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Change on detection of vegetation cover and soil salinity using GIS technique in Diyala Governorate, Iraq

Key words: differencing image, normalized difference, vegetation index (*NDVI*), salinity index (*SI*), GIS, Iraq

Introduction

Salinization is a serious environmental risk and is the main factor leading to land degradation and desertification. Soil surface salinity occurs as a result of superfluous irrigation and increased agricultural vitality (Machado & Serralheiro, 2017). As a result of the irrigation process in excess of the need, this increase led to the dissolution of salts in the soil, which after the water evaporates, the salts accumulate in the ground or spread out on the surface of the earth (Rafiq, Blaschke & Ur Rehman, 2014).

Provides remote sensing by satellite, an opportunity to discover the soil affected by salinity and sediments for specific features using reflected and emitted electromagnetic energy. The spectral reflection of the salt properties studied on the soil surface was addressed and mapped. In addition, it provides an indirect indication of vegetation in order to detect soil salinity and mapping (Al-Khakani & Sa'ad, 2019). It has become possible to estimate the changes by salinity land affected by and the vegetation cover through the use of multispectral satellite imagery (Allbed & Kumar, 2013).

Saline soils can be detected in two ways. The first method is directly from the multi-spectral image bands, which can be applied through high spectral reflection in the visible and near infrared range of the electromagnetic spectrum and the second method, indirectly through changes in the state of crops and loss of agricultural productivity in the agricultural lands (Taghadosi & Hasanlou, 2017).

Rapid improvements in remote sensing technologies in recent decades through integration with the geographic information system (GIS), greatly enable assessment and mapping of salinity processes, and thus are considered the most beneficial economic methods (Azabdaftari & Sunarb, 2016). Many vegetation indices are using in several studies, such as the normalized difference vegetation index (*NDVI*), the enhanced vegetation index (*EVI*), and the soil adjusted vegetation index (*SAVI*). The *NDVI* is the index most common assessment and control of differences in vegetation cover (Ke, Im, Lee, Gong & Ryu, 2015).

In this paper, image differencing technology was used to generate a difference image in order to capture changes in the study area. This study aimed to develop an effective change detection method for assessing vegetation change and soil salinity in measured the *NDVI* and the *SI* values, to estimate the relationship between the *NDVI* and the *SI*. In order to know the damages caused by increasing salinity, which have a great role in reducing the economic losses caused by increased salinity in Diyala Governorate.

Material and methods

Study area and data acquisition

Diyala Governorate is located in the central part of eastern Iraq, which is located at latitude (33°46′23″ N) and longitude (45°08′58″ E) and covers an area of about 17,685 km^2 as shown in Figure 1. It is bordered to the northeast by Sulaymaniyah Governorate, to the west by Salahuddin, to the east by Iran, to the south by Baghdad Governorate, and to the southeast by Wasit Governorate. Diyala Province differs from other provinces of Iraq, as it is located within two different regions, the northeastern part is located within the semi-mountainous region, the southern and southwestern part, located within the sedimentary region, so it has climatic properties that combine the characteristics of the arid and semi--arid regions. This location makes Diyala climate transitional between the desert climate and the Mediterranean climate,

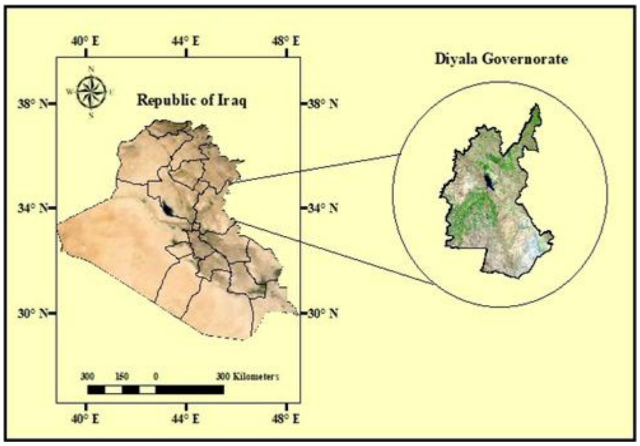

FIGURE 1. The geographical location of the study area (Diyala)

which is a continental climate characterized by drought and high temperatures in summer exceed 40°C and low with little rainfall in winter (Hussein, 2019).

The four images of Landsat, which path was 168 and row was 37, have been downloaded from the U.S. Geological Survey server (www.earthexplorer.com). The first image was Landsat 5 thematic mapper acquired on 14 March 2005, the second image was acquired on 29 April 2010, the third image was in 27 April 2015, while the fourth image was taken in 23 March 2020. The preprocessing of the images included geometric corrections. All images were geographically corrected to Universal Transverse Mercator (UTM) coordinate system utilizing the World Geodetic System (WGS) 1984 datum, Zone 38 by using ArcGIS 10.4 software. Including atmospheric correction for cloud pixel removal, and engineering data correction, while Excel 2010 software was used to achieve the Pearson correlation relationship between vegetation and salinity.

Differencing images technique

The change in the studied area can be detected using the image differences technique. Subtracting pixel values to the same position as two pictures includes two different time periods (Tan & Hao, 2017). The two images recorded jointly are compared to pixels, and pixels that indicate changing areas produce values that are distinctly different from those pixels accompanying regions that have not changed (Al-Khakani & Sa'ad, 2019). Mathematically, the image variation can be represented as follows:

$$ID = I(T_1) - I(T_2) \quad (1)$$

Where ID represents difference image and $I(T_1)$ and $I(T_2)$ represents the captured images during two different time periods. Hence, the variable images are classified into three categories. The zero value is assigned to the areas of no change, and value range from 1 to –1 for the areas of increase and decrease, respectively.

The normalized difference vegetation index

The vegetation indicators are a great way to detect changes in land use by interpreting remote sensing images in multiple time data and assessing the density of vegetation (Al-Doski, Mansor & Shafri, 2013). In general, it is calculated as a ratio of the red and the NIR bands depending on the type of sensor, and is characterized by the following equation:

$$NDVI = \frac{NIR - R}{NIR + R} \quad (2)$$

Vegetation are limited to values 0.1 and 1 of the $NDVI$. While non-vegetative surfaces such as water bodies, have negative $NDVI$ values according to the ability of the water to absorb energy, whereas the bare soil regions have zero values for $NDVI$, due to the high reflection in the visible parts and the NIR (Usman, Yelwa & Gulumbe, 2012). In this study, the $NDVI$ was used to monitor and evaluate changes in vegetation during the periods under study, in addition to the usage the value of the $NDVI$ difference image that was calculated by subtraction of the $NDVI$ image of the first date from the $NDVI$ image of second date as follow:

$$DNDVI = NDVI(t_1) - NDVI(t_2) \quad (3)$$

Salinity index

Among the various salinity indices, the *SI* was used to assess soil salinity based on two SWIR bands, because of the ability of these two ranges to completely distinguish in salinity areas, as follows:

$$SI = \frac{(SWIR_1 - SWIR_2)}{(SWIR_1 + SWIR_2)} \tag{4}$$

Soil salinity is calculated to enhance the spectral contribution of saline soils that cause the reduction and reduction of spectra associated with vegetation (Usman et al., 2012; Allbed & Kumar 2013; Al-Doski et al., 2013; Ke et al., 2015; Azabdaftari & Sunarb, 2016; Bannari, Guédon & El-Ghmari, 2016; Taghadosi & Hasanlou, 2017; Tan & Hao, 2017; Hussein, 2019). In the current search, the *SI* values were calculated for the different years 2005, 2010, 2015 and 2020, then the variation, the *SI* image (DSI) is calculated for the two change periods by subtracting the *SI* image for the first date from the *SI* image corresponding to the second date as shown in the following formula:

$$DSI = SI(t_1) - SI(t_2) \tag{5}$$

Positive and negative values of pixels are associated with increasing and decreasing salinity rates respectively, while zero values are indicated for salinity regions that do not change between the two change periods.

Results and discussion

Normalized difference vegetation index (*NDVI*) and salinity index (*SI*) were derived from Landsat images. Figure 2 illustrates the spatial variation of vegetation cover derived from the *NDVI* over the study area for the period 2005–2020. It can be seen that the vegetation cover varied from place to another, also from year to year in Diyala Province. The *NDVI* ranges between –0.6 and 1 in 2005, between –0.4 and 0.7 in 2010, between –0.7 and 0.5 in 2015, and also between –0.7 and 0.8 in 2020. The value more than 0.1 refers to vegetation cover, while the values from –1 to 0.1 represent the non-vegetation features as a bare surface, built-up area, and water body.

Table 1 data revealed the related statistics which included, the amount of area, and the percentage of area. The *NDVI* results showed that the vegetation cover in the year 2005, which was 10,454.796 km^2, accounted for 56% of the entire study area (17,685 km^2). On the other hand, the total coverage of the vegetation cover decreased in 2010 and 2015 to be 22% (4,066.21 km^2) and 19% (3,528.08 km^2), respectively. As for the year 2020, an increase in vegetation that cover most of Diyala regions of 41% (7,617.21 km^2) was seen.

Salinity index was applied to the TM and OLI images to extract the salinity information for the study area. Figure 3 shows the spatial variation of the soil salinity for the period from 2005 to 2020. Soil salinity analysis showed that estimated salinity lands were decreased gradually from 2005 to 2015, then it can be seen an increase in soil salinity in 2020.

Table 2 shows that area and percentage of soil salinity, in the year 2005 was 42.74% (7,940.74 km^2), while they decreased in 2010 and 2015 to be 22.5% (4,191.9 km^2) and 17.60% (3,270.1 km^2),

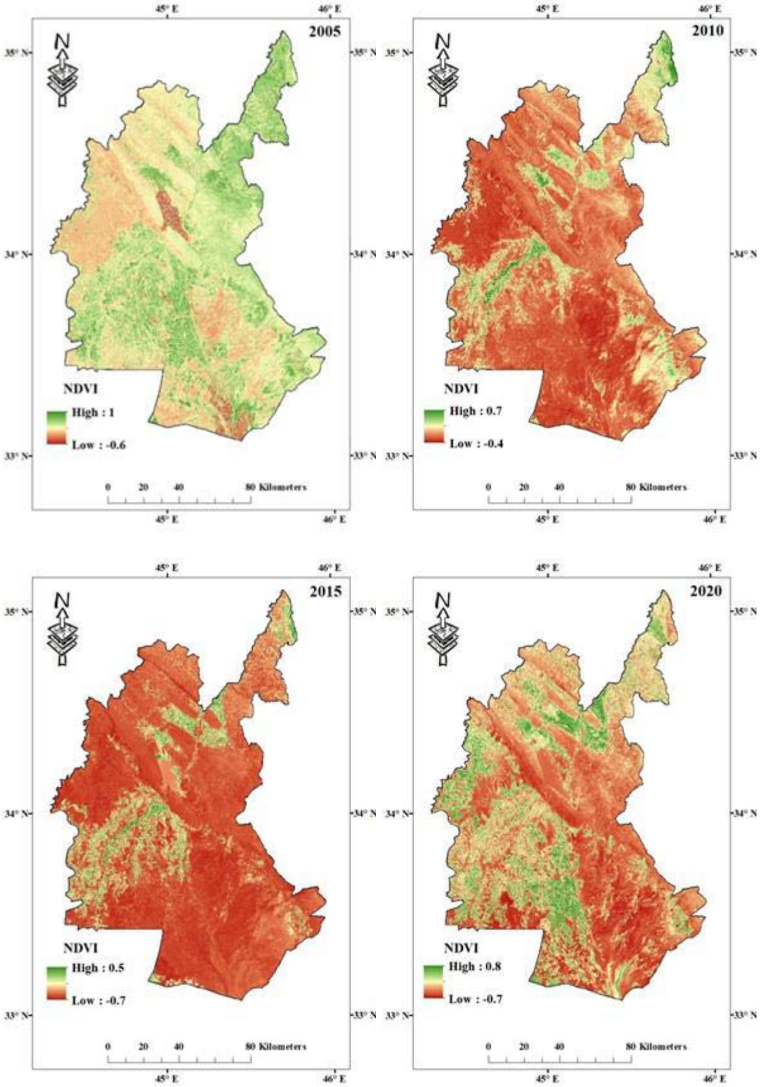

FIGURE 2. Spatial variation of the the normalized difference vegetation index based vegetation in 2005–2020 in Diyala Governorate

TABLE 1. Areas and percentages of change in the the normalized difference vegetation index values during for 2005–2020 periods

Classes	2005		2010		2015		2020	
	km	%	km	%	km	%	km	%
Non-vegetation	8 124.77	44	14 513.34	78	15 051.48	81	10 962.35	59
Vegetation	10 454.796	56	4 066.21	22	3 528.08	19	7 617.21	41

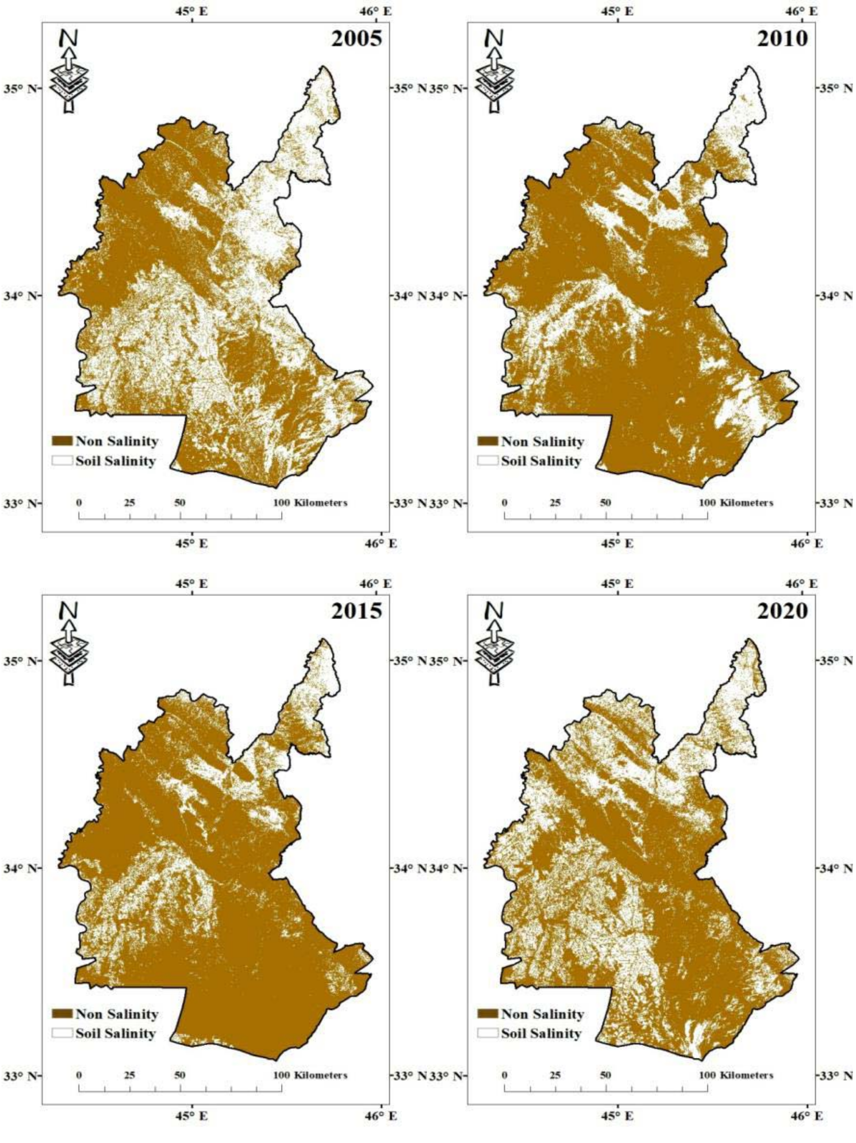

FIGURE 3. Spatial variation of the soil salinity in 2005–2020 in Diyala Governorate

TABLE 2. Areas and percentages of change in soil salinity index values during for 2005–2020 periods

Classes	2005		2010		2015		2020	
	km	%	km	%	km	%	km	%
Non-salinity	10 638.83	57.26	1 487.66	77.44	15 309.42	82.40	12 096.63	65.11
Salinity	7 940.74	42.74	4 191.90	22.56	3270.15	17.60	6 482.93	34.89

respectively. Then it can be seen an increase in coverage in soil salinity (6,482.9 km^2) about 34.89% stationed in the northwestern part of the study area in 2020. It can be seen that the highest salinity value was recorded in the year 2005 and the lowest salinity value recorded in the year 2015. Map of change detection for the *NDVI* and the *SI* illustrated in Figures 4 and 5. The change non-change maps of the DNDVI and DSI images for the change periods (2005–2010 and 2015–2020). The areas where changes occurred were displayed in red and blue to indicate the increase and decrease in vegetation or soil, respectively, while the areas that unchanged were shown in color yellow during the two study periods.

Figures 4 and 5 show a remarkable change in vegetation over a period of 20 years, mostly in the northern and southwestern regions of the study area between the two change periods. For the period 2005–2010, the increase in vegetation areas was clear in the small concentrated parts in the northern part of the study area. While, for the period 2015–2020, the increase in vegetation was more spread in the north and along the western side part of the study area. The decrease in vegetation has occurred in the southwestern and some eastern parts of Diyala Governorate for the period 2005–2020. Whereas, the decrease was mostly towards the northern part between in 2015–2020.

Table 3 summarizes the area and percentage change in the *NDVI* values between years 2005–2010 and 2015–2020. About 10% of the total study area experienced positive change that is increasing vegetation cover between 2005 and

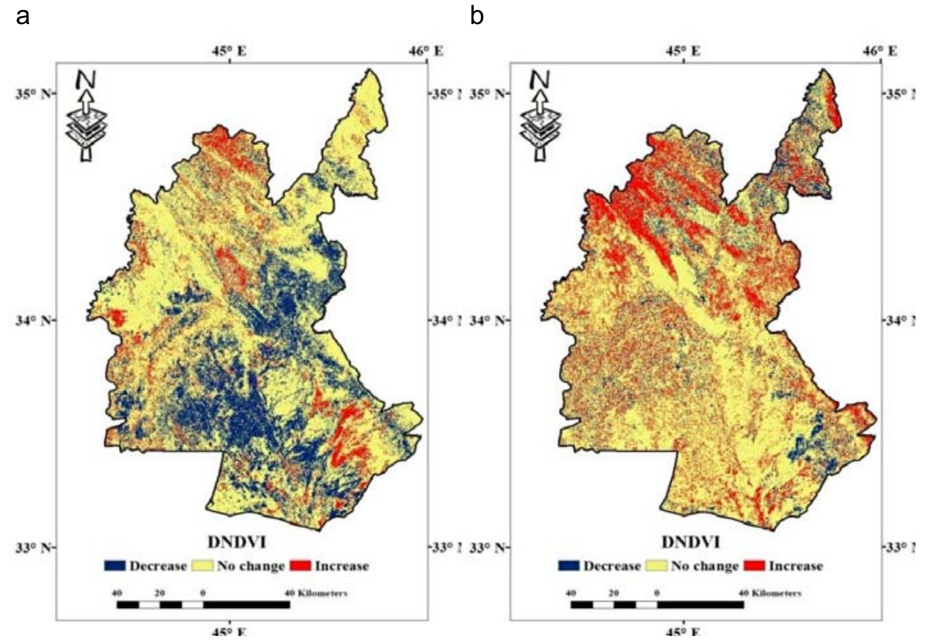

FIGURE 4. Change/no-change maps of the normalized difference vegetation index images: a – for 2005–2010 periods; b – for 2015–2020 periods

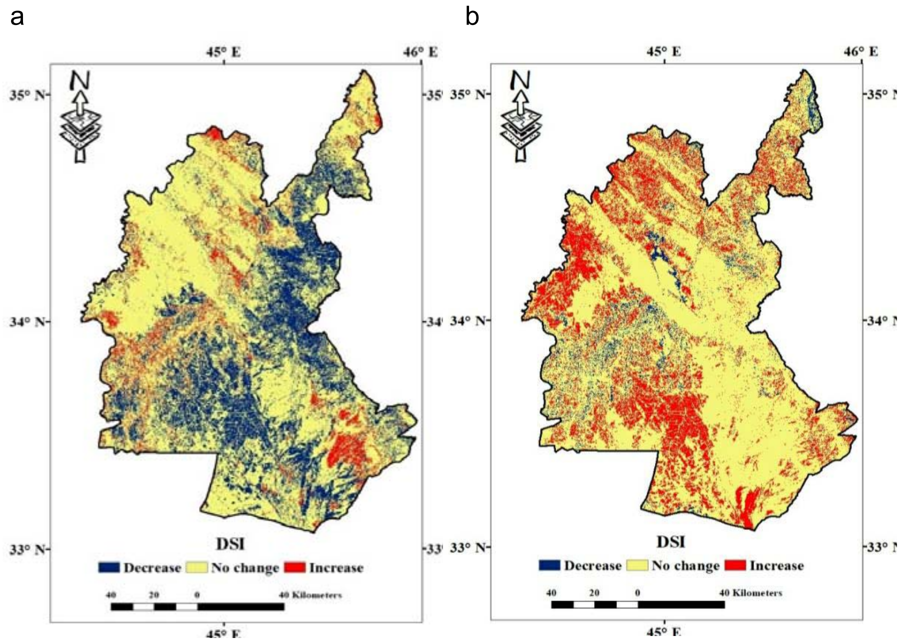

FIGURE 5. Change/no-change maps of the soil salinity index images: a – for 2005–2010 periods; b – for 2015–2020 periods

TABLE 3. Change area of the normalized difference vegetation index and the soil salinity index for the two change periods

Change classes	*NDVI*				*SI*			
	2005–2010		2015–2020		2005–2010		2015–2020	
	km	%	km	%	km	%	km	%
Change decrease	4 941.18	27	4 511.61	10	5 099	27.44	1 451	7.81
No change	11 751.85	63	12 229.18	66	12 131	65.29	12 107	65.16
Change increase	1 863.12	10	1 838.78	24	1 350	7.27	5 022	27.03

2010, whereas nearly 27% of showed negative change, that is decline in vegetation cover for the same period. However, in the 2015–2020 period, the positive changes increased to 24%, while the negative changes declined to 10%, indicating much vegetation increase during this period in the study area.

As for salinity changes, it can be observed that the period study attended a rise in saline areas from 7.2% in 2005–2010 to 27.03% in 2015–2020. It can be seen the increase in northwest and some southwestern parts of Diyala, while declining areas of salinity decreased from 27.4% in 2005–2010 to 7.8% in 2015–2020. This decrease is observed in southwestern and some eastern parts from Diyala Governorate. These results represent a significant increase in the sa-

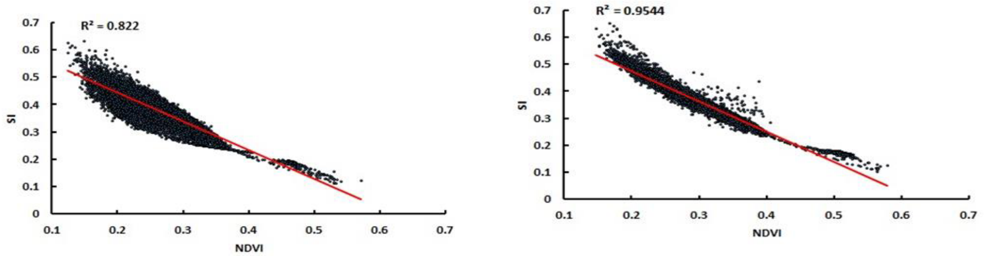

FIGURE 6. The correlation between vegetation cover and soil salinity changes in 2005–2010 change period

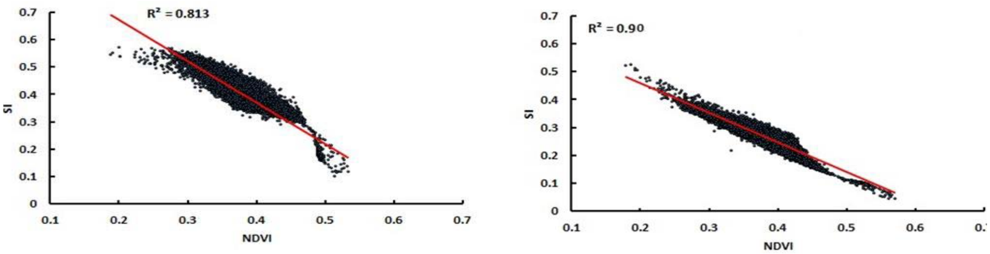

FIGURE 7. The correlation between vegetation cover and soil salinity changes in 2015–2020 change period

linity of the soil and its negative effects on plant growth. In addition to higher temperatures, the study period (2005––2015) experienced a significant decrease in rainfall levels which led to an increase in evaporation rates (Al-Khakani & Sa'ad, 2019).

This has led to a reduction in the cultivated area and hence a rise in soil salinity levels. There are several reasons for vegetation degradation, such as the reluctance of a large number of farmers' to farm and practice in other works, as well as the conversion of some agricultural land into residential areas. Consequently, the study results showed that the decrease in vegetative regions often does not coincide with the increased salinity of the soil. The relationship between soil salinity and vegetation cover change has been calculated. Figures 6 and 7 show the scatter plot between the *NDVI* and the *SI*. It can be seen that there is a high inverse correlation between the soil salinity and vegetation cover change for 2005–2010 and 2015–2020 periods. It is found the correlation coefficient between the *SI* and the *NDVI* at R^2 equal to 0.82, 0.95, 0.81 and 0.9 respectively.

Conclusions

Soil salinization is a complex process that changes over time and has adverse effects on agriculture, and so knowledge of the change in soil salinity dynamics over time and its impact on vegetation is required to help decision-makers working on the various steps needed to manage soil salinity and sustain vegetation. The purpose of this paper is to analyze the possibility of salinity mapping and vegetation cover using different soil salinity and normalized vegetation difference indicators for part of Diyala Governorate. Overall, the soil salinity level has undergone remarkable changes in the study area over the past 20 years probably due to improper land use.

The findings suggest that the satellite imagery used in detection technologies can provide sufficient information on changes in vegetation and salinity in the soil. During the study period, it was discovered that there have been a strong changes in vegetation and soil salinity. The paper results showed a strong inverse correlation between the normalized difference vegetation index and salinity index values, and this confirms that changes in vegetation have a strong correlation with changes in salinity in the soil. Overall, during the research period the study region observed significant changes in soil salinity. This may be due to the high temperature and low average rainfall which, in addition to weak irrigation system and land misuse, all of which helped change the salinity levels in the soil.

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Summary

Change on detection of vegetation cover and soil salinity using GIS technique in Diyala Governorate, Iraq. Soil salinity is one of the most important problems of land degradation, that threatening the environmental, economic and social system. The aim of this study to detect the changes in soil salinity and vegetation cover for Diyala Governorate over the period from 2005 to 2020, through the use of remote sensing techniques and geographic information system. The normalized difference vegetation index (*NDVI*) and salinity index (*SI*) were used, which were applied to four of the Landsat ETM+ and Landsat OLI satellite imagery. The results showed an increase in soil salinity from 7.27% in the period 2005–2010 to 27.03% in 2015–2020, as well as an increase in vegetation from 10% to 24% in the same period. Also the strong inverse correlation between the *NDVI* and the *SI* showed that vegetation is significantly affected and directly influenced by soil salinity changes

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