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Using an integrated approach for mapping soil salinity risk in Tadla Plain, Morocco

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ABSTRACT

Salinization is form of soil degradation that is expanding dramatically and reveal increasingly worrying aspects. It contributes to the decline of agricultural production in most of the world's irrigated areas, especially those arid or semi-arid climate. This phenomenon results from the synergy effects of climate, bedrock, the aggressiveness of natural conditions and the anthropogenic activities. With this in mind, the present study focuses on the mapping of soil salinity risk in Tadla Plain. To achieve this objective, the approach of Soil Salinity Risk Index (SSRI) was adopted. The necessary variables to calculate SSRI were weighted and overlaid using GIS. This operation allowed to develop a soil salinity risk map of the study area. The use of SSRI-based approach reveals the occurrence of three risk classes: low, moderate and severe. The moderate risk class dominates with a coverage representing 76% of the total area. The results achieved showed the prospect of this approach to delineate areas of soils prone to salinization risk, so as to manage soil salinization and reduce its effects on agricultural production.

1. INTRODUCTION

Salinization is a serious challenge for the development of modern agriculture and the preservation of environment. The global extent of soils affected by primary salinization is about 955 million hectares, while secondary salinization affects nearly 77 million hectares, of which 58% occurs in irrigated areas (Bakacsi et al., 2019; Metternicht and Zinck, 2003). About 20% of irrigated lands are affected by salt, and this proportion tends to increase despite considerable efforts devoted to land reclamation (Metternicht and Zinck, 2003). Human induced or secondary salinization, such as the use of high salt content water, super-irrigation and/or lack of drainage systems, in addition to excess fertilizer (Asfaw et al., 2016; El Gallal et al., 2016; Florinsky et al., 2009; Badraoui, 2006), instigates soluble salts accumulation.

In Morocco, the area of agricultural lands affected by salinity has been increased (Chaaou et al., 2020; Sadiqui et al., 2016) since the launch of irrigation. According to Badraoui (2003), about 16% of irrigated lands were affected by secondary salinization. Given the spread of this problem, Morocco must increase its efforts to evaluate the consequences of soil salinization, but also to develop appropriate conservation programs. In this regard, several studies have been carried out to develop a global strategy for the sustainable development of irrigated areas. In order to analyze the state of soil degradation by salinity and evaluate the risks of its extension and aggravation, several spatio-temporal monitoring approaches have been developed and applied worldwide. The use of models allows the control of salinity by knowing its spatial distribution and its evolution over time (Bouaziz et al., 2018; Lahlou, 2002). However, monitoring the process and mapping of soil salinity are not carried out with sufficient reliability without the integration of several factors (Aswaf et al., 2016; Nosetto et al., 2013). Given the complexity of the processes controlling soil salinity, the use of a multi-criteria approach makes it possible to identify areas at high risk of salinity and ensure spatiotemporal monitoring of chemical soil degradation (Triki et al.,

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2017; Bolinder et al., 2000). It is therefore necessary to develop an approach that allows the mapping on the basis of several factors of this (Castro et al., 2019). In this context, Chaaou et al. (2020) have developed a tool in the form of an index that uses several factors (soil types and bedrocks, climate and water table level) for mapping soil salinity risks. This approach allows the development of a soil salinity risk map that can be used as a decision-making tool to manage soil quality. In spite of its extensive use worldwide, this approach has never been implemented in the Mediterranean region, and particularly in Morocco.

2. MATERIAL AND METHODS

2.1. Study area

This study was carried out in the irrigated perimeter of Tadla in central Morocco “Fig .1”.

Geologically, the Tadla perimeter is characterized by a vast synclinal depression filled with Neogene (Miocene and Pliocene) and Quaternary deposits (Etienne et al.,1975). Soils studies carried out in the study site show the predominance of chromic Kastanozems soils (WRB,2016).

The climate is arid to semi-arid with average annual temperature of about 17 °C. Mean annual rainfall varies from 200 to 600 mm during 2001-2014 (Chaaou et al.,2020).

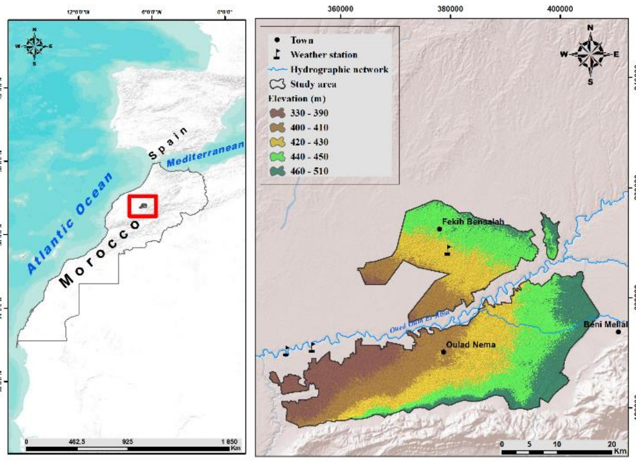

Figure 1. Location of the study area

2.2. Soil Salinization Risk Index (SSRI)

The soil salinization risk index (SSRI) is an additive method (Chaaou et al.,2020), which includes ten factors “Table 1”. The SSRI calculation is based on a 5 X 9 matrix with two levels weighting (1 or 2).

To calculate SSRI, the risk class index for each factor is multiplied by its respective weight. The weighted values for each factor are added together to estimate SSRI, which ranges from 10 "very low" to 50 "very high" depending on the risk class “Table 2”.

Table 1. Factors used to calculate SSRI

Indicators	Class limits and their rating score				
	None (1)	Slight (2)	Moderate (3)	Severe (4)	Very severe (5)
Depth of water table (m)	>5	3-5	1-3	0.5-1	<0.5
Soil texture	Coarse soils	Coarse to medium and medium	Moderately fine	Fine	Very fine
Slope (%)	>30	15-29	5-14	1-4	<1
Quality of irrigation water EC (ds/cm)	<0,25	0,25-0,75	0,75-2,25	2,25-5	>5
Quality of groundwater EC (ds/cm)	<0,25	0,25-0,75	0,75-2,25	2,25-5	>5
Efficacy of surface geology	<0.1	0.1-0.39	0.39-0.65	0.65-1	>1
Climate	Sub-humid and humid	Slightly semi-arid	Semi-arid	Arid	Very arid
Dry index (P/ETP)	>0.60	0.40-0.59	0.20-0.39	0.05-0.19	<0.05
Status of soil salinity EC (ds/cm)	<4	4-8	8-16	16-32	>32

SSRI original = (Status of soil salinity X 2) + 1 X (Quality of irrigation water + Depth of water table + Ground water quality + Soil texture + Climate + Dry index + Slope + Efficacy of surface geology)

Table 2. Salinity Risk Severity Classes

Class	None	Slight	Moderate	Severe	Very severe
Risk score	10-15	16-25	26-35	36-45	46-50

2.3. Data processing

The data used in this study comes from soil and water quality monitoring networks, established by the Tadla Agricultural Development Office. “Fig. 2” shows the data and the processing performed to calculate SSRI.

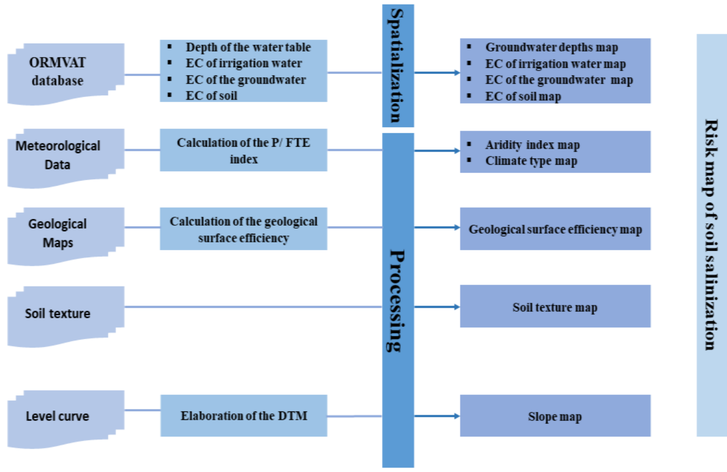

Figure 2. Data used and processing to develop the risk index for salinity.

3. RESULTS

The soil salinization risk map in “Fig.3” illustrates the spatial distribution of salinity risk in the Tadla plain using the SSRI approach. This map includes 4 classes, namely: moderate potential risk, low potential risk, moderate current risk and severe current risk.

The analysis of the spatial distribution of soil salinity risk classes led to conclude that SSRI is relevant for determining the soil salinization risk classes (current and potential) with the predominance of moderate potential risk class (76% of total area) “Fig.4”. It can also be noted that the areas of potential salinity risk correspond to the highly sensitive soils. It seems that soils with severe risk class are located in areas with high groundwater and soil salinity. Current severe risk class represents only 0.1% of the total area of the Tadla irrigated perimeter “Fig.4”.

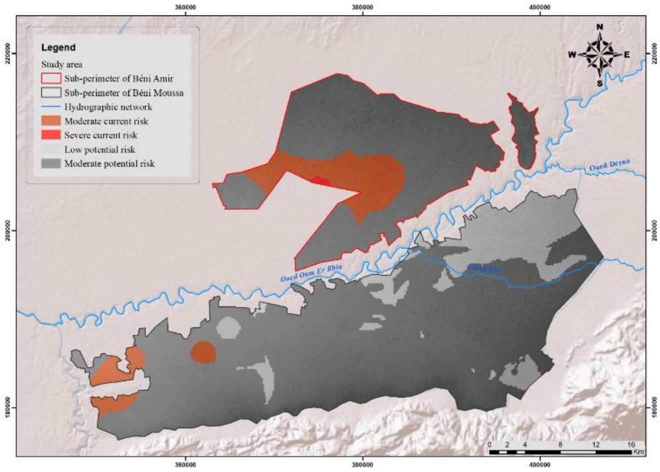

Figure 3. Soil salinization risk map

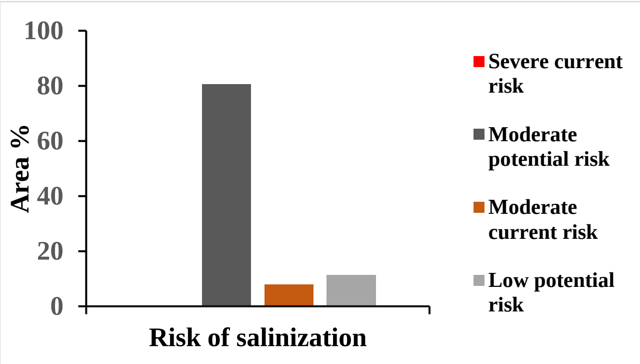

Figure 4. Areas of risk classes using SSRI

4. DISCUSSION

The combination of elements of the biophysical system such as relief, rainfall and lithological structure contributes to the mapping of soil salinity risk, taking into account soil characteristics (Castro et al., 2019).

The index approach allowed us to identify different levels of salinity risk in the irrigated perimeter of Tadla (current and potential). The results show the predominance of moderate potential risk with an extent of 76%. The area with potential risk includes soils that are very sensitive to salinity. On the other hand, area with severe risk class represents only 0.1% of the total surface of the irrigated perimeter of Tadla. In addition, severe risk class is located in area where salinity is high for groundwater and soils. This risk is higher during the dry season when rainfall is low.

Results show the interest of using this approach and the contribution of multi-source data in the study of soil degradation salinity. Moreover, it is noteworthy to mention the strong correlation between groundwater electrical conductivity and soil electrical conductivity. The same observation was also revealed by a study carried out by Badraoui (2003).

In fact, the electrical conductivity of groundwater explains 40% of the variability in the electrical conductivity of soils. Similarly, the depth of water table explains 28% of the variability in soil salinity in Tadla perimeter.

In our case study, the analysis of the results showed that the low spatial variability of the slope was not sufficient to explain the spatial dynamics of soil salinity in this perimeter. However, it should be noted that the current land use and cultivation practices seemed to control soil salinization. Similarly, the irrigation system and its efficiency could probably influence the salinization process.

5. CONCLUSION

In view of these results, we have demonstrated the interest of using the SSRI approach and the integration of multi-source data for the characterization of soil degradation risk by salinity in the irrigated perimeter of Tadla.

The use of this approach is also justified by its simplicity and ease of implementation in a GIS environment. The SSRI identified three classes of risk: low, moderate and severe. The low-risk class, largely represented in the Béni Moussa sub-perimeter, is explained by the low concentration of salts in irrigation water. Whereas the vast majority of the Béni Amir sub-perimeter is subject to a moderate risk of salinization. The severe salinization class is mainly observed in the downstream of the perimeter.

Monitoring the spatio-temporal dynamics of soil salinity is the key to understand the impact of rainfall, irrigation and agricultural practices on the evolution of soil salinity. Consequently, agricultural land users and managers using the SSRI can benefit from key intervention tools to mitigate the effects of soil salinization on agricultural production.

In light of these results, we suggest to improv this study by combining the SSRI with other variables, such as land use and irrigation system.

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