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Land use land cover change detection in Baghdad city for the years 2000 and 2024 using random forest algorithm

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Abstract

Rapid population growth is one of the serious and common issues in Iraq, and parts of this country have been facing an increase in the number and density of the population in recent decades, putting much pressure on Iraq's natural resources and sometimes economic activities. The growth of residential constructions and industrial zones has caused direct or indirect destruction of ecosystems and their natural lands. Landsat satellite imagery, TM sensors for 2000, and the OLI-TIRS sensor 2024 were used to detect land cover change. A supervised classification technique by Random Forest (RF) method was used for image classification, and the land cover map was obtained in two different years (2000 and 2024), with overall accuracy of 88.33% and 90.83%, respectively. The analysis results have shown that during 24 years, there has been an increase in urban areas: Urbanization increased significantly from 45.24% to 67.98%, indicating significant population and economic growth. Whereas there was a decrease in green spaces, the percentage of vegetated land decreased from 32.56% to 9.09%, which indicates the diminishment of agricultural and green spaces due to urban expansion.

Regarding the relative stability of water bodies, the percentage of water bodies decreased slightly from 3.08% to 2.53%. Finally, there was a slight increase in arid lands; the percentage of barren land increased from 19.12% to 20.40%, which may reflect land degradation and increasing desertification. Comparing land use and land cover changes over a long period shows the impact of human activities and climate change on the environment, allowing for a deeper assessment of environmental degradation and identifying the most affected areas.

Keywords: *Machine Learning, Land Use Land Cover, Classification, Random Forest Algorithm.*

1. Introduction

The change detection process involves quantitatively assessing temporal patterns using multitemporal data sets. Land use refers to man's activities in a specific spatial and time [1]. One of the most important variables is the vegetation due to the ever-changing weather conditions, which are further complicated by the ever-changing link between the environment and the vegetation [2]. Land used in a community indicates the country's economic and social growth. Land use is very significant in many nations since it serves as a roadmap for the country's capacity for successful economic and social development [3]. Researching the area's present and past usage-cover status is essential for doing optimal LULC planning for the future [4]. The importance of surface change data in monitoring environmental and resource conditions on a local, national, and international scale is growing [5]. LULC changes constantly with time at local, regional, and global scales. The location, severity, and variability of change and its causes, processes, reactions, and consequences may all be quantified using remote sensing [6].

Many temporal datasets must be used in the change detection procedure to quantitatively examine the effects of the phenomena on the period [7]. Data on surface changes is necessary for monitoring global, regional, and local ecosystems and resources [8]. The term "land cover" describes the various things that may be found on the surface of the Earth, both naturally and artificially [6]. Land use is significant because it provides services directly related to people's lives and needs [1]. On the other hand, the loss of natural vegetation cover due to human activity is the most effective factor in vegetation degradation [9]. Remote Sensing uses space-based satellites to classify unique features of the Earth that can help track changes in the Earth's surface as these satellites regularly observe the Earth's features [10]. Among the many industries that are at risk from drought, agriculture is among the most susceptible [11].

The literature review study applied supervised classification using random forest to binary land cover classification. Many scholarly articles have addressed the method's viability as a land cover classification tool for medium and high-resolution satellite data. Therefore, this paper's specific objectives were the detection of land use land cover from 2000 to 2024 and the investigation of detailed changes in land use concerning other major land cover categories through spatial and temporal analysis. Numerous studies have been conducted on changing LULC classification using RF, but the model's performance has not been well examined for classifying past images with ancient history. Previous studies utilized GEE (Google Earth Engine) and Google Earth. The accuracy of the classifications will be determined in this investigation using high-resolution topographic maps.
Importance of computing the changes: Iraq suffers from major environmental challenges, including desertification, water scarcity, vegetation loss, and air and water pollution. These problems have been exacerbated by climate change and human activities such as uncontrolled urban expansion, unsustainable agriculture, and mismanagement of water resources. Landsat imagery provides long-term temporal coverage (since the 1970s), allowing for analysis of changes in land use and land cover over decades. This ability to provide historical data makes it an ideal tool for studying long-term environmental changes. Satellite imagery such as Landsat provides multispectral data, allowing for analysis of different environmental patterns such as vegetation, agricultural land, urban areas, and water bodies at higher resolution and enhancing the ability to detect environmental degradation. With the increasing need for fast and accurate data to monitor environmental changes, satellites such as Landsat are becoming a more effective tool than traditional methods that may be affected by temporal and spatial factors.
In this paper, we will begin by describing the data and sources used to analyze changes in land use and land cover in Baghdad city between 2000 and 2024. Next, we will explain the data preprocessing techniques used, followed by the methodology of applying the Random Forest Algorithm to detect changes. The results will be presented and analyzed in detail in the next section. Finally, we will discuss these results and their implications for urban and environmental planning in the city, as well as conclusions and future recommendations.

2. Theoretical background

2.1. Classification

Optical or active rolling environmental changes using optical and microwave imaging from different sensors and spatial and spectral resolutions form the basis of the accurate classification systems, which account for ecological changes over time [12]. Investigating LULC, quantifying carbon storage, and assessing environmental impact are just a few of the many fields that may gain from more precise LULC classifications [13]. Local and regional planning are among the numerous sectors that depend on Earth's data, making it important to understand LULC trends [14]. Land use planning and limiting the effects of climate change are only two of the many activities and applications that have identified the need to track LULC changes [15]. In addition, trend and change identification evaluations of LULC have become a significant problem for investigators worldwide as they work toward achieving environmental security and sustainable development [16]. As a result, LULC change is more pronounced due to uncontrolled population expansion and industrialization, particularly in emerging countries [15].

2.2. Random forest

Random Forest is Breiman's latest non-parametric ensemble machine learning technique. [17]. Many environmental issues, such as managing water resources and natural hazards, have been solved using the Random Forest algorithm [18]. An ensemble of several decision trees methodically working together makes up a Random Forest. Figure 1 shows that a series of classification techniques called Random Forest (RF) algorithms relies on mixing many decision trees.
A decision tree is created by randomly selecting a vector from a training set; a classification vote is calculated, and finally, the tree with the most values becomes a classification model [20]. One of the many practical and adaptable methods is Random Forest, which has the following features: (1) it is one of the most accurate algorithms currently available and runs efficiently on big databases; (2) it can process thousands of input variables without deleting any of them; (3) it builds a more accurate estimate of statistical error internally as the forest grows; and (4) it has a good way to estimate missing data and keeps accuracy even when many data is missing [21]. Much recent research has shown that Random Forests perform adequately for LULC classification in remote sensing applications [22][23][24]. Implementing a large number of trees from this strategy improves image classification accuracy [25]. Given a node t and estimated class probabilities p (k / t) k = 1 … Q, the Gini index is defined as [26]:

$$G(t) = 1 - \sum_{k=1}^{Q} p^2 \left(\frac{k}{1}\right) \quad (1)$$

Where: Q is the number of classes.

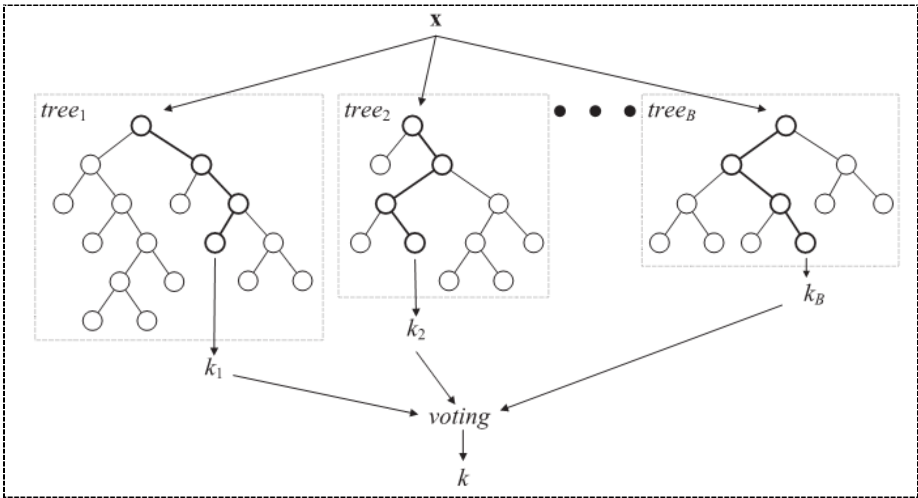


Fig. 1: General Architect of Random Forest [19].

2.3. Assessment

Satellites and other forms of remote sensing provide a treasure trove of data for studying the geographical and temporal variability of environmental parameters [27]. Thematic maps created from remote sensing data are an important area of research that has attracted much attention from remote sensing [28]. The overall classification accuracy is the most used statistic because of its simplicity and practical relevance; it indicates the proportion of cells that have been correctly classified [29]. The approach for determining the overall accuracy of classification:

$$\text{Overall accuracy} = \frac{\text{Number of correct classes}}{\text{Total number of classes}} \tag{2}$$

3. Methodology

The theoretical method of change in LULC of Baghdad city will be used in the research. This method is based on geomatics and the practical approach utilized in this work. The application of this method may be explained and defined as follows:

1. The gathering of information from a satellite.
2. The treatment of data.
3. Utilize the Random Forest (RF) classification techniques with ArcGIS 10.8 and ENVI 5.3 software applications to extract various LULC classes.
4. Change that extracted information.
5. It is essential to evaluate the accuracy and compare the results obtained. An illustration of the technique flowchart may be viewed in Figure 2.

The Random Forest algorithm is applied to classify data extracted from Landsat images based on multispectral features, such as infrared and visible light, as this algorithm is used for its high ability to handle large and complex data sets. The Random Forest algorithm is used to develop a classification model based on the collected training samples, where many trees (Decision Trees) are built, and their outputs are analyzed to determine the final class for each pixel in the images. The model's accuracy is tested using validation data, and its accuracy is evaluated through indicators such as the overall accuracy to determine the quality of the classification. The results are then evaluated by comparing the resulting classifications for different periods (2000 and 2024) to assess land use and cover changes, and spatial patterns of environmental changes were extracted. Finally, the classification accuracy is evaluated using reference data and field verification (Ground Truth) in some areas, where the correctness of the classification is confirmed by comparing the results with the available field facts.

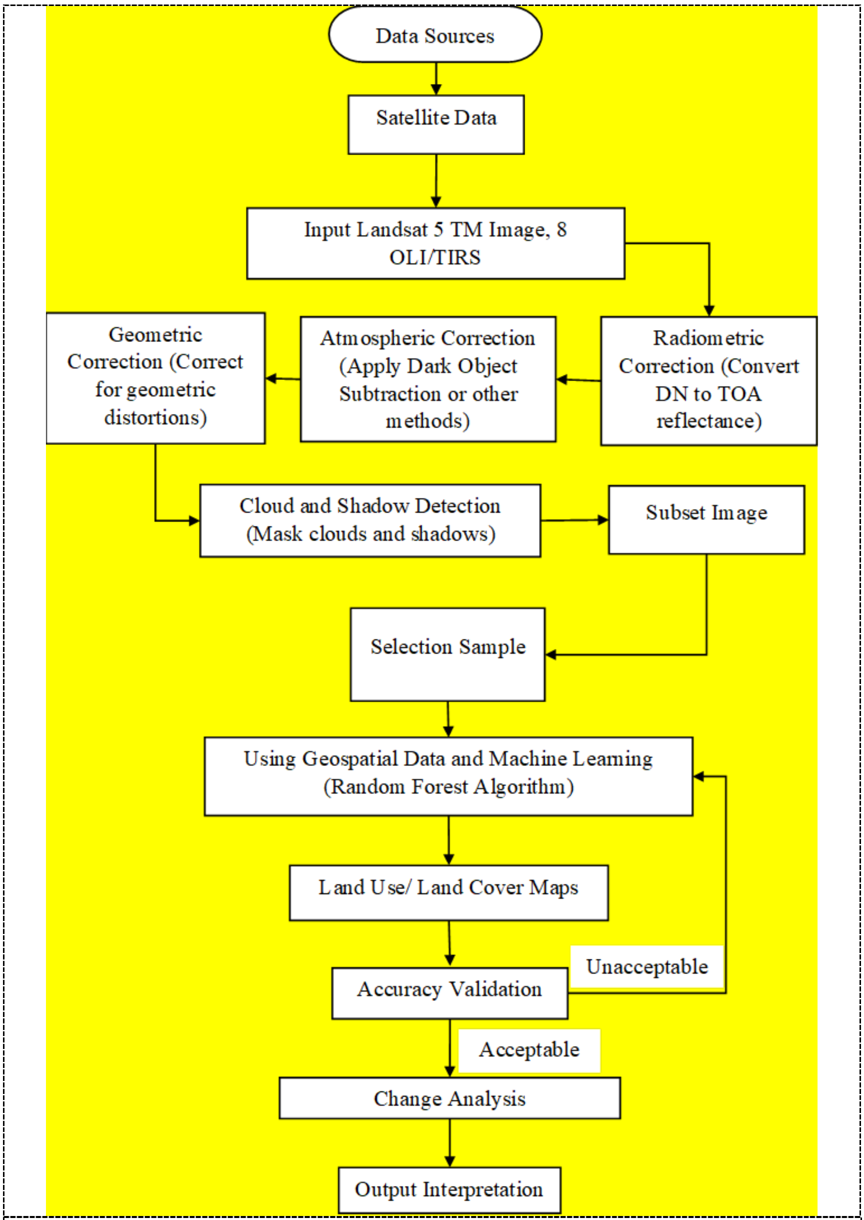


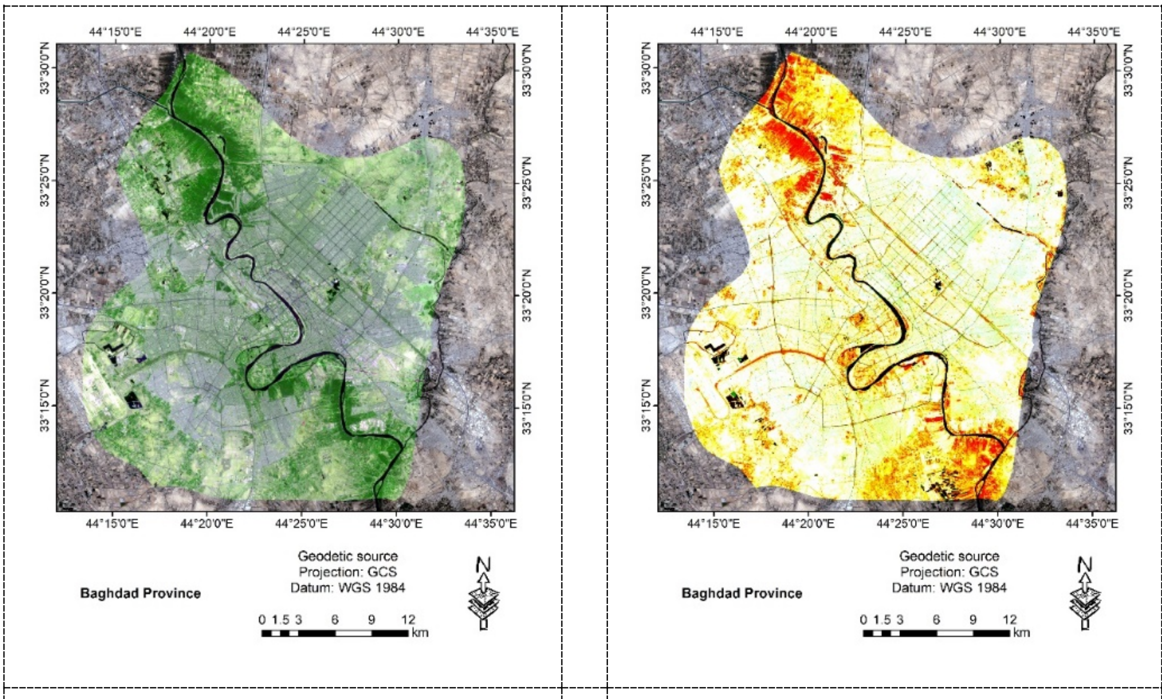
Fig. 2: Flowchart for the general work.

4. Available data

For this investigation, satellite data was used. Landsat-5 TM images for the years 2000 and Landsat-8 OLI/TIRS images for the year 2024 were collected from the USGS (https://earth explorer.USGS.gov/), details of which can be found in Table 1. These images and data were then used for the necessary geostatistical and geospatial analysis. These images were collected over twenty-four years to better comprehend Bagdad city's chronological changes. Before conducting the geo-special analysis, the images were adjusted using radiometric calibration and atmospheric correction. There are no clouds in the study area, and the images have a resolution of 30 meters. Figures 3a and 3b illustrates the study area in two years.
As shown in Figures 4a and 4b, the reference data consists of 200 points, with 50 points for each class created using 2000 topographic maps and 200 points for each class created using the 2024 observation field. This is the first step in determining the accuracy of an evaluation. Each location had been selected to represent various types of land cover.
In the case of this research, the objective is to detect changes in land use and land cover between 2000 and 2024. Based on this objective, the false-color composite image was used because it provides a clearer picture of changes in vegetation cover and other environmental changes that may not be visible in natural color images. This type of imagery helps identify changes in agricultural areas and green spaces and monitor LULC and the degradation of the natural environment over the two periods.

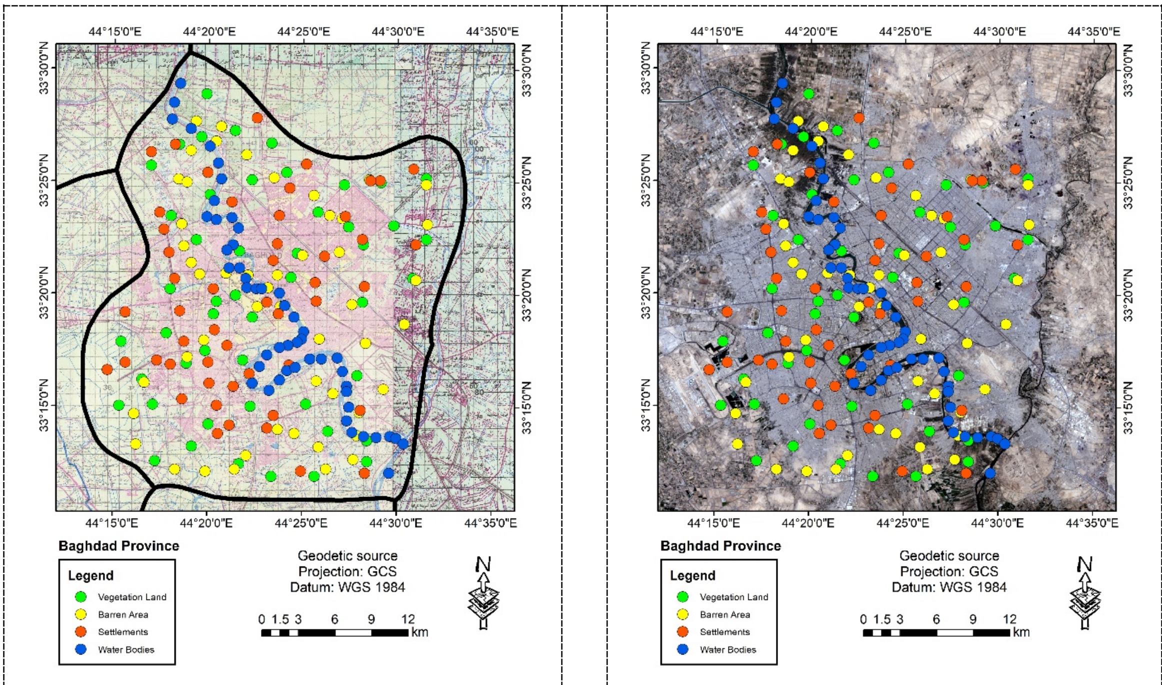
Table 1: The study used satellite data.

No.	Satellite	Sensor	Path/Row	Date of acquisition	Resolution
1	Landsat 5	TM	168/38	22/07/2000	30 m
2	Landsat 8	OLI/TIRS	168/37	13/07/2024	30 m



(a) **(b)**

Fig. 3: The study area for the years: (a) 2000, (b) 2024.



(a) **(b)**

Fig. 4: Reference data for the years: (a) 2000, (b) 2024.

5. Study area

Baghdad city is located in the central part of Iraq and is bordered by the governorates of Diyala to the east (Wasit, Babil) to the south, Anbar to the west, and Salah al-Din to the north. The area of Baghdad city is (5169) square kilometers, between the longitudes of 44°15'00" East and 45°35'00" East, as well as the latitudes of 33°00'00" North and 33°30'00" north, as in Figure 5. It includes (32) administrative units (districts) that constitute (10) districts. Baghdad's climate is considered a desert climate. In the summer, the temperature is intense and may exceed fifty degrees Celsius, while the atmosphere is dry. The city is also exposed to severe dust storms, the cause of which scientists attribute to global warming and Iraq's desert climate, in addition to the increase in the percentage of carbon in the atmosphere, the spread of the desertification phenomenon, and other environmental factors.

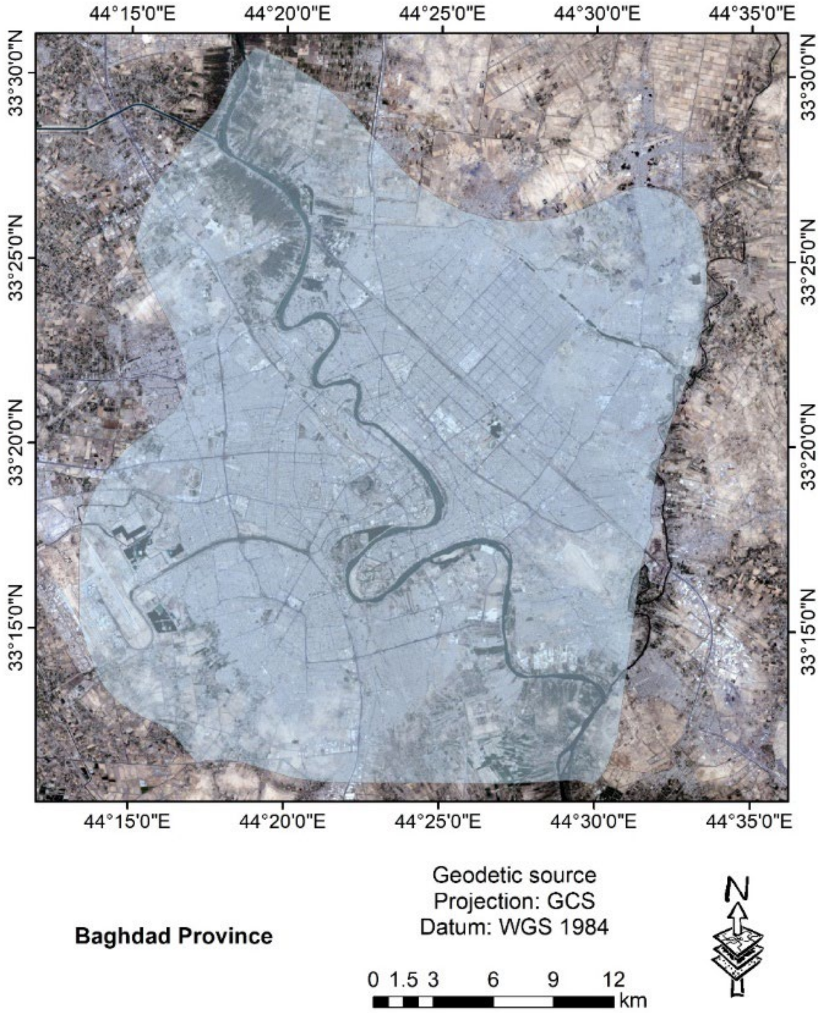


Fig. 5: Geographical location map of Baghdad city.

6. Results and discussion

The relationships and interactions between people and the natural environment may be better understood with the collection of information regarding changes in land cover. In this regard, remote sensing data has been one of the most important data sources for studying the spatial and temporal changes of land cover in different regions. For processing and analysis, remote sensing multi-temporal datasets provide the possibility of mapping and identifying landscape changes and provide an effective step for sustainable local planning and management. In particular, by integrating RS and GIS techniques, it is possible to analyze and classify the changing patterns of land cover over a long period and, as a result, better understand the changes in the target range. Today, it is well established that satellite remote sensing and GIS are the most common methods for quantifying, mapping, and detecting land use and land cover change patterns because they have precise spatial analysis techniques and provide a suitable digital format for computer processing and repetitive data collection. Geographic information systems and remote sensing have allowed researchers and scientists to monitor changes in land use patterns over long periods, providing regional authorities and politicians with the data they need to make informed decisions. Adopt the future more precisely. This classification was applied using the Random Forest package in QGIS.

Figure 6 map provides a comprehensive overview of the distribution of land uses in Baghdad City in 2000. It can be used for sustainable development planning and understanding the governorate's environmental and economic challenges. Spatial analysis can help make informed decisions about using land best to balance development and environmental conservation. This map shows the land classification of Baghdad city in 2000. The map is divided into four main land categories. We note that plant lands are concentrated in certain areas along the river course. This reflects the presence of agricultural activity or natural vegetation on the river banks, indicating the exploitation of the land for agriculture and grazing. A major river runs through the city from north to south. This indicates the importance of this watercourse in water distribution and perhaps irrigation and agriculture. Settlements are widely distributed in the governorate, reflecting significant urban development. It is found densely in the central areas and around the river, indicating the population concentration. Barren lands are largely found in areas surrounding settlements and on the outskirts of the governorate. This indicates the presence of areas that are largely underutilized agriculturally or urbanly, perhaps due to environmental conditions or unsuitable soil. It can be seen that the spatial distribution of terrestrial classes depends largely on the presence of the river, along which vegetation and settlements are concentrated. This reflects the importance of water in daily life and agriculture. Large areas of barren land indicate environmental challenges that the city may face, such as water scarcity in some areas or soil unsuitable for agriculture. The concentration of settlements in certain areas reflects urban growth and may indicate the concentration of economic activities and services. This can put pressure on natural resources in these areas.

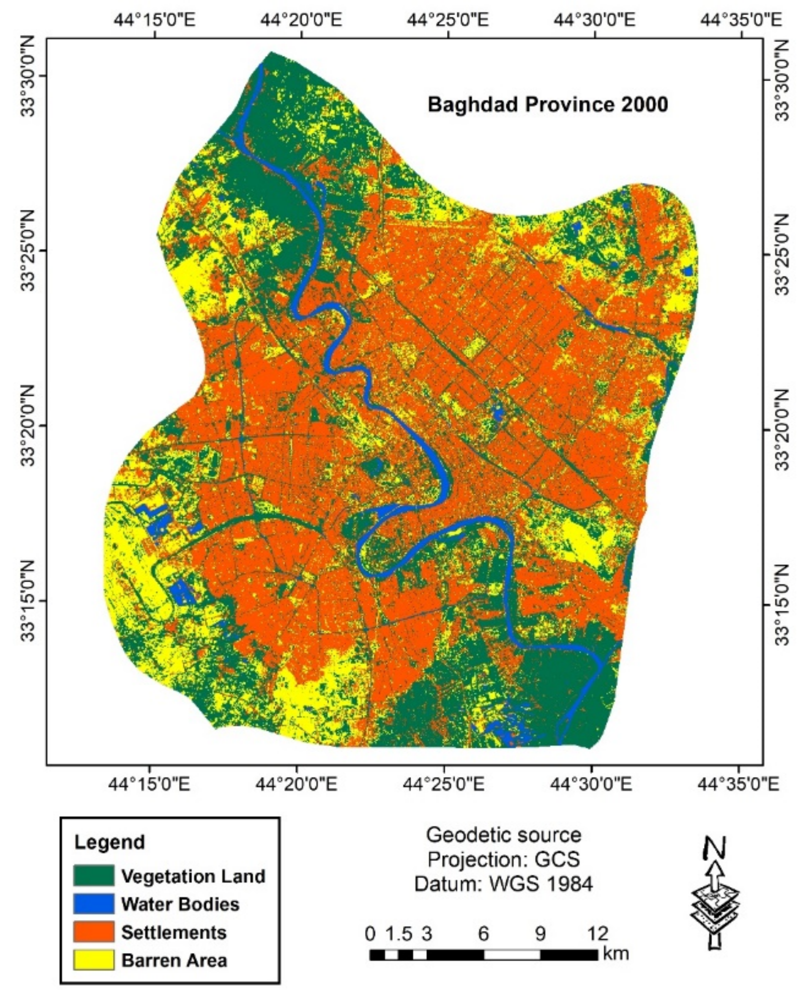


Fig. 6: Classification LULC Baghdad city for the year 2000.

Table 2 shows that settlements constitute the largest portion of the classified area in Baghdad city, at 45.24%, reflecting the great importance of urban infrastructure and population centers. Vegetation land comes in second place at 32.56%, indicating the presence of relatively large green spaces, which can be of environmental and agricultural importance. Barren areas represent 19.12% of the area, and they are areas that may be largely unexploited for either agriculture or housing. Water bodies constitute the lowest percentage at 3.08%, indicating the city lack of surface water resources.

Table 2: The results of a classification in Baghdad city for 2000.

No.	Classes	Percentage (%)	Area (km^2)	Ranking
1	Vegetation Land	32.56	267.06	2
2	Water Bodies	3.08	25.25	4
3	Settlements	45.24	371.01	1
4	Barren Area	19.12	156.81	3
	Total	100.00	820.11	10

Table 3 displays the results of the evaluation of classification accuracy for several land categories in the year 2000. The overall accuracy in the table represents the proportion of items that are classified correctly out of the total items. The overall accuracy is 88.33%, which is a good rate and shows that most classifications were correct. It can be noted that there are some errors in the classification of categories, such as classifying some vegetated lands as settlements or as bodies of water. These errors may arise from the similarity of class characteristics in the images used for classification or from natural interferences in land cover. This is a generally good classification accuracy assessment for 2000, with some minor errors that might be expected in any classification process. To improve accuracy in the future, we can benefit from advanced classification techniques or improve the quality of the data used in the classification process.

Table 3: Accuracy assessment results for classification year 2000.

Classes	Vegetation Land	Water Bodies	Settlements	Barren Area	Total	Overall Accuracy %
Vegetation Land	26	1	3	0	30	88.33
Water Bodies	1	28	1	1	31	
Settlements	0	1	25	2	28	
Barren Area	3	0	1	27	31	
Total	30	30	30	30	120	

Figure 7 Land Use and Land Cover Classification (LULC) for Baghdad city 2024. This map shows the changes in land uses and land cover for Baghdad city in 2024. The classification includes four main land categories. We note that vegetated land is still concentrated along the riverbed but appears less widespread than the 2000 map. This may indicate a decline in agricultural areas or natural vegetation. Water bodies are still concentrated along the main river, reflecting the continued importance of this waterway to the region. Settlements appear to have increased significantly, covering a larger portion of the map than in 2000. This indicates significant urbanization and population growth that may be linked to increased population density and urbanization. Barren lands appear on the map, especially in the outskirts and surrounding settlements. There appears to be an increase in barren lands, which may reflect environmental or economic challenges that hinder the exploitation of these lands.

Compared to the 2000 map, a significant change in land use can be observed. The areas devoted to vegetable land appear to have decreased while settlements have increased significantly. This may indicate urban expansion at the expense of agricultural land. The expansion of settlements reflects an increase in urbanization and population growth. It is important to consider how this urbanization affects the infrastructure and services provided to residents and the surrounding environment. The increase in barren lands indicates environmental challenges that the city may face, such as climate change or lack of water resources. This requires effective land management and environmental conservation policies to ensure resource sustainability.

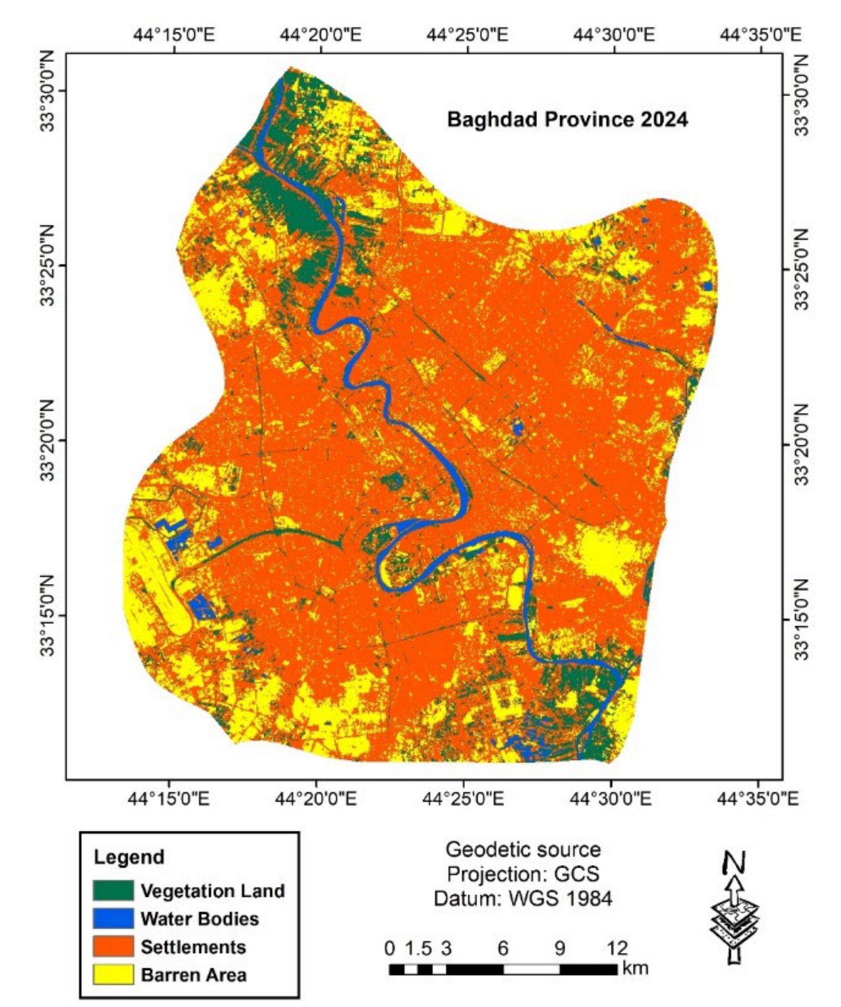


Fig. 7: Classification LULC Baghdad city for the year 2024.

Table 4 displays the results of land classification in Baghdad city for 2024. Settlements: The high percentage (67.98%) and large area (557.49 km²) indicate significant urban expansion, increasing construction, housing and infrastructure. This expansion could reflect population and economic growth in the city. Vegetation Land: The low percentage (9.09%) and small area (74.55 km²) indicate a shrinkage of green and agricultural areas. This decline could result from urban expansion and may negatively affect the environment and biodiversity in the region. Water Bodies: The low percentage (2.53%) and the small area (20.74 km²) reflect the city's lack of surface water resources. This requires effective strategies to manage water resources and ensure their sustainability. Barren Area: The moderate percentage (20.40%) and the average area (167.32 km²) indicate the presence of large areas that are not exploited agriculturally or urban. This could result from desertification or insufficient resources to convert these lands to other uses.

Table 4: The results of a classification in Baghdad city for 2024.

No.	Classes	Percentage (%)	Area (km^2)	Ranking
1	Vegetation Land	9.09	74.55	3
2	Water Bodies	2.53	20.74	4
3	Settlements	67.98	557.49	1
4	Barren Area	20.40	167.32	2
	Total	100.00	820.11	10

Table 5 presents the results of the classification accuracy evaluation for four classes of land in 2024. The overall class accuracy refers to the proportion of elements correctly classified out of the total elements, which is 90.83%. It appears that the classification for this category was highly accurate. Overall accuracy is a good performance in classification accuracy for the year 2024. To further improve accuracy across categories, consideration could be given to improving the input data and classification techniques and possibly enhancing the use of advanced machine learning techniques to improve overall classification accuracy.

Table 5: Accuracy assessment results for classification year 2024.

Classes	Vegetation Land	Water Bodies	Settlements	Barren Area	Total	Overall Accuracy %
Vegetation Land	24	0	0	0	24	
Water Bodies	1	29	1	1	32	
Settlements	2	1	28	1	32	90.83
Barren Area	3	0	1	28	32	
Total	30	30	30	30	120	

Table 6 displays the changes between 2000 and 2024, represents the distribution of land used in two different time zones, and shows the changes that occurred during this period. In terms of percentage and area in square kilometres, information is presented for each category (vegetated land, water bodies, settlements, and barren areas). In addition, the table shows the change that occurred from 2000 to 2024.

Table 6: Changes in Baghdad city (2000-2024).

No.	Classes	2000		2024		Change (2000-2024)	
		Percentage (%)	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)	Area (km^2)
1	Vegetation Land	32.56	267.06	9.09	74.55	-23.47	-192.51
2	Water Bodies	3.08	25.25	2.53	20.74	-0.55	-4.51
3	Settlements	45.24	371.01	67.98	557.49	22.74	186.48
4	Barren Area	19.12	156.81	20.40	167.32	1.28	10.51
	Total	100.00	820.11	100.00	820.11		

Figure 8 shows the changes in classification ratios in Baghdad City between 2000 and 2024 and gives a comprehensive view of improvements or deteriorations in different areas, which helps in future planning and making appropriate decisions. This analysis helps understand environmental and urban changes in Baghdad city over 24 years and provides recommendations for the future to ensure ecological and development sustainability.

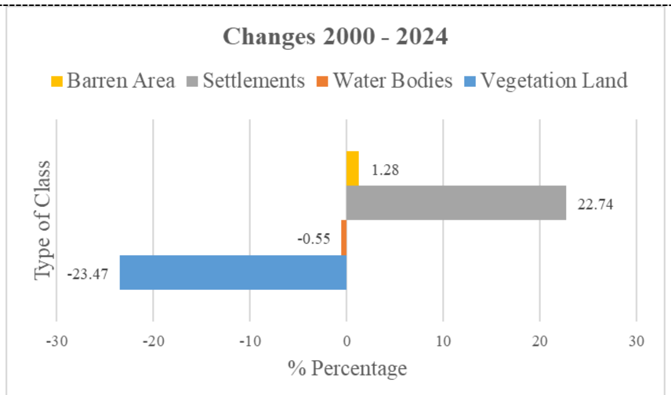


Fig. 8: The percentage of changes in Baghdad city between the years (2000 - 2024).

7. Conclusions

Great value is derived from studying the outcomes and achievements of studies associated with land change identification; this serves to justify the results and necessitate citation of the research findings while simultaneously laying the basis for future research by other researchers. Plant areas and water bodies have witnessed a noticeable decline. In contrast, the areas used for settlements and wastelands increased. Data indicate a significant shift from natural lands to human uses, especially in increasing settlement areas. The 2024 map shows significant changes in land use in Baghdad city, with a significant expansion of settlements and a decrease in vegetated land. These changes point to challenges and opportunities that must be addressed through effective urban planning and environmental management to ensure a balance between sustainable development and the protection of natural resources, as follows:

1. Barren Area: There is an increase of 1.28% in this category, which means a slight increase in the area of wasteland.
2. Settlements: There is a significant increase of 22.74% in this category, indicating a substantial expansion into residential or urban areas.
3. Water Bodies: There is a slight negative change of -0.55%, which means a slight decrease in the area of water bodies.
4. Vegetation Land: There is a significant decrease of -23.47% in this category, indicating a considerable decline in cultivated or forested land.

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