Seasonal Soil Salinity Detection Using Salinity Indices from Landsat 8 Satellite Images in El-Sharqiyah Governorate, Egypt

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Abstract

Soil salinity is a major issue that causes land degradation, especially in arid regions which affects negatively on soil properties and reduces agricultural productivity. Remote sensing is an essential tool for detecting and monitoring salinity changes upon time. In this research an assessment was carried out to determine the best representative salinity index based on filed measurements of soil salinity in El-Sharqiyah governorate in the northeast of Egypt. The index was validated in accord with other field soil salinity data in term of total dissolved salts (TDS) measured through 3-years intervals in 2015, 2018 and 2021. Landsat-8 satellite images were used to calculate NDSI (Normalized Difference Salinity Index). Seven indices were used to determine soil salinity, where the best correlated index was based on 2015 field work and used to produce salinity map of the study area. The best correlated index on 2015 was validated upon data of 2018 and 2021. Finally, this approach led to the sensitivity of remote sensing to soil salinity and the ability of its indices for soil salinity predication.

Keywords: Soil salinity, TDS, Indices of salinity, GIS and remote sensing.

1. Introduction

Soil salinization influence on about 100 countries (Shahid et al., 2013). The salinization process occurs due to the accumulation of salts in the soil, which adversely effects the growth of the crops and that issue is continuously increasing worldwide, so that issue has to be considered to overcome its spread. Old and traditional methods for soil salinity measuring are very expensive and require long time, where several researchers tried to find another easy and effective way to measure soil salinity. Remote sensing plays vital role in soil applications such as salinity and moisture content. Soil salinity mapping using remote sensing can be performed by comparing between laboratory measurements of soil salinity and salinity indices produced from satellite images. Excessive concentrations of salinity in the soil influence soil characteristics, which decrease productivity, limit the growth of crops, and constrain agricultural productivity.

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In case Electronic Conductivity (EC) is more than 4 ds/m-1 (Deci-siemens per meter) which represent about 2560 ppm in term of TDS at 25°c, that will be so harmful to crops and affects the plant growth rate (Morshed et al., 2016). Using of remote sensing to detect the soil salinity using band ratios of bands which have proven better detection of salts in soils and salt stressed crops (Schneier et al., 2010).

2. Study Area and Data

1. Description of the Study Area

The study area is located in Sharqiyah governorate in east of Egypt. It is geographically bounded by longitudes 31°05'0" E and 32°10'0" E and latitudes 30°10' 0" N and 31°10' 0" N as shown in Figure 1.

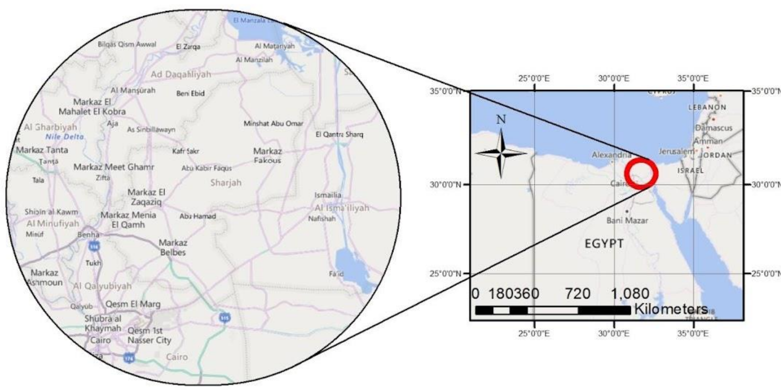


Figure 1: Study area.

2. Ground Truth Measurements

Field work for soil salinity data was collected in three years 2015, 2018 and 2021, locations of these sampling was rectified to UTM (Universal transverse Mercator) as shown in Figure (2). The depth of these field soil samples is up to 0.5 m. Number of soil samples is 69 at depths 0-50 cm. sampling was carried in accord with uniformly distribution in the study area as shown in Figure 2. The field measurements and sampling analysis were carried out by the Drainage Research Institute (DRI) of National Water Research center (NWRC) in Egypt.

Figure 2: locations of soil sampling sites.

Laboratory analysis was carried to these soil samples to measure their EC with 1:2.5 soil: H_2O volumetric ratio. The EC values in this area were varying from 0.22: 10.67 ds/m-1, and from 141: 6829 ppm in terms of TDS.

3. Satellite Images Data

Landsat-8 satellite images with 30m resolution were used. The images were corrected and rectified to UTM zone 36 (Universal Transverse Mercator) coordinate system. The used images were acquired in 15 Dec 2015, 22 Feb 2018 and 18 Mar 2021 for the study area. These images were downloaded from USGS (United States Geological Survey) website with clouds coverage less than 10% as shown in Figure 3 in sequence.

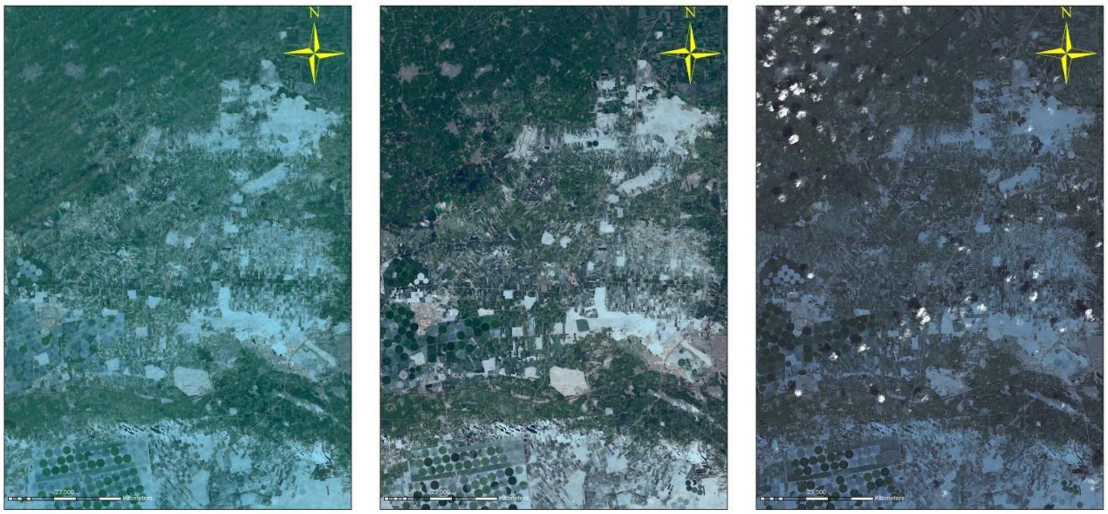


Figure 3: Study area Landsat-8 reduced images from USGS website.

3. Methodology

The methodology used is divided to 3 stages (preprocessing of both augers map and Landsat image, processing of data, and post processing) as shown in Figure 4.

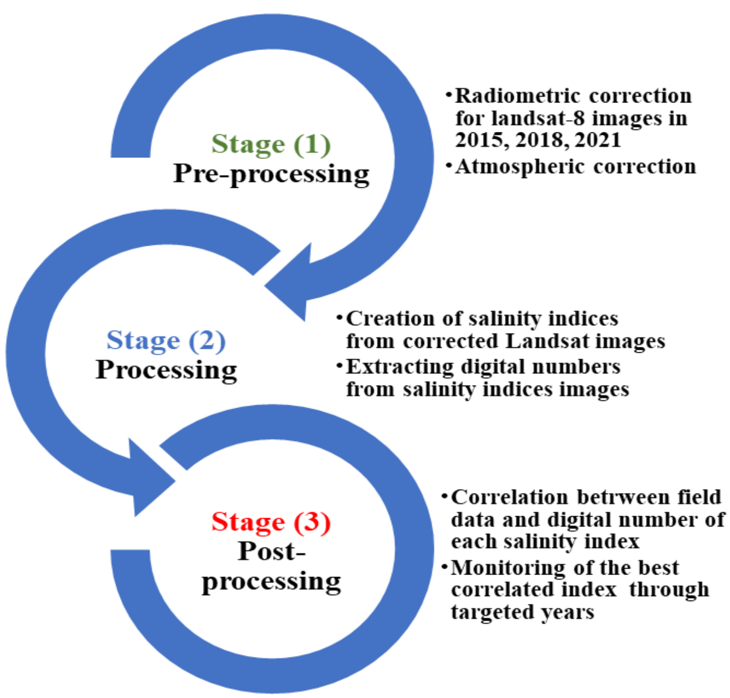


Figure 4: Methodology diagram.

1. Preprocessing of Data (stage 1)

Step 1: Preprocessing of Soil Augers Map

Shape file was made for augers using Arc map, then that shape file was exported to ERDAS IMAGINE software for image analysis.

Step 2: Preprocessing of Landsat Image

Landsat images downloaded require radiometric and atmospheric corrections. Radiometric correction must be done for Landsat images for reduction of error ratio. The atmospheric and topographic correction are important processes to get the correct land cover reflectance for images in 2015, 2018 and 2021 on sequence which were used for processing is shown in Figure 5.

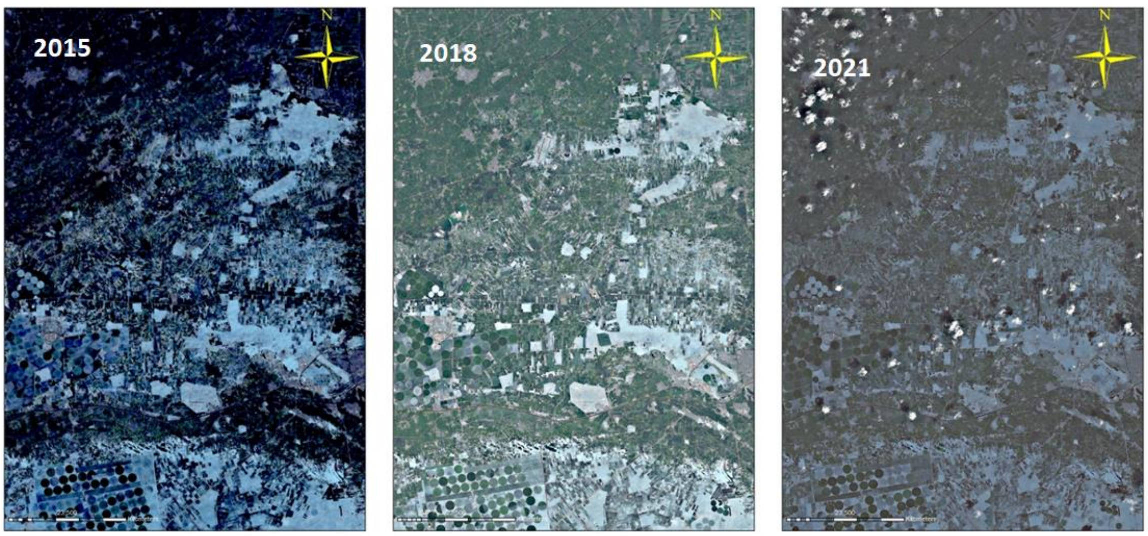


Figure 5: the study area Landsat image after radiometric and atmospheric correction.

2. Processing of image (stage 2)

The spatial modular of ERDAS imagine software was used to determine the salinity indices (Table 2) from corrected Landsat satellite images. These indices depend on the correlation between DNs (Digital Numbers) of bands combination and field measured EC records. The field truth data were compared with the of the spectral salinity, as there is correlation between salinity indices DN and EC of the soil (Alavi et al., 2001, Abbas et al., 2007, Tran et al., 2018). The assessment of the spectral salinity indices was carried out to detect the best representative salinity index for the study area.

Table 1: Spectral salinity indices

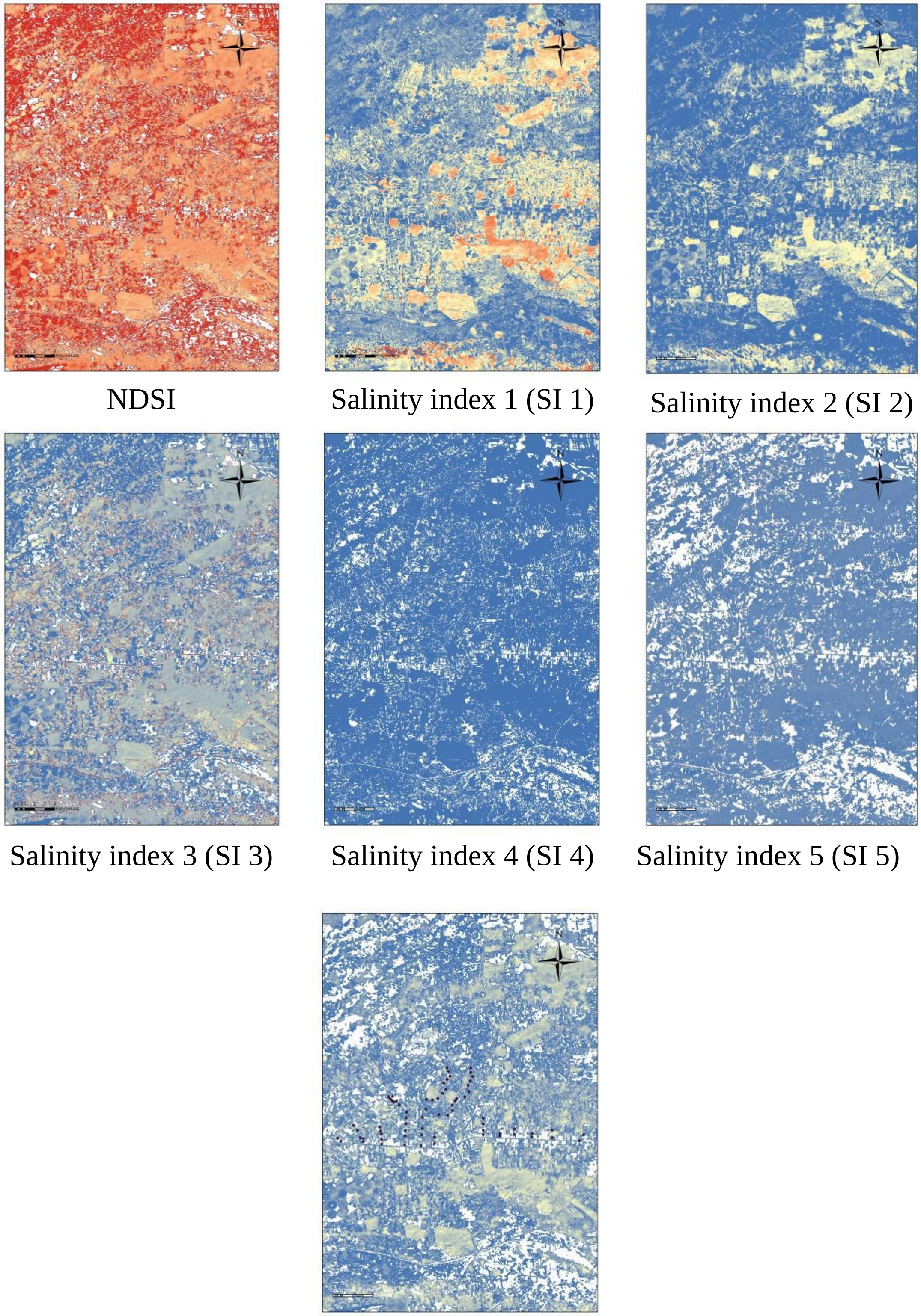
Index	Reference
Normalized difference salinity index (NDSI) $= \frac{R-NIR}{R+NIR}$	(Khan et al. 2001)
Salinity index 1 (SI1)= $\sqrt{G * R}$	(Abd El kader et al. 2006)
Salinity index 2 (SI2)= $\sqrt{B * R}$	(Khan et al. 2001)
Salinity index 3 (SI3) = $\frac{B-R}{B+R}$	(Bannari et al. 2008)
Salinity index 4 (SI4)= $\frac{NIR}{R}$	(Major et al . 2015)
Salinity index 5 (SI5)= $\frac{R*NIR}{G}$	(Abbas et al . 2007)
Salinity index 6 (SI6)= $\frac{B*R}{G}$	(Abbas et al .2007)

1. Post processing (stage 3)

Salinity indices deduced from the digital number values of Landsat image 2015 were correlated to the field data of TDS. SLR (simple linear regression) was calculated to determine the best representative index as shown in table 2. These salinity indices were validated on the data of Landsat images for 2018 and 2021 to improve its accuracy as shown in Figure 7.

2. **Table 2: Spectral salinity indices correlation with field data of EC**

Index	Correlation of index with 2015 salinity data	Correlation of index with 2018 salinity data	Correlation of index with 2021 salinity data
$NDSI = \frac{R - NIR}{R + NIR}$	0.005	0.191	0.075
SI1= $\sqrt{G * R}$	-0.128	0.312	0.488
SI2= $\sqrt{B * R}$	0.668	0.888	0.807
SI3 = $\frac{B-R}{B+R}$	0.133	0.128	0.297
SI4= $\frac{NIR}{R}$	-0.111	0.174	0.037
SI5= $\frac{R*NIR}{G}$	-0.001	-0.077	0.251
SI6= $\frac{R*B}{G}$	-0.118	-0.164	0.313



NDSI

Salinity index 1 (SI 1)

Salinity index 2 (SI 2)

Salinity index 3 (SI 3)

Salinity index 4 (SI 4)

Salinity index 5 (SI 5)

Salinity index 6 (SI 6)

Figure 6: salinity indices images.

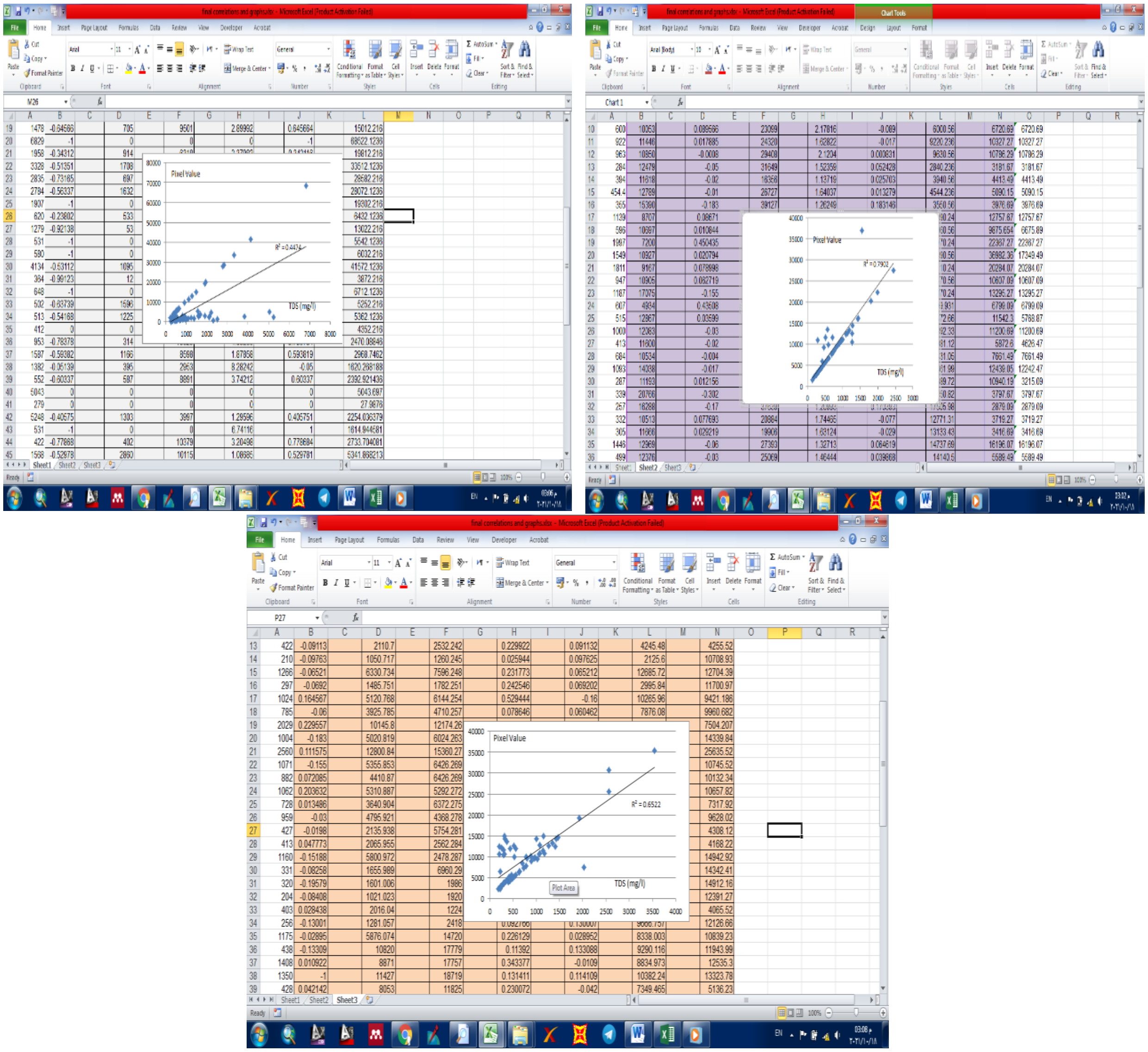


Figure 7: Correlations between best salinity index and TDS

3. Discussion and Results

Several studies proved that there is a high correlation between reflectance of the soil and its properties such as, content of moisture, soil minerals composition, soil color, and the content of salt (Abdou et al. 2008). This was proved by the methodology adopted in this research as salinity index SI2= $\sqrt{B * R}$ proved good correlation with field truth data of total dissolved salts through the study years compared to other remaining salinity indices as shown in Figure 7 and Table 2.

4. Conclusion

The process of salinity mapping and monitoring for soils which are affected by salinity are so exhausting due to the dynamicity of salinization. Remote sensing is a strong tool to detect the soil salinity in accord with salinity field data samples. The correlation between measured soil salinity and salinity indices in this research showed that best index was SI2 with best significant correlation and R2. This index performed a good correlation continuously in the other two years in 2018 and 2021. The used methodology enabled to to map and monitore soil salinity without avoiding the cost and effort spent in traditional field measurements. It is recommended to depend on this approach in the future research studies which enable the decision-makers to develop effective, cheap and accurate method to detect the soil salinity.

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