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Satellite-Based Environmental Modeling of Land Use/Land Cover (LULC) Area Changes in the Hilla River Region, Iraq

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Abstract

Since LULC has been varying and continuing to change, the trend of this change has become tremendously significant in the environmental studies. In this research, LULC changes were characterized remotely at a regional scale based on NDVI categories (water, lands or soil, vegetation) where no LULC methodology studies have been conducted previously (Hilla River basin and Babylon Governorate, Iraq) by using GIS tools and Landsat-8 Level-2 surface reflectance datasets (2013-2019). Both of the spatial and temporal variations were explored, making the tendency of change in land cover easy to evaluate and providing source of information about these changes. Results concluded that lands, vegetation, and water occupied about 85%, 15%, and 1%, respectively. The higher increase in Babylon Governorate water areas was during 2018-2019 (an increase of 24.4089 km2) compared to the rest of years (positive trend in NDVI maximum values), improving the vegetation areas (an increase of 286.3791 km2). In addition, statistical analysis indicated that there is no significant linear model between NDVI and Hilla River flow rates.

Key words: LULC, NDVI, Remote sensing, LANDSAT 8, Hilla River.

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1 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 (LULC). The complex dynamics among LULC composition (lands, water, and vegetation) and between LULC and climate impact the LULC area change spatially and temporally[1]. 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 LULC can be remotely detected by using a variety of temporal and spatial resolutions (satellite-based data), revealing the LULC area change quantitatively and visually [2],[3],[4]. 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 [5], leading to various LULC 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 LULC 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.

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 LULC and NDVI changes over time exist. In addition, the previous studies were performed based Level-1 satellite datasets (Fadel 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. Previous studies were conducted on the basis of Level 1 satellite datasets (Fadel et al. [5]; Faraj et al. [6]; Muhammad et al. [7]; Dosky et al. [8]]; al-Qurashi and Komer et al. [9]; Leung et al. [4]; Kafi et al. [10]; Muhammad Hani et al. [11]). These data sets were preprocessed prior to NDVI identification using different machine learning languages and software, with the potential for error encountered.

Thus, this paper outlines a new approach by using NDVI vegetation index for assessing and monitoring LULC 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 LULC over time was modeled to link the changes with river flowrates.

2 Materials and Methods

2.1 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 Figure 1.

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.

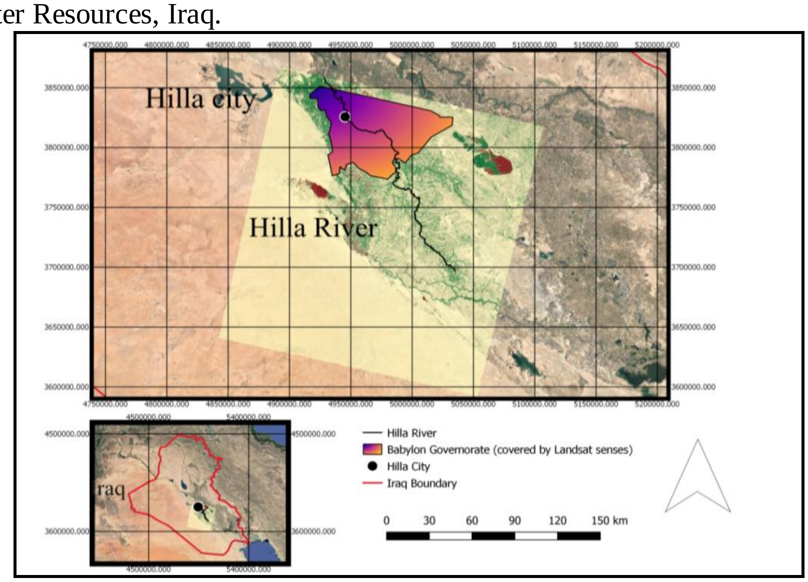

Figure 1: The study area of Iraq,Babylon Govermnorate,Hilla City.

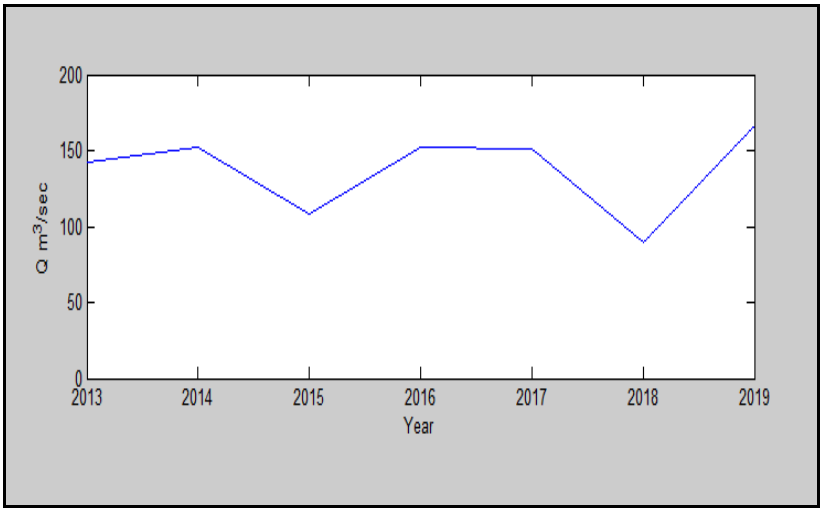

Figure 2: Hilla River average flowrates (Q), 2013-2019.

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

2.2 Landsat-8 Datasets

This study deals with various multi-temporal data products Level-2 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 [12][13]. Senses of 30 m of 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 LULC 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 [14],[15]. 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.

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

2.3 General Framework of the Study

Figure 3. illustrates a 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 LULC changes and NDVI trend, Landsat- 8 data products were chosen, downloaded from Earth Explorer of United State Geological Survey (USGS) website, explored statistically, and then processed in QGIS.

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 LULC 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 Figure 1.

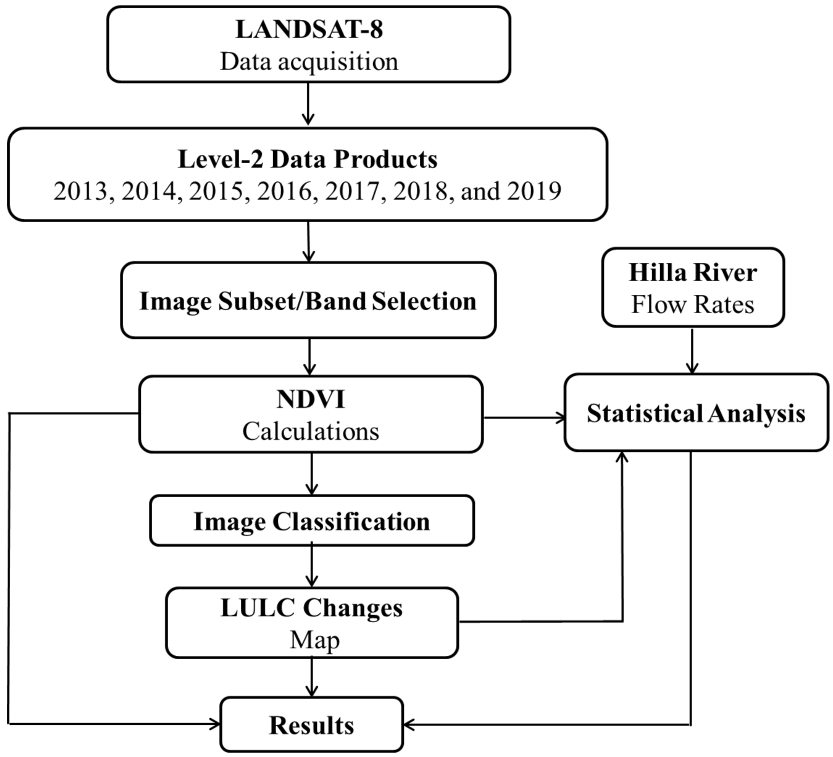

Figure 3: The research methodology.

2.4 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 LULC (Vegetation, Lands, and Water).

2.5 Classification of LULC and Area Change

Urban land use/land cover information (LULC) is important, and it has necessary information for urban and environmental management. However, it is difficult to extract urban LULC information automatically in details from remote sensing images, especially for a large urban area. Urban homogeneous LULC types can be derived, which are waterbodies, Lands, and vegetation [2]. 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 LULC 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, LULC area changes between years were revealed visually and quantitatively.

2.6 Modeling of LULC Area Change

In order to explore the relationship between LULC 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.

3 Results and Discussion

3.1 NDVI Spatial-Temporal Distribution

The NDVI values were calculated for the years 2013-2019 by using Landsat-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 Figure 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 values difference between red and near infrared radiation Registered by the sensor, a condition associated with a high degree photo synthetically-active vegetation. Low values of NDVI point to a little difference between the red signal and NIR signal. This happens when there's little photosynthetic activities, or when there is just very slight reflectance little of NIR light . 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 Figure 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 Figure 2, the flowrate was the lowest in 2018 (90 m3/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 165m^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 Figure 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).

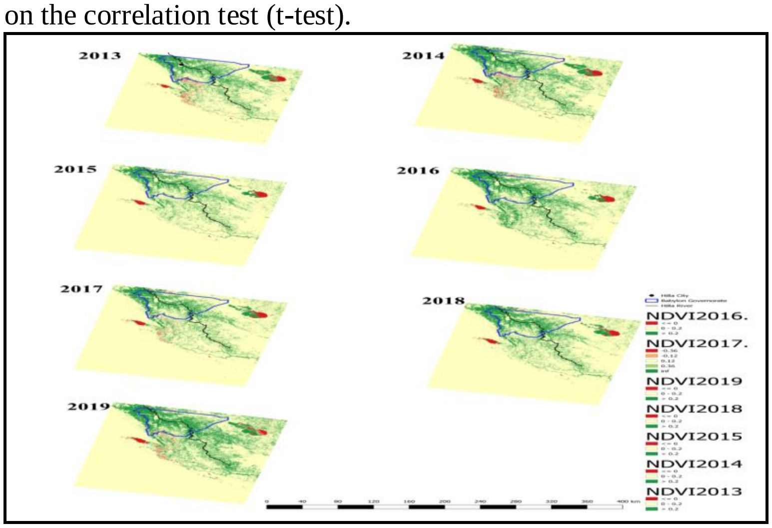

Figure 4: NDVI spatial-temporal variation for Hilla River basin and Babylon Governorate. 2013-2019.

Table 3: Summary statistics (maximum, mean, minimum, range, and standard deviation) of NDVI values for Hilla River basin, 2013-2019.

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

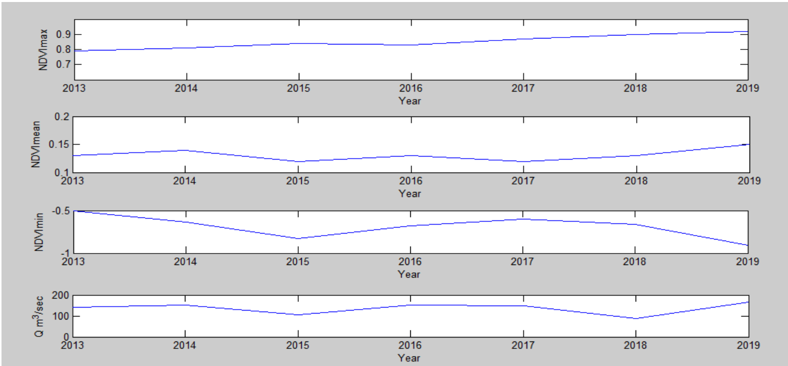

Figure 5: The relationship between NDVI and Hilla River flowrates

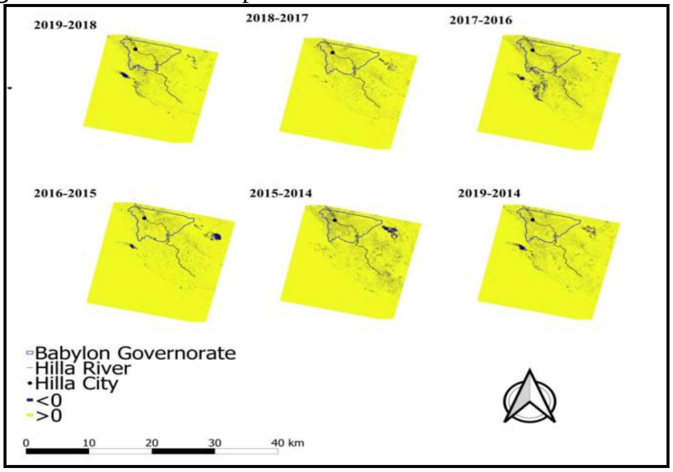

Figure 6: Total spatial-temporal changes of NDVI for Hilla River basin over years; The positive yellow part represents the places where NDVI became higher, while the negative dark changes point to the NDVI decline

3.2 LULC Categories and Area Changes

Lands or soil was the main LULC class in the study area. It occupied vast area of about 31004.7 km^2 (85%) out of the total study area. Vegetation extended over an area of about 5108.1 km^2 (14%), and water was the lowest area of about 383.7 km^2 (1%). Figure 7 highlights the percentage of each LULC 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 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 LULC class within a single Babylon Governorate polygon, see Table 5 and the related Figure 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 Figure 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 Figure 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 LULC over the Hilla River basin.

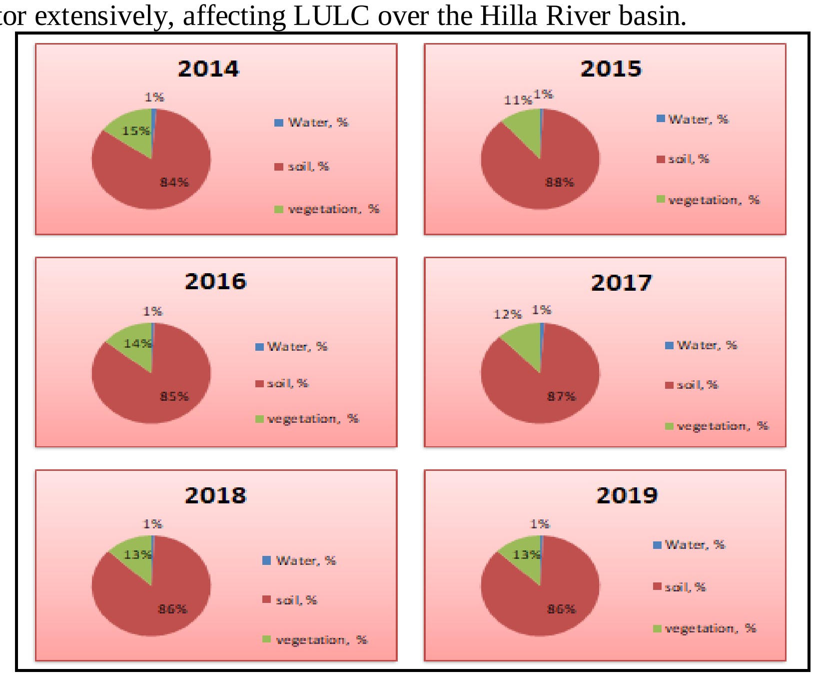

Figure 7: Percentage of LULC categories for Hilla River basin over years; Vegetation, Lands or Soil, and Water.

Table 4: LULC categories for Hilla River basin over years; areas and percentages

Year	Water (km^2)	Water (%)	Lands or Soil (km^2)	Lands or Soil (%)	Vegetation (km^2)	Vegetation (%)	Total area (km^2)
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

Table 5: LULC area changes for Babylon Governorate polygon over years within Landsat-8 senses

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

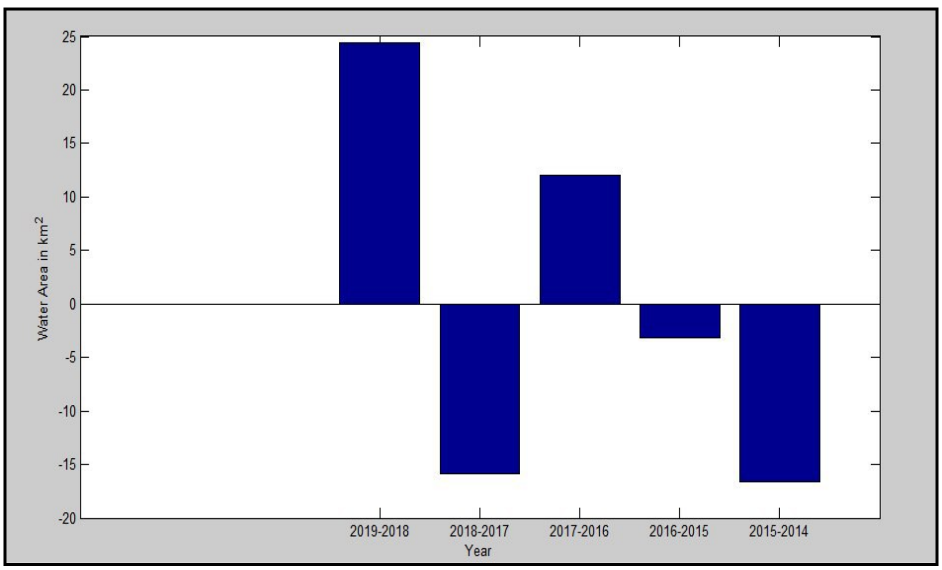

Figure 8: Water area change between years for Babylon Governorate polygon within Landsat-8 sense.

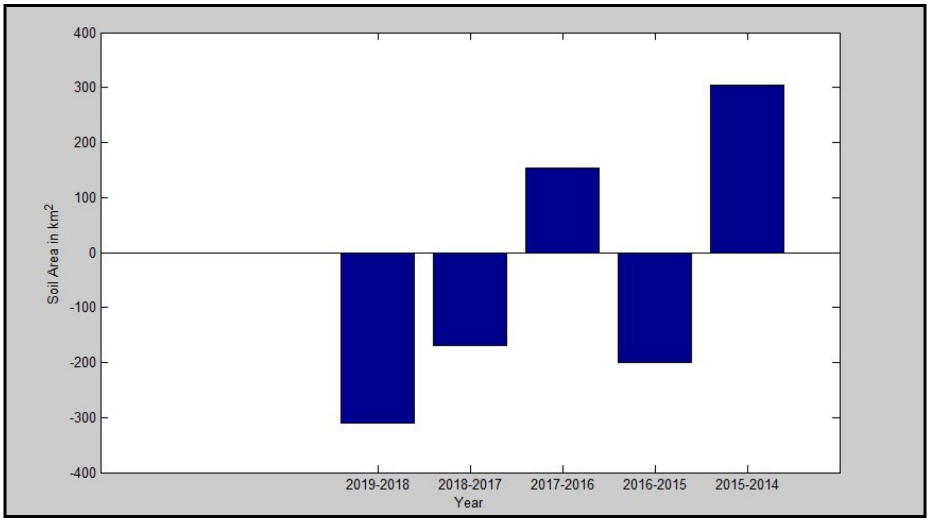

Figure 9: Soil area change between years for Babylon Governorate polygon within Landsat-8 sense.

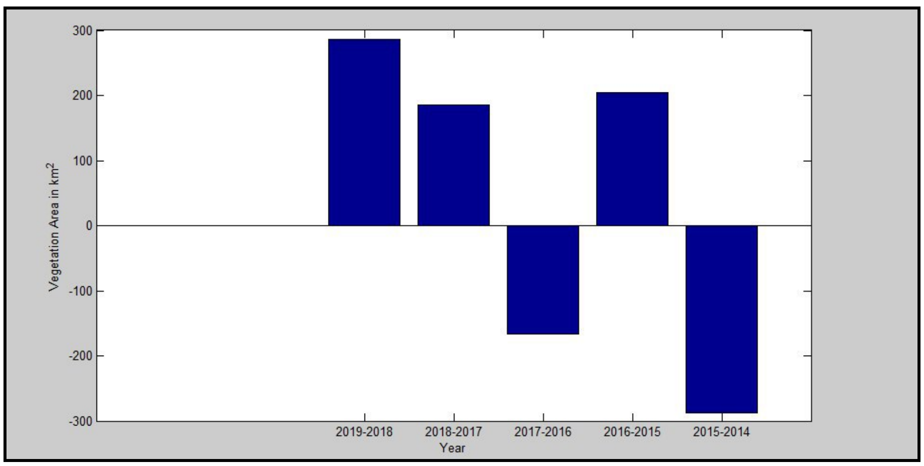

Figure 10: Vegetation area change between years for Babylon Governorate polygon within Landsat-8 sense.

4 Conclusions

Spatial and temporal distribution of LULC 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 darker and 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 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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Biographies

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