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# Spatiotemporal monitoring of soil salinization in irrigated Tadla Plain (Morocco) using satellite spectral indices

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ABSTRACT

Soil salinization is major environmental issue in irrigated agricultural production. Conventional methods for salinization monitoring are time and money consuming and limited by the high spatiotemporal variability of this phenomenon. This work aims to propose a spatiotemporal monitoring method of soil salinization in the Tadla plain in central Morocco using spectral indices derived from Thematic Mapper (TM) and Operational Land Imager (OLI) data. Six Landsat TM/OLI satellite images acquired during 13 years period (2000–2013) coupled with in-situ electrical conductivity (EC) measurements were used to develop the proposed method. After radiometric and atmospheric correction of TM/OLI images, a new soil salinity index (OLI-SI) is proposed for soil EC estimation. Validation shows that this index allowed a satisfactory EC estimation in the Tadla irrigated perimeter with coefficient of determination $R^2$ varying from 0.55 to 0.77 and a Root Mean Square Error (RMSE) ranging between 1.02 dS/m and 2.35 dS/m. The times-series of salinity maps produced over the Tadla plain using the proposed method show that salinity is decreasing in intensity and progressively increasing in spatial extent, over the 2000–2013 period. This trend resulted in a decrease in agricultural activities in the southwestern part of the perimeter, located in the hydraulic downstream.



## 1. Introduction

Soil salinization is a major problem of land degradation and negatively affects plants growth (Hamzeh et al., 2013). Besides that, it is reducing the world's irrigated area by 1–2% per year, and is becoming more intense in arid and semi-arid regions such as Morocco (FAO, 2002). Unfortunately, irrigated land are rapidly and strongly vulnerable to soil salinization; approximately 0.01 $km^2$ of fertile land are lost every minute and 30% of this loss is due to salinization (Metternicht and Zinck, 2009). In this paper, the Tadla irrigated perimeter was chosen as study area for its agricultural importance in Morocco. Increased use of saline groundwater and surface water, coupled with agricultural intensification in this perimeter leads to soil salinization and weakening of regional agricultural production (Bellouti et al., 2002; Lhissou et al., 2014). Soil salinization is a very dynamic phenomenon both in time and space, whilst commonly used methods (field measurement, laboratory analysis) are expensive, laborious and unsuitable to the change speed of this phenomenon (Allbed et al., 2014; Barbouchi et al., 2015). Therefore, it became necessary to develop effective methods for mapping, monitoring and trend analysis of soil salinization in order to take suitable and immediate mitigation decisions (Metternicht and Zinck, 2003). In this context, many studies have described the usefulness of satellite techniques, airborne imagery and in-situ spectroradiometry for soil salinity mapping. These techniques are promising because of the sensitivity of soil spectral response to its salt content (Farifteh et al., 2007a,b; Bannari et al., 2008; Abbas et al., 2013; Sidike et al., 2014). Thus, several authors have demonstrated the benefit of combining spectral indices derived from various sensors with the geochemical laboratory measurements (Dehaan and Taylor, 2002; Khan et al., 2005; Bouaziz et al., 2011; Abbas et al., 2013; Hamzeh et al., 2013; Allbed et al., 2014). However, there are very few studies on spatiotemporal monitoring of soil salinization using the Soil Salinity Spectral Indices (SSSI).

In this paper, an approach based on SSSI is developed for spatiotemporal monitoring of soil salinization in the Tadla irrigated perimeter. To achieve this purpose, the SSSI and laboratory measurements of electrical conductivity (EC) during the 2000–2013

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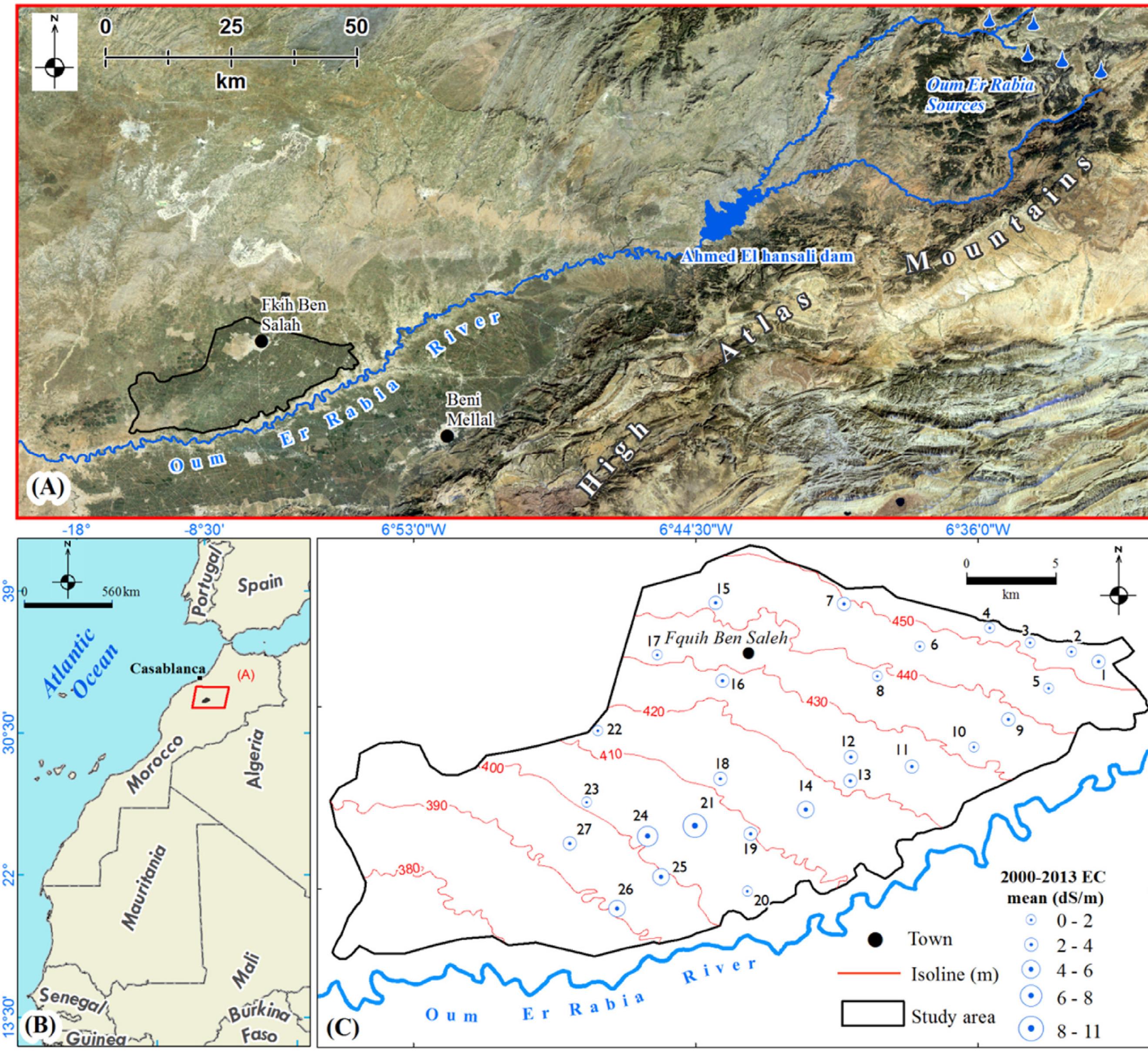


**Fig. 1.** Study area, A: Location of the Tadla irrigated perimeter according to surface water resources, B: Overview of study area at national scale, C: Location of numbered soil samples and terrain elevation.

period were used for soil salinity modeling. Afterward, developed models were used for derive soil salt contents maps using SSSI derived from the image data.

## 2. Study area and data sources

### 2.1. Studied area

This study was performed in the irrigated perimeter of Tadla Plain in central Morocco (Fig. 1). In this site, soil salinization is caused by the irrigation, poor agricultural practices and climate effects (Lhissou et al., 2014; Barbouchi et al., 2015).

Geologically, the study area soils are formed by loam and marly-calcareous Quaternary (El Antaki and El Boustani, 1991). The soils of the irrigated perimeter of Tadla are mainly isohumic type, which are suitable for agriculture because of their depth and their balanced texture (Missante, 1963). The irrigation of agricultural land in the study area is provided by the surface waters of the Oum Er Rabia River. The later is fed by saline sources that cross the Triassic salt formations of High Atlas Mountains. In addition to surface water, saline groundwaters are also used for irrigation.

According to the Analysis laboratory of soil, water and plant of the ORMVAT office (Regional Office of Agricultural Development of Tadla), the ionic balance of saturated paste of the soil samples from the study area showed a dominance of sodium, chloride, bicarbonate and calcium. In addition, the high sodicity in the study area (The amount of exchangeable sodium varies between 3.50 and 13.50%) results from excessive use of groundwater containing sodium. The EC of soils does not exceed 20 dS/m, which shows that the study area is not experiencing severe salinization. Fig. 2 illustrates some field photographs of soil salinity classes in the Tadla irrigated perimeter. The efflorescence of salt can appear as a very thin layer in restricted places in the saline zones as illustrated by the upper photograph in Fig. 2.

The climate of the region is arid to semi-arid with a dry season from April to October and a rainy season from November to March.