An assessment of soil salinity and vegetation cover changes for a part of An-Najaf governorate using remote sensing data

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Abstract. This paper deals with assessing and detecting the changes of soil salinity and vegetation cover for a part of An-Najaf Governorate and verification regarding the impression of soil salinity on the change of vegetative regions, over the period from 2001 to 2015. The results demonstrated a clear reduction in vegetative cover with salinity rates increased. The normalized difference vegetation index (NDVI) and Soil Salinity Index (SI) were applied for each date using the multispectral images derived from Landsat ETM+ and OLI data. Then image differencing technique was utilized to detect the change/no-change for vegetation and salinity for the two study periods. The results revealed that soil salinity increased from 6.36 in 2001-2009 period to 10.59% in 2009-2015, whereas the vegetation cover deteriorated to 9.95% for the same period. Finally, the strong inverse correlation which found in this paper between NDVI and SI emphasizes that vegetation cover on long term is heavily and directly affected by changes of soil salinity.

Key words: Change Detection, Vegetation Cover, Soil Salinity, Differencing Image, Normalized Difference Vegetation Index (NDVI), Salinity Index (SI), GIS.

1. Introduction
Soil salinity considers the most serious environmental risks that have restricted in arid and semiarid regions causing soil degradation and deterioration. Soil salinization especially occurs due to exacerbated natural and human activities at or near the surface including land clearing and excessive irrigation [1-2]. Satellite Remote sensing offers an opportunity to detect salt-affected soils and deposits of specific features using electromagnetic energy reflected and emitted from targets. The spectral reflectance of the studied salt features at the soil surface were processed and mapped. Besides, it presents an explicit indicator indirectly from vegetation cover for the sake of soil salinity detection and mapping [3]. The basic concept of remotely sensed images reflects the close direct that influenced by other factors including atmospheric conditions, illumination, and viewing angle [4-5].

Spectral vegetation indices (VIs) characterize keys to assess and monitor natural resource through the monitoring of change detection in vegetative patterns and the analysis of vegetation itself [6-7]. Due to salinity expansion in the affected regions and its adverse effects on growth of plant, a decline in vegetation index values can be construed as an indicator for soil degradation and salinity spread. In contrast, salinity indices highlight spectral reflectance values of salt affected regions in the case of less vegetation, therefore, increase in salinity index values during years of study represents salinization of bare soil lands [8].

Several vegetation indices are using in numerous studies, such as the Normalized Difference Vegetation Index (NDVI), the Enhanced Vegetation Index (EVI), and the Soil Adjusted Vegetation Index (SAVI), NDVI is considering as the most commonly for assessing and monitoring the variations
in vegetation and land features [9-10]. Multi-temporal remotely sensed imagery detecting and recording attributes regarding long-term and their impact on vegetation cover for the sake of making better management in preventing further salinization and preserve vegetation cover. The most effective process of remote sensing imagery is the study of change detection to discriminate the differences in the phenomena and terrain properties at different times [11], especially in tracking and inspecting natural resources and concluding environmental effect via quantitative analysis of the thorough spatial occurrence of the variance [12]. The resultant difference image is performed by compare pixel-by-pixel for two (or more) temporal acquiring images [13].

Many researchers studied soil salinity and the impression on vegetative dispersion, recalling them for example, Masoud et al. (2004) [14] revealed the variation of distribution in the salt marshes and their impact on vegetative regions change. Goto et al. (2015) [15] demonstrated a decrease in NDVI values in regions of plants affected by salinization. Taghadosi, et al. (2017) [8] picked up a large potential of vegetative indices (EVI and GDVI) and salinity indices through soil salinity assessment in regions of vegetative regions and bare soil, respectively. Allbed et al. (2017) [16] concluded that there is a strong relation between change in vegetative regions and soil salinity change by finding the strong negative relationship between the NDVI and SI values.

In this research, image differencing technique has been used to generate the difference image for the sake of picking up the changes in the study area. The aim of present study is to advance an efficient change detection method to evaluate vegetation cover change and soil salinity from the measured NDVI and SI values, and then evaluate the relationship between NDVI and SI, for the purpose of estimation the damages caused by increased salinity, which have a large and direct role in reducing the economic losses resulting from increased soil salinization in An-Najaf Governorate.

2. Materials and Methods

2.1. Study Area

The study area represents the eastern part of An-Najaf province, 160 km south of the Capital Baghdad. It is situated within latitudes (31º 35′- 32º 11′ N) and longitudes (44º 11′- 44º39′ E) with total area about 1748.5 km² (Fig.1). The elevation of the area is about 70 m above sea level. The climate is hot and dry in summer, cold and moderately rainy in winter with an average temperature of about 26 °C and average annual rainfall of 80 mm/year. The study area involves agricultural fields which is characterized by varying vegetation density, urban areas and bare lands. Thus, it presents a suitable test area of change detection utilizing remote sensing data.

![Figure 1(a). Color composite(RGB:543) of Landsat 8 March 2015 and position map of study area](image-url)
2.2 Data Acquisition and Pre-processing

In order to detect land cover changes, it is necessary that the multi-temporal data sets be acquired in the same time. Therefore, to guarantee accuracy all 2001, 2009, and 2015 images were acquired in spring season during the day. In this study, three multi-temporal Landsat 7 (ETM+) and Landsat 8 (OLI) images acquired respectively on March 27, 2001, March 17, 2009 and March 10, 2015 have been used. All the images used were picked up during the day. All Landsat data have been obtained from USGS Earth Explorer site with (30m) resolution. The images have been geo-rectified to a Universal Transverse Mercator (UTM) coordinate system utilizing World Geodetic System (WGS) 1984 datum, Zone 38 and Path 168 Row 38. ArcGIS 10.2 Software have been used for pre-processing including atmospheric correction to remove cloud pixels, geometric correction of data, while Excel 2016 Software has been used to achieve correlation relationship.

2.3 Differencing Images Technique

Change detection for the studied area can be achieved using image differences technique. It involves subtracting of the pixels values which have the same positions of two images collected in two different time periods. The two co-registered images are compared pixel-by-pixel, and pixels referred to changed areas produce obviously values different from those pixels accompanied to unchanged areas [17-18]. Mathematically, image differencing can be represented as follows:

$$\text{ID} = I(T_1) - I(T_2)$$  \hspace{1cm} (1)

Where ID represents difference image and $I(T_1)$ and $I(T_2)$ represents the captured images during two different time periods.

For identifying the changed regions in an image of different dates, a threshold method has been used that are based on histogram of differencing image. In this case, the significant changes were present in the tails of the histogram distribution, while pixels of no significant change had a tendency to be clustered around the mean value [19]. The threshold was determined using the mean and standard deviation (SD) computed for each differencing image via the formula $(\mu \pm C \times \text{SD})$, where $\mu$ and SD are the mean and standard deviation of the sample data of unchanged objects in the study area, and C is a
constant [20]. For the sake of determining the most suitable threshold value, an iterative process was performed by testing varied threshold values of the SD (from 0.4 $SD$ to 2.2 $SD$). Reclassification has been done for the changed images into three categories. The value (0) was allocated for no change areas, and (1, -1) for increase and decrease change areas respectively.

2.3.1 Calculation of NDVI and DNDVI

The importance of vegetation indices depends on their usefulness in the interpretation of remote sensing images, they represent remarkably a method for detecting of the changes in land use in multi temporal data, and the evaluation of vegetative cover density [20]. Generally, its calculated as a ratio of red and NIR bands depending on the sensor type, and is characterized by the following equation:

$$\text{NDVI} = \frac{\text{NIR} - R}{\text{NIR} + R}$$  \hspace{1cm} (2)

Owing to the high reflectance in NIR portion of the Electromagnetic Spectrum (EMS), healthy vegetation is restricted by (0.1 and 1) values of NDVI. Contrariwise, non-vegetated surfaces such as water bodies have negative values of NDVI according to the water capability to absorb energy. Whereas the bare soil areas have zero values of NDVI because of the high reflectance in both visible (R) and NIR portions of the (EMS) [21]. In this study, NDVI index was used for the purpose of observe and assess the changes in vegetation cover during the periods under study, in addition to the usage the value of NDVI difference image (DNDVI) that was calculated by subtraction of the NDVI image of the first date from the NDVI image of second date as follow:

$$\text{DNDVI} = \text{NDVI} (t1) - \text{NDVI} (t2)$$  \hspace{1cm} (3)

2.3.2 Calculation of SI and DSI

Among the multiple salinity indices, SI that based on the two SWIR bands have been used to identify soil salinity, due to the ability of these two bands to completely discriminate saline areas [16-22], as follows:

$$\text{SI} = \frac{(\text{SWIR}_1 - \text{SWIR}_2)}{\text{SWIR}_1 + \text{SWIR}_2}$$  \hspace{1cm} (4)

SI is calculated to enhance the spectral contribution of saline soils that cause minimizing and suppressing the spectra accompanied to the vegetation [3]. So, the increased spectral signature the increased salt content at the terrain surface [23].

In the current research, SI values for the 2001, 2009 and 2015 changing years have been calculated, then SI difference image (DSI) for the two change periods was calculated by subtracting SI image of the first date from the corresponding SI image of second date as shown in the following formula:

$$\text{DSI} = \text{SI} (t1) - \text{SI} (t2)$$  \hspace{1cm} (5)

From the results of $\Delta$SI image, the positive and negative values of pixels are related for increasing and decreasing salinity rates respectively, while the zero values are indicated for unchanging salinity areas between the two periods of change.

2.4 Visualization of changes using additive color theory
In the current research, the visual interpretation method has been carried out based on the additive color theory to create a basis of reference data to assess changes in vegetation cover and soil salinity [24]. Thus, to visualize the reference data for change of vegetation areas, the NDVI images acquired in 2001, 2009 and 2015 have been allocated to the red, green, and blue channel, respectively. The combination of three primary colors permitted to create a classification system for three dates (2001–2009–2015) to identify change areas.

As showed in the first row of table (1), pixels of red color refer to a high NDVI values of the 2001 image and a low NDVI values of the two images of 2009 and 2015. These red pixels could be interpreted as decreased vegetation cover from (2001-2009) and no change from (2009-2015). In the same way, the other colors can be interpreted to identify the increase and decrease of vegetation cover for the two study period as indicated in the table (1). The same procedures can be applied on SI images to determine soil salinity change for the three dates.

**Table 1. Interpretation of additive colors in three date RGB–NDVI and SI images.**

| Additive color | (R) 2001 NDVI or SI | (G) 2009 NDVI or SI | (B) 2015 NDVI or SI | Interpretation of change | Change classes 2001-2009 | Change classes 2009-2015 |
|---------------|----------------------|----------------------|----------------------|--------------------------|--------------------------|--------------------------|
| Red           | H                    | L                    | L                    | Decrease 2001-2009; Change 2009-2015 | Negative change          | No change                |
| Green         | L                    | H                    | L                    | Increase 2001-2009; Decrease 2009-2015 | Positive change          | Negative change          |
| Blue          | L                    | L                    | H                    | No change 2001-2009; Increase 2009-2015 | No change                | Positive change          |
| Yellow        | H                    | H                    | L                    | No change 2001-2009; Decrease 2009-2015 | No change                | Negative change          |
| Magenta       | H                    | L                    | H                    | Decrease 2001-2015; Increase 2009-2015 | Negative change          | Positive change          |
| Cyan          | L                    | H                    | H                    | Increase 2001-2009; No change 2009-2015 | Positive change          | No change                |
| Black         | L                    | L                    | L                    | No change in (vegetation cover or soil salinity) | No change                | No change                |
| Gray/White    | H                    | H                    | H                    | No change in (High vegetation cover or soil salinity) | No change                | No change                |

2.5. **Relationship of Soil salinity - vegetation cover change**

A Pearson correlation as was performed to illustrate the relationship between soil salinity and vegetation cover changes. Random points (n = 120) have been selected from DSI and DNDVI images through the study region. The statistical analysis has been achieved via excel software, and the level of significance has been determined at (p < 0.05).

3. **The Results and Discussion**

3.1. **Change vegetation cover with soil salinity**

Figures (2) and (3) illustrates the difference images of the NDVI (DNDVI) and SI (DSI) for (2001-2009) and (2009-2015) change periods. The white pixels are representing the positive changes for the
two change periods (i.e., increase of vegetation cover or salinity), whereas dark pixels refer to negative change (i.e., decrease of vegetation cover or salinity) for the same dated. Grey pixels refer to unchanged regions.

Figure 2. The difference images of the NDVI (DNDVI) for the change periods (a) (2001-2009), (b) (2009-2015)

Figure 3. The difference images of the SI (DSI) for the change periods, (a) (2001-2009), (b) (2009-2015)

Figures (4) and (5), demonstrate the change / no-change maps for DNDVI and DSI images of the two change periods based on threshold value of (1SD). Areas where changes have occurred were showed with red and blue colors to indicate the increase and decrease in vegetation or soil in respectively, while areas with unchanged were displayed in yellow color within the two periods of
study. Table (2) illustrates the areas and percentages of the change in the values of NDVI and SI during the two study periods

| Change classes | 2001-2009 (Km) | 2001-2009 (%) | 2009-2015 (Km) | 2009-2015 (%) |
|----------------|----------------|---------------|----------------|---------------|
| Change increase | 95.62          | 5.46          | 90.43          | 5.17          |
| Change decrease | 137.35         | 7.85          | 174.11         | 9.95          |
| No change       | 1515.56        | 88.66         | 1483.96        | 84.88         |

Table 2. Change area of NDVI and SI for the two change periods

As shown in figure (4a) and table (2), a decrease in vegetative regions was observed in eastern, southeastern and some northwestern parts of the value 7.85%. Besides, an increase in vegetative regions was obvious in small parts concentrated in different parts of the northern and central parts with 5.46% of the studied region. Of figure (4b), the decline in vegetative regions was occurred along the eastern side and in the northern part of the study area with 9.95%, while the increase in vegetation was observed in the central, western and northwestern parts about 5.17% of the same region.

As for salinity changes, from figure (5a and b) it can be observed that the period study attended a rise in saline areas from 6.36% in (2001-2009) to 10.59% in (2009-2015). While declining areas of salinity decrease from 11.14% in (2001-2009) to 5.82% in (2009-2015). These results represent a serious increase in soil salinity and its negative impact on plant growth.

The study period (2001-2015) experienced significant decrease in rainfall levels in addition to higher temperatures that led to an increased in evaporation rates. This has caused in reduction in
cultivated area and thus rise levels of salinity in the soil. There are several reasons for the degradation of vegetation, such as the reluctance of a large number of farmers to agriculture and their practice to other works, as well as the conversion of some agricultural land into residential areas. Therefore, the results of the study showed that the decrease in vegetative regions sometimes does not coincide with increased soil salinity.

**Figure 5.** Change/no-change maps of DSI, (a) for (2001-2009) periods, (b) for (2009-2015) periods

But generally research results indicated the inverse relationship between soil salinity and vegetative regions, where most of the areas showed an increase in salinity in the saline map accompanied with a decrease in vegetation and vice versa. This is confirmed by the strong inverse relationship between the soil salinity and vegetative cover which have been obtained, as we will see in the paragraph 3.3.

### 3. Accuracy Assessment of Change Detection

Accuracy assessment is a significant procedure of change detection and classification evaluation. The more common accuracy assessment elements consist of user’s accuracy, producer’s accuracy, overall accuracy, and Kappa coefficient. The classification results of DNDVI and DSI were appraised using accuracy assessment, for the two change periods as revealed in table (3).

The high overall accuracy of DNDVI for (2001-2009) period was obtained with 91.56%, (Kappa 0.87), whereas it was slightly less for DNDVI in (2009-2015) period with overall accuracy of 91.11, (Kappa 0.86). For the two change periods of DSI, high accuracies were also achieved with overall accuracy (94.54%, Kappa 0.91) for (2001-2009), and for (2009-2015) it was less about (91.66%, Kappa 0.87). Finally, producer’s and user’s accuracies for
both change periods for DNDVI and DSI change classes were also having high values. This denotes that the classification was done with high accuracy.

Table 3. Change no/change classification accuracy of DNDVI and DSI for the two change periods

| Change class   | 2001-2009 | 2009-2015 |
|---------------|-----------|-----------|
|               | DNDVI     | DSI       | DNDVI     | DSI       |
|               | AU% PA%   | PA% AU%   | AU% PA%   | PA% AU%   |
| Change increase| 93.63 91.66 | 96 92.3 | 92.8 88.6 | 93.75 93.75 |
| Change decrease| 96.42 90   | 95.45 95.45 | 86.6 92.8 | 100 85.75 |
| No change     | 84.37 93.10 | 88.88 96 | 83.3 93.7 | 85 94.44 |
| Overall accuracy| 91.56 94.54 | 91.11 91.66 |
| Kappa Coefficient | 0.87 0.91 | 0.86 0.87 |

PA= producer’s accuracy, UA= user’s accuracy

3.3. The Relationship between Soil Salinity and Vegetation Cover Change

The correlation between NDVI and SI is assessed for (2001-2009) and (2009-2015) periods, as demonstrated in figure (6). It is found that, there is a clear and high inverse correlation between the soil salinity and vegetation cover changes at (p < 0.0001) with $R^2=0.88$ and 0.85 for the two change period respectively. For this reason, the NDVI and SI are selected to study the vegetation cover change with soil salinity in this paper.

![Figure 6. The correlation between vegetation cover and soil salinity changes in, (a) 2001-2009 change period, and (b) 2009-2015 change period](image)
4. Conclusions
The research results indicate that satellite images utilized in change detection techniques be able to provide suitable information about the changes in vegetation cover and soil salinity. It was reveal that there has a clear changes of vegetation cover and soil salinity over the period of study.

Hence, the knowledge of the variations in soil salinity over time and its effects on vegetation cover is essential to assistance the concerned to take an appropriate procedures necessary to reduce soil salinity and maintain the vegetation cover. Using difference images for NDVI and SI, changes in the soil salinity and vegetation cover have been revealed. The paper results showed that, there is a strong inverse correlation between the NDVI and SI values, this confirms that vegetation cover changes have strong relation by changes of soil salinity. Generally, study region experienced notable changes in soil salinity levels during the period of study. This may due to temperature increasing and decreasing average of rainfall which led to high evaporation in addition to poor irrigation system and bad land use, all of this has helped to raise salinity levels of soil.

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