



## Environmental Investigation of Bahar Al-Najaf Region Using Sentinel-2 Images

Mustafa H. Al-Helaly\*, Imzahim A. Alwan , Amjed N. AL-Hameedawi 

Civil Engineering Dept., University of Technology-Iraq, Alsina'a street, 10066 Baghdad, Iraq.

\*Corresponding author Email: <mailto:bcc.19.75@grad.uotechnology.edu.iq>

### HIGHLIGHTS

- This paper aims to throw light on environmental impact assessment during the past five years in a representative area of the western part of Iraq
- There is a rise in water levels in the Bahar Al-Najaf which lead to different LULC Patterns
- Flooded areas increased in 2020 to 50% more than in 2016.
- The vegetation cover in 2020 is 56% higher than in 2016.

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### ABSTRACT

This study aims to shed light on the indicators of environmental change and environmental impact assessment during the past five years in a representative area of the western part of Iraq (BAHAR-ALNAJAF). This is to understand the leading causes that led to the environmental changes from (2016 to 2020) due to the change in land cover in the study area. The paper refers to an environmental study for the study area using satellite data within the software environment (ArcGIS) and the application of remote sensing from two aspects: Ecological indices retrieval and the monitoring environment for land cover. Remote sensing and GIS software have been utilized to categorize (Sentinel-2) imagery into seven land use and land cover (LULC) classes: cropland land, orchards land, wetland, sandy area land, mixed barren land, built-up land, and water bodies. Supervised classification and Normalized Difference Vegetation Index (NDVI), Normalized Difference Built-up Index (NDBI), Normalized Difference Water Index (NDWI), and Normalized Difference Salinity Index (NDSI) were approved and utilized respectively to retrieve its class boundary. From a practical point of view, it was found that there is a rise in water levels in the Bahar Al-Najaf; this rising has led to the flooding of many built-up and vegetated lands. As a result, flooded land areas increased in 2020 to about 50% more than in 2016. Consequently, the built-up growth regions in the study area were very slow to change during the study period (2016-2020). The vegetation cover for 2020 is 56% higher than in 2016 because of the abundance of water and agricultural policy of this year.

## 1. Introduction

The natural environment is vital for continuing human life and development as it offers water resources, land resources, biological resources, climate resources, etc. The environment and its preservation, in most developing countries, are not considered a priority and are almost ignored. Constant neglect of the environment can cause an irreparable problem [1]. Accordingly, it is the turn of researchers and conservationists to warn officials and submit scientific reports. One aspect that encourages assessing the environment case is estimated land use/cover changes. Land use/cover (LULC) affects the local and global environment, and climate and land degradation affect ecosystem services and functions [2-3]. The land cover of the earth's surface has changed for a long time and is probable to endure variation in the future [4]. These changes occur at various spatial scales from local to global and at temporal frequencies from days to thousands of years. Both natural and human forces are in charge of the variation. Natural forces such as continental drift, glaciation, floods, tsunamis, and human forces such as the change of forests to agriculture, urban sprawl, and forest plantations have altered the dynamics of land use/land cover types worldwide. Recently, manufactured land use/land cover change has been proceeding faster than natural change. This ordinary ratio of variation is a primary environmental concern worldwide. Accordingly, nearly all of the world's ecosystems are considerably enhanced or are being changed by humans, undermining the ability of the planet's ecosystems to provide goods and services. Technological development and population increase are two major forces in charge of human variations [5]. The RS plays a vital function in giving geospatial data needed for databases and monitoring the whole earth's surface. Satellite observations of land, oceans, atmosphere, and particularly during phenomena have become significant to guard the global

environment, reduce disaster losses and ensure sustainable development. Satellite remote sensing utilizes space-borne sensors and is a state-of-the-art technology that allows data acquisition systematically and comprehensively-temporary high accuracy between several minutes and several days [6]. RS and Geographical Information System (GIS) approach, combined with earth recognition, provide new methods for developed ecosystem management by observing the variation overtime at the local, regional and global scales [7]. In the last decade, RS has been positively implemented as an environmental monitoring tool, particularly for assessing ecosystems containing forests, grasslands, urban areas, and rivers, allowing remote assessment of the environment through generalized quality indicators.

Several countries have carried out extensive environmental monitoring using remote sensing technology. Several studies were also achieved in Europe, the United States, and other regions. Several individual remote sensing indicators have been created to determine the environmental state [8]. Many previous local studies were conducted on the spectral classification process to classify satellite images based on various algorithms such as MLC and ANN [9; 10; 11; 12] when classifying land covers based on satellite images. Bahar Al-Najaf is a distinct topographical feature and a unique geographical feature in the middle Euphrates region, with a water swamp named Najaf Lake in the center. The opening of the Najaf Sea to the sedimentary plain on its southern side, as well as the ease with which irrigation water can be delivered to it, aids agricultural activities, as there are huge tracts of agricultural land on its boundaries, estimated to be around 20,000 dumdots [13]. This study aims to shed light on the environment change indicators and environmental impact assessment during the last five years in a representative area of the western part of Iraq (BAHAR- ALNAJAF). Such a study could assist in understanding the main causes that led to the environmental changes during the period from 2016 to 2020 as a result of the change in land cover in the study area.

## 2. Problem Statement

The environmental change that occurred in the Bahar Al-Najaf region resulted from the change in LCLU during the time from (2016 to 2020). During the past five years, this study area has witnessed remarkable changes in land cover due to the high-water level in the Bahar Al-Najaf. Furthermore, field visits indicated the main following points:

- 1) Agricultural lands in the east and south of Lake of Najaf were flooded.
- 2) The water has flooded the barren and the empty lands stretching towards the desert south and west of the lake.
- 3) The water has flooded the built-up area (Al-Noor city) southwest of the lake.
- 4) Large parts of the main roads (the Strategic oil pipeline road- the Hajj Bree Road) were flooded, leading to these roads' collapse, making them out of service.
- 5) The water has flooded most industrial lands (brick factories - screening factories), which led to their collapse, making them out of service.

## 3. Background

The area is assessed for environmental variation using the mainland degradation index method and GIS tools, and then to analyze the effects of LULC class expansion on the environment. The method was used to retrieve class boundary indices. The five indices adopted here were tested for vegetation changes;

### 3.1 Normalized difference vegetation index (NDVI)

It is the vegetation cover indicator extracted through the red and near-infrared band according to Equation 1.

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}} \quad (1)$$

Where  $\rho_{RED}$  and  $\rho_{NIR}$  are the red and near-infrared bands. For more information, the numbered research [14-15] can be reviewed.

### 3.2 Normalized difference built-up index (NDBI)

It is used to restore urban lands from photos. The mathematical expression for this indicator is based on the short-wave infrared and near-infrared bands according to Equation 2.

$$NDBI = \frac{\rho_{SWIR} - \rho_{NIR}}{\rho_{SWIR} + \rho_{NIR}} \quad (2)$$

Where  $\rho_{SWIR}$  and  $\rho_{NIR}$  are the short-wave infrared and near-infrared bands. For more information, the numbered research [16-17] can be reviewed.

### 3.3 Normalized difference water index (NDWI)

This is an important indicator in determining open water. NDWI uses reflected near-infrared light and visible green light to extract its value according to mathematical model No 3.

$$NDWI = \frac{\rho_{GREEN} - \rho_{NIR}}{\rho_{GREEN} + \rho_{NIR}} \quad (3)$$

Where  $\rho_{GREEN}$  and  $\rho_{NIR}$  are the green and near-infrared bands. For more information, the numbered research [17-18] can be reviewed.

### 3.4 Normalized difference salinity index (NDSI)

The salinity index is the inverse of the vegetation index, and therefore the red and near-infrared ranges are used within the algorithm used to extract it, as shown below.

$$NDSI = \frac{\rho_{RED} - \rho_{NIR}}{\rho_{RED} + \rho_{NIR}} \tag{4}$$

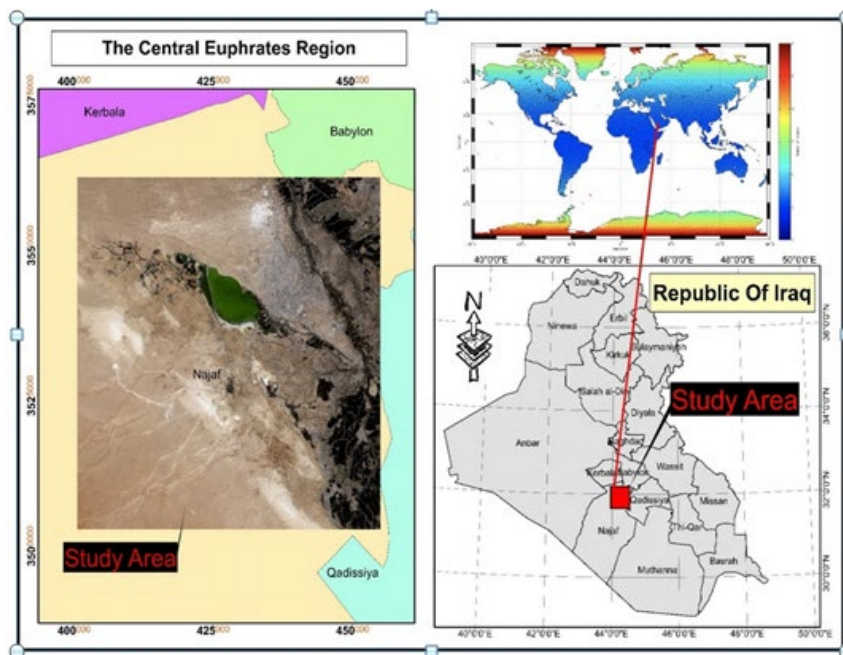
Where  $\rho_{RED}$  and  $\rho_{NIR}$  are the red and near-infrared bands. For more information, the numbered research [19-20] can be reviewed.

## 4. Study Area

The study area, which includes the Bahar Al-Najaf region, is rectangular with dimensions of (54.438<sup>km</sup> – 58.542<sup>km</sup>) and is located in the central Euphrates region within the Al-Najaf Governorate, as shown in Figure 1. The governorate is in southwestern Iraq, about (161<sup>km</sup>) southwest of the capital of Baghdad, and it borders Saudi Arabia, which lies in the arid zone. It also has internal boundaries with the cities of Anbar, Karbala, Babel, Qadisiya, and Methane, as shown in Figure 1. It has an area of about 28,824 <sup>km</sup><sup>2</sup> which is about 7% of Iraq’s total area. The study area is in Bahar Al-Najaf, Iraq. The geographic coordinates of this area are longitude (31° 40' 00" N - 32° 10' 00" N), and latitude (44° 00' 00" E - 44° 30' 00" E). The subset area occupies an area of (3186.913 <sup>km</sup><sup>2</sup>), as shown in Table 1.

**Table 1:** The information about the study area. WGS 1984 UTM ZONE 38 N

Study Area Shape	Study Area Area	Coordination of the corners of the study area		
		NO.	East	North
rectangle	3186913 Km2	1	455000 E	3561342 N
		2	400562 E	3561342 N
		3	400562 E	3502800 N
		4	455000 E	3502800 N



**Figure 1:** The study area boundaries

## 5. Data Sets

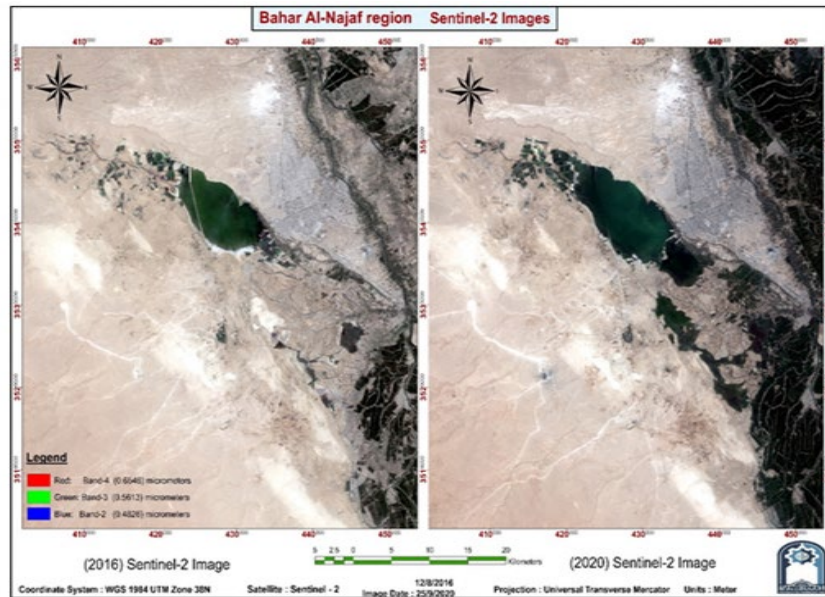
Two Sentinel-2 satellite images were downloaded from ([earthexplorer.usgs.gov](http://earthexplorer.usgs.gov)) [21] and prepared for this study, as shown in Figure 2. The date of acquisition for each image is illustrated in Table 2.

**Table 2:** Date of acquisition for the sentinel-2 data sets

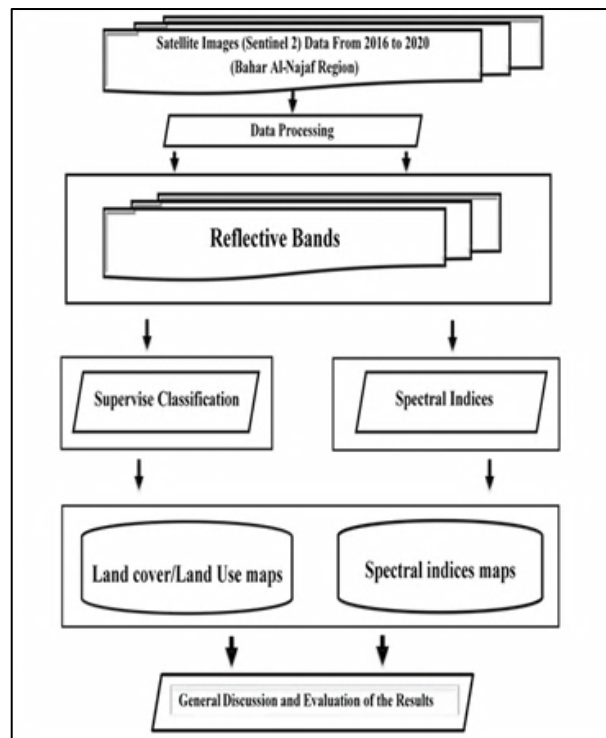
Dataset	Sensor-ID	Parameter	Characteristics	Platform
Sentinel-2	MSI	Platform	2016-08-12 2020-09-25 10m-20m-60m	Sentinel-2A Sentinel-2B
		Date		
		Spatial Resolution		

### 6. Methodology

The implemented processing procedures can be categorized into two parts. The first one concerns the extraction and recognition of the land features based on spectral indices, i.e., NDVI, NDBI, NDWI, and NDSI. The second category belongs to the extraction of LULC map based on performing maximum likelihood classification method by adopting seven classes (cropland land, orchards land, wetland, sandy area land, mixed barren land, built-up land, and water bodies) based on Anderson (1976) [22]. The overall processing of the two categories is illustrated as shown in Figure 3.



**Figure 2:** Map of the Sentinel-2 (2016-2020) images



**Figure 3:** The overall sequence of processing



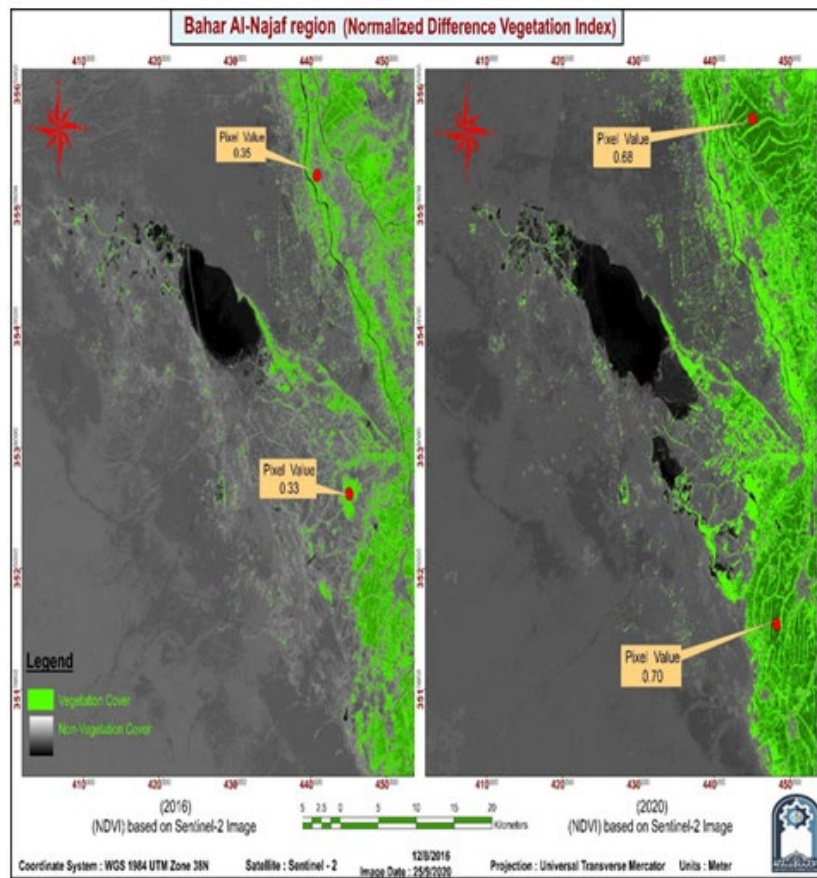
## 7. Results and Discussion

### 7.1 Spectral indices

Empirically, it is found that the 0.2 NDVI value has been considered as a threshold value, such that the NDVI with values greater than 0.2 are represented as vegetation cover. While the values that are less than 0.2 are represented as non-vegetation covers, as shown in Figure 4 [23]. The green color is gradual depending on the density and health of the plant. Large positive pixels indicate healthy plants and vice versa. It is noticed that the orchards adjacent to the Euphrates are rather weak, as their trees are not in good condition (pixel value 0.33-0.35) compared to the healthy rice crop (pixel value 0.65-0.70). The area of vegetation through this indicator can be almost calculated accordingly, as shown in Table 3, where the area for vegetation cover for the year 2016 was 387.94 km<sup>2</sup>. For the year 2020, it was 605 km<sup>2</sup>.

**Table 3:** Information extracted from the NDVI indicator for 2016 and 2020

Indices	Class	2016	2020
NDVI	Vegetation Cover	387.940 km <sup>2</sup>	605.250 km <sup>2</sup>
	Non-Vegetation Cover	2798.770 km <sup>2</sup>	2581.660 km <sup>2</sup>



**Figure 4:** Map of the NDVI based on Sentinel-2 images

As for the open water index (normalized difference water index), it is found that [ , the 0 of NDWI value has been considered a threshold value. Therefore, the NDWI with values greater than 0 is represented as water area. While the values that are less than 0 are represented as non-water area, as shown in Figure 5. Table 4 shows the area of water cover in 2016, which was 93.284 km<sup>2</sup>, while in 2020, it will become 160.025 km<sup>2</sup>.

**Table 4:** Information extracted from the NDWI indicator for 2016 and 2020

Indices	Class	2016	2020
NDWI	Water cover	93.284 km <sup>2</sup>	160.025 km <sup>2</sup>
	Non-Water cover	3093.632 km <sup>2</sup>	3026.891 km <sup>2</sup>

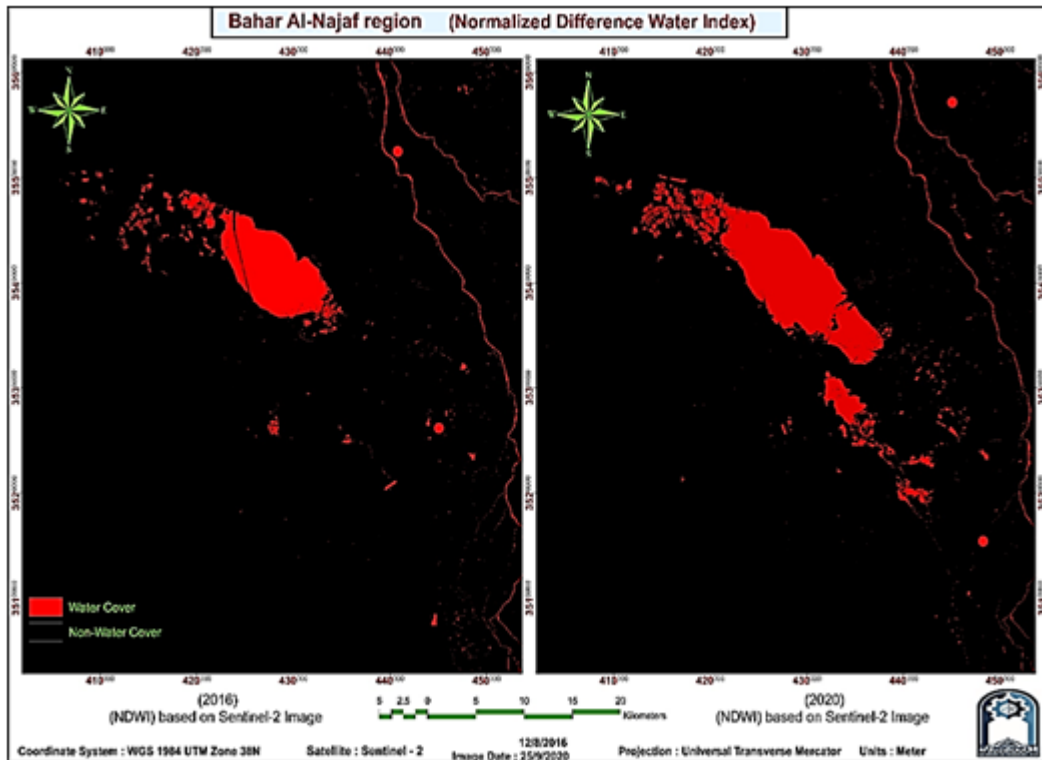


Figure 5: Map of the NDWI based on Sentinel-2 images

Regarding the NDBI indicator, it was noted that the values of pixels ranging from 0.01 to 0.04 represent the built-up areas. Sand dunes, bare soil lands, and arid lands are somewhat overlapping with built-up areas, so the NDBI indicator cannot be adopted for distinguishing among these classes. The surfaces of many buildings within the study area, built from the clay brick, have a very close spectral signature of spectral signatures for dunes, base soil lands, and aired lands. There is a clear convergence between the values of the NDVI and NDWI indicators. Consequently, there is a lot of overlap between the vegetation cover and the water areas within the study area.

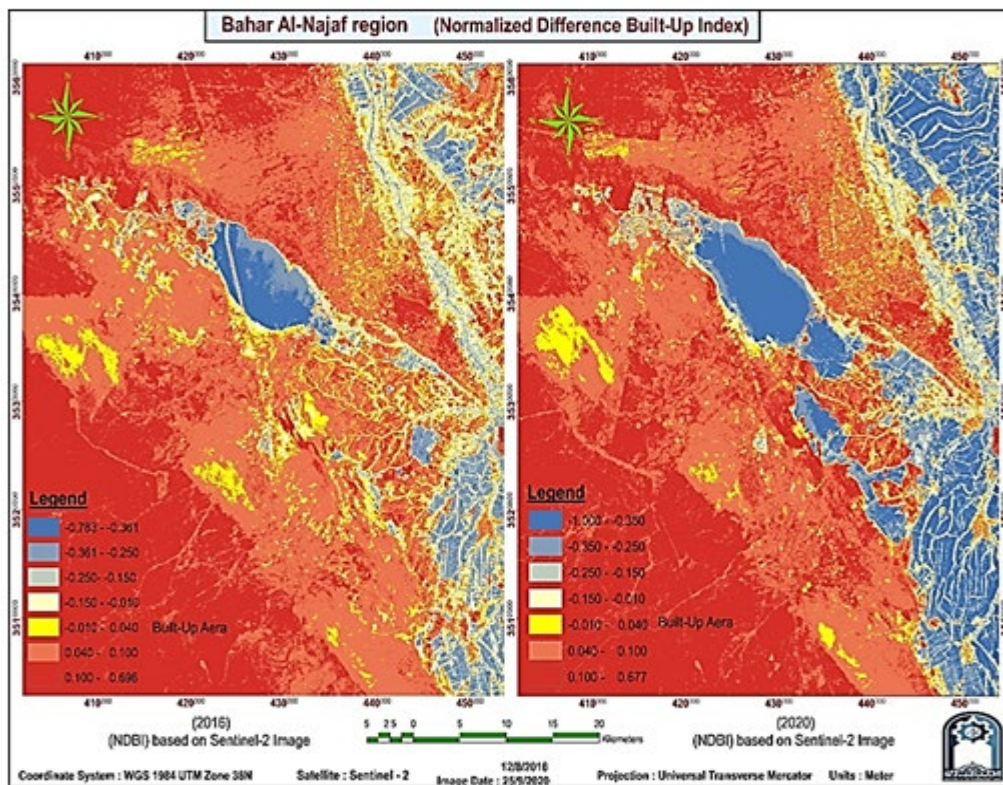


Figure 6: Map of the NDBI based on Sentinel-2 images



Figure 7 refers to NDSI, one of the essential spectral indices used in environmental studies. The following things can be summarized: good and clear insulation between water cover ( $>0.049$ ) and vegetation cover ( $<- 0.138$ ), collect all kinds of soil (sandy soil - gypsum soil - clay soil) pixel values range from ( $- 0.139- 0.049$ ). Finally, the ability of this indicator to isolate water, plants, and soil and various results can be deduced from comparing other environmental indicators.

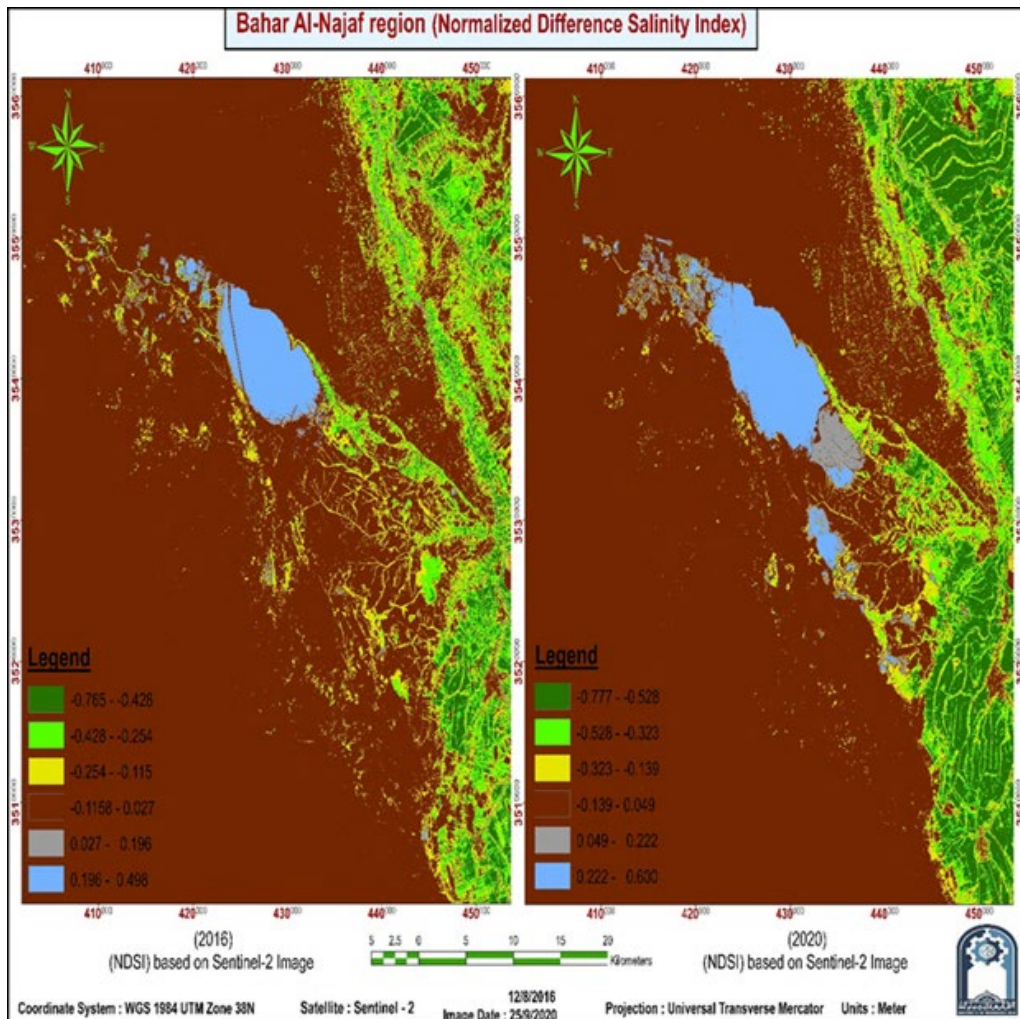


Figure 7: Map of the NDSI based on Sentinel-2 images

## 7.2 Maximum likelihood classification

To extract the LULC map of the study area for 2016 and 2020, 10-meter spatial resolution bands of sentinel-2 were used as input. The maximum likelihood classification method is selected to extract the seven classes mentioned above. The initial training areas for each class have been determined based on the site visit to the study area. The output thematic LULC maps for the 2016 and 2020 years were prepared as shown in Figure 8. Depending on the confusion matrix used for the classification process's accuracy assessment, the resultant average overall accuracy is about 85%, as shown in Table 9. Some related statistical analysis for these classes is conducted as illustrated in Table 5 and Figure 10. Changes in LULC provide significant social and economic benefits and come at a high cost to the natural ecosystem. Changes in terrestrial ecosystems, biodiversity, and landscape ecology may result from natural and human-caused processes [6].

The regions of the northern Bahar Al-Najaf witnessed the establishment of many unlicensed artificial ponds during the past few years, which are used to raise fish, and these ponds depend on drilling artesian wells, as many of these wells have been dug. Also, these areas within the study area include about (57) natural water springs. Since ancient times, these springs have supplied the area with water (General Commission for Groundwater/Map of the distribution of wells BaharAl-Najaf). Thus, the north of the lake became a water source that supplies the lake to a large proportion. The southern part of the Bahar Al-Najaf: Theater sources come from the Euphrates River through the three rivers (Al-Sudair–Abu Jadoah–Al-Badairya), which are water released in large quantities for the recovery of agriculture, crops, and vegetables, and the cultivation of rice in the Bahr Al-Najaf region, which eventually flows into the lake. Water sources come to the lake from the (Al-KiflShanafiya project) drainage network, which is the output of cultivating the lands south of the lake with the rice crop. Three drainages flow into the lake from the south (Abu Jadoah right puncture–Abu Jadoah left puncture–National trench). South of the lake, there is a heavy water and sewage treatment plant located on the (Abu Jadoah) river. The dimensions of this plant are( 1000m\*1000)m, and it is a wastewater treatment plant for the entire city of Najaf.

The western part of the Bahar Al-Najaf: Large torrential water flows into the Bahar Al-Najaf, carried by the valleys to the west and southwest during the rainy seasons. The lands adjacent to the lake of Najaf from the northern and western sides are seraph lands, except for the lands on which the Noor city was built in 2012, with 15,000 housing units and the increase in the water level of the region posed a significant threat to this city. From the southwestern side, the lake of Najaf is bordered by gypsum lands and sandy lands, a natural extension of the Najaf Badia region [24]. Agricultural lands extend over vast areas to the east and southeast of the Bahar Al-Najaf region. The people of these areas have started to make earth payments to avoid the risk of rising water levels and the sinking of their farms. Within the southern regions of the study area, some brick factories and the manufacture of building materials are spread. It has been noticed that these areas have been submerged in water during the last three years. The vegetation cover is mainly distributed within the lands east of the Euphrates River. The soils of this region are characterized by their fertility because they are mixed soils (mud and sand). There is a state of stability in vegetation areas, being somewhat far from the Bahar Al-Najaf depression. As for the built areas, most of them are concentrated to the east of the Najaf Sea depression, which significantly reduced the risk of flooding in the event of an increase in water levels in Bahar Najaf, except for some areas (City of Al-Noor). Concerning the future planning of the land uses within the study area, it was noticed that there is a lack of coordination and a conflict of visions between the concerned authorities. The Ministry of Water Resources prefers to go towards projects that promise the Najaf Sea to be an evaporative lake and a source of environmental balance. This trend reinforces the vision of the Ministry of Environment, which prefers to consider the Najaf Sea depression as a natural reserve due to the availability of biological diversity within the region. The municipality is preparing to implement complex housing projects within the same region. As for the Najaf Investment Commission, it has granted many investment opportunities to agricultural projects of hundreds of dunes and industrial ones to establish factories for bricks and building materials, which negatively affects the region's environment and dramatically increases the rates of pollution in it.

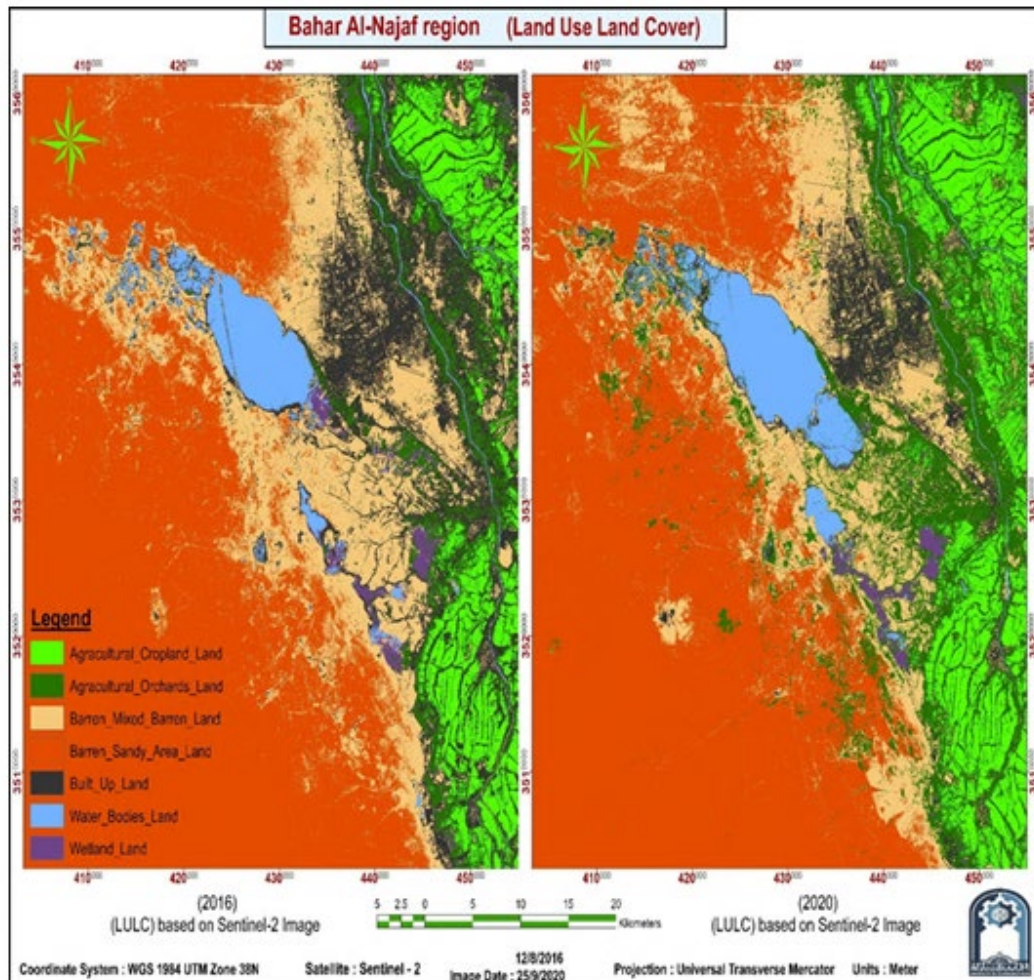


Figure 8: Map of the LULC based on Sentinel-2 images

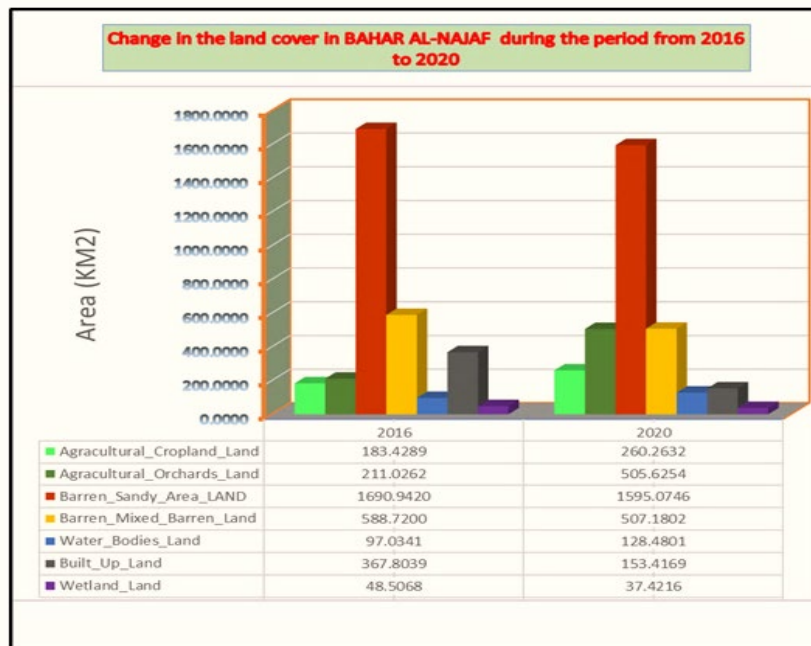


**Table 5:** The confusion matrix analysis on the maximum likelihood classification method

Class		Cropland Land	Orchards Land	Sandy Area	Mixed Barren	Water-Bodies	Built-Up	Wetland	total	Theoretical Calculations	
2016 year	Cropland-Land	57	1		2	2			62	Sum of Diagonal Entries	216
	Orchards-Land		48		3	8	2	3	64		
	Sandy-Area			15	2		4		21	Toyal Observation	282
	Mixed-Barren	1	6	1	20		5		33		
	Water-Bodies		3				36	2	4	45	PERCENTAGE CORRECT
	Built-Up		1	3	2			35	45		
	Wetland		3		2		2	5	12	76.00%	
total		58	62	19	31	46	50	12	282		
2016 year	Cropland-Land	66							66	Sum of Diagonal Entries	290
	Orchards-Land	3	62		2	2	1	2	72		
	Sandy-Area			55	2		2		59	Toyal Observation	317
	Mixed-Barren		1		31		4	1	37		
	Water-Bodies				1	41			42	PERCENTAGE CORRECT	
	Built-Up		1		3		24		28		
	Wetland		1		1			11	13	93.00%	
total		69	65	55	40	43	31	14	317		

**Table 6:** Information about the classes of land cover in Bahar Al-Najaf

Value	Name-Class	Area Class-2016	Area Class-2020	Differences in Areas between Classes
1	Agracultural_Cropland_Land	183.4289	260.2632	76.8343
2	Agracultural_Orchards_Land	211.0262	505.6254	294.5992
3	Barren_Sandy_Area_Land	1690.9420	1595.0746	-95.8674
4	Barren_Mixed_Barren_Land	588.7200	507.1802	-81.5398
5	Water_Bodies_Land	97.0341	128.4801	31.4460
6	Built_Up_Land	367.8039	153.4169	-214.3870
7	Wetland_Land	48.5068	37.4216	-11.0852



**Figure 9:** The seven classes with their statistical variation during the study period

## 8. Conclusions

The rise in water levels in the Bahar Al-Najaf has led to the flooding of many lands with water. The areas of flooded lands increased in 2020 to about 50% more than they were in 2016. The urban growth in the study area is very slow, and this is evident from the indicator of the change in the areas of constructed areas, as the year 2020 witnessed a very slight increase of (only 2%) than it was in 2016. The period of abundant agricultural production was represented in 2019 and 2020, as the areas of agricultural land increased by 56% over what they were in 2016. This was due to the policy of expansion of the agricultural plan for the year 2020, as this year witnessed an abundance of water. Generally, the accuracy of the classification process depends on the accuracy and timeliness of the training samples. It reached 93% for 2020 because these samples were collected within this year. In contrast, it reached only 76% in 2016. Finally, the overall classification accuracy was about 85%.

### Author contribution

All authors contributed equally to this work.

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### Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

### Conflicts of interest

The authors declare that there is no conflict of interest.

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