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Land use/ Land cover assessment for Karbala City by using geographic information systems (GIS) technique

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Abstract

The Earth's surface is experiencing swift changes in (LUALC) due to diverse socioeconomic activity and natural events. The primary aim of this research is to acquire a quantitative comprehension of the alterations in (LUALC) in Karbala from 2000 to 2023. The study utilized the supervised classification-maximum likelihood approach in Geographic Information Systems (GIS) to identify (LUALC) changes in Karbala. Multispectral satellite data from Landsat 5 and 9 were employed for 2000 and 2023, respectively. The maps were categorized into four primary (LUALC) classifications: water, vegetation, building, and soil. The results explained an increase in the area of building and vegetation by 7.67% equivalent to 388.7668km^2 and 7.81% equivalent to 395.9646km^2, respectively, and a decrease in the area of water and soil, by -5.81% equivalent to -294.6234km^2 and -9.67% equivalent to -490.188km^2, respectively. The accuracy evaluation was conducted, revealing that the photos classified for the years 2000 and 2023 had overall accuracies of 90.90% and 93.33%, respectively. Finally, the Kappa coefficient values for the two photos were 0.8779 and 0.9095, respectively. Therefore, these statistics Demonstrate that the precision of (LUALC) classifications is convenient.

Introduction:

(LUALC) appraisal is a basic process for understanding spatial changes in cities and analyzing their effect on the environment and society [1]. Multiple variables, including factors, such as population increase and urban development, agricultural loss, climate variability, and others, have caused rapid and uncontrolled changes to the land cover of the Earth in the past years [2]. The aforementioned changes have led to the occurrence of deforestation, degradation, and the diminishment of biodiversity. The mishandling of agriculture, the occurrence of natural disasters, and the escalation of global warming have been documented [3, 4]. Recently, there has been a growing interest in analyzing the land cover status on a regional and global scale. Assessing land cover changes is crucial for effectively managing natural resources in a sustainable manner [4-9]. Reviewing past research on the application of remote sensing for the analysis and identification of changes in the land (LUALC) is crucial. Napas and Sarchel conducted an analysis and made predictions about future changes in (LUALC) in the Kurdistan Region of Iraq, specifically for the Erbil Governorate. Three (LUALC) maps were generated, each containing different categories. Maps were generated using several classifications, followed by a change detection analysis [10]. Claudia and Ines examined the process of detecting changes in two sets of multispectral data in the Bostanlik District of Tashkent, Uzbekistan. They utilized Landsat-5 TM data from 1989 and Landsat-8 OLI data from 2017. The data were classified into six land use categories, which could be useful for government officials and stakeholders in future land use planning efforts [11]. Karbala City in Iraq testifies to important land-use changes, land cover, and urbanization expansion [12]. Geographical information systems (GIS) technology is a visualization tool to analyze and document these changes and evaluate their effects[13]. The (GIS) way is a technological system that gathers, stores and analyzes spatial data and spatial information. Geographical information systems (GIS) authorize scientists and engineers to explore geospatially and analyze spatial data effectively and inclusively [8, 14]. Land use change analysis is necessary to understand better the relationships between natural effects and human factors to improve resource management and decision-making. land use analysis involves sensing information using multiple periods to analyze and identify changes associated with (LUALC) characteristics over those periods. monitoring the dynamics of (LUALC) change can be applied by comparing a map of present-day land cover and use with a map of land cover and use in previous years [5, 15, 16]. The study aims to determine the changes in LUALC that occurred in Karbala, Iraq, for 23 years.

Material and Methods

Study area

Region Karbala is located in central Iraq, approximately 110 kilometers southwest of Baghdad. The region is situated within the geographical coordinates of latitude 32N to latitude 33N and longitude 43E to longitude 44E. Its total area spans around 5.065 square kilometers. The city of Karbala comprises three provinces: Karbala, Hindiyah, and Ean-tamer. Over the past twenty years, Karbala has had a significant increase in urbanization due to the annual population rise and influx of migrants. The region is adjacent to Anbar Governorate to the north and west, Najaf Governorate to the south, and Babil Governorate to the east [17]. The shrines of Imam Hussein and Imam Abbas (peace be upon them) are significant architectural and cultural landmarks in Karbala City, as they serve as spiritual hubs for Shiite Muslims. Consequently, the ancient downtown sector and the city of Karbala were first-hand impacted due to their geographical positioning [18]. The climate of the region is characterized as semi-arid, with scorching hot and dry summers and chilly winters [19]. Typically, rainfall occurs between the months of November and April. **Figure 1** displays the location and boundaries of the study area and its surrounding areas.

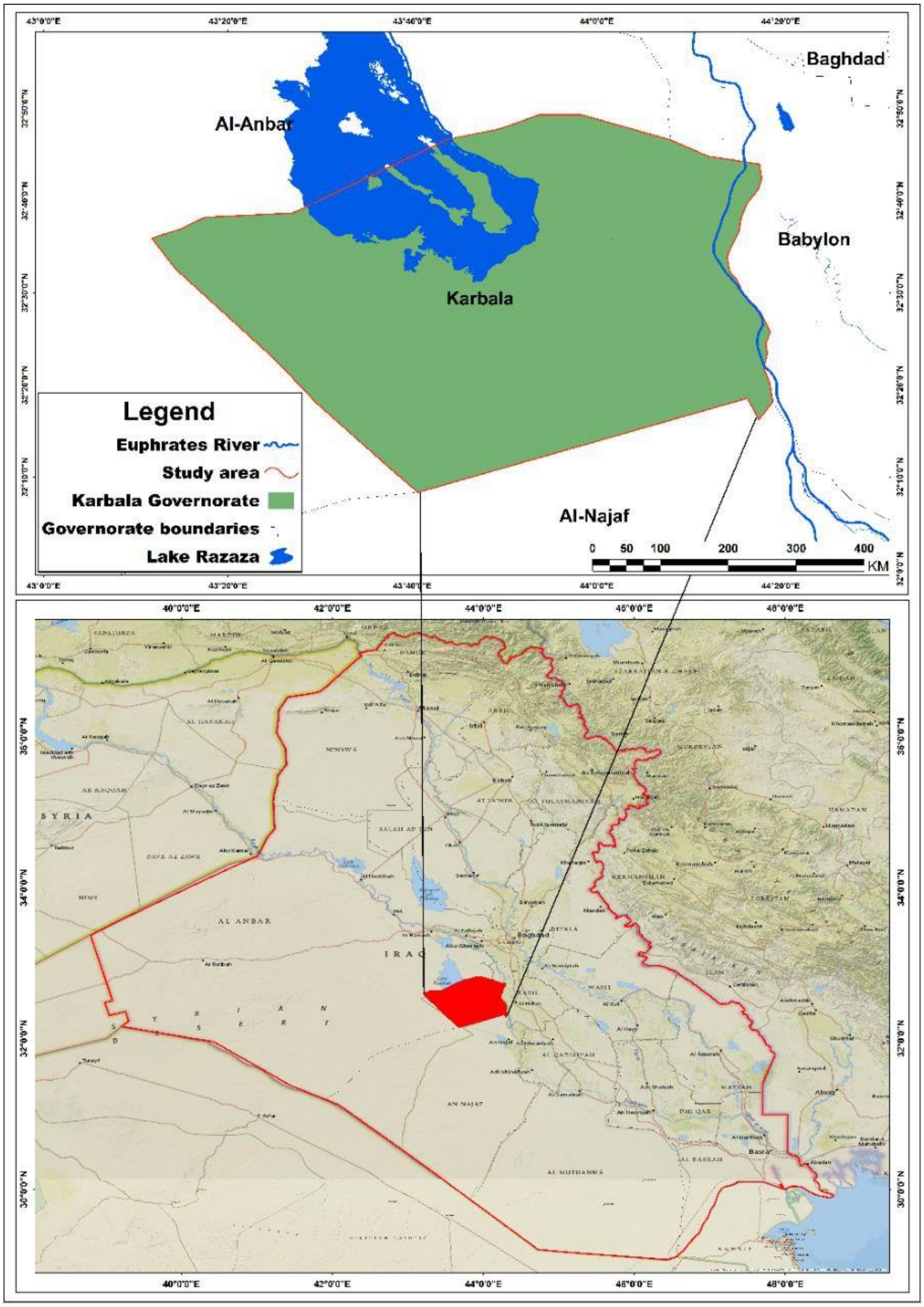

Fig. 1. Research Area

The source is from: the Ministry of Water Resources, the General Authority for Survey, Map Production Department, the administrative map of Iraq at a scale of 1: 100,000, Baghdad 2018.

Data sources and preparation:

Landsat multitemporal photos were sourced from the USGS Earth Explorer website (https://earthexplorer.usgs.gov). Satellite image data for the years 2000 and 2023 were selected from

Landsat 5 and Landsat 9 respectively. The satellite data was acquired at that same time period to avoid changes that occur in land cover over time, as shown in **Table 1** and **Figure 2**.

Table 1: Information on satellite data used in the study

	Date of photography	Sensor	Sensor Type	Spatial Resolution	Number of Bands	Format
2000	10 / 11 / 2000	Landsat 5	TM	30m	7	Geo TIFF
	10 / 11 / 2000			30m	7	
	10 / 11 / 2000			30m	7	
	10 / 11 / 2000			30m	7	
2023	10 / 11 / 2023	Landsat 9	OLI-TIRS	30m	7	Geo TIFF
	10 / 11 / 2023			30m	7	
	10 / 11 / 2023			30m	7	
	10 / 11 / 2023			30m	7	

Data preprocessing and image classification

This study's analysis made use of the free, open-source ArcGIS 10.8.1 geographic information system. The study outlines four distinct land cover/use types, including water, vegetation, buildings, and soil. In classification, a maximum likelihood algorithm was used.

a. Preprocess:

satellite imagery undergoes several preprocessing steps to ensure suitability for analysis; these steps include radiometric and geometric corrections, atmospherics correction, and image enhancement techniques. Radiometric correction eliminates systematic errors and variations in pixel values, ensuring imagery accurately represents actual reflectance or radiance of Earth's surface. geometric correction removes distortions caused by sensor orientation and terrain relief, aligning imagery to desired coordinate system. Atmospheric correction removes atmospheric effects such as scattering and absorption of light and retrieves surface reflectance values. These steps are crucial for the accurate quantification of land surface properties. To improve visual interpretation, image-enhancing techniques are used on the imagery, enhancing specific features of interest and improving overall image quality, these preprocessing steps transform acquired satellite imagery into more accurate, consistent and visually appealing dataset suitable for various applications, including (LUALC) analysis, change detection, and environmental monitoring.

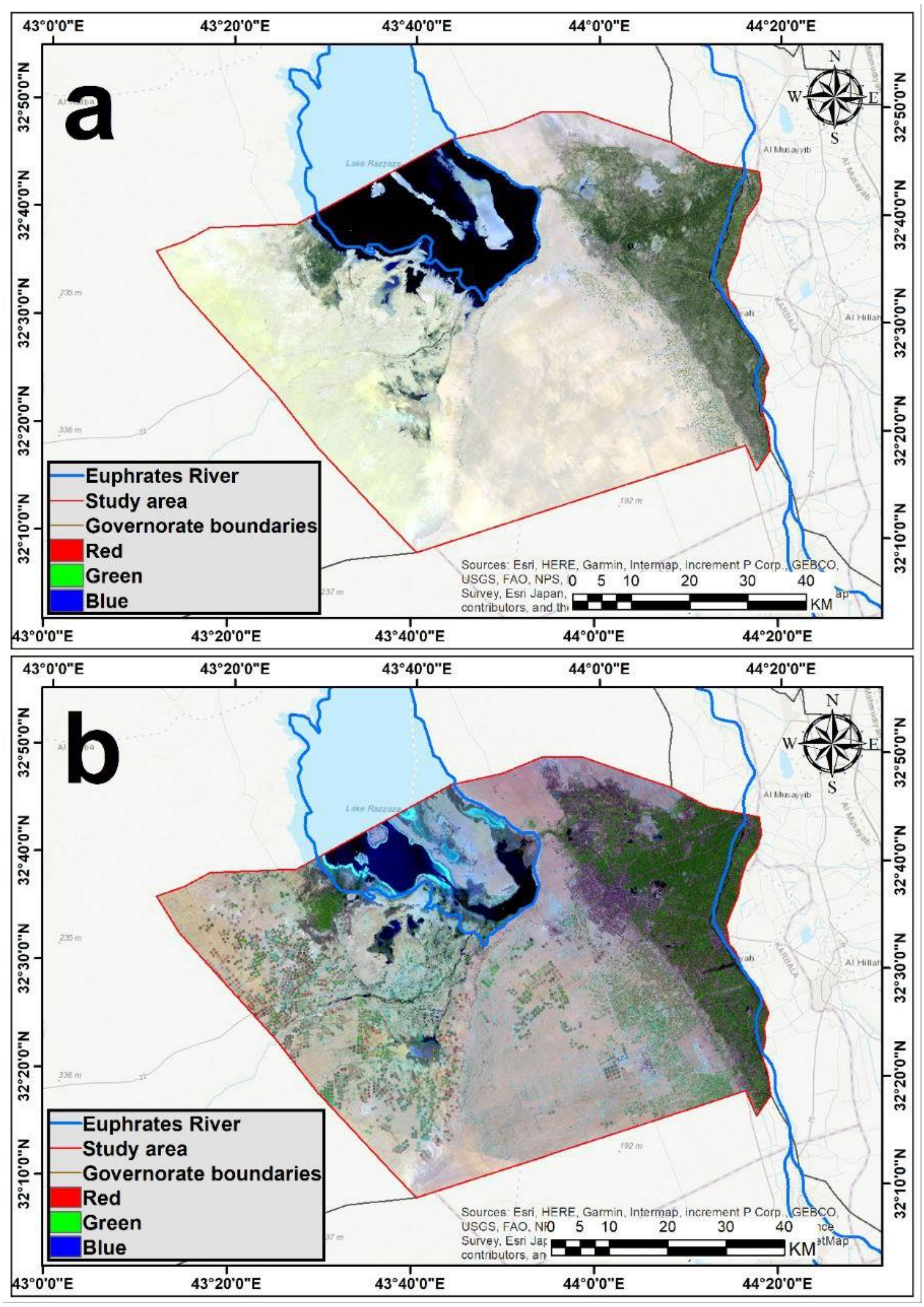

Fig. 2. Satellite images used in the study: (a) in 2000, (b) in 2023.

b. Classification:

In this study, the land cover/use categorization procedure was implemented using the supervised maximum likelihood algorithm. This algorithm, which is based on pixel probabilities, is widely used to process remotely sensed image data [3, 7, 8]. This algorithm determines the likelihood that a given pixel belongs to a certain class by assuming that the statistics for each class in each band are normally distributed. Every pixel is assigned to the category with the highest likelihood. In order to apply this approach, each training area needs a sufficient amount of pixels in order to generate the covariance matrix.

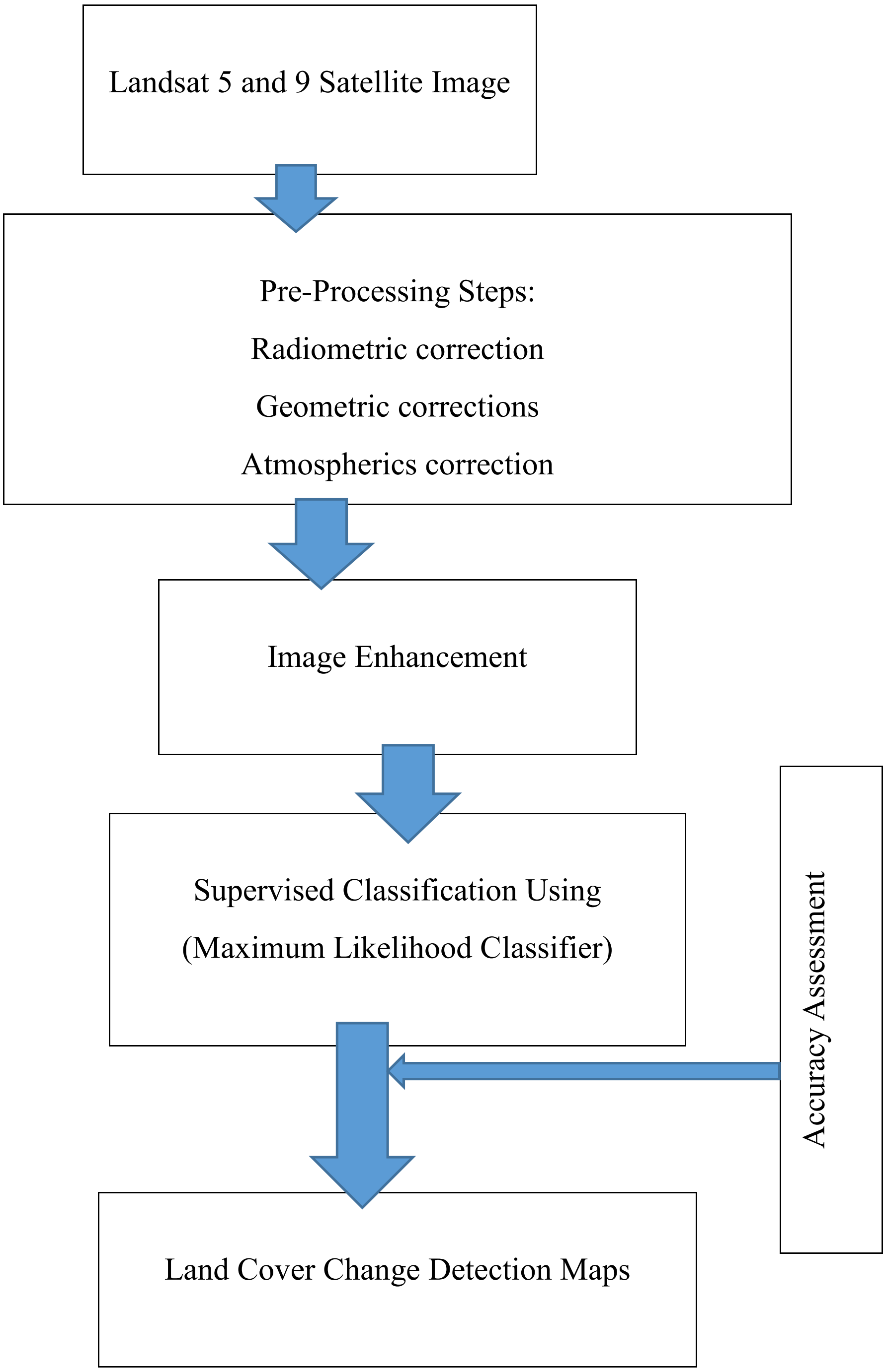

Fig. 3. Outline of the methodology of the current study

Results and Discussion:

Analyzing changes in (LUALC):

The study area (LUALC) was categorized into four distinct classifications, (1) water (2) vegetation (3) buildings (4) soil, as in Figure (4). The results indicate that in the 2000 image, approximately 10.33% (523.3443km^2) was water, 16.91% (856.7314 km^2) was vegetation, 1.21% (60.972 km^2) was buildings, and 71.55% (3632.962 km^2) was soil and all shown in Figure 5. The research region in the 2023 image was categorized into four categories based on (LUALC), approximately 4.52% (228.7209 km^2) of water, the area fell by 5.81% due to the decline in the water levels of Lake Al-Razzaza during this era. Vegetation increased by 7.81% in an area of 395.9646 km^2, while building areas increased by 7.67% in an area of 388.7668 km^2. On the other hand, soil decreased by 9.67% in an area of 490.188 km², all shown in (**Figure 6**). **Table 2** shows a comparison between (LUALC) for the years 2000 and 2023, respectively, in the Governorate of Karbala.

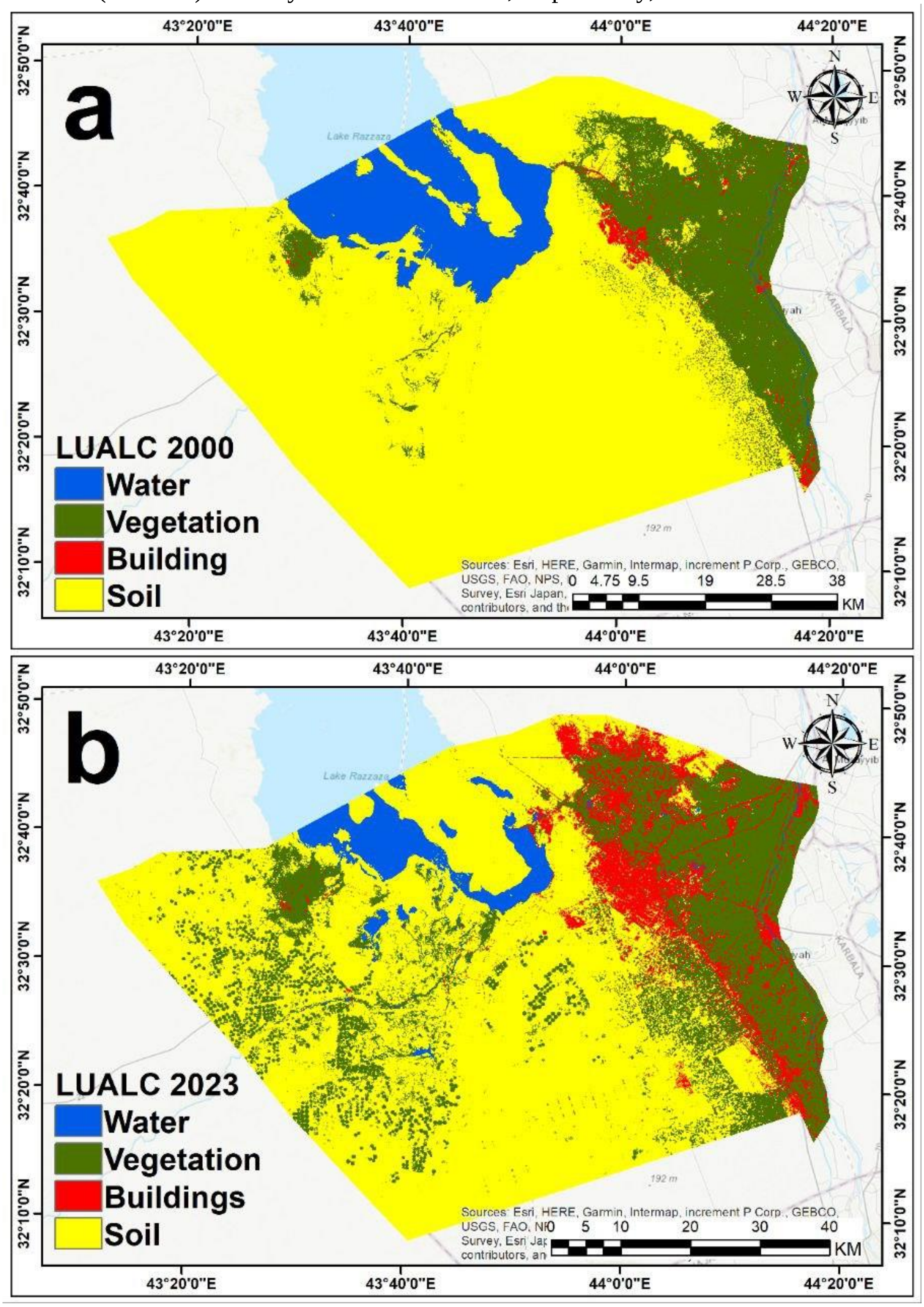

Fig. 4. LUALC of Karbala Governorate; (a) in 2000, (b) in 2023

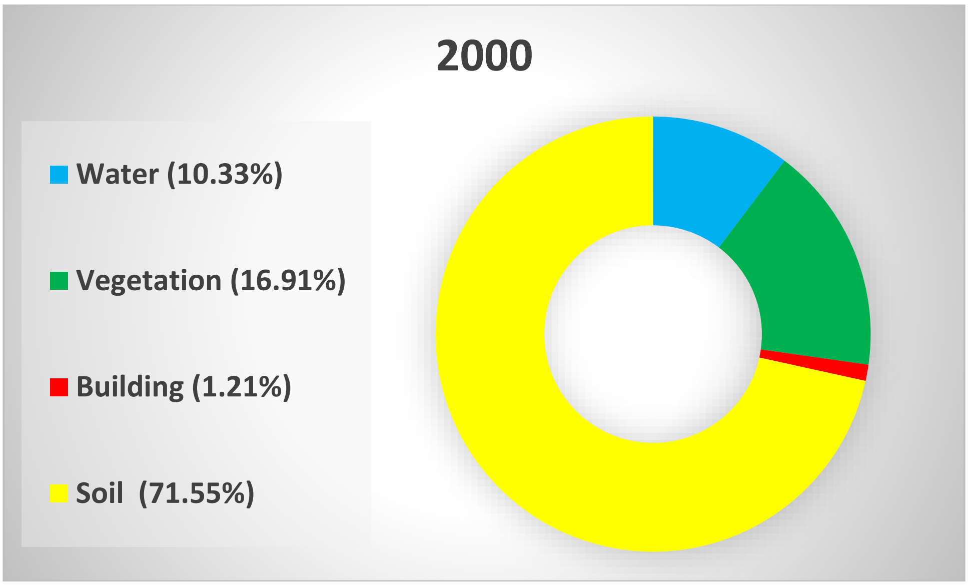

Fig. 5. A diagram illustrating the percentage of (LUALC) in the year 2000.

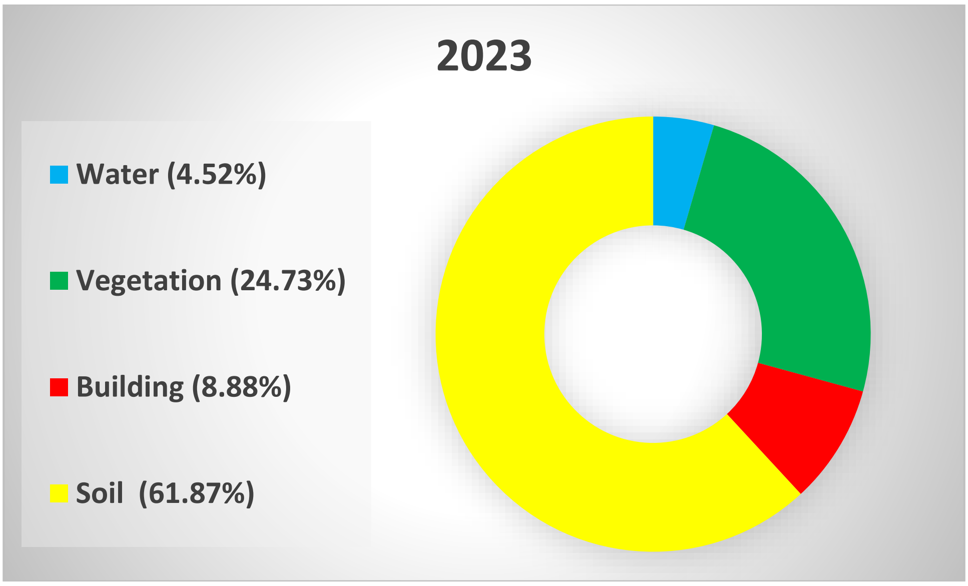

Fig. 6. A diagram illustrating the percentage of (LUALC) in the year 2023.

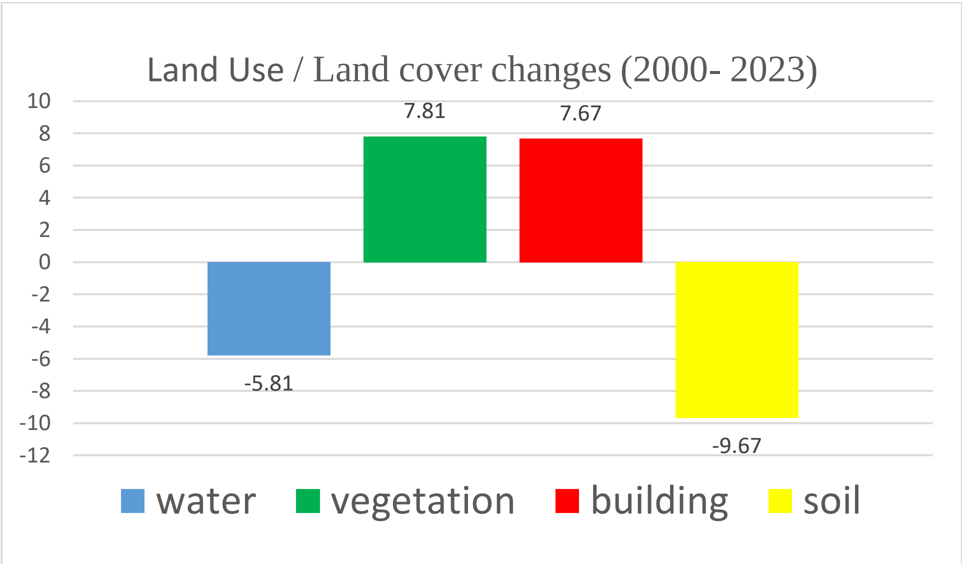

Fig. 7. The alterations in (LUALC) from 2000 to 2023

Table 2. The area and percentage of change in (LUALC) categories in Karbala, from 2000 to 2023.

LUALC	2000 (km^2)	%	2023 (km^2)	%	Change of the Area (km^2)	Change in %
water	**523.3443**	**10.33**	**228.7209**	**4.52**	**-294.6234**	**-5.81**
vegetation	**856.7314**	**16.91**	**1252.696**	**24.73**	**+395.9646**	**+7.81**
Built up	**60.972**	**1.21**	**449.7388**	**8.88**	**+388.7668**	**+7.67**
soil	**3623.962**	**71.55**	**3133.844**	**61.87**	**-490.188**	**-9.67**
total	**5065**	**100**	**5065**	**100**	**0**	**0**

Assessment classification accuracy

In the past, there was not a strong emphasis on accuracy evaluation in picture categorization investigations. Due to the growing risk of inaccuracies associated with digital imaging, the review of accuracy has grown increasingly crucial in contemporary times [20]. Error matrix is one of the most common and used methods in evaluating the classification of land use satellite imagery. This matrix relies on comparing a group of cells for each land cover in the classified satellite imagery with information about the cells themselves, which was obtained in the stage of creating random reference points, and then knowing the number of cells that have been classified, correctly and others that were classified incorrectly. This matrix not only determines the total errors in the classification of each category, but it also determines the classification errors between groups because of the similarity of the reflective properties of some components of the Earth that are different in nature. Therefore, it is also called the Confusion matrix. However, this matrix is a set of rows that indicate the land cover categories within the classified satellite imagery and a set of columns that indicate the reference data, which intersect with each other to form a grid of squares in which the diagonal values represent the number of cells that were correctly classified. Further, in such matrix the reference data corresponds to the cover, the ground in the classified image, while the rest of the data passes outside the diagonal cells indicating the lack of spatial agreement between the classified image and the reference data as a result of errors in the reference data or as a result of the classification data rules that often assume separate boundaries along a continuum in nature or as a result of the inappropriateness of the visuals used In land cover mapping [21-23]. The user's accuracy percentage indicates the probability that a pixel in the classified image represents the same class on the ground according to the reference data. This accuracy can be calculated by dividing the number of points correctly in each class (diagonal value) by the total number of points classified in this class or (row). The product's accuracy percentage indicates how accurately the satellite imagery classification is compared to the reference data and is calculated by dividing the number of cells that were classified correctly (diagonal cells) by the total number of reference points in the same column. This accuracy was given this name due to the product's interest in the accuracy of classification of the reference data [24, 25]. The Kappa coefficient is a discrete multivariate measure used to measure classification accuracy and takes into account the possibility of change occurring when comparing classification and ground truth in remote sensing software. This measure expresses the extent of agreement and disagreement between the classification and ground facts [26, 27]. The reference points were created by specifying them precisely, as shown in Figure 8, based on Google Earth images, which are characterized by great spatial accuracy through which one can segregate between the different land covers in the region. The program also has a feature of displaying historical images that help in covering the area. The study and knowledge of the land cover in ancient periods is useful in evaluating the accuracy of the classification of the Landsat 5 and Landsat 9 images used in the study by referring to the time when these images were taken, which dates back to the years (2000, 2023). By analyzing the error matrix in Table (3,4), it becomes clear to us that the results of the classification process for land cover in the study area were accurate and therefore reliable, as the total accuracy of the classification process for the year 2000 was about 90.90% of the total number of reference data, while The kappa value reached 0.8779. The situation is not much different for the visuals in 2023, as the total accuracy reached 93.33%, while the kappa value reached 0.9095 **Table 5**.

Table 3. Error matrix to assess the accuracy of the supervised classification of cover types for the year 2000

S.NO.	LUALC	water	vegetation	built-up	soil
1	water	47	1	0	2
2	vegetation	1	59	1	5
3	built-up	0	4	42	1
4	soil	0	3	2	52

Table 4. Error matrix to assess the accuracy of the supervised classification of cover types for the year 2023

S.NO.	LUALC	water	vegetation	built-up	soil
1	water	42	1	0	2
2	vegetation	2	83	3	2
3	built-up	1	2	81	1
4	soil	1	3	2	74

Table 5. Evaluating the accuracy of Landsat 5 and Landsat 9 satellite images classified by supervised classification

S.NO.	LUALC	User Accuracy in %		Producers' Accuracy in %	
		2000	2023	2000	2023
1	water	94.00	93.33	97.91	91.30
2	vegetation	89.39	92.22	88.06	93.26
3	built-up	89.36	95.29	93.33	94.18
4	soil	91.22	92.50	86.67	93.67
Total reference points				220	300
Overall classification accuracy value				90.90	93.33
Overall Kappa coefficient value				0.8779	0.9095

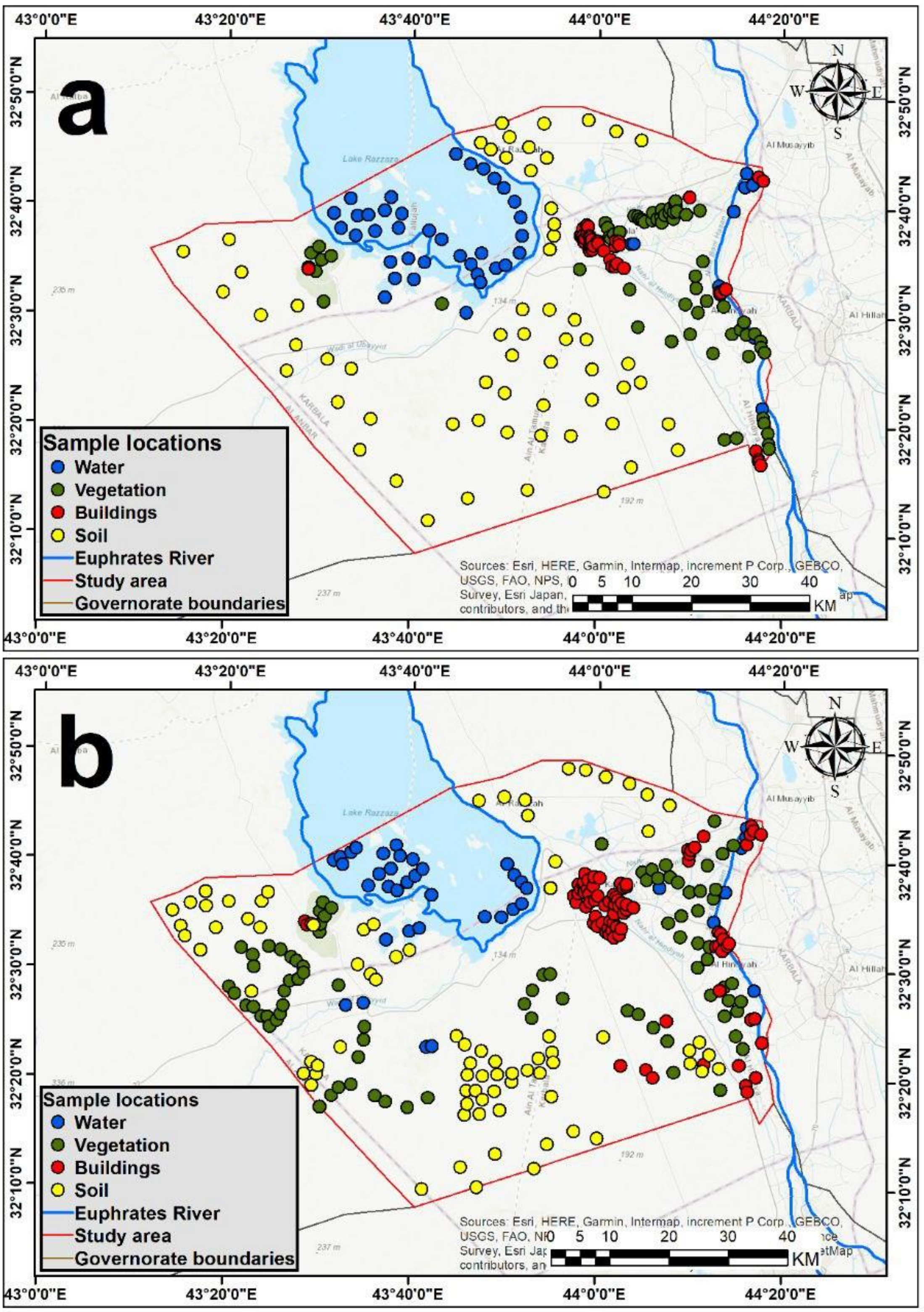

Fig. 8. Geographic distribution of reference data points; (a) in 2000, (b) in 2023

Conclusions

The study conducted in a significant religious city in Iraq asserts that the combination of multi-temporal satellite imaging, remote sensing, and GIS techniques is crucial in efficiently monitoring urban expansion over time. This combination allows for the production of accurate (LUALC) maps and everything related to statistics on change. The study indicates that the primary land utilization in the examined region is urbanized. The building area has expanded by 7.67% (388.7668 km2) between 2000 and 2023. The second primary classification of land is vegetation, which has likewise experienced growth between 2000 and 2023, there was an increase of 7.81% (395.9646 km2) in vegetative land. The third primary classification of land is water, which had a reduction of 5.81% (294.6234 km2) as a result of conversion into the plant, and building land. The extent of soil land, specifically categorized as the fourth category of land, has experienced a notable decrease of 9.67% (equivalent to 490.188 km2) over the past two decades. The application of Geographic Information Systems (GIS) with Remote Sensing methods in the study of (LUALC) change in Karbala has shown conclusive results. It has been determined that there have been considerable alterations in (LUALC) patterns in the studied region over 23 years.

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