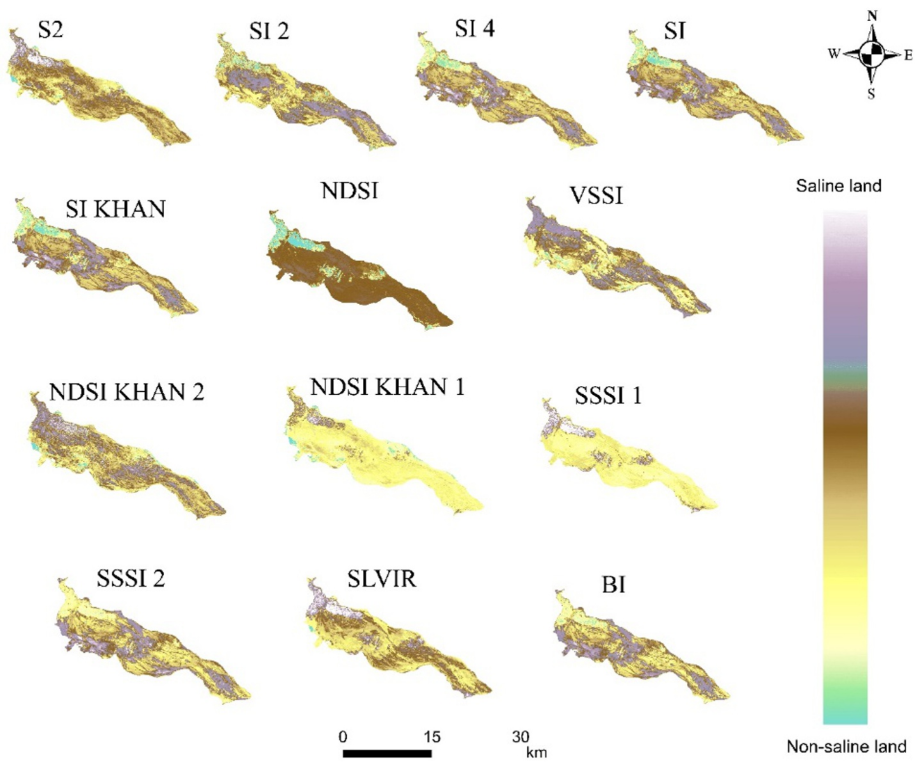

Fig. 2. Spatial variability of the different normalized SSI based on satellite data.

3.2 Visual and statistical validation of the salinity model

Figure 3 shows the results of the mean R^2 from the residuals of the test data set of cross-validation performed for all 14 examined SSSI's. It is shown, that the differences between

SSSI's are more pronounced than the differences between the regression models examined for individual SSSI's from the 14 examined, the complex cubic regression shows the best performance for most of the SSSI's (5 out of 15).

Fig. 3. Values of mean R^2 for the test data according to the 5-fold cross-validation for the 14 examined SI's (Table 4) and for tested Regression models. Exp = exponential model, Lm = linear model, Poly2 = quadratic model, Poly3 = cubic model.

This research tested 14 indices with 4 correlation models and 6 parameters of evaluation. The results showed that the SI index with the D3 polynomial model was the most suitable for spatio-temporal monitoring of soil salinity in this region.

4 Conclusion

Soil salinity is a significant environmental challenge worldwide, especially in arid climatic regions such as the Rheris Oasis. RS techniques have been applied to detect and map saline fields, as well as to monitor changes in spatial and temporal variability from year to year and inter-seasonally.

We recommend using crops that are more tolerant to salinity in the southern half of the study area and providing a leaching requirement to keep the soil suitable for the cultivated crops in order to sustain crop productivity.

The crops that are commonly cultivated in the perimeter, taking into account the availability of water resources. Barley, wheat, fodder barley, and alfalfa are the most commonly cultivated crops, while other crops are more tolerant to salinity including Rye grass, fescue, and couch grass.

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Author Contribution

Ismail Ait Lahssaine, Badre Messaoudi, Mohammed El Hafyani, and Helen Alice Kretzschmar contributed to the study design and methodology. Ismail Ait Lahssaine prepared the draft manuscript, with Kabiri Lahcen providing supervision, data interpretation. Badre Essafraoui, Abdelhakim Kadiri, Mohamed El Ouali, Edgardo Canas Kurz, Ulrich Hellriegel, and Jan Hoinkis reviewed and refined the manuscript. All authors approved the final version of the manuscript.

Ethics approval and consent to participate

Not applicable.

Consent for publication

All the authors have agreed to publish this article.

Competing interests

The authors declare that they have no competing interests

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