

Spatiotemporal Analysis of Land Cover Changes in Karbala City Using GIS and Remote Sensing

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Hum215.balsem.marzouk@student.uobabylon.edu.iq , Ealyasiri@uobabylon.edu.iq |
ORCID: 0000-0001-8002-4683

*Department of Geography , College of Education and Human Sciences, University of
Babylon, Hilla, , Iraq.*

Abstract

This study was conducted to identify and examine spatial and temporal land cover changes in Karbala city from 2016 to 2026. The methodology involved integrating remote sensing with geographic information systems (GIS) to understanding environmental transformations and their underlying patterns. Sentinel-2 satellite data provided a time series 2016 and 2026. Pixels based supervised classification was applied to classify the land study area to farm, water, barren, urban areas, and deserts has been classified accordingly into Desert and Barren soil. The results indicate notable shifts in land cover between 2016 and 2026, including increases in urban and barren land cover by 20.66% and 2.51%, respectively, while agricultural land, desert areas, and water bodies declined by 6.48%, 13.75%, and 2.93, with Kappa coefficient (> 0.80).

Keywords: Land Cover Change (LCC), Remote Sensing, Geographic Information Systems (GIS), Sentinel-2, Supervised Classification, Change Detection

تحليل التغيرات المكانية والزمانية للغطاء الأرضي في مدينة كربلاء باستخدام تقنيات نظم المعلومات الجغرافية والاستشعار عن بعد

بلسم مرزوك عبد شاوي ، أ.م. د ايلاف عامر مجيد الياسري

قسم الجغرافيا ، كلية التربية للعلوم الإنسانية ، جامعة بابل ، الحلة ، العراق

المخلص

بحثت هذه الدراسة تحديد وتحليل التغيرات المكانية والزمانية في الغطاء الأرضي في مدينة كربلاء خلال الفترة 2016-2026 . حيث اعتمدت على التكامل التقني الجغرافي بين نظم المعلومات الجغرافية والاستشعار عن بعد بهدف فهم أنماط في إنشاء سلسلة زمنية لسنوات الدراسة Sentinel-2 التحولات المكانية البيئية . تم استخدام بيانات القمر الصناعي (2016-2026) وقد أُستخدِم في تصنيف الغطاء أسلوب التصنيف الموجه القائم على البكسل وتم تصنيف منطقة الدراسة الى خمس فئات رئيسية شملت: المناطق الحضرية ، الأراضي الجرداء ، الأراضي الزراعية ، المسطحات المائية ومناطق

صحراوية. لذلك أظهرت نتائج الدراسة وجود تغيرات ملحوظة في الغطاء الأرضي خلال هذه المدة إذ سجلت زيادة ملحوظة في الأراضي الحضرية والأراضي الجرداء بنسبة (20.66%، 2.51%) على التوالي بينما انخفضت نسبة كل من الأراضي الزراعية و الصحراوية والمسطحات المائية بسبب تصل الى (6.48%، 13.75%، 2.93%) على التوالي وان نتائج تقوي الدقة التي خلصت اليها الدراسة باستخدام معامل كبا حيث تجاوزت النسبة (0.80) مما يدل على دقة نتائجنا وموثوقيتها . في تحليل الغطاء الأرضي مكانياً ودعم اتخاذ القرار .

الكلمات المفتاحية: تغيرات الغطاء الأرضي ، الاستشعار عن بعد ، نظم المعلومات الجغرافية ، التصنيف الموجه ، كشف التغير .

1. Introduction

Land cover (LC) serves as a critical indicator of the dynamic interplay between natural processes and human activities. Such alterations may encompass diverse changes in LC (Mumtaz et al., 2023). Land alterations are often linked to significant socio-economic challenges, including disproportionate population growth, infrastructure development, and changes in land management policies (Fang et al., 2022). Researchers, policymakers, and environmental organizations frequently examine land cover change (LCC) patterns—which refer to alterations in the observable physical and biological cover of the Earth's surface—to evaluate their effects on ecosystems, habitats, biodiversity, hydrology, air quality, and the overall health of the planet. For instance, deforestation LCC can result in the loss of habitat for endangered species and disrupt local water cycles, highlighting the real-world significance of these changes (Hussain et al., 2024). In developing countries like Iraq, urban growth and expanding settlements often result in decreased vegetation and agricultural land, leading to a shift toward urbanization. (Kuzevic et al., 2026; Alyasiri et al., 2023). According to the Food and Agriculture Organization of the United Nations (FAO), land cover is defined as “the observed biological and physical cover on the Earth's surface,” encompassing plants, inland water, bare soil, and infrastructure. Land cover serves as a reference base for monitoring climate change, overseeing forest and rangeland health, and facilitating investment planning. Conversely, land use refers to “the arrangements, inputs, and all activities undertaken by humans to produce or alter a particular type of land cover.” The strong interconnection between these two concepts is clear, which is why they are both classified under land use and land classification. (De Gregorio & Jansen, 1998; Alyasiri E.A, 2021).

To assess changes in LC, it is necessary to gather data reflecting the area's condition over different periods. Satellite-based Remote Sensing (RS), combined with Geographic Information Systems (GIS), offers an efficient and reliable approach in terms of speed, accuracy, and cost-effectiveness. This method delivers valuable insights across numerous disciplines, enables coverage of extensive and otherwise inaccessible regions through repeated satellite passes, and provides high spatial resolution in the resulting imagery (Karam & Ahmed., 2026). Through this spatial data it is possible to understand and assess the effects of landscape changes on the environment. (Macarringue et al., 2022; Hosseiny, 2022). Lack of studies in the City of Karbala using Sentinel – 2 time series and the the limitation of integration GIS and RS to detect LCC; Therefore, the study aims to examine the spatio-temporal dynamic of land cover and environmental Transformations in the city of Karbala, Derived from 2016 for 2026 Based on multi-temporal satellite Imagery Sentinel -2 MSI.

Spatiotemporal Analysis of Land Cover Changes in Karbala City Using GIS and Remote Sensing

Balsam Marzouk Abd Shawi , Elaf Amer Alyasiri Ph.D.

2- General Background

Recent land cover and utilization patterns research underscores the significance of region-specific analyses. Certain locations are often neglected in LULC studies, despite their distinct geographic features and diverse ecosystems, which create valuable opportunities to investigate localized LULC impacts.

The growth of urban areas has a significant impact on land use by replacing areas of vegetation with residential and commercial areas and their related infrastructure (Faqe, G. 2017. A detailed examination of the area's attributes and developments not only contributes a meaningful regional case study but also provides perspectives on broader human-environment relationships worldwide (Duan et al., 2025; Mir et al., 2025).

This study seeks to address this research gap by presenting a comprehensive and systematic review of the advancements, challenges, and potential opportunities associated with the application of remote sensing techniques in assessing and monitoring land-cover (LC) changes and their impacts on water quality and quantity within semi-arid tropical environments. Literature review examining the historical context, urban growth trends, and concepts related to land use and land cover changes is essential for understanding the impact of urban growth on these dynamics. Several studies have been examining the spatial and temporal change in different areas. (Cavur et al., 2019) measure LULC using remote sensing data in land cover change dynamics detection in nature. Population growth and increasing land consumption, particularly in urban areas, are driving factors in land use and land cover (LULCC) change patterns. RS classification approaches mainly exploit information derived from the spatial and spectral domains of a single image, and also the temporal information in the case of using image time series (Compos Taberner et al., 2020). Integrating geographical technology with remote sensing data medium spatial resolution (10 m to 100 m) has been widely adopted in previous studies to classify land cover types (Hu ,B et al. 2021; Dange et al.,2023) . Khawarзад., 2026 studied the city suburban Warrenton, Virginia and urban Portland, Oregon. The aims study their contrasting land use policies, relationship between suburban development and loss of vegetation suburban 75 sprawl contributes to loss of vegetation when compared to urban densification in these two cities . Akintunde et al., (2026) examined the in Nigeria investigated the rate of vegetation degradation, using RS date multiple sensors assessed the influence of climate and human with the increase in urbanization across the globe activities on vegetation loss Belhaj et al., (2024) measure LULCC The study area is located along the United States–Mexico border, extending between San Antonio, Presidio, and Ojinaga, encompassing the urban centers of El Paso, Ciudad Juárez, and Las Cruces. The findings indicate a significant decline in native land cover (LC), which has increasingly been replaced by urban growth and agricultural expansion.. Sajjad Hussain et al., 2024 studied the change in land use land cover in Southern Punjab, Pakistan this study showed the quantity and amount changes that limit the accessibility of services and products for livestock and humans. Another study by Duan et al., (2025) studied LULC change driven primarily by urbanization in Okara District better understanding of LULC dynamics in rapidly changing regions, supporting informed decision-making for sustainable development. Bikis et al., (2025) studied Mizan Aman City Southwest Ethiopia size of LULCC due to urbanization and how to protect environment. Then Noor et al., (2026) examined the change land cover in Mosul evaluate and explain the current state of the vegetation condition.

The present study differs from The present study differs from previous studies in several important aspects. While most previous research has focused on general land use and land cover (LULC) changes across various regions, this study specifically investigates spatial and

temporal land cover changes in Karbala City, which has received limited attention in earlier research.

In terms of data and methodology, many previous studies relied on medium-resolution remote sensing data and general classification approaches. In contrast, the present study utilizes Sentinel-2 satellite imagery with higher spatial resolution (10 m), enabling more accurate detection and classification of land cover changes.

Moreover, this study incorporates a more detailed analysis by linking land cover classification with the natural characteristics of soil types in the study area, particularly the distinction between desert soils and floodplain soils. This aspect has not been clearly addressed in most previous studies. Another key difference lies in the temporal scope. The present study covers a recent and extended time period (2016–2026), providing updated insights into land cover dynamics, whereas some previous studies focused on shorter or earlier periods. Finally, this study places greater emphasis on urban expansion and its impact on different land cover categories, aiming to support spatial planning and decision-making processes. Therefore, it provides a more localized, detailed, and application-oriented analysis compared to previous.

Data and Methodology

This section describes the combined methodology used in this research. Firstly, a brief description of the study site is given followed by a detailed description of the steps adopted in the methodology.

2.1 Study Area

The study area is the city of Karbala; Iraq located in the northeastern part of Karbala governorate covering 79.85 km². It is located between longitudes (43 degrees and 57 minutes - 44 degrees and 4 minutes) east, and latitudes (32 degrees and 33 minutes - 32 degrees and 39 minutes) See Figure. 1.

Spatiotemporal Analysis of Land Cover Changes in Karbala City Using GIS and Remote Sensing

Balsam Marzouk Abd Shawi , Elaf Amer Alyasiri Ph.D.



Figure 1. the Location of the Study Area in Iraq

2.2 Data Collection

In 2014, the European Space Agency's (ESA) Program launched its first satellite. Since then, it has put several satellites into orbit, including those from the Sentinels-1, 2, 3, and 5 missions. A major achievement was the deployment of the multispectral Sentinel-2 satellites, which consist of two identical units: Sentinel-2A and Sentinel-2B. These satellites offer top-tier spatial, spectral, and temporal resolutions, making them crucial for the ESA-supported Global Monitoring for Environment and Security program. The Multi-Spectral Instrument (MSI) on each satellite includes 13 bands that range from visible light to shortwave infrared (SWIR). Additionally, they provide spatial resolution options of 10, 20, and 60 meters for different specialized applications. Seen Table 1. Three in the visible spectrum, with bands 5, 6, and 7 positioned within the Red Edge range at a spatial resolution of 20 meters. Band 8 belongs to the Near Infrared (NIR) range. Bands 1, 9, and 10 are located in the Thermal band range with 60-meter resolution and were excluded from consideration due to their irrelevance to land-use applications Ecosystem, C. D. S. (2025, September 26). For this study Spring-

season satellite imagery MSIL2A was selected with 10-meter spatial resolution. The first imagery for 2026 was in 22 of February 2026 S2C_MSIL2A_20260221(T073931_N0512_R092_T38SMB). Datasets that used were projected to the Universal Transverse Mercator (UTM), with map projection system zone 38N, and datum of World Geodetic System 84 (WGS84). N0500_R092_T38SMB), and the second imagery was on the 5th of March 2016.

Table.1 The Multi-Spectral Instrument (MSI) Band of Sentinel-2

Band	Resolution	Central Wavelength	Description
B1	60. m	443. nm	Ultra Blue (Coastal and Aerosol)
B2	10. m	490 .nm	Blue
B3	10. m	560. nm	Green
B4	10 .m	665. nm	Red
B5	20. m	705. nm	(VNIR)
B6	20. m	740. nm	(VNIR)
B7	20. m	783. nm	(VNIR)
B8	10. m	842. nm	(VNIR)
B8a	20. m	865. nm	(VNIR)
B9	60. m	940. nm	(SWIR)
B10	60. m	1375. nm	(SWIR)
B11	20. m	1610 .nm	(SWIR)
B12	20. m	2190 .nm	(SWIR)

(<https://sentinel.esa.int/web/sentinel/missions/sentinel-2>).

Spatiotemporal Analysis of Land Cover Changes in Karbala City Using GIS and Remote Sensing

Balsam Marzouk Abd Shawi , Elaf Amer Alyasiri Ph.D.

2.3 Methodology

The platform enables the implementation of classification algorithms for land-cover (LC) mapping, change detection (CD), and time-series analysis, thereby serving as an effective tool for monitoring environmental transformations and urban expansion. Its cloud-based architecture facilitates efficient data access, processing, and interactive visualization, making it a vital resource for researchers, scientists, and developers within the remote sensing field (Gomes et al., 2020).

2.3.1 Supervised Classification (Pixel Based)

Supervised classification is a widely used technique for categorizing remotely sensed imagery according to the numerical values of image pixels, with the aim of extracting quantitative information from satellite data (Richards, 2006). This approach requires the analyst to identify a sufficient number of known sample pixels to establish representative statistical parameters for each land-cover class of interest. The classification process is performed through the selection of training points, which are used to train the classification algorithm. After the training stage, the classifier assigns labels to all image pixels based on the derived parameters. Among the various supervised classification techniques, the Maximum Likelihood Classification (MLC) method is considered one of the most commonly applied approaches, particularly when using medium- or high-spatial-resolution imagery (Forget et al., 2018). The classification results are primarily determined according to the spectral and spatial characteristics of the image objects (Alyasiri, 2021). Supervised classification usually requires a priori knowledge about the region, where ground truth data are collected for each LC class. In the study area, LC will be categorized into five classes: Water, Urban, Barren, Farm, and Desert. It is important to distinguish between Barren LC and Desert LC, as the City of Karbala contains two types of soil—floodplain soil and desert soil—which exhibit different spectral wavelengths.

2.3.2 Change Detection (CD)

Change detection (CD) refers to the process of identifying and assessing access points within multi-spectral imagery that has experienced spatial or spectral variations. CD is commonly characterized as the comparison between two co-registered images of the same geographic area, acquired at different time intervals. The objective of change detection is to determine pixel groups in an earlier dataset exhibiting substantial changes, such as those related to land cover, deforestation, disaster monitoring, urban development, or environmental studies. Accurate and timely change detection of the Earth's surface is essential for understanding the interconnections and dynamics between human and natural activities, there by supporting more informed decision-making (Goswami et al., 2022). The capacity to detect possible label changes on the ground is facilitated by the availability of imagery captured by sensors over multiple periods (Goswami et al., 2022). In recent decades, remotely sensed data have become a crucial source of information for numerous change detection applications (Bovolo, 2007).

2.3.3 Accuracy Assessment

Evaluating remote sensing data is essential for producing accurately classified images. By integrating ground-based control points with satellite geographic data, both reliability and precision are increased through the provision of reference markers (Foody, 2002). Accuracy assessment is employed to evaluate land cover classification, providing a measure of how closely classifications reflect the actual values being studied. Metrics such as overall accuracy and the kappa coefficient (k) help determine whether the confusion matrix significantly differs from random sampling (Alyasiri, 2021). This classification process incorporates several key concepts, including the Confusion Matrix and Kappa coefficient, which are regarded as highly dependable. Ideally In an ideal classification process, all non-diagonal elements within the error matrix would equal zero, indicating the absence of misclassified pixels (Congalton et al., 1983; Alyasiri, 2021). Furthermore, Producer's Accuracy (PA) is used to evaluate the reliability of the classification results from the producer's perspective, reflecting the probability that a reference pixel has been correctly classified (Story & Congalton, 1986). In contrast, User's Accuracy (UA) measures the proportion of correctly classified sample pixels within each category, thereby indicating the reliability of the classification for end-users (Foody, 2002; Alyasiri, 2021).

The development of accuracy assessment techniques has demonstrated increasing levels of detail and precision alongside advancements in digital image processing. Consequently, accuracy assessment has become a fundamental component in the production of reliable and visually accurate classification maps derived from remotely sensed imagery (Foody, 2002). In addition, the Kappa coefficient (k) is widely applied as a statistical indicator to evaluate the degree of agreement between remote sensing classification results and reference data, as well as to determine the overall correctness of the classification process. Conceptually, the Kappa coefficient can be expressed as follows:

$$(1) OA = \frac{x}{y}$$

$$(2) k = \frac{OA - Z}{1 - Z}$$

where x represents number of sampling classes classified correctly; y shows number of reference sampling classes and z indicates chance assessment (Foody, 2002).

4. Results

4.1. Supervised Classification

Urbanization has increased markedly in Karbala city, resulting in notable conflicts between urban expansion and LCC. This evolving situation presents considerable ecological and developmental challenges for urban communities, underscoring the importance of analyzing the interplay between sustained urban growth and spatial-temporal land cover transitions. Urban development constitutes a rapid anthropogenic alteration of land cover, posing significant risks to biodiversity and public welfare. These transformations can negatively impact human health, hinder progress toward Sustainable Development Goals (SDGs), and

Spatiotemporal Analysis of Land Cover Changes in Karbala City Using GIS and Remote Sensing

Balsam Marzouk Abd Shawi , Elaf Amer Alyasiri Ph.D.

diminish ecosystem services by affecting the integrity of adjacent urban environments and modifying local microclimates (Jung et al., 2019; Tong et al., 2022). Research has shown that in this region—characterized by flat topography—urban expansion has intruded upon extensive farmland and desert areas. Furthermore, human activities have led to decreases in both the size and flow of nearby water bodies, complicating efforts to conserve water resources.

After collecting reference samples, the area has been classified into five LC classes: water, farm, barren, urban, and desert. Significant changes are observed in the use of these lands. Seen in Table2, Figures 2 and 3, the area and percentage for each class were calculated to indicate the change. In 2016, the water LC covered approximately 4.02 km² of the total study area, while barren LC accounted for about 40.70km², urban LC about 46.50 km², farm LC was 15.55 km² and desert made up roughly 51.05 of the total LC area.

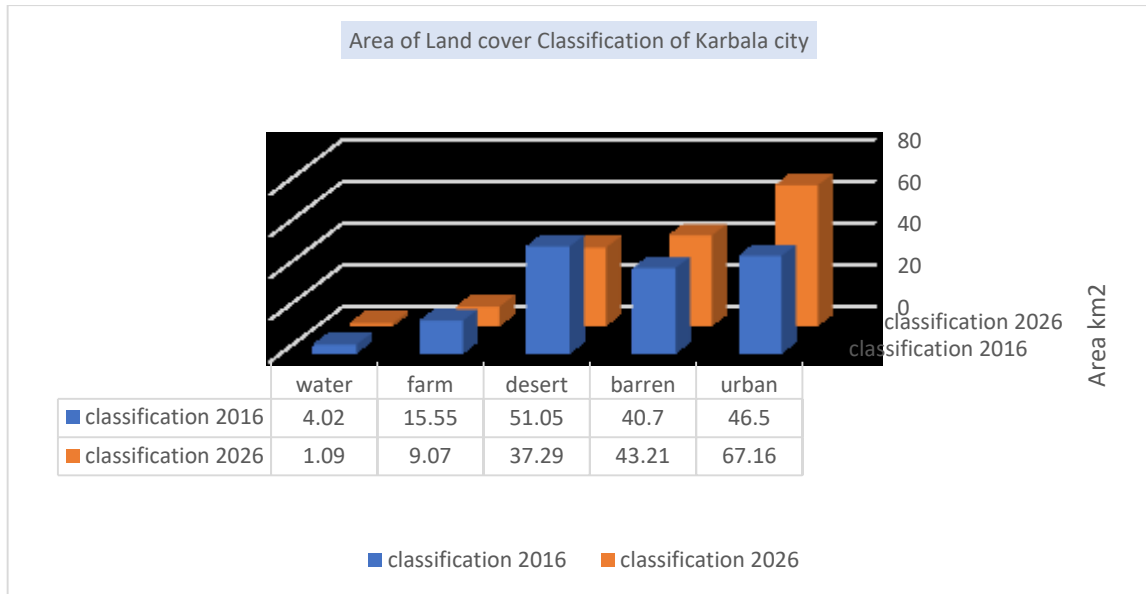
In the southern part of Karbala city, which consists largely of desert landscapes, urban development has consumed significant forested and less-utilized lands. Similarly, in arid climates, grasslands and hard-to-use land are increasingly being converted to urban uses. As such, analyses of urban expansion must account for geographical characteristics as key land cover factors (Sun et al., 2020; Yang et al., 2022; Wang et al., 2023). Employing spatial analysis techniques is instrumental in elucidating the spatial relationships between urban expansion and associated economic and social factors.

In 2026, indicate decrease in water LC of 1.09 km² while increase urban areas, representing a growth of 67.16km² , farms decreased by 9.07 km² and desert land decreased by 37.29 km². This decline in land area reflects the magnitude of urban sprawl at the expense of these sectors. These results highlight the importance of adopting sustainable planning policies to reduce haphazard expansion and protect agricultural and water resources.

Table. 2 Area of Land Cover Classification of the City of Karbala

Land Cover Classification 2016			Land Cover Classification 2026		Land cover changes 2016-2026
	Area km ²	Area%	Area km ²	Area%	Change (km ²)
barren	40.70	25.78	43.21	27.00	2.51
Farm	15.55	9.85	9.07	6.00	-6.48
Urban	46.50	29.46	67.16	43.00	20.66
desert	51.05	32.34	37.29	24.00	-13.75
water	4.02	2.54	1.09	1.00	-2.93
Total Area	157.82	100	157.82	100	0.00

Fig.2: Area of Land cover classification of Karbala city.



that changed to barren LC from the other classes was 26.58 km². The area that changed to farm from the other classes was 4 km². The total area changed to desert from the other classes was 11.28 km². Lastly the area that remained the same with no change was 79.85 km².

The results presented in Table 3 indicate significant spatial variations in land cover transitions across Karbala City between 2016 and 2026. The observed changes are not merely numerical but reflect underlying spatial dynamics driven primarily by urban expansion. The conversion of agricultural land, barren land, and desert areas into urban land highlights the continuous outward growth of the city, particularly toward peripheral zones. This pattern suggests increasing pressure on surrounding land resources, leading to a decline in productive agricultural areas and natural landscapes.

Conversely, the transformation of some urban areas into other land cover classes, although limited, may indicate localized land use adjustments or reclassification effects. The notable transitions between barren and desert classes also reflect the influence of environmental conditions such as soil characteristics and land degradation processes. Overall, these transitions demonstrate a clear trend of urban dominance over other land cover types, emphasizing the need for sustainable land use planning to manage spatial growth and minimize environmental impacts.

Table 3. Change Detections of Land Cover classes in the City of Karbala

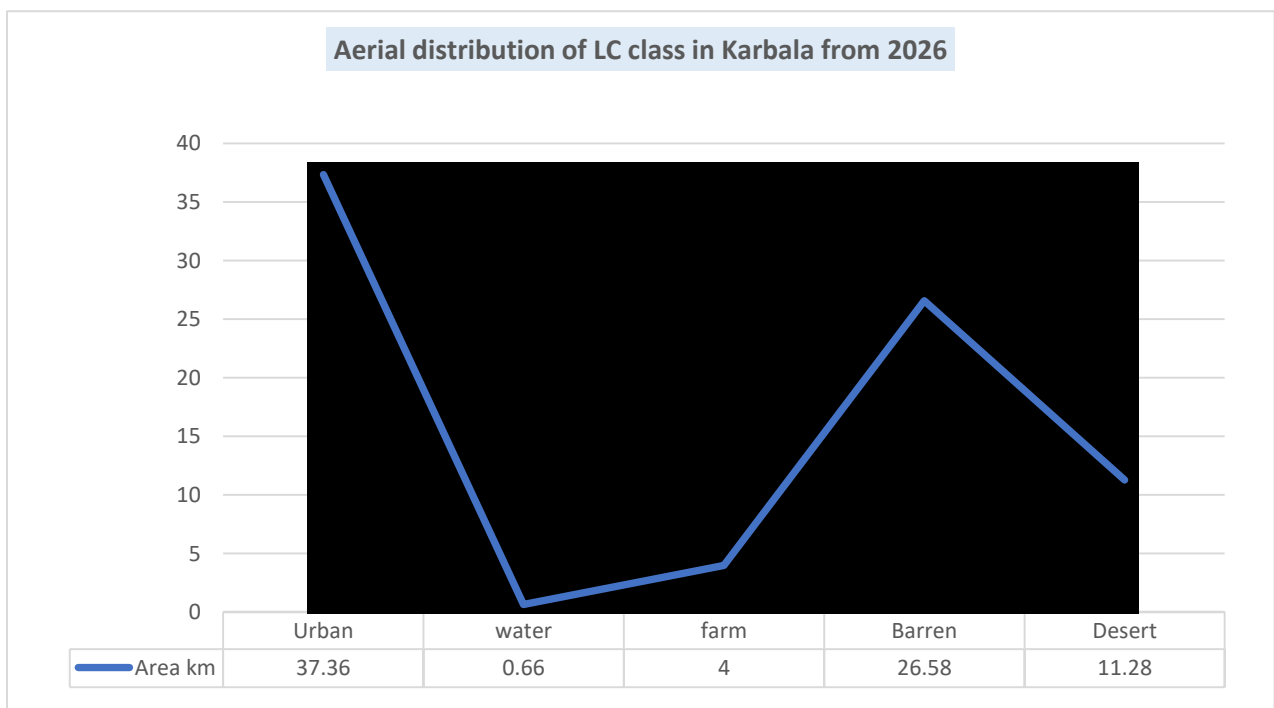
Class from	Class to	Area km ²	Sum Area Changed from Change km ²	Class from	Class to	Area km ²	Sum Area Changed from Change km ²
Water	Urban	1.15	3.58	urban	Water	0.14	0.66
	Barren	1.29		barren		0.19	
	Farm	0.77		Farm		0.27	
	Desert	0.37		Desert		0.05	
Urban	Water	0.14	16.69	water	Urban	1.15	37.35
	Barren	10.14		barren		17.43	
	Farm	0.63		Farm		3.87	
	Desert	5.78		Desert		14.90	
Barren	Water	0.19	24.08	water	Barren	1.29	26.58
	Urban	17.43		urban		10.14	
	Farm	2.01		Farm		5.66	
	Desert	4.45		Desert		9.49	
Farm	Water	0.27	10.47	water	Farm	0.77	4
	Urban	3.87		urban		0.63	
	Barren	5.66		barren		2.01	
	Desert	0.67		Desert		0.59	
Deserts	Water	0.05	25.03	water	Desert	0.37	11.28
	Urban	14.90		urban		5.78	

Spatiotemporal Analysis of Land Cover Changes in Karbala City Using GIS and Remote Sensing

Balsam Marzouk Abd Shawi , Elaf Amer Alyasiri Ph.D.

No Change	Barren	9.49	79.85	barren	Same	4.45	79.85
	Farm	0.59		Farm		0.67	
No Change	Same	77.81	79.85	No Change	Same	77.81	79.85

Figure 4. Change Detections Land Cover of the city of Karbala



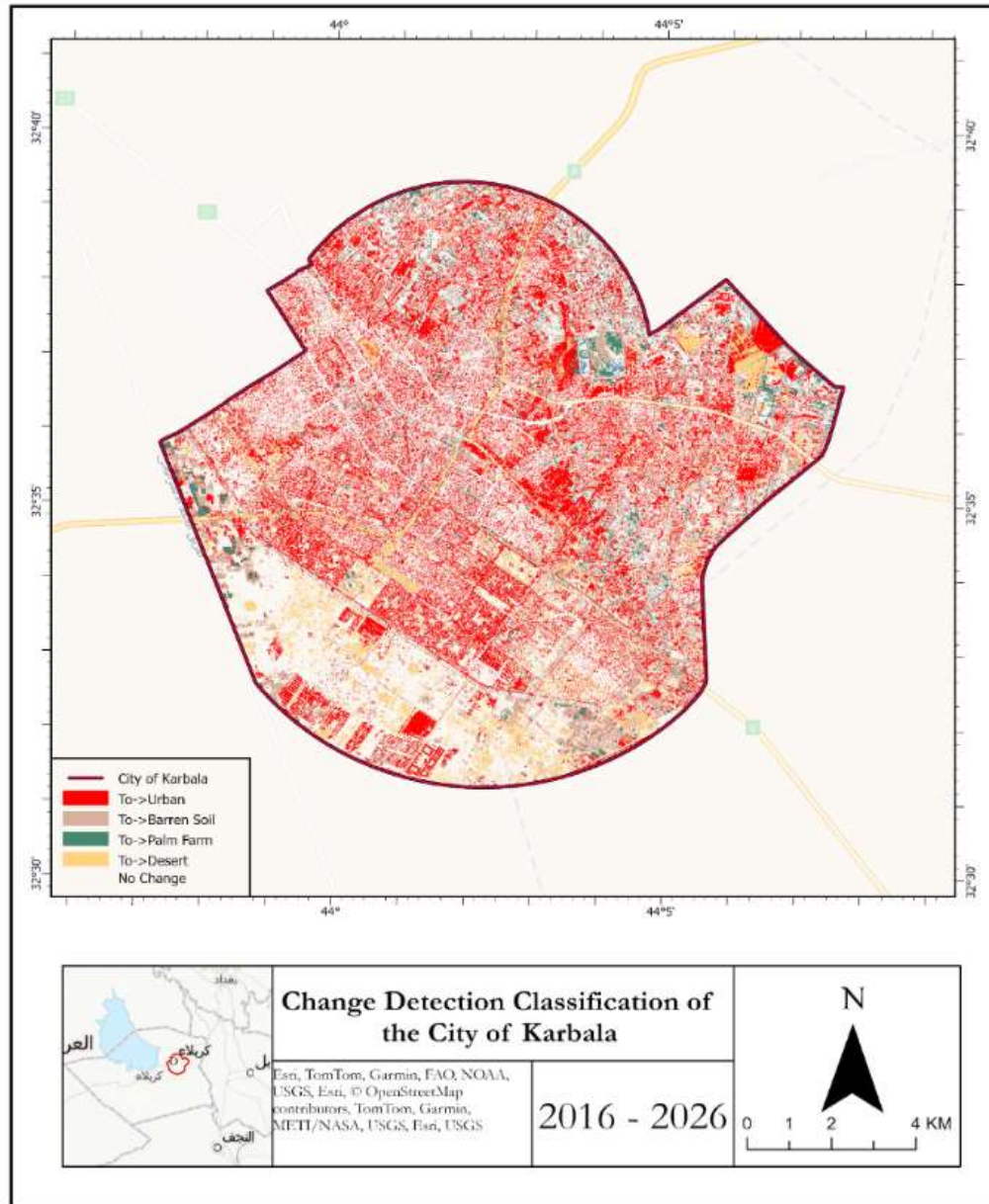


Figure 5. Change Detection of the land cover of the City of Karbala

4.3. Accuracy Assessment

Two maps were classified to change detection (2016-2026). Accuracy assessment techniques were employed to evaluate the reliability of the land-cover (LC) classification methods by comparing the classified pixels with the original imagery and reference ground-truth data (Alyasiri, 2021). For this purpose, 70 random sample points were selected for each study year. The present study utilized both Overall Accuracy (OA) and the Kappa Coefficient (K) to assess the performance of the classification process. Overall accuracy is expressed as a percentage, where higher values indicate greater classification reliability and precision. In addition, the Kappa coefficient is used to quantify the degree of agreement between the classified results and the reference data beyond chance agreement. the accuracy between 0-1, where 1 means

Spatiotemporal Analysis of Land Cover Changes in Karbala City Using GIS and Remote Sensing

Balsam Marzouk Abd Shawi , Elaf Amer Alyasiri Ph.D.

high accuracy and agreement between the classification scheme and the original image (Myint et al.,2011).

Table 5: Error Matrix Demonstrating the Classification Accuracy for the 2016 Classification Map

Classifiey	Random Samples							
	water	Urban area	Barren	Farm	Desert	Total	U- Accuracy	Kappa
Water	8	0	1	1	0	10	0.8	0
Urban area	0	13	1	0	1	15	0.866667	0
Barren	1	3	9	0	0	13	0.692308	0
Farm	0	0	0	10	0	10	1	0
Desert	0	0	1	0	15	16	0.9375	0
Total	9	16	12	11	16	64	0	0
P-Accuracy	0.888889	0.8125	0.75	0.909091	0.9375	0	0.859375	0
Kappa	0	0	0	0	0	0	0	0.822441

Table 6. Error Matrix Demonstrating the Classification Accuracy for the 2026 Classification Map

classifiey	Random Samples							
	water	Urban area	Barren	Farm	Desert	Total	U- Accuracy	Kappa
water	9	0	1	0	0	10	0.9	0
Urban area	0	21	4	0	1	26	0.807692	0
Barren	0	2	12	0	2	16	0.75	0
Farm	0	0	1	9	0	10	0.9	0
Desert	0	0	0	0	14	14	1	0
Total	9	23	18	9	17	76	0	0
P-Accuracy	1	0.913043	0.666667	1	0.823529	0	0.855263	0
Kappa	0	0	0	0	0	0	0	0.813041

Table 5 provides an assessment of accuracy across various LC classes for the year 2016. The Kappa coefficient for the 2016 classification was reported as 0.82. As shown in Table 6, the Kappa coefficient for the 2026 classification was recorded as 0.81. Overall, both the accuracy

values and the Kappa coefficients (> 0.80) indicate that the classification results are highly dependable and can be confidently utilized for spatial change analysis and to inform planning decisions within the study area.

5. Discussion

The study examines LCC over a ten-year period (2016–2026) utilizing remote sensing and geographic information systems. LCC Land transformation refers to the process through which human activities alter and reshape the natural landscape (Zvoleff et al., 2017). These transformations are primarily driven by the pursuit of maximizing economic benefits and are further intensified by population growth and the expansion of human settlements (Kobayashi et al., 2020; Lambin et al., 2003; Shao et al., 2006). The analysis is divided into two intervals: 2016–2026, as presented in Table 2. Results reveal notable alterations in LC characteristics throughout the study period. Specifically, the percentage of water bodies decreased by 2.93% between 2016 and 2026. Agricultural and desert land cover declined by 6.48% and 13.75%, respectively, while barren land and urban areas increased by 2.51% and 20.66%. Residential expansion occurred within the administrative boundaries of the city, with substantial growth concentrated in the city center and along previously established expansion axes. Urban saturation has been observed in the northern, eastern, and western regions, prompting settlement development to shift towards the south, particularly along the Najaf-Karbala axis, where active growth is taking place.

LC and water resources are closely interrelated (Gyawali et al., 2013). Water stress within a region is influenced by the type of LCC. Variations in surface water quality and quantity have been found to correlate strongly with unsustainable anthropogenic activities (Meneses et al., 2015). Similar to other dryland cities, the City of Karbala encounters substantial challenges, such as diminished water availability and growing competition for resources among sectors including agriculture and human settlements.

Effective management of these sensitive water resources is essential. In the study area, the primary water sources are the rivers and their main tributaries, particularly those located in the eastern region. The reduction in water levels is primarily due to climatic changes, such as increased temperatures and decreased inflow from the Euphrates River, which itself has experienced declining flow rates. These factors have resulted in growing deficits in water supply and heightened challenges in meeting the competing demands of different sectors, despite the overall surface water demand remaining stable. Consequently, there is increasing pressure on multi-purpose surface water reservoirs. This situation is especially pronounced in the Al-Hussainiya River and its tributaries, which constitute the principal surface water source for Karbala City.

Climate change is manifested by increasing temperatures, while human activities such as urbanization and the expansion of construction significantly disrupt agricultural land and native vegetation. LCC leads to the degradation of natural resources, reduction of ecosystem services, species loss, and the exacerbation of extreme climate events, all of which have serious implications for humanity (Roy et al., 2022). Barren soils have experienced severe stress due to the combined influences of population growth and climate change (Ojima et al., 1998). Barren LC describes areas with minimal vegetation or exposed soil, often arising from environmental constraints, climatic conditions, or anthropogenic modifications. Continuous monitoring of spatio-temporal Transforms in land cover is essential to improve un-derstanding

Spatiotemporal Analysis of Land Cover Changes in Karbala City Using GIS and Remote Sensing

Balsam Marzouk Abd Shawi , Elaf Amer Alyasiri Ph.D.

of the impacts stemming from both human activity and environmental processes (Eliades et al., 2024).

The area classified as barren land increased notably from 24.08 km² in 2016 to 26.58 km² in 2026. This expansion is primarily attributed to factors such as reduced soil productivity resulting in land abandonment, as well as inadequate reclassification or subdivision of these plots for alternative uses. Desertification represents not only a process of soil degradation and loss, but also a significant challenge affecting regional stability, resource development, and human populations. The increasing severity of desertification in many regions has consequently influenced the planning and implementation of land-management policies. In particular, sandy desertification is considered one of the major environmental and socio-economic problems resulting from intensive human activities (Islam et al., 2022; Wahla et al., 2025).. Between 2016 and 2026, the desert area decreased from 25.03 km² to 11.28 km². This reduction is attributed to regional economic development, which has facilitated land reclamation and repurpose for residential complexes and strategic developmental projects. Significant initiatives include Al-Kafeel Farms, various industrial establishments such as the Al-Ittihad Company factories, and the construction of Karbala International Airport. The ongoing investment activity is supported by the favorable topographical features of these lands, enhancing their viability for development and structural expansion.

Conclusion.

(Remote sensing and GIS technologies were employed as cross-boundary tools to facilitate the visualization, quantification, and evaluation of land cover change (LCC) in Karbala city. There is a noted lack of research in Karbala utilizing Sentinel-2 time series data and limited integration of GIS and remote sensing for LCC detection. Therefore, this study aims to examine the spatiotemporal patterns of land cover and environmental change in Karbala city Based from 2016 for 2026, using multi-temporal remote sensing image data from the Sentinel-2 MSI satellite)

Pixel based classification is employed to categorize images by analyzing the numerical values of pixels. The results indicate notable shifts in land cover between 2016 and 2026, including increases in urban and barren land cover by 20.66% and 2.51%, respectively, while agricultural land, desert areas, and water bodies declined by 6.48%, 13.75%, and 2.93%. This study provides a comprehensive assessment of LCC in Karbala, illustrating the allocation of land for human settlements. It serves as an effective for visualizing and analyzing spatial and temporal environmental changes within the region, thereby supporting decision-makers and stakeholders at multiple levels. in balancing development needs with ecosystem protection. Urban expansion has resulted in the construction of multiple residential complexes in the southern parts of the city, primarily utilizing desert land. Future studies could benefit from the integrated of advanced remote-sensing techniques with higher spatial and spectral resolution for getting a better result for time series, environmental monitoring approaches, and policy-driven frameworks.

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