

Impact of Al-Ahdeb Oil Field on the Surrounding Environment Using Remote Sensing and GIS Techniques, Wasit Governorate, Iraq

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Abstract
Remote sensing and Geographical Information System (GIS) are used in this study to detect environmental changes in the vicinity of Al-Ahdeb oil field, southwest of Kut City, Wasit Governorate. Different image indices, such as Normalized Differences Vegetation Index (NDVI), Normalized Differences Soil Index (NDSoI), and Normalized Differences Salinity Index (NDSI) are used. Two LANDSAT images with acquired data of September 2007 and 2016 are used to detect the environmental changes and to detect the effect of Al-Ahdeb oil field before and after construction and industrial operation. The results of change detection show there is a high decrease in the vegetation cover during the year 2016 compared with 2007, where the area of vegetation cover has decreased from (165.85 Km^2) in 2007 to (119.62 Km^2) in 2016. The change detection results from NDSI show that the saline soil in (2016) is higher than those in (2007). The NDSI derived from Landsat TM (2007) image confirms that there is significant increase of salinity in the study area, where the calculated area of the salinity in 2007 is (5.65 Km^2) while in 2016 it is (21.951 Km^2). Change detection, using NDSoI, show that the land in the study area is going toward desertification and soil degradation. The decrease in the vegetation cover, which in turn led to soil erosion in addition to water shortage and the pollution by the waste of the oil field, could be the main reasons of the desertification in the area.
Keywords: Environmental change detection; Image Indices; NDVI; NDSI; NDSoI; Al Ahdeb oil field.
DOI: 10.7176/JEES/12-8-03
Publication date: August 31st 2022

1. Introduction

In recent years, remote sensing and Geographical Information System proved very useful in monitoring and studying the environmental impact assessment and pollution from satellite image (Hadeel *et al*., 2011). The process of explaining the differences in the state of an object or phenomenon by observing it at different periods is known as change detection. It includes the ability to quantify temporal effects using multi temporal datasets. The land degradation can be considered as the loss of actual or potential productivity or utility as a result of natural or anthropogenic factors and indicates the dropping in land quality or reduction in its productivity (Othman *et al*., 2014). Change detection involves the application of multi-temporal datasets to quantitatively analyse the temporal effects of the phenomenon, (Muhsin and Mohammed, 2017).

The study area lies in Wasit Governorate, southwest of Kut City (Figure1), where Al Ahdeb oil field is located to the south of Al-Ahrar District, as shown in (Figure2).

The study area is covered by different types of Quaternary units including Flood Plain Sediments, Crevasse Splay, Shallow Depression Sediments, Marsh Sediments, Sand Sheets and the Anthropogenic Sediments (Barwary and Yacoub, 1992), (Figure2). Several NW-SE subsurface anticlinal structures have been detected by geophysical means in the SE parts of Iraq and Al-Ahdeb structure is one of them.

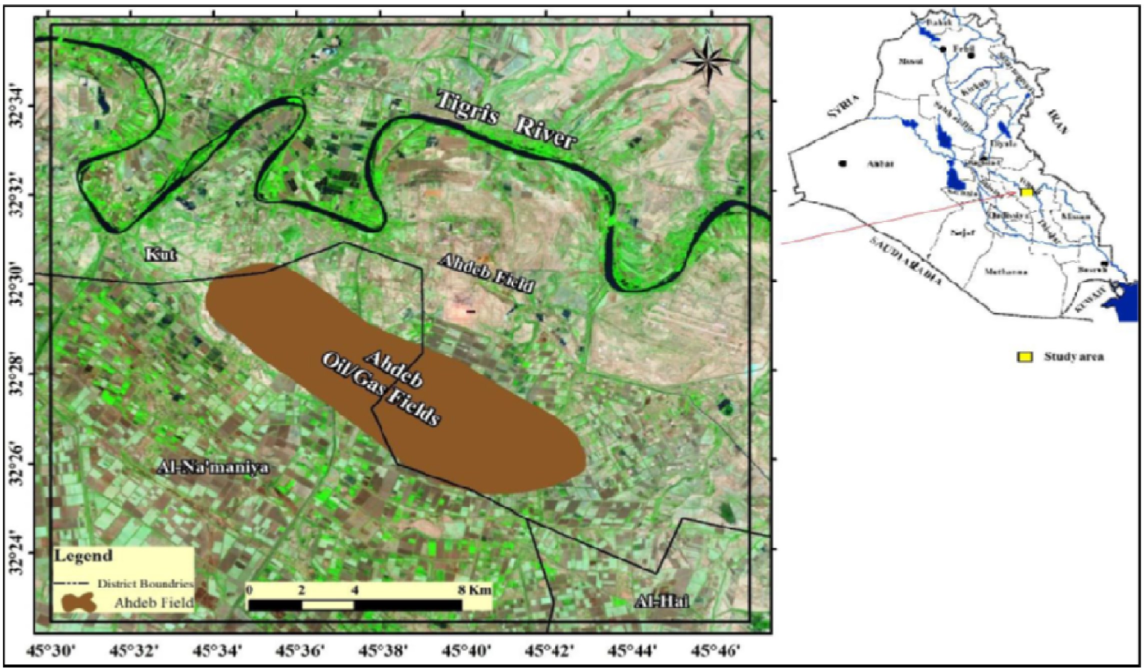

Figure1. Location map of the study area showing Al Ahdeb oil field in 753 RGB based on Landsat 8 image.

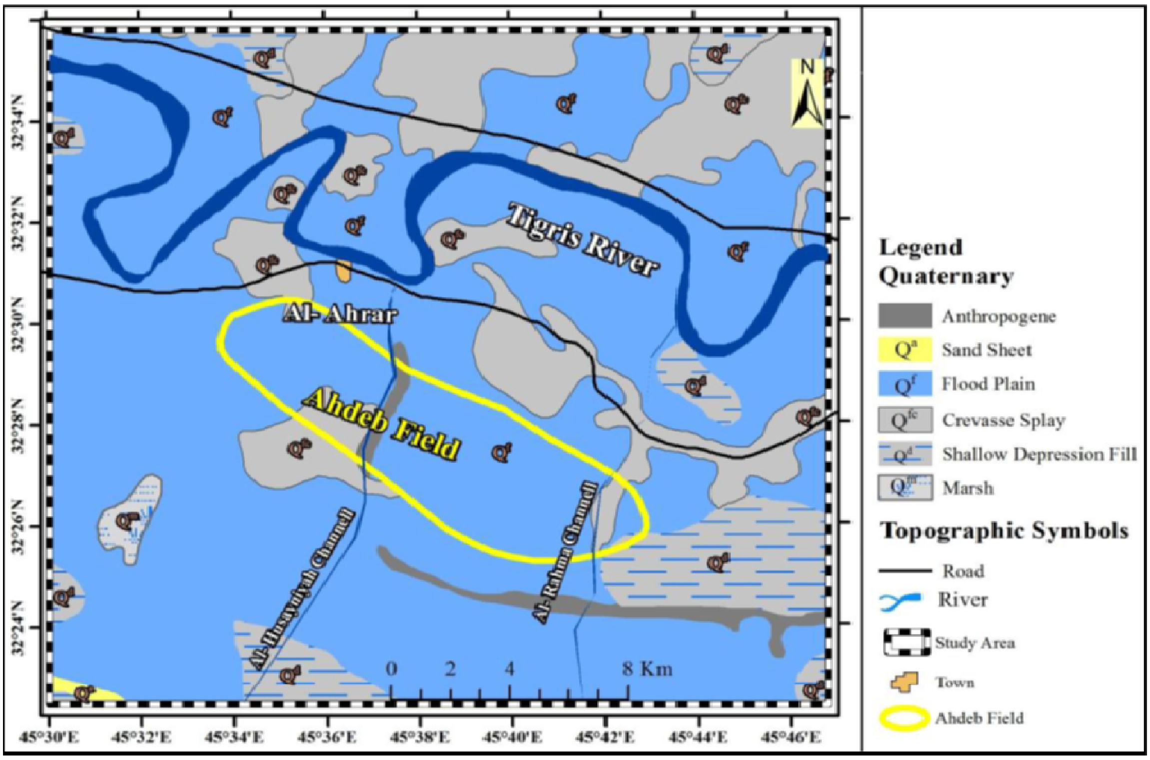

Figure 2. Geological map of the study area (after Barwary and Yacoub, 1992).

Several geological projects have been accomplished during the past years in the area (Barwary & Yacoub, 1992; Fadhil,2009; Al-Saady and Al-Rubaiay, 2012 and Abdul Sattar,2013) where this area is considered important because of the fertile nature of the soil. Remote sensing technique is used to evaluate the environmental changes in the study area since the operation of the Al-Ahdeb oil field until recent days. Al-Ahdeb is a structural oil field, located in Wasit Governorate (Al Ahrar district). The operation of Al-Ahdeb oil field began in 2009 for the production of oil. The development of this field and the start of oil production have created pollution problems in the area caused by emissions of toxic gases and solid and liquid waste disposal from the oil extraction operations. The present study aims at detecting environmental changes in the vicinity of Al-Ahdeb oil field using remote sensing technique by comparing data from two periods (2007 and 2016), using image indices such as; Normalized Difference Vegetation Index (NDVI), Normalized Difference Soil Index

(NDSoI), and Normalized Difference Salinity Index (NDSI).

Towards achieving a higher level of efficiency and competitiveness in manufacturing operations, the European Community (EC), European Free Trade Association (EFTA), Australia, Canada, Japan, and the United States (US) founded an international collaborative research programme called Intelligent Manufacturing Systems (IMS) in 1993. This programme consists of six major projects, wherein the fifth one is entitled “Holonic Manufacturing Systems: system components of autonomous modules and their distributed control”. It is important to emphasise that HMS does not represent a new technology, as it is merely a conceptual modelling approach to connect and make use of existing technologies with human interfaces (McFarlane 1995). HMS became one of the first fully endorsed IMS projects in 1997, and so the International HMS Consortium was formed and dedicated to replicate in manufacturing the strengths that holonic systems provide to living organisms and societies. These holonic strengths encompass stability in the face of disturbances, adaptability and flexibility in the face of change, and efficient use of available resources. Succinctly, autonomy and cooperation are known as the prime attributes of HMS (Valckenaers *et al.* 1997; Bongaerts 1998).

2. Climate

The climate is one of the most important factors in the environmental studies because it has effects on the other environmental components such as; water, soil and air, (Al-Saady, 2008). Climatic data of Al-Hay Meteorological Station for the periods from 1990 to 2014 are used and it shows that the mean rainfall in the study area is low (not exceed 31mm in January). The monthly mean, maximum and minimum temperatures show increase in temperature in the study area in the summer season (reaching $45.4^{\circ}C$ in July and August), while the temperature decreases in the winter season (minimum value recorded $6.8^{\circ}C$ in January). The monthly mean evaporation rate records show that the evaporation in the summer season is increased (reaching maximum value 660.3mm in July), while the low period of evaporation in the winter season are in January (89.6mm).

3. Materials and methods

3.1. Materials

Two types of satellite images were obtained from USGS archive website (http://earthexplorer.usgs.gov/), which are Landsat 5 TM (acquired data 12 September 2007) and Landsat 8 OLI (acquired data 4 September 2016). Both of these satellite imageries are used in this study (Tables 1 and 2). EARDAS IMAGING 9.1 and ENVI V.5 are used to process the above-mentioned imagery, by classifying and applying the indices for these images. The Arc map 10.4 is used to analysis and layout the final maps.

Table 1. Characteristics of Landsat 8 OLI sensor (USGS, 2016).

Landsat8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) Launched September 04/2016	Bands	Wavelength (micrometers)	Resolution (meters)
	*Band 1 – Coastal aerosol	0.43 – 0.45	30
	Band 2 – Blue	0.45 - 0.51	30
	Band 3 – Green	0.53 – 0.59	30
	Band 4 – Red	0.64 – 0.67	30
	Band 5 – Near Infrared (NIR)	0.85 – 0.88	30
	Band 6 – SWIR 1	1.57 – 1.65	30
	Band 7 – SWIR 2	2.11 – 2.29	30
	*Band 8 – Panchromatic	0.50 – 0.68	15
	*Band 9 – Cirrus	1.36 – 1.38	30
	*Band 10 – Thermal Infrared (TIRS)	10.60 – 11.19	100 * (30)
	*Band 11 – Thermal Infrared (TIRS)	11.50 – 12.51	100 * (30)

* Not used

Table 2. Characteristics of Landsat 5 TM sensor (USGS, 2016).

Instrument	LANDSAT 5
Sensor	TM
Acquisition Date	12/9/2006
Path/ Row No.	168/37
Spectral bands (m)	7 bands (10)- 0.45 – 0.52 µm(blue) (20)- 0.52 – 0.60 µm (green) (30)- 0.63 – 0.69 µm (red) (40)- 0.76 – 0.90 µm (near-infrared) (50)- 1.55 – 1.75 µm (mid-infrared) (60)-10.4 – 12.5 µm (thermal bands) (70)- 2.08 – 2.35 µm (mid-infrared)
Ground Resolution	30 m*30 m for multispectral bands, 120 m for thermal bands
Dynamic Range (bit)	8-bit

3.2. Methods

The satellite image of the study area is converted to Top of Atmosphere (TOA) reflectance and all the information is obtained from the metadata file such as Sun elevation, reflectance rescaling coefficients and average elevation that obtained from digital elevation model (DEM) (Li and Chen, 2014 and Al-Saady *et al.*, 2015). This work is carried out using ENVI 5.1 Fast Line-of-sight Atmospheric Analysis of Hypercubes (FLAASH). Different image indices, such as NDVI, NDSI, and NDSoI, are applied to classify the image as follows:

NDVI: This index is used to calculate the vegetation cover (agricultural vegetated lands and natural vegetated lands) and used to isolate the vegetation from the other lands. The NDVI index is the difference between the near-infrared band (NIR) and the red band (R) divided by the sum of the near-infrared band and the red band combination, (Rouse *et al.*, 1974), as illustrated in equation (1):

NDVI = (NIR – R)/ (NIR + R) ……………… 1

NDSI: This index is reversed to NDVI. It is used to extract the area covered by salt and obtained by the differences between the red band (R) and the near-infrared band (NIR) divided by the sum of the red band and the near-infrared band (Tripathi *et al.*, 1997) as illustrated in equation (2):

NDSI = (R – NIR)/ (R + NIR) ……………… 2

NDSoI: Soil has various chemical and physical properties, which make it a complex material in the earth surface. Consequently, the spectra of the soil are complex that preclude direct connection between the spectral pattern response of the soil and properties (Deng *et al.*, 2015). The soil is developed in the study area on the surface of sheet run off sediments and includes bare soil and soil of cultivated lands. The soil coverage index (NDSoI) is obtained by the difference between reflectance of shortwave 2 and green band divided by the sum of the same reflectance bands (Deng *et al.*, 2015), as shown in equation (3):

NDSoI = (SW2 – G)/ (SW2 + G) ……………… 3

4. Results and discussion

4.1. Deterioration in the Vegetation Cover

The vegetation cover in the study area is highly decreased between 2007 and 2016 as indicated by comparing the NDVI of these two years as illustrated in (Figure3 and 4). The field investigation shows that the agricultural production of the land has been decreased in the study area by about 25% since the oil production complex was constructed. The optimal threshold used to isolate the NDVI is (0.225077286) for Landsat 8 OLI 2016, while in Landsat 5 TM 2007 it is (0.003331015). The area of vegetation cover was 165.85 Km2 in 2007, while in 2016 it was 119.62 Km2. This decrease in the vegetation cover may have been caused by many factors, such as the system of oil production, the large areas exploited by the oil-producing facilities, soil erosion because of lack of vegetation cover and the waste disposal of the oil production which affects soil productivity and vegetation cover. In addition, the acquisition date of the satellite images coincides with the harvest season in the area which could be one of the reasons of showing decreased vegetation cover. Moreover, the fertile natural soil of the area, which is considered suitable for agriculture, has suffered increase in soil salinity induced by lack of water resources and climate change during the recent years (scarce rainfall) which led to decrease in the vegetation cover.

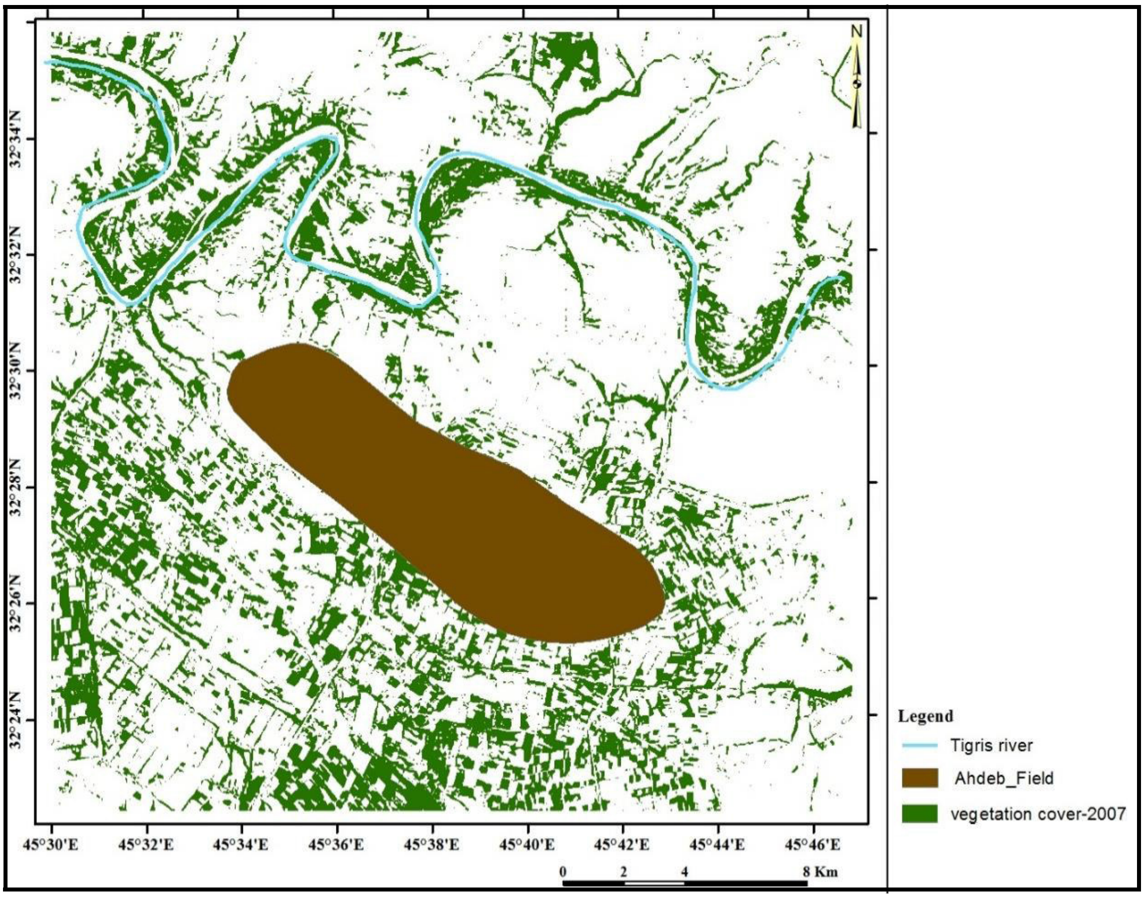

Figure 3. Vegetation cover in 642 RGB for TM 2007 image.

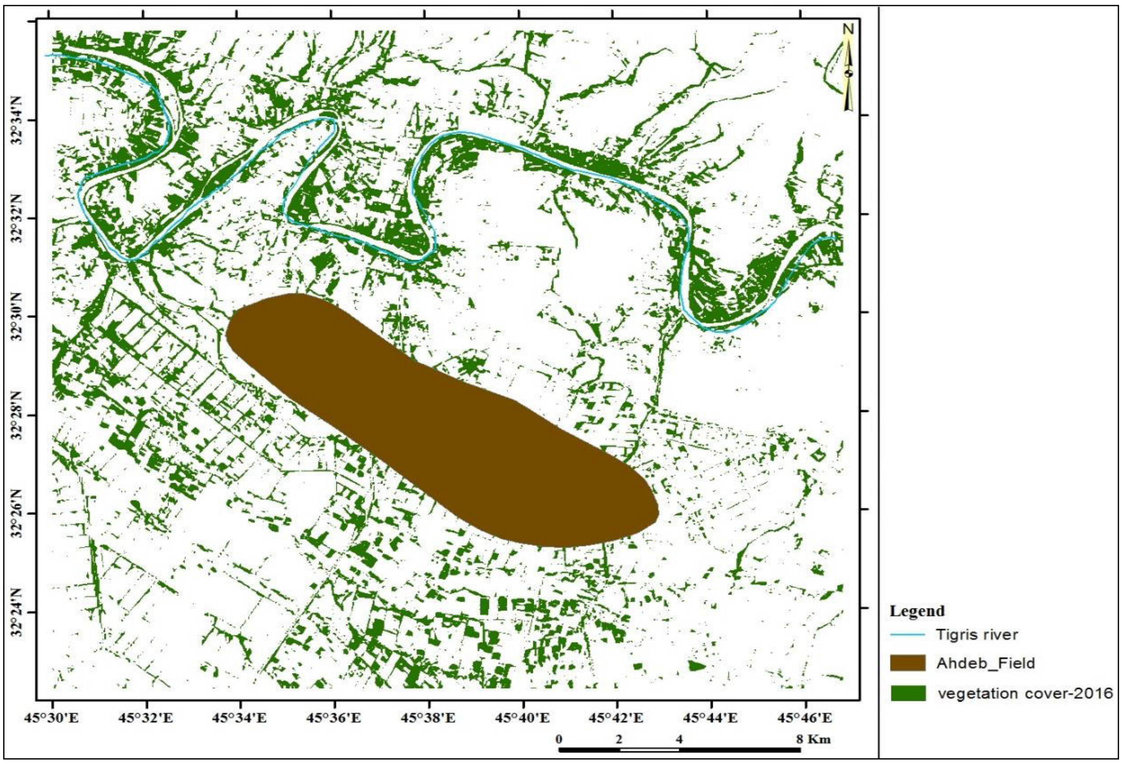

Figure 4. Vegetation cover in 753 RGB for Landsat 8 OLI 2016 image.

4.2. Soil Salinization

Salinity of soil is a big problem faces the world especially in regions with arid to semiarid climate. Soil salinity is considered as a major environmental hazard because it leads to degradation of the agricultural land, thus lose of the soil fertility. Moreover, it inhibits plant growth and soil erosion. The salinity index (NDSI), which only uses soil spectra, may not detect soil salinity effectively and quantitatively, because of the complicated soil context (vegetation cover, moisture, surface roughness, organic matter and the weak spectral features of salinized soil, (Wang *et al*., 2013). The optimal threshold used to isolate the NDSI is (0.251017213) for Landsat 8 OLI 2016, while in Landsat 5 TM 2007 it is (0.190858329). The results show that the study area has suffered from salinization in 2016 more than 2007, which caused decrease in land productivity. In 2007, the study area shows small area affected by salinity because of abandoned agricultural land and shortage in water resource. The total area in 2007 was (5.65 Km^2) as shown in (Figure5). While, in 2016, the total area became (21.951) Km^2 (Figure6), which shows the increase in soil salinity induced by further decrease in water resource, which led to the massive immigration of the farmers and abandonment of the agricultural land. The increase in soil salinity may be partly due to the human activities and also due to the decline in vegetation cover leading to the increase of the barren land area, accompanied by long draught periods and very high temperature and high evaporation rates during the summer season.

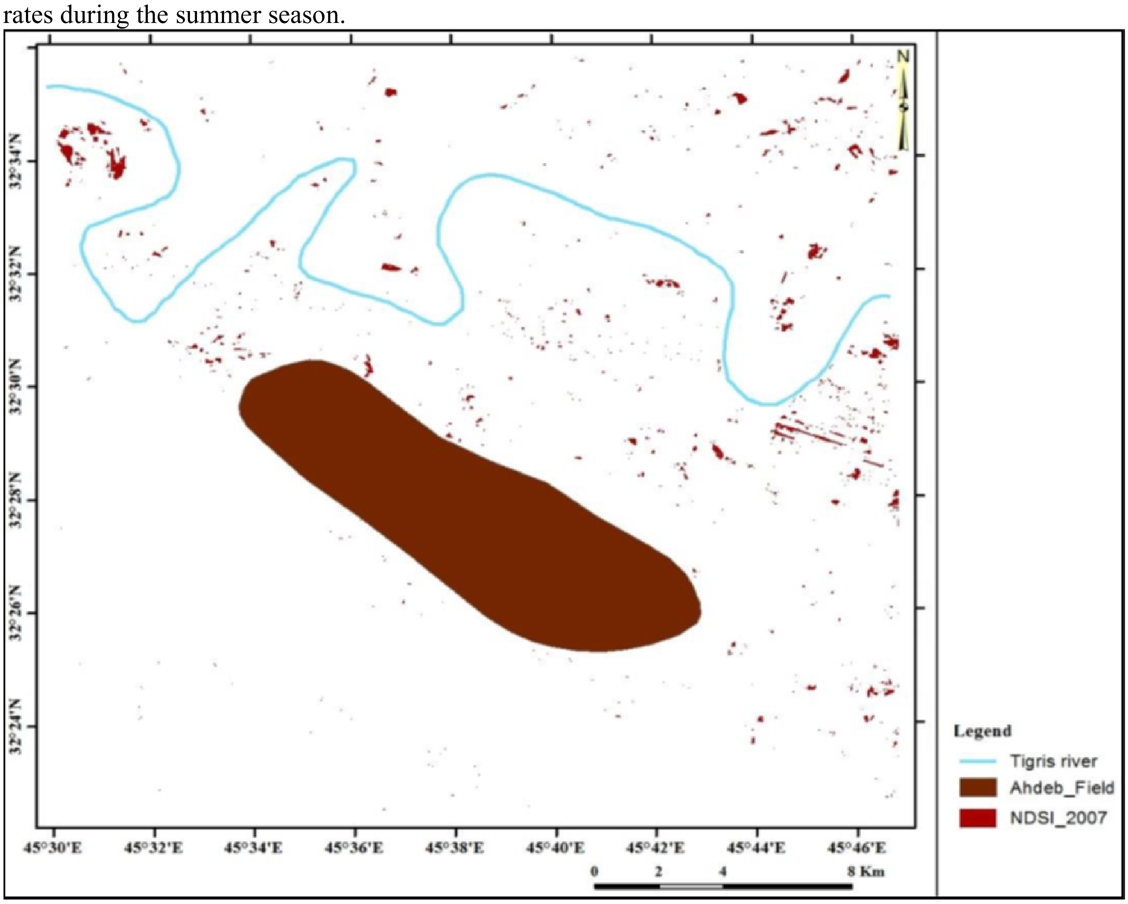

Figure 5. The NDSI in 642 RGB for TM 2007 image.

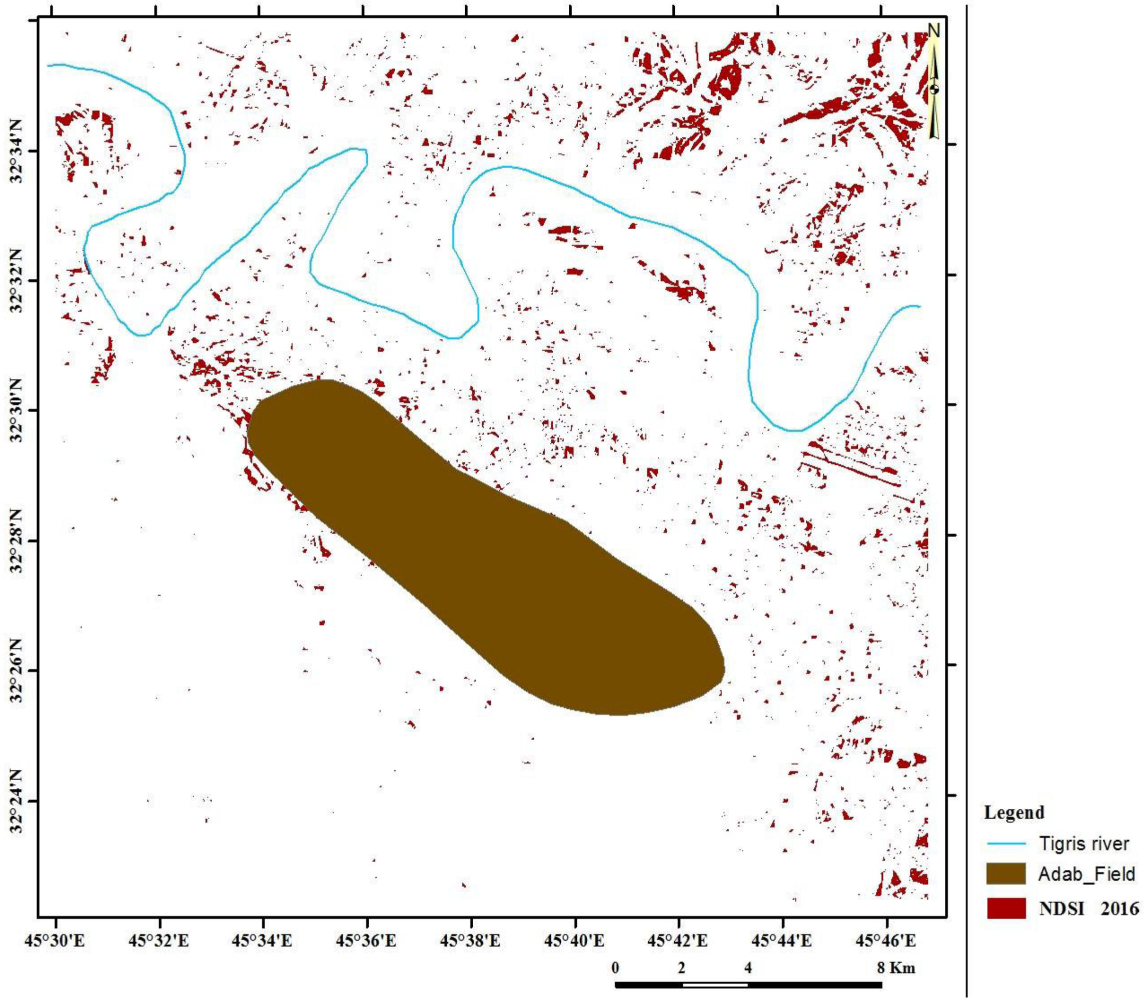

Figure 6. The NDSI in 753 RGB for Landsat 8 image.

4.3. Soil Coverage

The results of NDSoI show that the soil in the study area can be classified in to two types: baren soil and cultivated land. The soil coverage area in 2007 was 145.12 Km2 (Figure 7), while in 2016, the coverage area was reduced to 117.36 Km2 (Figure8). The optimal threshold used to isolate the NDSoI is (0.16949941) for Landsat 8 OLI 2016, whereas, in Landsat 5 TM 2007 it is (-0.889161399). The decrease in the soil coverage refers to farmers negating agriculture due to climate change, in addition to the impact of the beginning of oil production during this year (2007) which induced pollution of the study area with various types of waste, such as toxic gases, liquid and solid wastes. Part of these waste materials leak over time into the ground and part of them are floating on the surface in the winter season when it rains. All these factors affect soil productivity which became unsuitable for cultivation.

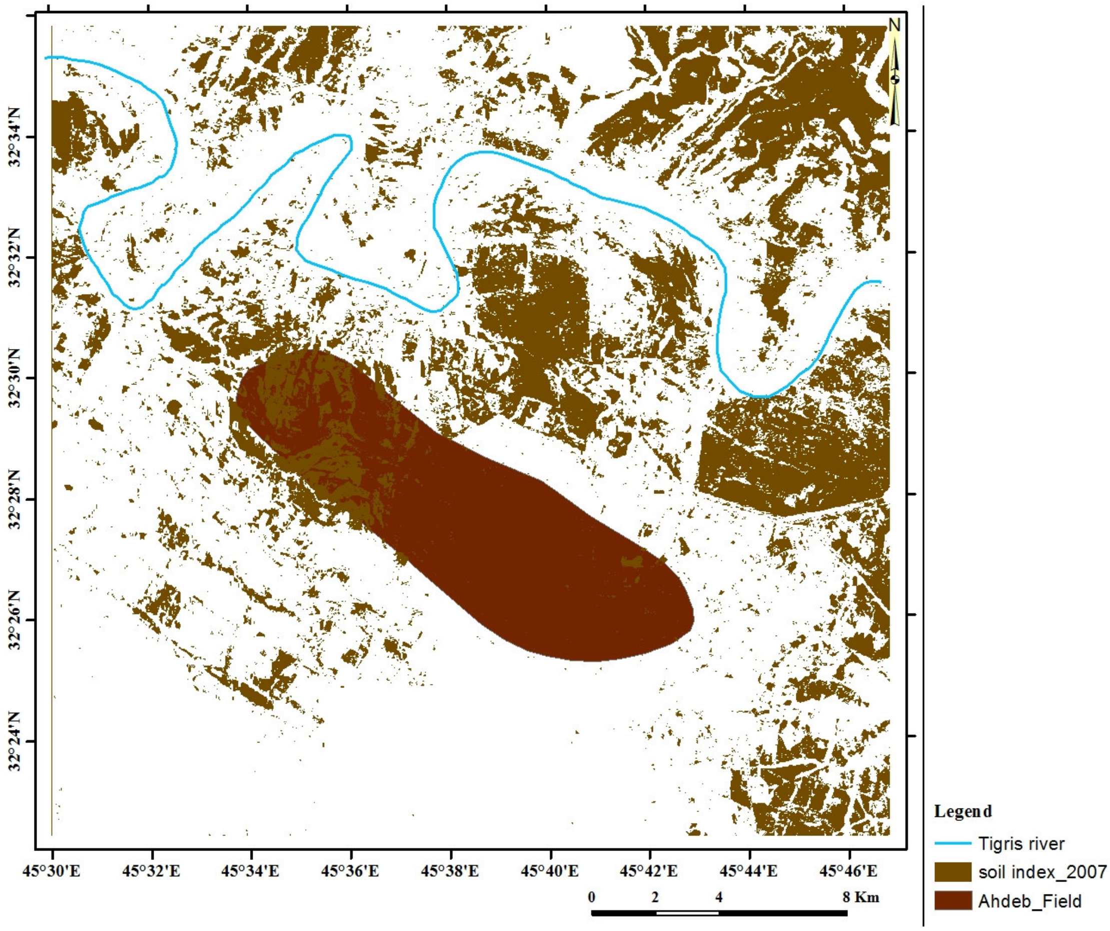

Figure 7. The Soil Index in 642 RGB for TM 2007 image.

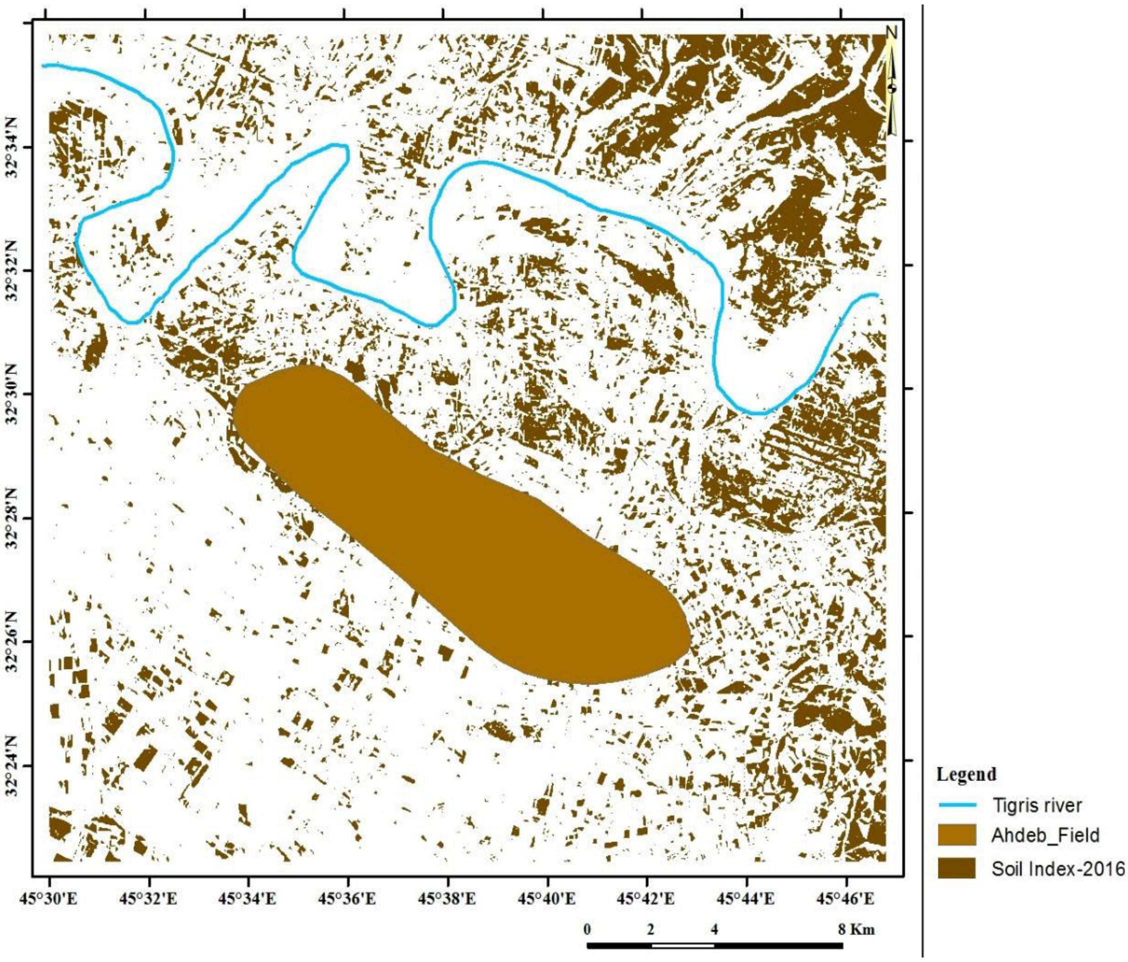

Figure 8. The Soil Index in 753 RGB for Landsat 8 OLI 2016 image.

5. Conclusions

The soil in the vicinity of Al-Ahdeb oil field can be classified in to two types: bare soil and cultivated land. The change detection results during the period 2007 – 2016, using remote sensing indices show that the study area has suffered severe desertification, evidenced by the decrease in the vegetation cover and increase of soil salinity. The area of vegetation cover has decreased from 165.85 Km2 in 2007 to 119.62 Km2 in 2016, whereas the area affected by salinity in 2007 was 5.65 Km2 which increased to 21.951 Km2 in 2016, and the soil coverage area decreased from 145.12 Km2 in 2007 to 117.36 Km2 in 2016. Several factors are involved in this land deterioration; some are caused by natural climate change phenomenon, such as long draughts and anomalous temperatures in the summer season as well as significant shortage of surface water resources and the consequent abandoning of agricultural lands. On the other hand, anthropogenic factors are equally important in this respect and the most serious of which is the oil production operations at Al-Ahdeb oil field which result in the irresponsible disposal of gas, liquid and solid toxic wastes to the surrounding environment.

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