Journal of Al-Azhar University Engineering Sector

Vol.17, No. 65, October 2022, 1143-1156

ESTIMATING SALINITY USING REMOTE SENSING DATA

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Received :15 June 2022 Accepted:21 July 2022

ABSTRACT

Remote sensing data has proved to be an effective method of estimating soil salinity in land cover. Remote sensing data is used in soil salinity studies as it is quick and useful for making soil changes predictions. Soil salinity causes many problems for agriculture as it has bad effects on water absorption of the plants, which results in yield reduction. This study was conducted in El-Sheikh Zayed city in Giza governorate in Egypt, to understand the correlation between field truth data of soil salinity in terms of TDS (Total Dissolved Salts) and soil salinization indices. In this study, a Landsat-7 image taken in October 2009 was used after radiometric and atmospheric corrections. SLR (Simple Linear Regression) was applied between truth data and salinization indices. The best representative index for the study area was SI6, which achieved a correlation 0.78 and the minimum value of RMSE (Root Mean Square Error). This approach enables precise monitoring of the spatial distribution of soil salinity, especially in the reclaimed areas, by the combination of remotely sensed data, GIS, and field truth data.

Keywords: Soil salinity, TDS, salinization indices, GIS, and remote sensing.

حساب الملوحة بإستخدام بيانات الإستشعار عن بعد

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الملخص :

بيانات الإستشعار عن بعد قد أثبتت فعالية كبيرة كمصدر لحساب الملوحة التى تحدث فى الغطاء الأرضى. بيانات الإستشعار عن بعد تستخدم فى دراسات ملوحة التربة حيث أنها تتميز بالسرعة ومفيدة فى عمل تنبوءات التغيرات التى تحدث فى ملوحة التربة. ملوحة التربة تسبب العديد من المشاكل للأرض الزراعية حيث تؤثر على قدرة إمتصاص النبات للمياه والذى بدوره سيؤدى إلى نقص إنتاجية المحصول من الأرض الزراعية. تم

عمل هذه الدراسة فى منطقة الشيخ الزايد فى محافظة الجيزة بجمهورية مصر العربية, للوصول لمدى الإرتباط بين القياسات الحقلية للملوحة معبرا عنها بالأملاح الذائبة الكلية ومعادلات الملوحة الخاصة بالتربة. فى هذا البحث تم إستخدام صورة القمر الصناعى الأمريكى (لاندسات-٧) التى تم إلتقاطها فى أكتوبر ٢٠٠٩ بعد عمل التصحيحات الإشعاعية والمناخية. بإستخدام تحليل الإنحدار على كلا من القياسات الحقلية ومعادلات الملوحة تم الوصول إلى أن (معامل الملوحة رقم٦) حقق أعلى قيمة إرتباط تساوى ٠,٧٨ وأقل قيمة جذر متوسط المربعات. هذا الإستنتاج يمكننا من مراقبة ملوحة التربة خاصة فى المناطق المستهدفة للإستصلاح بإستخدام بيانات الأقمار الصناعية ونظم المعلومات الجغرافية والقياسات الحقلية للملوحة.

الكلمات المفتاحية : ملوحة التربة, المجموع الكلى للأملاح المذابة, معاملات الملوحة, نظم المعلومات الجغرافية, الإستشعار عن بعد.

1. INTRODUCTION

Egypt's development program to reclaim the desert faces many challenges soil salinity is one of them. Soil salinization in Egypt causes losses in cultivated areas, which Egypt urgently needs to meet the increasing food demand of its increasing population. Soil salinity hazards not only affect agriculture but also affect infrastructures such as roads, dams, and water pipes. Soil salinity is the process when soluble salts enrich the soil, and it is becoming a serious issue in the agricultural society [1]. Soil salinity reduces the productivity of the land all over the world [2]. More than 76 million hectares all over the world are affected by soil salinity [3]. The increased salinization of the soil and groundwater are considered major problems that have bad effects on the agricultural society. Egypt is suffering from the increasing population, so the cultivated land is a matter of survival that must be protected. Soil salinity monitoring and tracking is vital to adjust management processes and undertake suitable reclamation programs. Remote sensing data proved a good and accepted efficiency in the field of soil properties changes. Satellite data has been used for mapping and detecting salt-affected soils using different techniques such as a combination of physiographic maps and spectral classification [4]. Remote sensing and GIS have boosted the capability of mapping soil salinity. This paper aims to develop a model that integrates soil salinity measured in the field with old methods with remotely sensed data from satellite images, especially Landsat-7. Studies proved that the usage of band ratios of visible to near-infrared and between infrared bands led to better detection of salt-affected soils and salt-affected crops [5]. Remote sensing is very sensitive in soil salinity detection when the depth is less than 70 cm. So the used soil samples were at a depth between 0-50 cm from the ground surface.

2. STUDY AREA AND DATA

2.1 Description of the Investigated Area

The study area is located in Giza governorate in Egypt, and it is bounded by longitudes 30°56' E and 31°10.5' E and latitudes 30°1' N and 30°5' N as shown in **Fig.1**.

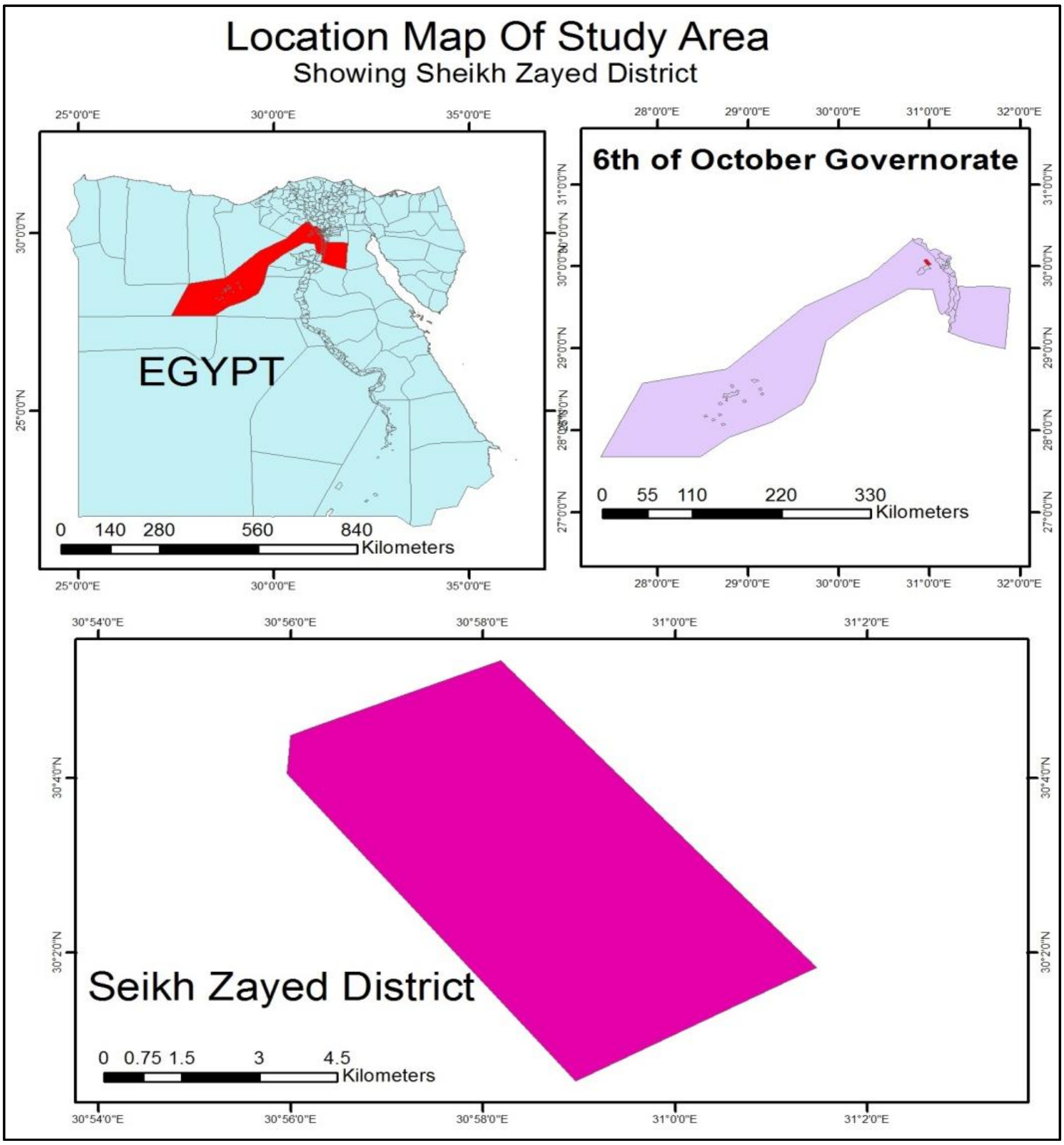


Fig.1: Study area of El-Sheikh Zayed.

The study area has an arid climate during field surveying, which was conducted in October 2009. The temperature of the area was 36°C and the humidity was 48%. The average temperature for the month was 35°C, the average humidity for the month was 42%, and there was no rainfall. The soil texture varies from sand to rock.

2.2 Ground Truth Data

Fieldwork for salinity measuring of the soil was performed in the period from 8 October to 19 October 2009 by Horema soil investigation lab, which was directed by the Engineering Consultant Group (ECG) for the Palm Hills project in El-Sheikh Zayed district in Giza governorate. Nine samples of soil were taken with depths between 0 and 50 cm. These samples were performed at approximately equal intervals; these soil locations were GPS control points as shown in **Fig. 2**.

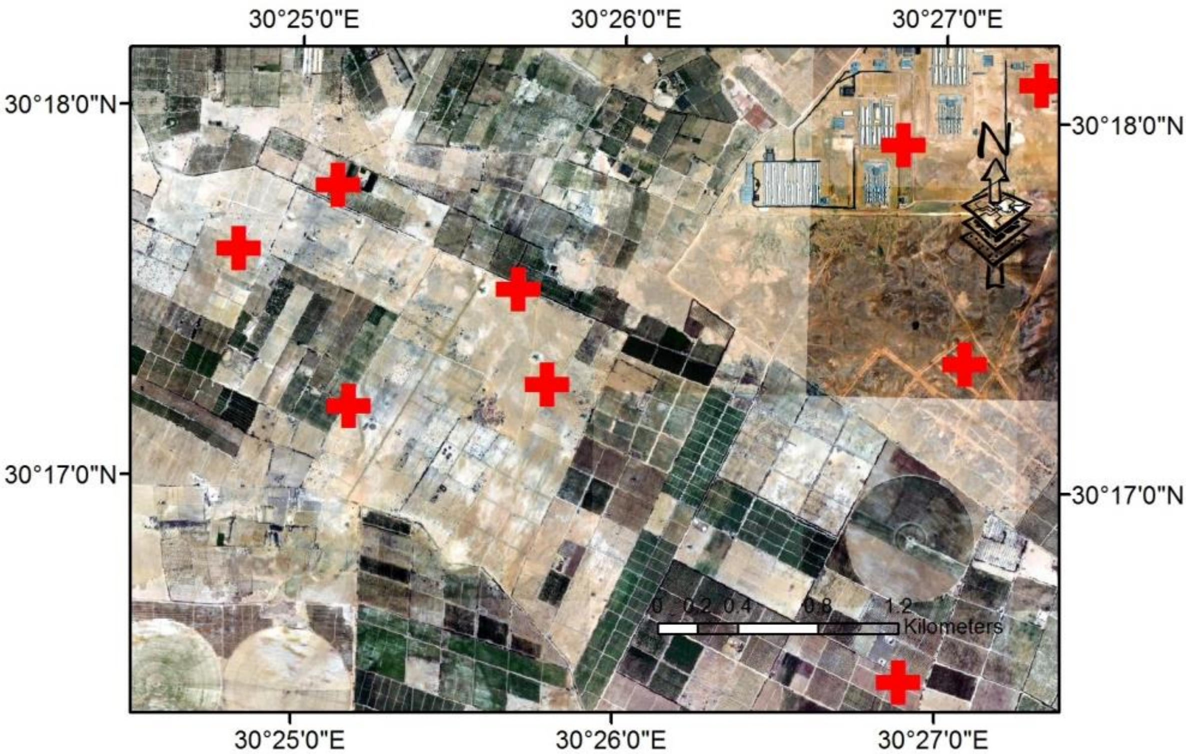


Fig. 2: GPS Locations of the soil samples.

Each sample of soil was dried in the air and sieved using a 2-mm sieve to release bigger rock soil particles, then saved in a bag made from plastic until the analysis to ensure their water content. The soil salinity of samples was determined in the laboratory in terms of TDS (total dissolved salts).

2.3 Satellite Data

Landsat-7TM (Thematic Mapper) with band specifications shown in **Table 1** was used.

Table 1: Landsat-7 band specifications.

BANDS	Wavelength (µm)	Spatial resolution (m)
Band 1 (Blue)	0.45-0.52	30
Band 2 (Green)	0.52-0.6	30
Band 3 (Red)	0.63-0.69	30
Band 4 (NIR)	0.76-0.9	30
Band 5 (SWIR-1)	1.55-1.75	30
Band 6 (Thermal)	10.4-12.5	120
Band 7 (SWIR-2)	2.08-2.35	30
Band 8 (Panchromatic)	0.52-0.9	15

The image was referenced to UTM (Universal Transverse Mercator) and to coordinate system WGS84 (World Geodetic System) 1984 assigned to zone 36 North, Row 39, and path 177. The image on 10 October 2009 was downloaded from the USGS website (United States Geological Survey) (http://earthexplorer.usgs.gov/). The downloaded image had clouds of less than 10%, as shown in **Fig. 3**.

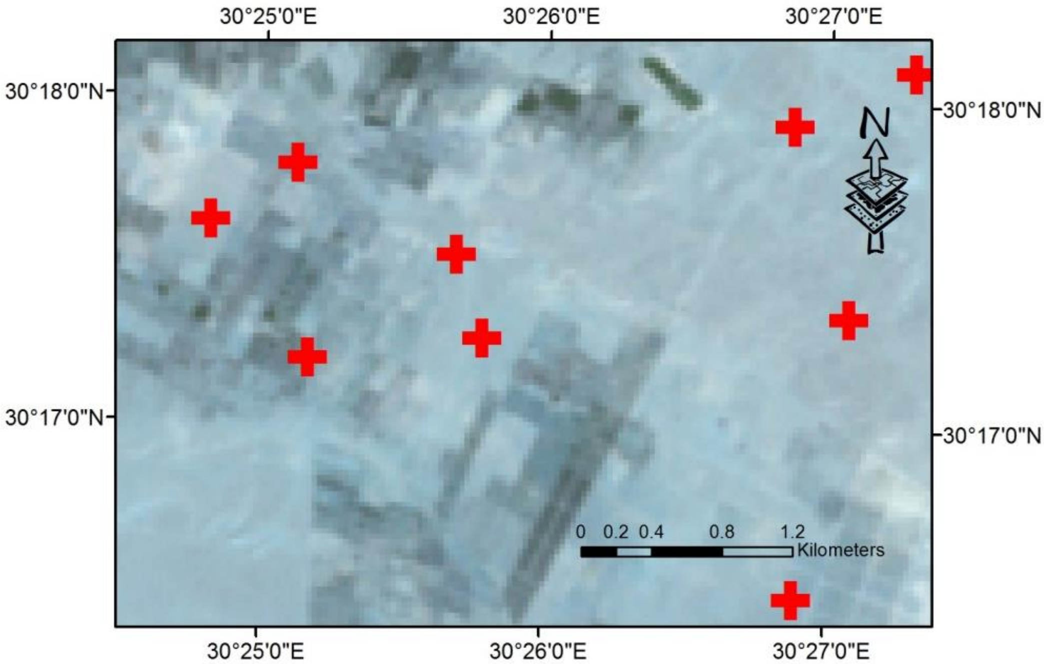


Fig. 3: study area landsat image from USGS.

3. METHODOLGOY

Three main stages express the methodology adopted in the research. The preprocessing of data, processing of data, and post-processing are as shown in **Fig .4** and subsection followed.

3.1 Preprocessing of Data (stage 1)

Step 1: Preprocessing of Soil Augers Map

At first, the soil locations obtained from the ECG company report were imported to GIS software, and then rectified to WGS84 datum and Zone 36 North UTM, and then a shape file for points was made. The ERDAS IMAGINE software was used to export the shape file.

Step 2: Preprocessing of the Landsat Image

Landsat images must be radiometrically and atmospherically corrected

- Radiometric Correction

Radiometric correction must be made for Landsat images to reduce digital number errors; this step was done using ERDAS software

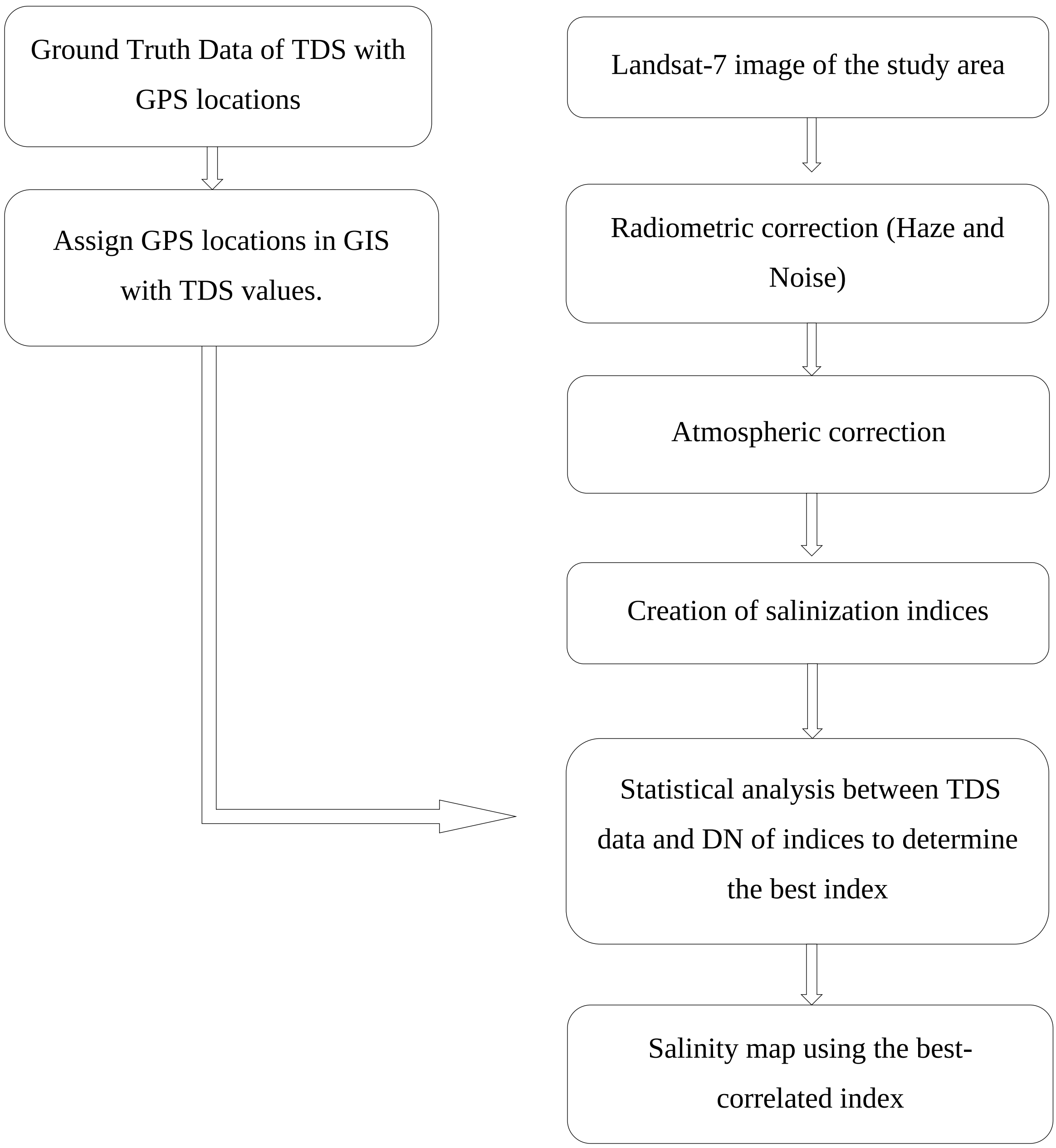


Fig .4: Flow chart of used methodology.

- Atmospheric Correction

Atmospheric correction is the most important part of satellite image preprocessing to get the corrected true reflectance by removing the solar effect. ATCOR-3 (Atmospheric and Topographic Correction) was used as it is very accurate in atmospheric correction [6]. The image after corrections is shown in **Fig. 5**.

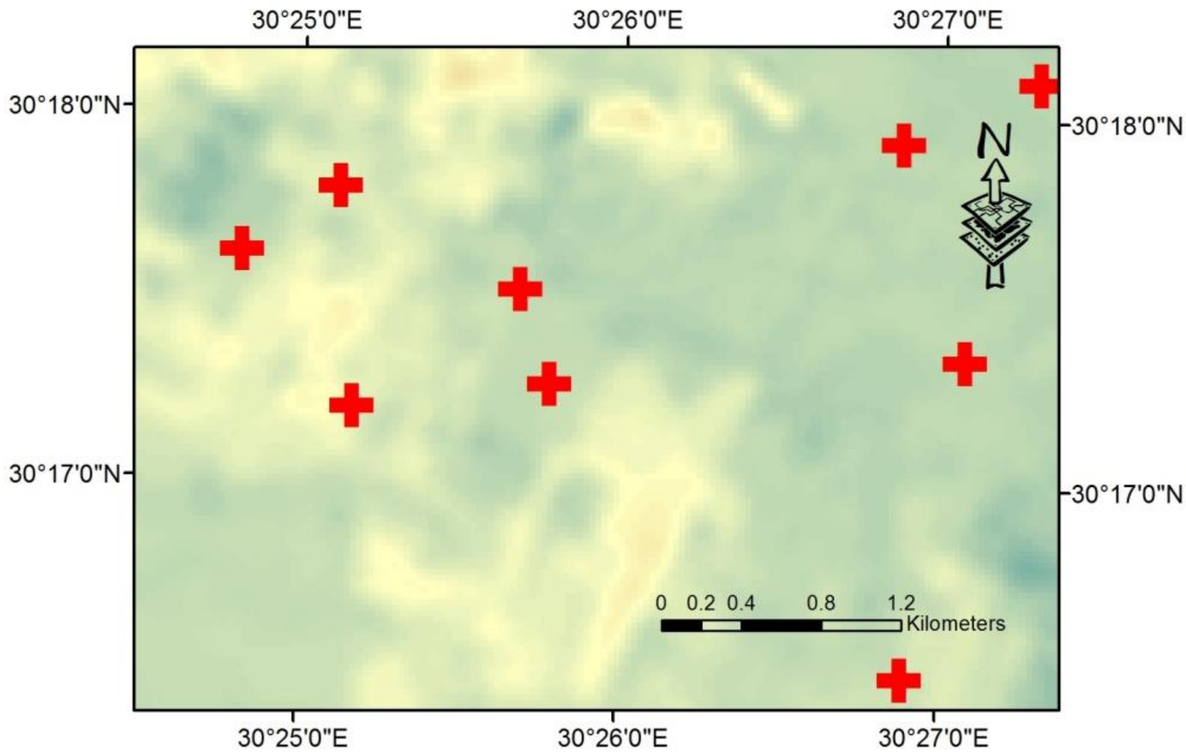


Fig. 5: Satellite image after corrections.

3.2 Processing of image (stage 2)

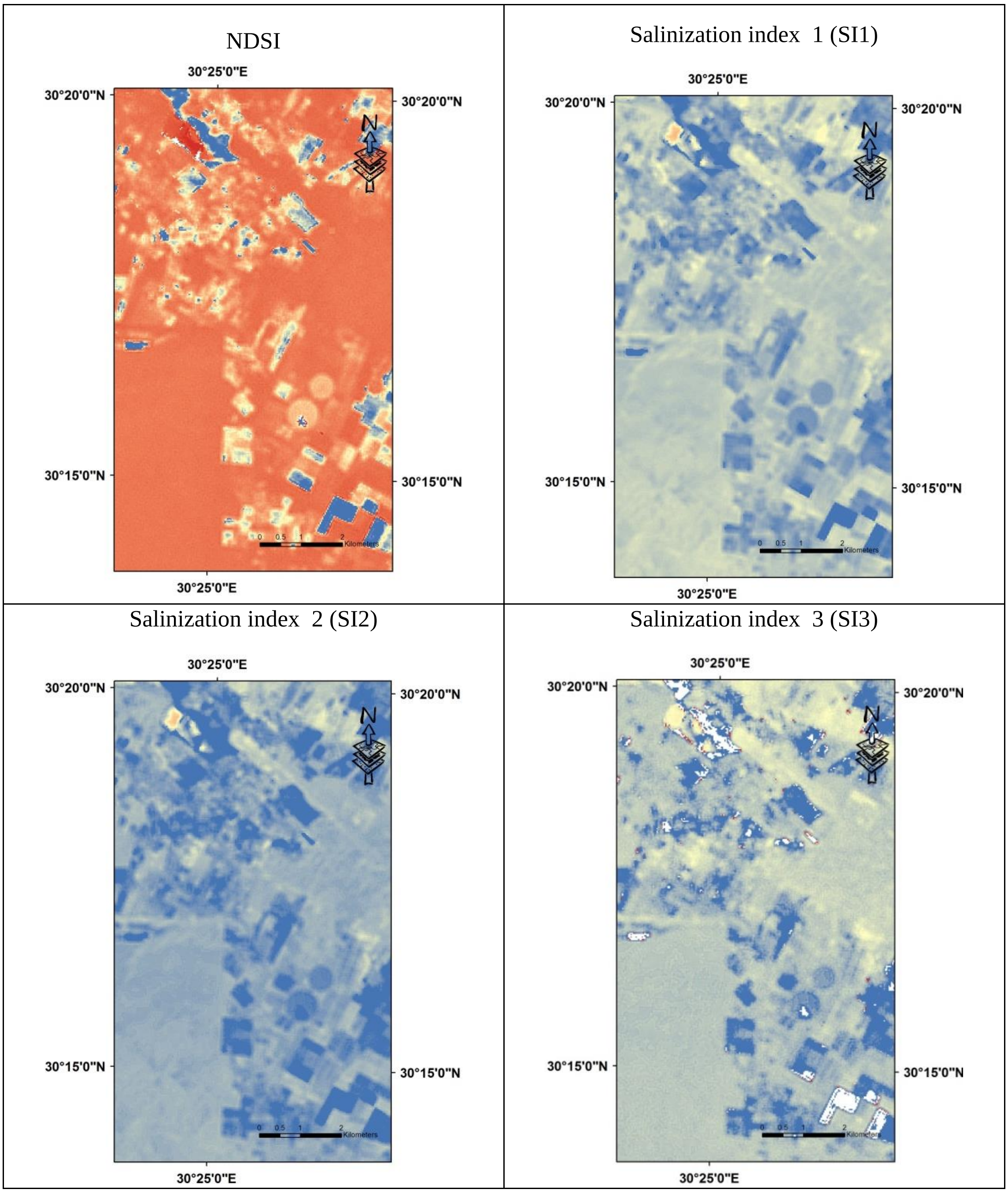
After correcting the Landsat image, seven popular spectral salinization indices in **Table 2** were created using spatial modular in the ERDAS software.

Table 2: Salinization indices adopted in the research.

Index	Reference
Normalized difference salinity index (NDSI) $= \frac{\mathbf{R-NIR}}{\mathbf{R+NIR}}$	[7]
Salinization index 1 (SI1)=$\sqrt{\mathbf{G*R}}$	[8]
Salinization index 1 (SI2)=$\sqrt{\mathbf{B*R}}$	[7]
Salinization index 1 (SI3) =$\frac{\mathbf{B-R}}{\mathbf{B+R}}$	[9]
Salinization index 1 (SI4)=$\frac{\boldsymbol{NIR}}{\boldsymbol{R}}$	[10]
Salinization index 1 (SI5)=$\frac{\boldsymbol{R*NIR}}{\boldsymbol{G}}$	[11]
Salinization index 6 (SI6)=$\frac{\boldsymbol{B*R}}{\boldsymbol{G}}$	[11]

3.3 Post-processing (stage 3)

The salinity values for points were compared with corresponding digital numbers for each salinization index, as there is a good correlation between salinization indices and salinity values in the El-Behira governorate in Egypt [12]. Many previous types of research proved that there is a correlation between spectral salinization indices and the salinity of soil [11,13], and [14]. An assessment process took place to find the best correlated salinization index for the study area. Salinization indices images shown in **Fig. 6** were produced and the digital numbers were extracted from GIS software to make a statistical comparison between soil salinity and digital numbers. R^2 (coefficient of determination) using SLR (simple linear regression) and RMSE (root mean square error) for the nine percentages were calculated as follows: $RMSE\% = \sqrt{\frac{\sum_{i=1}^{9}(perdicted\ percentage - actual\ percentage)^\wedge 2}{8}}$, as shown in **Table 3** and **Fig. 7**.


NDSI
Salinization index 1 (SI1)
Salinization index 2 (SI2)
Salinization index 3 (SI3)
30°25'0"E
30°20'0"N
30°15'0"N
N
0 0.5 1 2
Kilometers

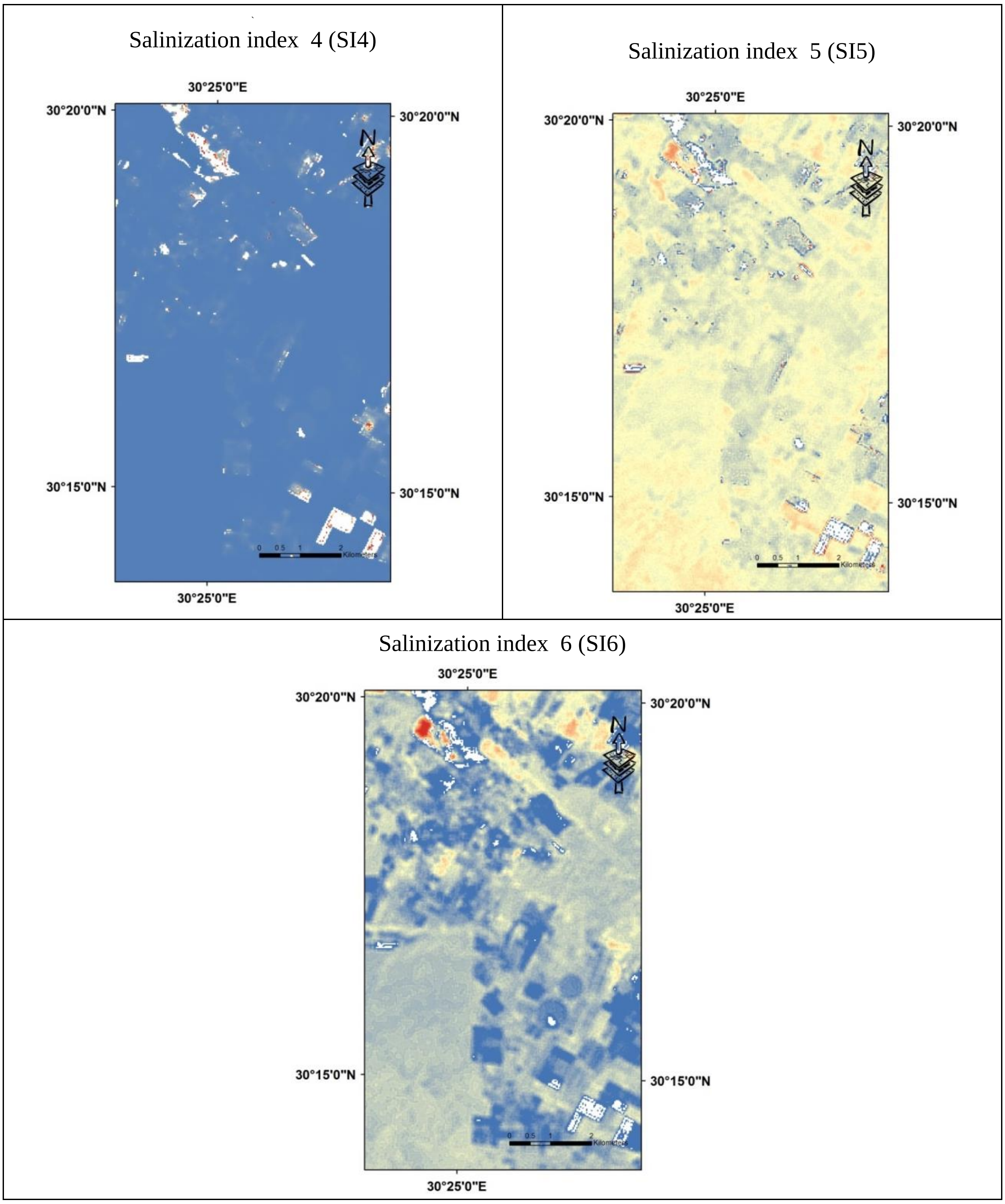


Fig. 6: Images of Salinity indices.

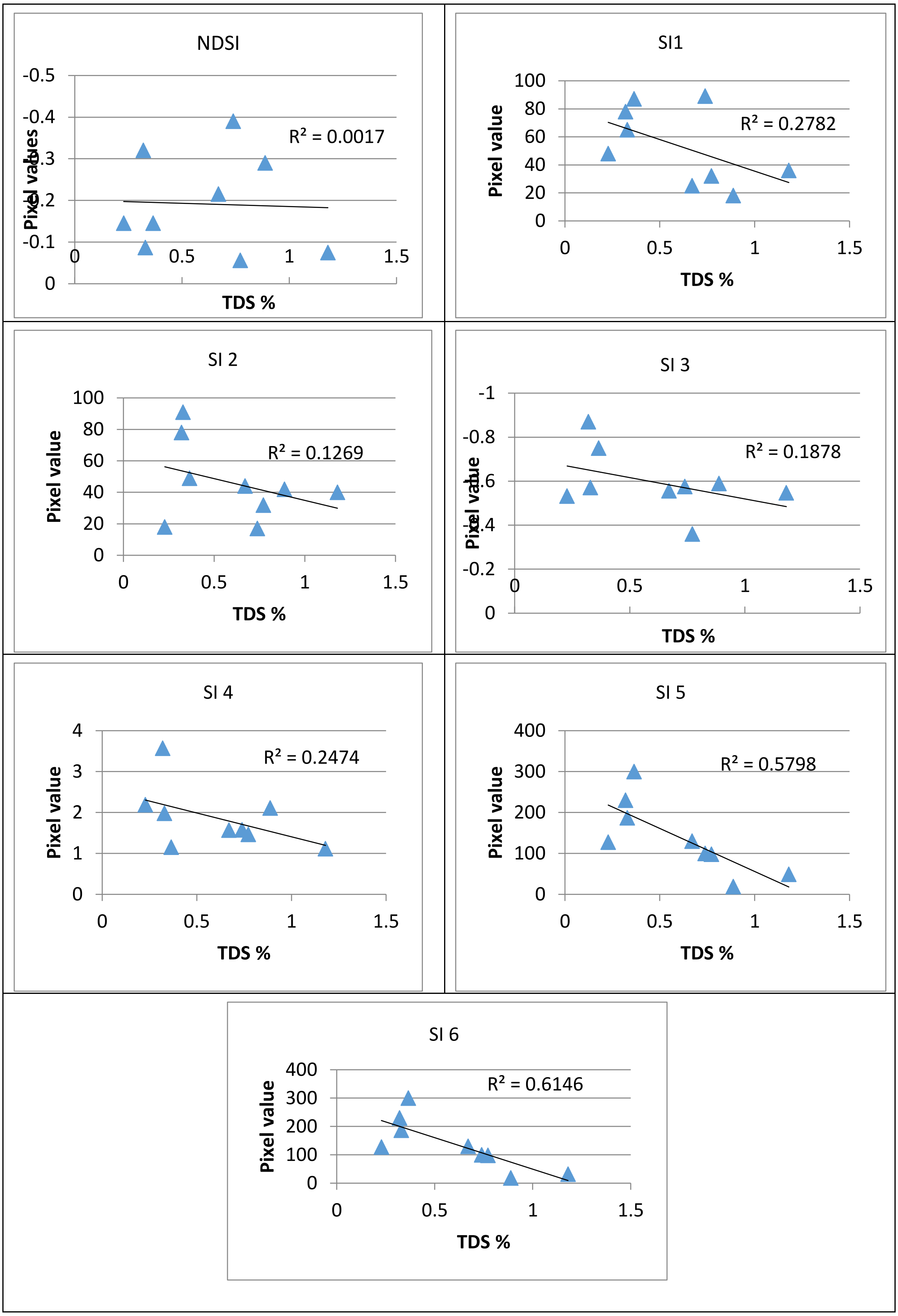


Fig. 7: Field salinity vs spectral salinization indices.

Table 3: Spectral salinization indices correlation, R^2, and RMSE with field data of TDS.

Index	Correlation	R^2	RMSE %
NDSI	0.042	0.001	0.301
SI1	-0.523	0.278	0.256
SI2	-0.35	0.127	0.281
SI3	-0.43	0.189	0.271
SI4	-0.49	0.247	0.261
SI5	-0.76	0.580	0.196
SI6	-0.78	0.614	0.187

4. DISCUSSION AND RESULTS

Results proved that there is a high correlation between salinity indices and soil salinity. This concurs with approach which showed that reflectance of the soil is highly correlated with soil properties such as water content, mineral composition, color, and salt content [15]. Results gotten by using SLR (simple regression analysis) led to determining the correlation of spectral salinization indices with the measured TDS. SI5 and SI6 had a highly acceptable correlation with soil salinity data. This concurs with results gotten by [16-20], etc., who proved that salinization indices can express soil salinity with a high correlation. The spectral salinization index (SI6) $= \frac{R*B}{G}$ had the best correlation value with field measurements equal to 0.78 and the lowest RMSE value equal to 18.72% compared to other salinization indices as shown in **Table 3** and **Fig. 7**. The best-fit equation is y=-0.0028x + 0.9863, where y values represent salinity in TDS% and x values represent the DN for the point.

5. CONCLUSIONS

Old methods for measuring soil salinity are costly and time-consuming. For its synoptic coverage, remote sensing data was used as it has a high sensitivity to soil parameters such as soil salts. This research approach proved that soil salinity can be measured in less time with about no cost by remotely sensed data, as there is an acceptable correlation with salinization index SI5 and SI6 with values equal to 0.76, 0.78, and values of RMSE equal to 19.55% and 18.72%, while NDSI and SI2 had the lowest correlation with values equal 0.042, 0.35 and the highest RMSE with values equal to 30.1% and 28.16%. That approach can led to mapping soil salinity with salinity indices without traditional methods. Thus, it is recommended to use remote sensing techniques to make effective solutions to face or deal with increases in soil salinity in the future. It is also recommended to make other trials of applying salinity indices in other study areas.

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