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Environmental assessment of land cover changes for Hilla River basin, Iraq

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ABSTRACT

In all parts of the world, vegetation cover has undergone continuous changes, especially in areas with high population density, as a result of population activities and growth. Since Land Cover (LC) may differ and continue to change, the direction of this change has become important in environmental studies. This study focused on monitoring the changes that occurred in LC patterns of the Hilla River basin and Babylon Governorate, Iraq for a period from 2013-2019.LC were characterized on a regional scale based on Normalized Difference Vegetation Index (NDVI) categories (water,soil, plants) where no systematic LC studies were conducted previously (Hilla River Basin, Babylon Governorate, Iraq) using GIS tools and Landsat-8 Level-2 surface reflectance datasets (2013-2019) that provide accurate information on land use and vegetation change. The results showed that soil, plants, and water occupied about 85%, 15%, and 1%, respectively. The increase in water in the regions of Babylon Governorate during the period of 2018-2019 was 24,4089 km^2 compared to the previous years (positive trend in the maximum values of NDVI), improving the vegetation areas (an increase of 286.3791 km^2). For soil, the increase in the period of 2014-2015 was 303.9399km^2.Furthermore, LC indicated an increase in water area in 2013, 2014, and 2019 and a decrease in water in 2018, followed by 2016 and 2015. For soil, there was an increase in 2013 and 2016, and decrease in 2019, 2014 and 2018. For vegetation cover, a large percentage in 2019, 2018 and 2014 and decrease in 2016, 2013 and 2015 existed. As a result, the statistical analysis indicated that there is no large linear model between NDVI and the Hilla River flow rates.

Key words: *Environmental assessment, Hilla River, Land cover (LC), NDVI, LANDSAT 8.*

Introduction

A vital part of the land elements on the earth surface with physical structure and characteristics associated with human lives is Land Use Land Cover (LC). The complex dynamics among LC composition (lands, water, and vegetation) and between LC and climate impact the LC area change spatially and temporally (Yulianto, 2016). Since the availability of remote sensing data at various scales of area and time has made it suitable for detecting and monitoring changes in large and regional areas, the dynamic LC can be remotely detected by using a variety of temporal and spatial resolutions (satellite-based data), revealing the LC area change quantitatively and visually (Cihlar, 2000; Beckers *et al*., 2013; and Leong *et al*., 2015).

There is lack of information related to the region of interest (Babylon Governorate and Hilla River surrounding areas), Iraq. The present study area has not been explored based on Remote Sensing and GIS technology in cases where LC and NDVI changes over time exist. In addition, the previous studies were performed based on Level-1 satellite datasets (Fadhil *et al.,* 2009; Farag *et al.,* 2014; Mohammed *et al.*, 2013; AlDoski *et al.*, 2013; Alqurashi and Kumer *et al*., 2013; Leong *et al.,* 2015; Kafy *et al*., 2018; and Mohammed Hani *et al.,* 2018). These datasets were pre-processed before determining NDVI by using different machine learning languages and software, experiencing error possibility.

Because the biomass amount in vegetation is directly related to the absorbed spectral signature, Normalized Difference Vegetation Index (NDVI) has been utilized to differentiate the health and stressed vegetation, leading to various LC characteristics. However, the NDVI accuracy depends on the images processing method since NDVI is a function of two spectral bands (the red band and the near-infrared band). Thus, the overall accuracy of NDVI product depends on the accuracy of the individual spectral bands.

In remote sensing practices associated to Landsat satellite imagery, it is often impractical to recognize LC properties due to different image processing methods applied on specific Landsat product (Level-1 product). To get rid of this issue, Landsat 8 Level-2 Surface Reflectance (SR) data products distributed by the U.S. Geological Survey (USGS)/EROS and NASA can be employed. Using the SR data products which are already processed by a specialized software called Landsat 8 Surface Reflectance Code (LaSRC) (Vermote *et al*., 2016) removes errors that are relevant to image processing rather than processing Landsat 8 Level-1to Surface Reflectance by the user.

Thus, this paper outlines a new approach by using NDVI vegetation index for assessing and monitoring LC temporal and spatial changes from 2013 to 2019 at the Hillah River region, Iraq based on Landsat 8 OLI/TIRS Level-2 datasets, atmospherically corrected and processed by USGS/EROS and NASA. In addition, the variation of LC over time was modeled to link the changes with river flowrates.

Materials and Methods

Study area

Hillah River or Shatt al-Hillah is one of the most well-known river in Iraq and the most important in terms of water resources. It is a branch from Euphrates River with length of more than 101 km, flowing from the northern border of Babylon Governorate to Diwaniya Governorate, providing all water demand for the cities located on the river and irrigation water for agricultural lands. Fortunately, Landsat 8 senses (row: 168 and path: 038) cover the entire Hillah River watershed, see Fig. 1.

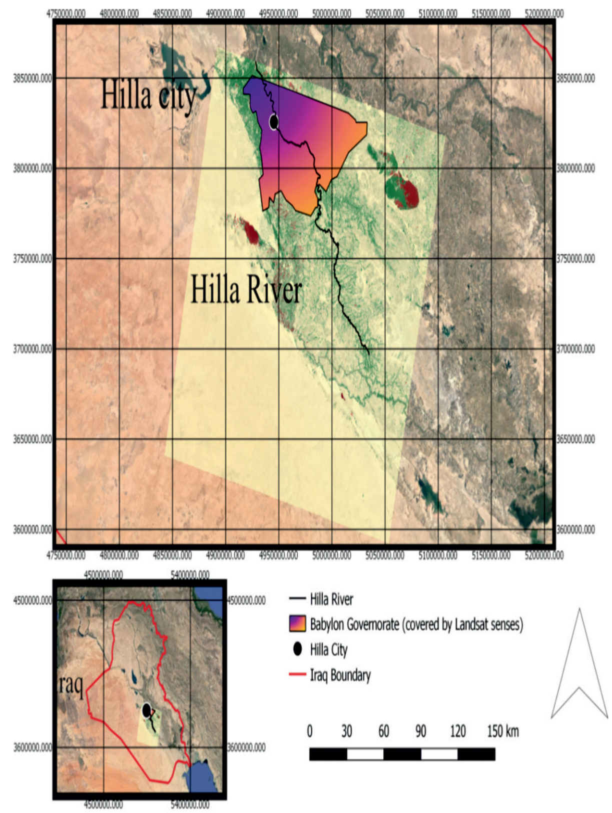

Fig. 1. The study area and region of interest

Hillah River is used for agriculture and drinking as well as for tourist attraction, but in recent years the river has been neglected and heavily polluted by wastes. The River is regulated by Al-Hindiyah Barrage, the river upstream dam. The river flowrate is unstable due to issues related to Euphrates River water levels, the Hilla River water resource. This fact has been impacting the Hillah River watershed and mainly the land cover distribution. Figure 2 shows the yearly variation of Hillah River flowrates from 2013 to 2019 based on Table 1 dataset, provided by the Ministry of Water Resources, Iraq.

Landsat-8 Datasets

This study deals with various multi-temporal Level-

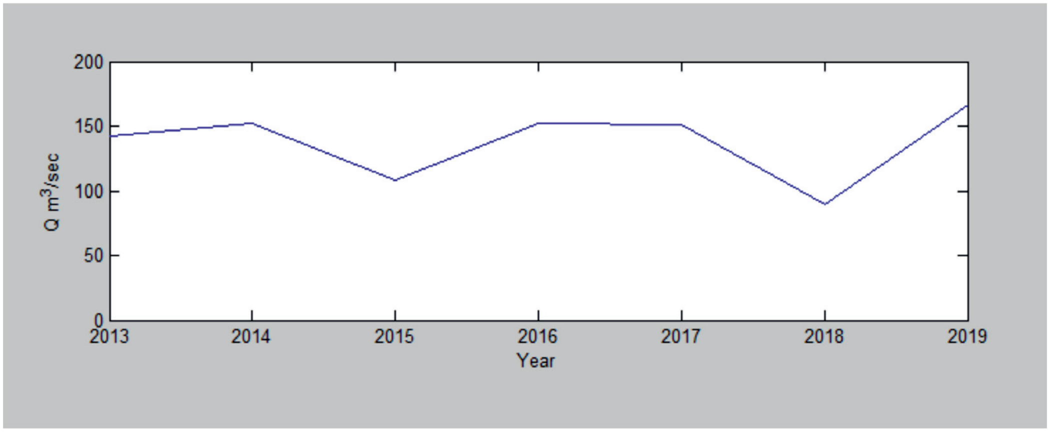

Fig. 2. Hilla River average flowrates (Q), 2013-2019.

Table 1. Monthly averaged Hilla River flowrates, 2013-2019.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2013	84	135	163	115	92	161	180	176	149	174	134	144
2014	80	105	160	98	176	182	186	180	149	159	200	151
2015	139	137	122	86	90	86	93	104	87	81	102	140
2016	137	134	143	140	135	142	160	174	159	157	180	167
2017	139	151	157	157	139	159	167	160	175	136	137	132
2018	118	104	124	112	80	80	80	72	66	66	87	88
2019	125	139	167	116	147	165	189	200	195	176	229	142

2 data products from Landsat-8 Surface Reflectance (SR) derived from Landsat-8 Operational Land Imager (OLI) using the Landsat-8 Surface Reflectance Code (LaSRC) developed by NASA (Vermote *et al.,* 2016). Senses of 30 m spatial resolution have been downloaded from the USGS website (https://earthexplorer.usgs.gov) for the years 2013, 2014, 2015, 2016, 2017, 2018, and 2019 on June 24, 11, 14, 16, 19, 22, and 25, respectively, (Path:168/Row:37) and used to prepare NDVI and LC images. During the downloading stage, the cloud coverage was chosen to be less than 10% to avoid the atmospheric conditions that could affect the classification accuracy (Allam *et al.,* 2019). In addition, these senses, used in this work, were picked up from USGS website during the same season on summer in which the atmosphere was not highly affected by scattering and absorption, and free of clouds. Some meta-data of Landsat-8 senses are given in Table 2. The images were processed and mapped for the final outputs by using in QGIS version 3.6.

General framework of the study

Figure 3 illustrates the general framework of the study, the distribution and patterns focused in the study. Image processing techniques used in this study were applied using QGIS. To determine LC changes and NDVI trend, Landsat- 8 data products

Table 2. Details of Landsat-8 senses used in the present study.

Landsat-8 Sense Identifier	Sensor	Path/Row	Acquisition Date	Center Latitude	Center Longitude	Bands (used)
LC81680382013175LGN01	OLI/TIRS	168/38	6/24/2013	31°44’30.98"N	44°41’36.42"E	4 and 5
LC81680382014162LGN01	OLI/TIRS	168/38	6/11/2014	31°44’31.38"N	44°40’59.02"E	4 and 5
LC81680382015165LGN01	OLI/TIRS	168/38	6/14/2015	31°44’31.27"N	44°41’08.63"E	4 and 5
LC81680382016168LGN01	OLI/TIRS	168/38	6/16/2016	31°44’32.68"N	44°42’22.14"E	4 and 5
LC81680382017170LGN00	OLI/TIRS	168/38	6/19/2017	31°44’32.28"N	44°41’09.60"E	4 and 5
LC81680382018173LGN00	OLI/TIRS	168/38	6/22/2018	31°44’31.67"N	44°41’59.35"E	4 and 5
LC81680382019176LGN00	OLI/TIRS	168/38	6/25/2019	31°44’31.13"N	44°40’57.58"E	4 and 5

were chosen, downloaded from Earth Explorer of United State Geological Survey (USGS) website, explored statistically, and then processed in QGIS.

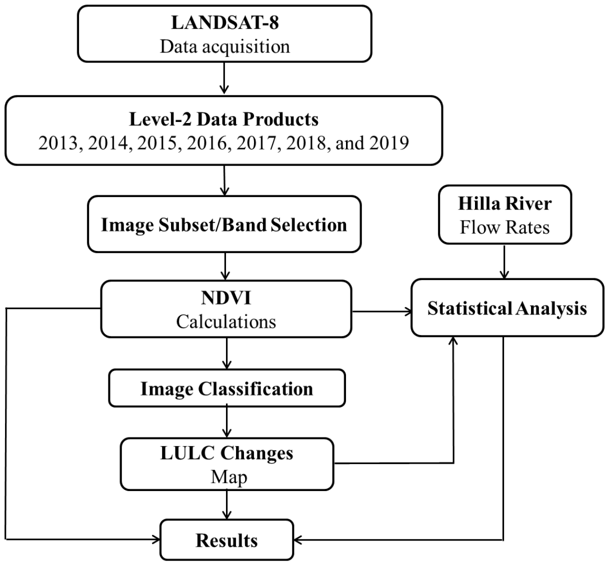

Fig. 3. The flowchart of research methodology.

In order to analyze the data and conduct the study, several essential and effective steps are required: Image data acquisition, image processing, image classification, and other remote sensing processes. Mainly NDVI was determined for the selected years to be classified for LC purposes. Classes Change in area between years was revealed visually and quantitatively. Finally, NDVI and Hilla River flowrates were correlated to determine how significant the relation between them by using R software. This framework was applied at the regional study area for the entire senses and Babylon Governorate area as shown in Fig. 1.

Estimation of NDVI

The Normalized Difference Vegetation Index (NDVI) was used to calculate vegetation health and water distribution over the study area. It depends on the amount of light reflection to distinguish between soil, vegetation, and water. Using NDVI to determine the intensity of green on Earth, we can observe the (wavelengths) of visible and semi-red sunlight reflected by plants, lands, and water. Mathematically, NDVI can be calculated as follows:

NDVI = (NIR - RED) / (NIR + RED)

Where NIR is the near infrared wavelengths of light spectrum, and RED is the red wavelengths. Both NIR and RED are in terms of reflectance units.

For LANDSAT-8,

NDVI = (Band#5 – Band#4) / (Band#5 + Band#4)

Where Band#5 and Band#4 are the band number 5 and 4 from the LANDSA-8 surface reflectance geo-tiff file formats in units of reflectance.

NDVI values range between - 1 and +1. If NDVI is less or equal to zero, the location is considered water. Values between 0 and 0.2 mean lands or soil. If it is greater than 0.2, vegetation exists. These three classes consist the three categories of LC (Vegetation, Lands, and Water).

Classification of LC and area change

Urban land use/land cover information (LC) is important, and it has necessary information for urban and environmental management. However, it is difficult to extract urban LC information automatically in details from remote sensing images, especially for a large urban area. Urban homogeneous LC types can be derived, which are waterbodies, Lands, and vegetation (Cihlar *et al.,* 2000). The goal of image classification is to identify separate pixels that comprise the image into groups depending on the type of ground cover it represents. Therefore, three categories of LC were recognized (Water, Lands, and Vegetation) for the study area (Hilla River basin and Babylon Governorate) by this supervised classification. As a result, seven maps were created for the years 2013, 2014, 2015, 2016, 2017, 2018, and 2019 by using QGIS and Google Earth. Area of each class (Water, Lands, and Vegetation) and the related statistics were calculated too. Finally, LC area changes between years were revealed visually and quantitatively.

Modeling of LC area change

In order to explore the relationship between LC and Hilla River flowrate variation, statistical analysis was performed to make a decision whether the relationship is significant or not. Hilla River flowrates data were provided by the Department of Water Resources in Babylon Governorate for the study period (2013-2019). The available daily discharges were moved averaged to calculated the yearly values. R software were used to investigated this relationship by performing t-test between the considered variables, flowrates and NDVI. Furthermore, the flowrates data were explored to build a linear regression model by which researches can predict

NDVI in terms of Hilla River flowrates.

Results and Discussion

NDVI spatial-temporal distribution

The NDVI values were calculated for the years 2013-2019 by using Lands at-8 Level-2 products. Figure 4 shows the spatial-temporal distribution during these years over the region of interest, Hilla River Basin and Babylon Governorate part within the Landsat-8 senses. Statistics summary of each image in Fig. 4 was listed in Table 3. The high NDVI mean values were in 2019 and 2014, and the lower values were in the rest of years. However, the maximum value of NDVI was in 2019. The values of NDVI can range from -1.0 to +1.0. Higher values mean a larger difference between the red and near infrared radiation recorded by the sensor, a condition associated with highly photo synthetically-active vegetation. Low NDVI values point to a little difference between the red and NIR signals. This happens when there is little photosynthetic activities, or when there is just very little NIR light reflectance. On the other hand, water reflects very little NIR light. Therefore, in 2015, 2016, and 2018, low amount of water can be seen, see the red color in Fig. 4.

Since Hilla River is the only water source for vegetation in this region, the variation of its flowrates from 2013 to 2019 was considered. Based on Fig. 2,

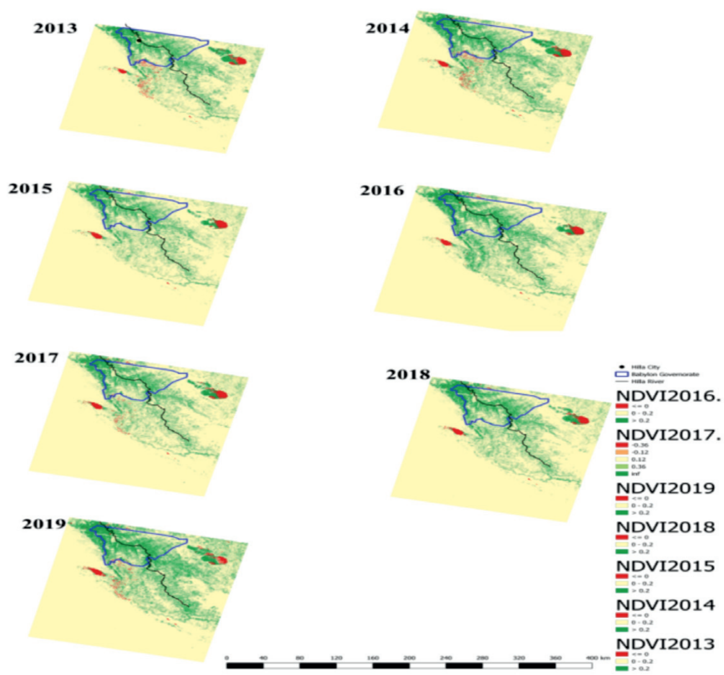

Fig. 4. NDVI spatial-temporal variation for Hilla River basin and Babylon Governorate.

Table 3. Summary statistics of NDVI values for Hilla River basin.

Year	NDVImax	NDVImean	NDVImin	NDVIrange	NDVIsd
2013	0.79	0.13	-0.50	1.30	0.08
2014	0.81	0.14	-0.64	1.46	0.09
2015	0.84	0.12	-0.83	1.67	0.08
2016	0.83	0.13	-0.68	1.51	0.09
2017	0.87	0.12	-0.60	1.47	0.09
2018	0.90	0.13	-0.66	1.57	0.09
2019	0.92	0.15	-0.91	1.83	0.10
Max	0.92	0.15	-0.50	1.83	0.10
Min	0.79	0.12	-0.91	1.30	0.08

the flowrate wasthe lowest in 2018 (90 m^3/s) compared to the other years, followed by another low value of 105 m^3/s in 2015, while the rates were almost the same in the other years. The highest river rate was 165 m^3/s in 2019 due to releasing extra amount of water at the river inlet, increasing the NDVI values during 2019. In general, Turkey has reduced the quantity of water in Euphrates River due to building a big dam the Euphrates River inlet, lowering the Hilla River flowrates.

Figure 5 shows the change occurred in NDVI compared to Hilla River flowrates. It generally shows that when the flowrates increases, the value of NDVI increases, improving the vegetation in the basin. Although it was found a sharp decrease in flowrates in 2015 and 2018, a positive trend in NDVI maximum values exist. In addition, when the river flowrate goes down, photosynthesis decreases, and thus vegetation decreases and becomes unhealthy, reflecting less NIR and making the vegetation unhealthy. This behavior impacted the vegetation health in 2015, 2016, and 2018. The total spatial increase or decrease of NDVI between years was displayed visually in Fig. 6. Also, in an attempt to find a linear model connecting NDVIs with the flowrates statistically, a non-significant statistical relationship was found based on the correlation test (t-test).

LC categories and area changes

Lands or soilwas the main LC class in the study area. It occupied vast area of about 31004.7 km² (85%) out of the total study area. Vegetation extended over an area of about 5108.1 km² (14%), and water was the lowest area of about 383.7 km² (1%). Figure 7 highlights the percentageof each LC category for the study period based on results in Table 4. The widest water distribution was in 2014 and 2019 compared to the percentages in 2015, 2016, and 2018. On the other hand, the lands increased in 2015, 2016, and 2018 and decreased in 2014 and

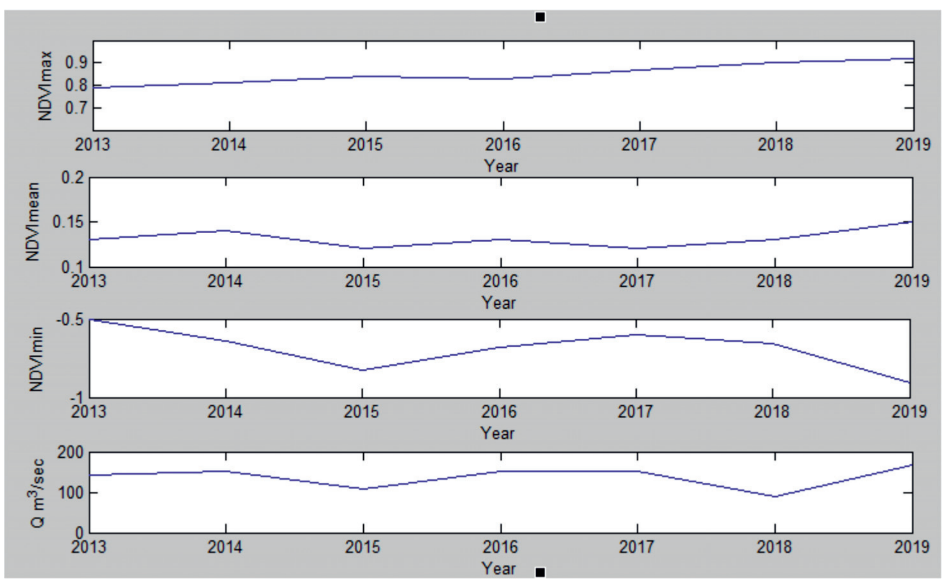

Fig. 5. The relationship between NDVI and Hilla River flowrates.

Table 4. LC categories for Hilla River basin over years; areas and percentages.

Year	Water (km²)	Water (%)	Soil (km²)	Soil (%)	Vegetation (km²)	Vegetation (%)	Total area (km²)
2014	504.90	1.38	30471.12	83.49	5521.47	15.13	36497.49
2015	290.21	0.80	32084.31	87.91	4121.85	11.29	36496.37
2016	292.10	0.80	31045.55	85.07	5158.34	14.13	36495.99
2017	425.69	1.17	31689.42	86.84	4378.02	12.00	36493.14
2018	295.07	0.81	31495.81	86.29	4710.11	12.90	36500.99
2019	494.33	1.35	29242.37	80.13	6759.12	18.52	36495.82

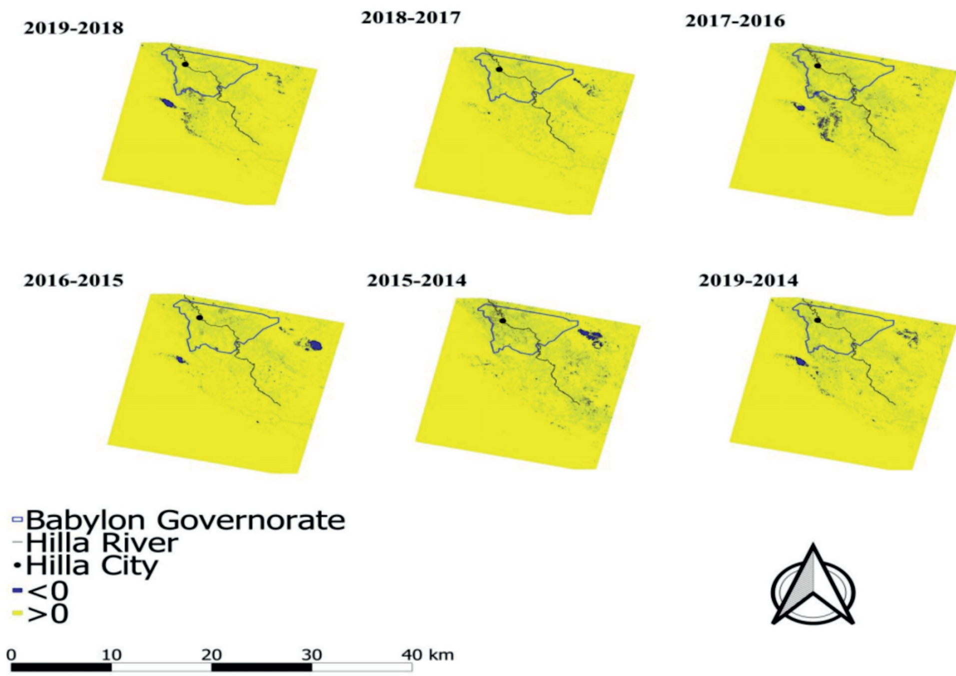

Fig. 6. Total spatial-temporal changes of NDVI for Hilla River basin over years; The positive yellow part represents the places where NDVI became higher, while the negative dark changes point to the NDVI decline.

2019. As a result, water loss led to increase lands or soil clearly, impacting green areas.

In addition, area changes between successive years were investigated for each LC class within a single Babylon Governorate polygon, see Table 5 and the related Fig. 8, 9, and 10. Water increased during 2018-2019 clearly, and it decreased during 2014-2015. Therefore, lands decreased and vegetation increased during 2018-2019, while lands increased and vegetation decreased during 2014-2015. This can be clearly seen in Fig. 4 where the green plants became darker in 2019 compared to 2014. Furthermore, the maximum NDVI values varied positively during the entire study period as shown in Fig. 5. As a matter of fact, in 2019, Iraq region has become stable more than before due to war and political issues within this region previously. These issues impacted the water resources and the agricultural sector extensively, affecting LC over the Hilla River basin.

Conclusion

Spatial and temporal distribution of LC changes and NDVI were remotely investigated based on Landsat-8 Level-2 Surface Reflectance datasets for Hilla River basin, Iraq for the study period 2013-2019. Results showed that there is an improvement in vegetation area in 2019 compared to the previous years due to an increase in the amount of water in this region. Vegetation areas became darkerand wider spatially in 2019, and the maximum NDVI values increased over time positively. In this basin, the study indicated lands or soils was the dominant

Table 5. LC area changes for Babylon Governorate polygon over years.

Year	Water(km^2)	Lands or Soil (km^2)	Vegetation (km^2)
2019-2018	24.4089	-310.788	286.3791
2018-2017	-15.8274	-169.8858	185.724
2017-2016	12.024	153.6867	-165.7215
2016-2015	-3.1581	-200.7828	203.9409
2015-2014	-16.6599	303.9399	-287.28

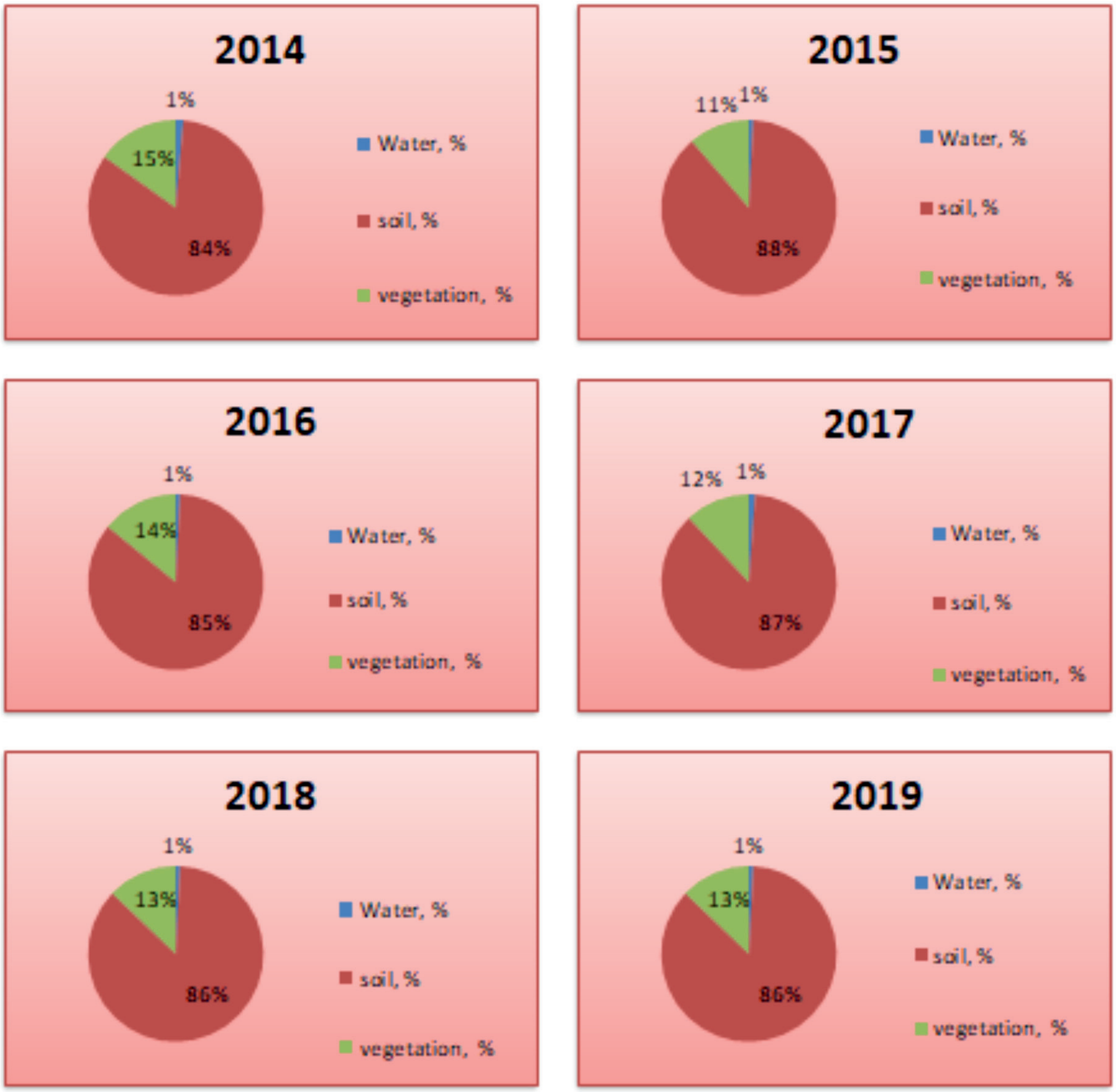

Fig. 7. Percentage of LC categories for Hilla River basin over years.

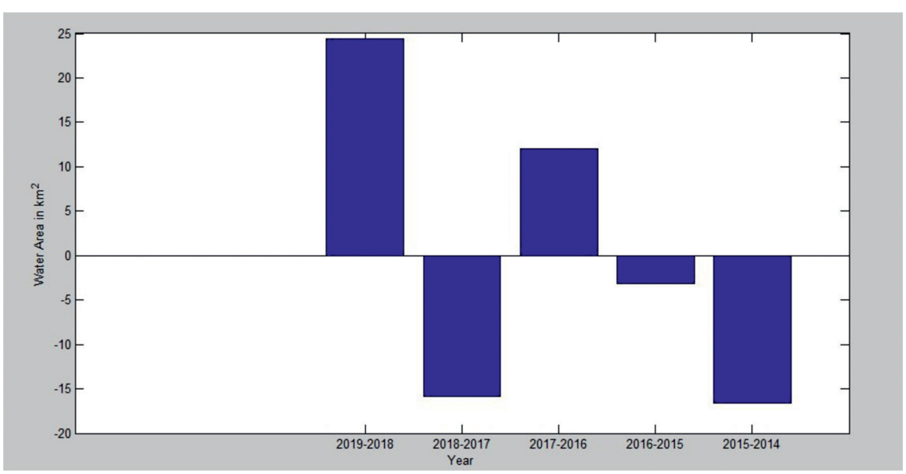

Fig. 8. Water area change between years for Babylon Governorate polygon within Landsat-8 sense.

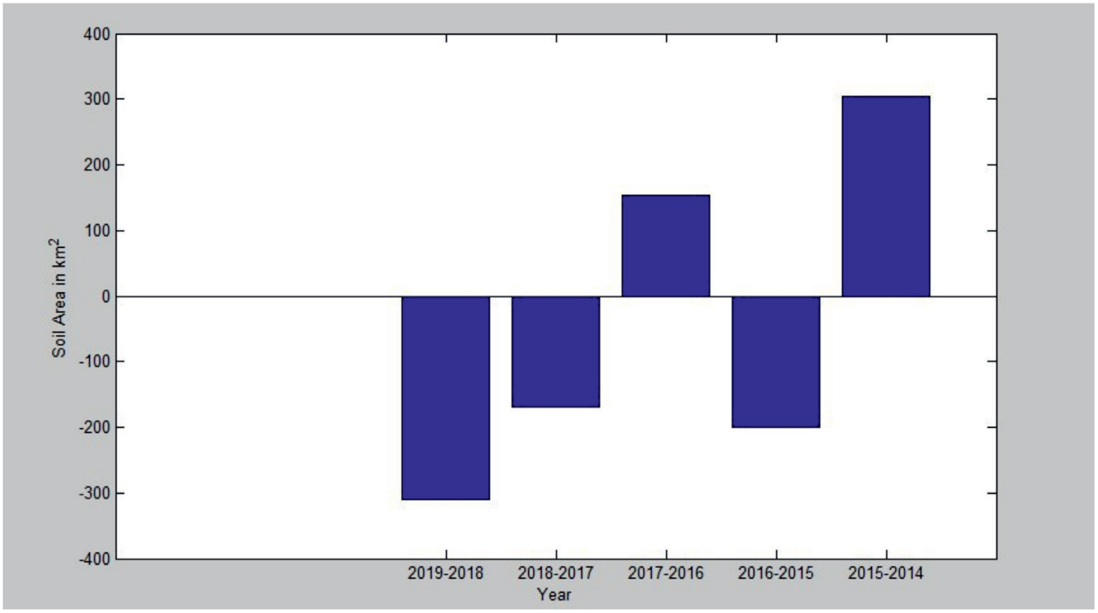

Fig. 9. Soil area change between years for Babylon Governorate polygon within Landsat-8 sense.

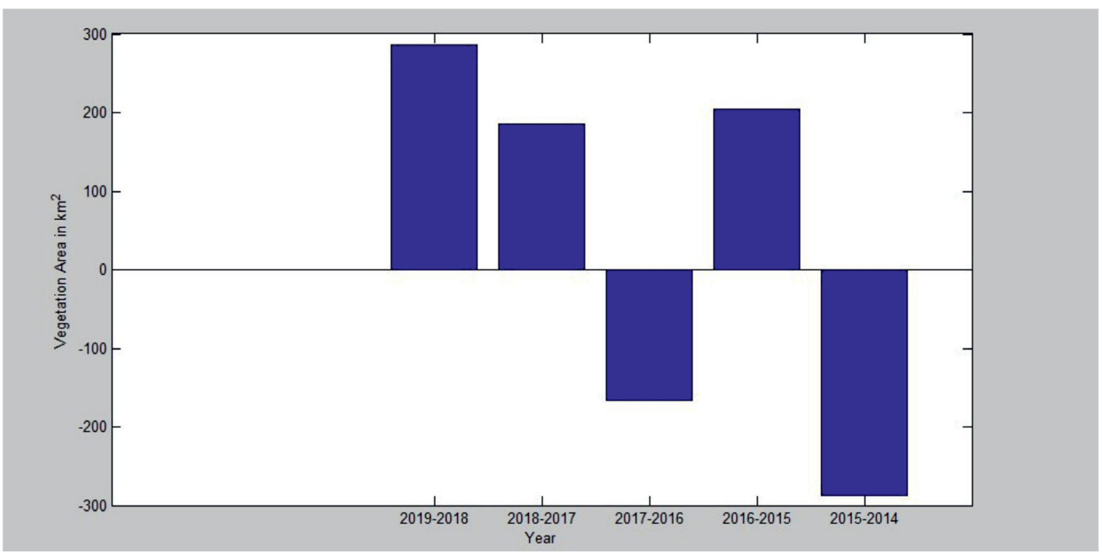

Fig. 10. Vegetation area change between years for Babylon Governorate polygon within Landsat-8 sense.

category, followed by vegetation and water. In addition, Hilla River was the main forcing factor. The higher the river flowrates, the better maximum NDVI values can be observed.

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