



## Vegetation Cover Classification and Change Detection in Northern Kirkuk Governorate Using Satellite Data and GIS (1993–2023)

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### Abstract

The objective of this research is to identify and analyze the changes in vegetation cover, agricultural lands, and barren lands in Northern Kirkuk Governorate over the period from 1993 to 2023. The study seeks to understand the dynamics of these changes and their underlying causes, while also creating detailed maps that visually represent the results. To achieve this, a validated classification methodology, using satellite imagery and Geographic Information Systems (GIS), was used to effectively analyze and classify the land cover and land use in the area. This approach allows for an in-depth assessment of the shifts in land use patterns, providing valuable insights into the environmental and socio-economic factors driving these changes. To achieve this, satellite imagery collected from satellites, such as Landsat 5 and Landsat 7, was utilized using TM, ETM+, and OLI-TIRS sensors. These images are an effective source that saves significant time and effort, as well as providing accurate and reliable results. Six land cover and land use patterns were identified in the region. Agricultural land, natural vegetation, water cover, and built-up land witnessed significant increases in 2023, reaching 23.37%, 21.15%, 0.32%, and 4.62%, respectively. In contrast, rock deposits and barren lands covered vast areas in 1993, representing 58.12%, but experienced a significant decline in 2023, falling to 27.23%. This change was the result of natural and human factors that positively impacted the region. These findings constitute a critical information database for monitoring land cover changes in the region, facilitating the tracking of these changes, analyzing their causes, and predicting their future developments. These results will help develop strategic plans to address future challenges related to land and natural resource management in northern Kirkuk Governorate.

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**Keywords:** Land Cover Classification, GIS, Satellite Images, Kirkuk, Iraq

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### 1. Introduction

The aim of this study is to analyze the changes that have occurred in vegetation cover, agricultural land, and barren lands in northern Kirkuk Governorate between 1993 and 2023. The research utilizes satellite imagery and Geographic Information Systems (GIS) to analyze and classify these changes over this extended period (Ouchra *et al.*, 2022)<sup>[11]</sup>. This period is significant for understanding how economic, social, and climatic shifts have impacted the environment in this region. Satellite images from Landsat 5, Landsat 7, and Landsat 8 were used, as they provide high accuracy in identifying land features and land use. Previous studies have shown that remote sensing technology and modern techniques, such as supervised classification of satellite imagery, have become essential tools for studying land cover changes. (Macarringue *et al.*, 2022)<sup>[9]</sup>. These tools help provide precise analyses that contribute to monitoring biodiversity and land use changes. In similar studies, researchers have used imagery from various periods to assess the impact of human activities, such as agriculture and grazing, as well as natural changes such as erosion and desertification.

It has been observed in many studies that the expansion of agricultural land and urban development at the expense of barren and rocky areas is common in many parts of Iraq. This is due to increasing human activity, such as irrigated agriculture, urbanization, and industrial activities, as well as climate changes. According to (Othman *et al.*, 2019) [10], utilizing satellite data has provided effective solutions for analyzing these changes and monitoring future trends, in addition to laying the foundation for developing strategies for improved land management (Al-Quraishi & Negm, 2019) [2]. Satellite imagery, such as those obtained from Landsat satellites, provides valuable data about various land cover types and land uses. The results of these studies show how land cover changes are closely linked to economic and social transformations occurring in the region, such as the expansion of agricultural lands and improvements in vegetation cover in certain areas (Long *et al.*, 2021) [8]. Therefore, it becomes necessary to conduct an accuracy assessment of the digital classification to measure the reliability of these maps and determine their suitability for achieving research objectives. On this basis, assessments of the accuracy of digital classification of satellite images for land cover and land use maps of the study area were conducted for the years 1993 and 2023, according to a study (Pistorius & Poona, 2014) [12].

Geographic Information Systems (GIS) are important in monitoring land cover changes in northern Kirkuk over the period (1993-2023). Modern technologies, such as satellite imagery and geographic information systems (GIS), can be used to monitor these changes.

## 2. Materials and Methods

The process of distinguishing and identifying land cover types and land uses in the north of Kirkuk Governorate was adopted, as the descriptive approach and the analytical approach were used in interpreting and classifying the land cover and monitoring changes for the period from (1993-2023), and relying on spatial arrangements on a set of interpretation bases, which are: shape, size, shade, and pattern (Shareef *et al.*, 2019) [14]. Since there is no reliable data available to determine the extent of urban expansion on agricultural lands during the study period extending from 1993 to 2023, satellite images were used to identify the change in land use in northern Kirkuk and create a spatial database for it through the directed classification process of satellite image data from the Landsat series and matching the derived categories using Anderson's classification. (Kassaye, R. H., 2013).

The study area is located astronomically between longitudes ( $44^{\circ} 49' 0'' - 43^{\circ} 44' 0''$ ) east, and latitudes ( $35^{\circ} 52' 0'' - 35^{\circ} 18' 0''$ ) north., and geographically it is located in the northeastern part of Iraq and the northern part of Kirkuk Governorate, which includes several areas (Shwan, Altun Kopri, Qara Hanjir, Kirkuk Center, Yaji, Al-Multaqa, Al-Dibs, Sarkaran), while it is bordered to the north by Erbil, to the east by Sulaymaniyah, to the west by Nineveh, and to the south by the administrative borders of Kirkuk, as its total area is (4109) km<sup>2</sup>, as in Map Based on the administrative map of Iraq at a scale of 1/1000000, and the administrative map of Kirkuk Governorate at a scale of 1/500000, and using Arc GIS 10.7. Figure (1).

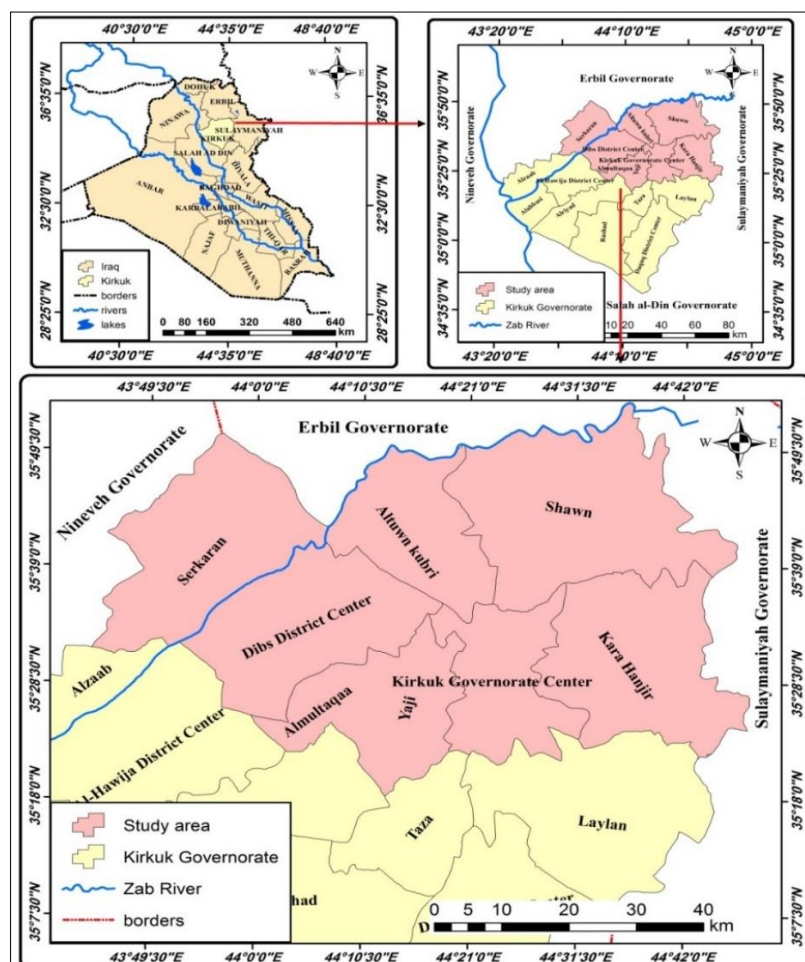
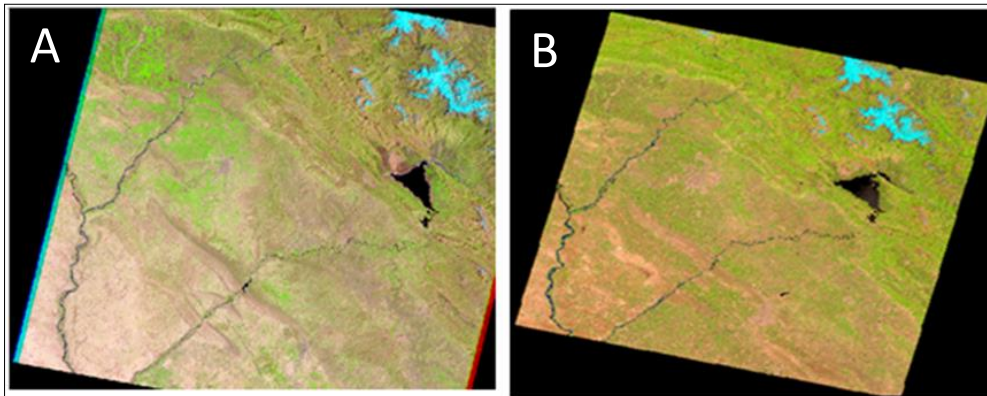


Fig 1: Map of the location of the study area.

**The First Stage:** in this stage was based on the Land sat 5 Mss satellite image dated 4/18/1993, and the Land sat 8 oil satellite images dated 5/15/2023, as the bands for water, natural vegetation, agricultural lands, and terrain were combined, and the thermal bands were excluded.

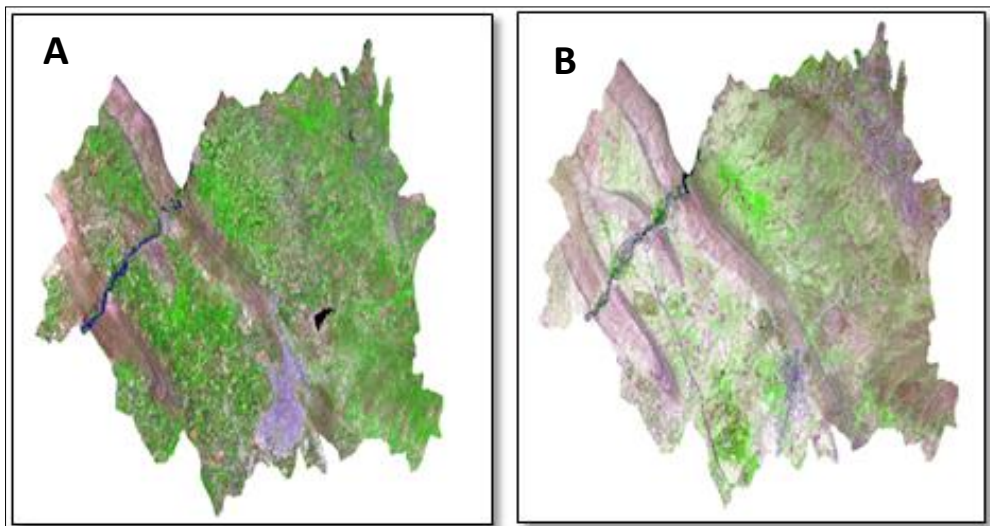
**Second Stage:** After merging the bands for the ground appearance, the visuals appear in their final form as shown in the Figure below



**Fig 2:** A. Satellite broadcast for the year 18/4/1993. B. Satellite broadcast for the year 5/15/2023.

**The Third Stage:** is the process of extracting visuals on the borders of the study area to complete the process of

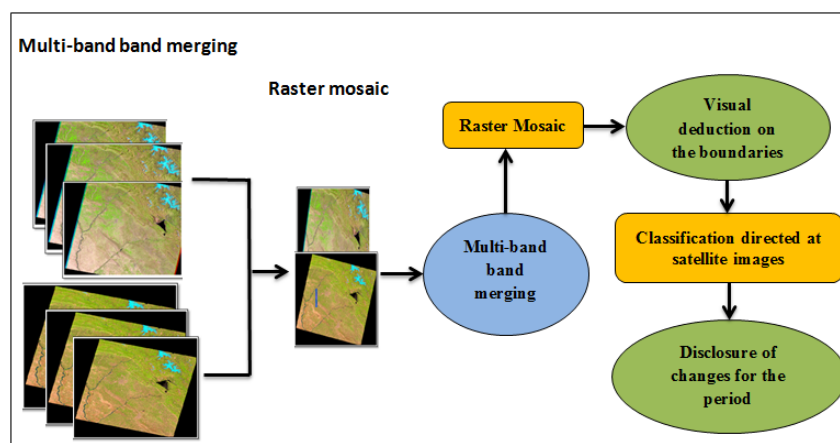
classifying the landform and monitoring changes in land cover between the years 1993-2023.



**Fig 3:** Deduction process A. 18/4/1993. B. 5/15/2023.

**The Fourth Stage:** is the process of conducting a wave classification of space images by taking spectral fingerprints of the studied area, which reveals six categories that will be

studied in detail and the changes between them will be monitored figure (4).



**Fig 4:** Flowchart of the general method for land cover classification process.

### 3. Results & Discussion

#### Interpretation and Classification of Land Cover and Land Use in Northern Kirkuk in 1993

Through the color compositing of the image captured by the Landsat 5 satellite within the TM sensor, a true-color classification was obtained that closely resembled real-world conditions. The green, brown, blue, and gray color composites effectively distinguished various land cover and land use types in northern Kirkuk. These composites helped to identify six distinct classifications, which align with the first level of the Anderson classification system (Sreelekha & Reddy, 2023) [15], as illustrated in Map (5). From Table (1), it became evident that there was a notable variation in the areas of land cover and land use across the study area in 1993. This variation is clearly visible in the distribution and proportions of land cover types in northern Kirkuk Governorate during that year, as shown in Figure (5). The distribution of land cover types varied significantly, and this variation can be interpreted by analyzing the areas in descending order, starting from the largest to the smallest. This approach allows for a clearer understanding of how land cover types dominated the landscape of northern Kirkuk in 1993, and the extent to which different land cover categories impacted the

study area.

For example, the image revealed that barren lands and rocky areas covered a large proportion of the region, which was characteristic of the land cover in the early 1990s. These areas were primarily characterized by dry, sparsely vegetated surfaces, with minimal agricultural activity. Meanwhile, agricultural lands and urban areas, though present, occupied relatively smaller proportions of the region in comparison to barren lands (Farooqi *et al.*, 2025) [4].

The satellite image used for this analysis was from Landsat 5, taken on April 18, 1993, and processed with the ArcGIS 10.7 program to generate detailed outputs that aided in the classification and interpretation of the land cover data. The classification process involved analyzing the spectral properties of different land cover types and then assigning them to the appropriate categories within the Anderson classification scheme, ensuring a high level of accuracy and consistency in the results (Braik & Koliou, 2024) [3].

The results of this analysis are crucial in understanding the historical land use dynamics in northern Kirkuk and serve as a baseline for comparison with more recent satellite imagery, allowing for a comprehensive assessment of land cover changes over the study period (1993-2023).

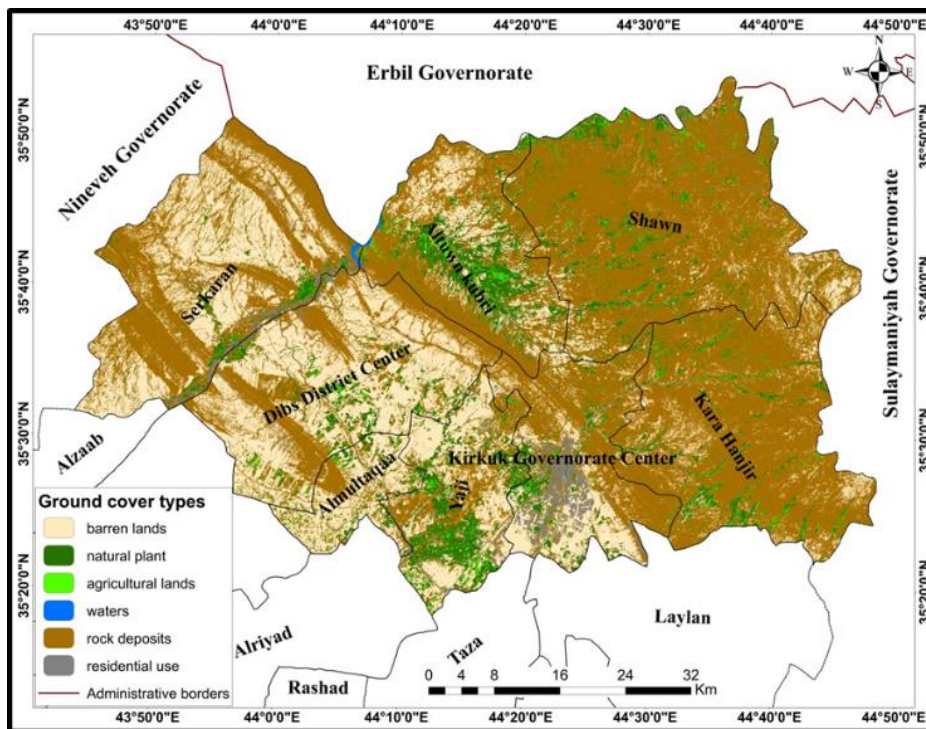


Fig 5: Ground cover in northern Kirkuk 4/18/1993.

Table 1: Area and percentage of land cover in northern Kirkuk 4/18/1993.

| No | Description                 | Area (km <sup>2</sup> ) | Percentage(%) |
|----|-----------------------------|-------------------------|---------------|
| 1  | Rock deposits (mountainous) | 2391.192715             | 58.1          |
| 2  | Barren lands (slopes)       | 1173.627723             | 28.6          |
| 3  | Agricultural lands          | 72.175732               | 1.8           |
| 4  | Natural plant               | 390.574117              | 9.5           |
| 5  | Water cover                 | 5.637811                | 0.2           |
| 6  | Residential use             | 76.259603               | 1.8           |
| 7  | Total                       | 4109.467701             | 100           |

**1. Rocky deposits (mountainous):** Rocky deposits occupied the first place, covering an area of 2,391,192,715 km<sup>2</sup>, representing 58.1% of the total area of the study area. Their distribution varies across large parts of the study area, including the northern and northeastern parts, as well as the central, southern, southeastern, and southwestern parts of the study area. These include sandy lands, rocky lands, sabkha lands, and other barren lands.

**2. Barren lands (slopes):** These include barren rocky lands, rocky slopes, lands unsuitable for agriculture, and areas with low vegetation cover. Sloping and barren lands ranked second, and their distribution varied across the eastern, central, and southern parts, reaching an area of 1,173,627,723 km<sup>2</sup>, representing 28.6% of the total area of the study area.

**3. Agricultural Land:** Agricultural land appears in third place, covering an area of 72,175,732 km<sup>2</sup> of the study area, representing 1.8% of the total area of the study area. This allows for near-realistic color reproduction, as it can be visually distinguished by color, as well as by the geometric shape of some farms. Agricultural land is spread across various parts of northern Kirkuk Governorate due to the fertility of the soil and the extension of the water drainage networks. The peak of vegetation growth, based on visual data, occurs in April.

**4. Natural Vegetation:** The distribution of natural vegetation varies in the study area, ranking fourth in the total land area, amounting to 390,574,117 km<sup>2</sup>, with an occupancy rate of 9.5% of the total area of the study area. This vegetation covers a wide area spread across the western and southwestern parts, as well as the central and southern parts of the study area, in addition to the southeastern parts.

**5. Water Cover:** Water ranked fifth, occupying an area of 5,637,811 km<sup>2</sup>, representing 0.2% of the total study area. This appears in almost true colors, if visually distinguishable by color. Water was also distinguishable by shape, as irrigation canals and streams took the form of blue wavy lines. This included the Lower Zab River, irrigation canals and streams, as well as ponds.

**6. Residential Use:** Built-up land ranked sixth and last in terms of area occupied in the study area, amounting to 76,259,603 km<sup>2</sup>, representing 1.8% of the total study area. Built-up land (urban) was clearly distinguished by color, including buildings with concrete roofs, transportation roads, bridges, and industrial areas.

### **Interpretation and classification of land cover and land uses in northern Kirkuk Governorate for the year 2023**

Land cover and land use in northern Kirkuk Governorate for 2023 were interpreted and classified using satellite images captured by the Landsat 8 satellite, equipped with the OLI-TIRS sensor. These images have a spatial resolution of 30 meters and include 11 spectral bands, as well as a panchromatic spectral band with a spatial resolution of 15 meters, which enhances the level of detail in the images. The higher spatial resolution provided by the panchromatic band allows for more accurate identification and classification of land cover types (Rwanga & Ndambuki, 2017) <sup>[13]</sup>. This makes Landsat 8 an ideal tool for assessing land cover changes in large areas, such as northern Kirkuk. To enhance the interpretation of the land cover types, color compositing techniques were applied to the satellite images, resulting in true-color images that closely resemble real-world conditions (Wang *et al.*, 2021) <sup>[16]</sup>. These images were composed using the red, green, and blue spectral bands, allowing for the identification of different land cover features, including water bodies, vegetation, and urban areas. The true-color images are particularly useful for distinguishing between various land types, as the spectral response contrast between water, soil, and vegetation is more easily discernible (Ghaseminik *et al.*, 2021) <sup>[6]</sup>. By analyzing these spectral contrasts, land cover types were classified into six distinct taxonomic classes following the first level of the Anderson classification system. The Anderson classification system is widely used in remote sensing applications because it provides a standardized approach for categorizing land cover types based on their spectral characteristics (Anderson, J. R., *et al.*, 1976). This classification system divides land cover into broad categories, such as urban, agricultural, forest, water bodies, barren land, and others, making it easier to analyze changes over time and across different regions (Aftab *et al.*, 2024) <sup>[1]</sup>. In this study, the first level of Anderson's classification was applied, and the six categories identified were reflective of the most significant land cover types in northern Kirkuk in 2023. The results of the classification showed clear variations in the areas of land cover and land use within the study area. These variations were analyzed in descending order based on the area covered and the percentage of occupancy for each land cover classification. For example, the areas of agricultural land, natural vegetation, and urban areas were more prominent compared to barren land and rocky areas, reflecting changes in land use practices and urbanization trends over the past few decades. Figure (6) illustrates the distribution of these land cover types and their spatial extent within the study area.

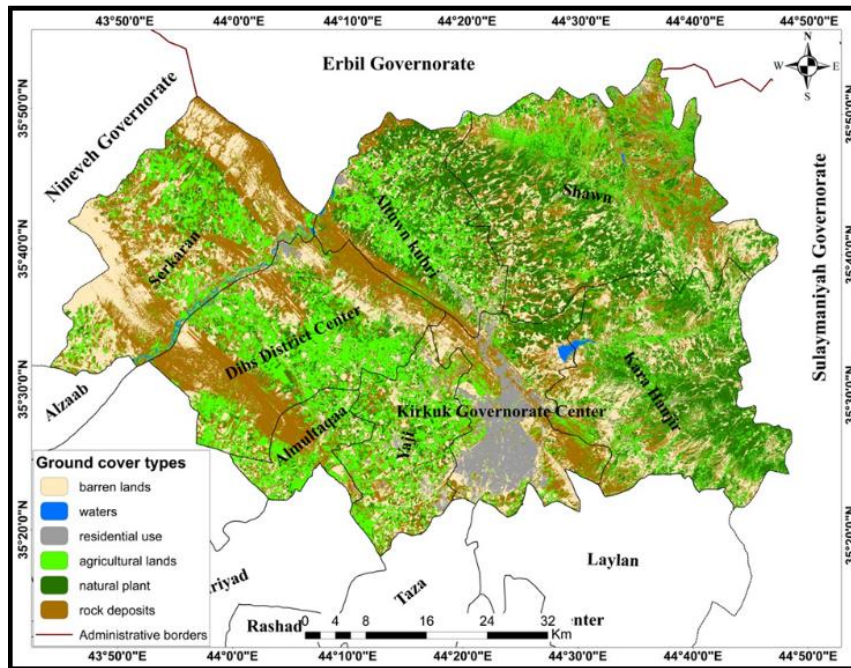


Fig 6: Land cover in northern Kirkuk 5/15/2023.

Table 2: Area and percentage of land cover in northern Kirkuk 5/15/2023.

| no | Description                 | Area (km <sup>2</sup> ) | Percentage(%) |
|----|-----------------------------|-------------------------|---------------|
| 1  | Rock deposits (mountainous) | 1109.645834             | 27            |
| 2  | Barren lands (slopes)       | 967.257536              | 23.54         |
| 3  | Agricultural lands          | 960.263406              | 23.37         |
| 4  | Natural plant               | 869.233445              | 21.15         |
| 5  | Water cover                 | 13.096166               | 0.32          |
| 6  | Residential use             | 189.971315              | 4.62          |
| 7  | Total                       | 4109.467702             | 100           |

**1. Rock deposits (mountainous):** The distribution of rock deposits varies, with rock deposits appearing in first place. Rock deposits continued to decrease significantly in 2023, covering an area of 1,109,645,834 km<sup>2</sup>, representing 27% of the total area of the study area. Their distribution varies across different parts of the study area, including the northern and northeastern parts, as well as the central, southern, southeastern, and southwestern parts of the study area, in line with the rock formations, which include sandy soils, rocky soils, sabkha soils, and other barren lands.

**2. Barren lands (slopes):** Barren lands fall into the second category, as barren lands continued to decrease significantly until 2023, decreasing in area to occupy 967,257,536 km<sup>2</sup>, with an occupancy rate of 23.54% of the total area of the study area. Barren lands were clearly visible through the color element, including marshlands, rocky lands, and sandy lands, distributed in the northern, northeastern, and northwestern parts, as well as the central, southern, and southeastern parts.

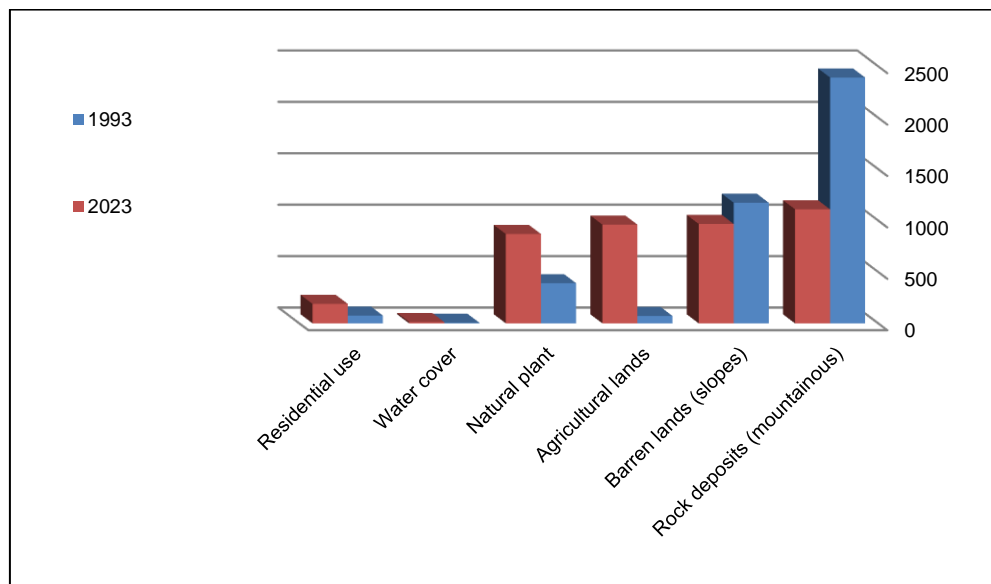
**3. Agricultural lands:** These fall into the third category, as agricultural land areas increased significantly, rising to 960,263,406 km<sup>2</sup> in 2023, representing 23.37% of the total area. This is due to the increase in rainfall, which quickly led to the growth of vegetation and agricultural lands.

**4. Natural vegetation:** The distribution of natural vegetation

in the study area is evident, ranking fourth in the total land area, amounting to 869,233,445 km<sup>2</sup>, with an occupancy rate of 21.15% of the total area of the study area. This significant increase is due to the large amounts of rainfall compared to previous years. It encompassed a wide area spread across the northern and southeastern parts, as well as the central and southern parts of the study area.

**5. Water Cover:** Water came in fifth place in terms of the area it occupied, which amounted to (13,096,166) km<sup>2</sup>, with an occupancy rate that rose to (0.32%) of the total area of the study area. It was possible to identify water through two elements: shape and color, as water took the form of winding lines of irrigation canals and streams that spread throughout most of the study area, and some geometric shapes such as rectangles and squares, farms and orchards that spread throughout the northern, central and southern parts.

**6. Residential use:** It falls within the sixth category, as the built-up land continued to expand until 2023 at the expense of agricultural lands and abandoned lands, so that the area it occupies reached (189,971,315) km<sup>2</sup>, with a percentage that rose to (4.62%) of the total area of the study area, as it was identified through the color element, as it spread with the extension of transportation roads and irrigation canals in the north, center and west of the study area, in addition to the southern, southwestern and southeastern parts of the study area.



**Fig 7:** The Chart of Area and types of land cover in northern Kirkuk for the period 1993-2023

#### 4. Conclusions

This study reached several conclusions, the most important of which are:

1. The land cover of the northern part of Kirkuk Governorate was classified using the Andersen classification of the United States Geological Survey, which includes six categories: rocky deposits (mountainous), barren lands (slopes), agricultural lands with natural vegetation, water cover, and residential use. The proportion of each of these categories varied over the years of the study.
2. The study demonstrated the ability and integration of satellite imagery and geographic information systems to monitor and detect spatial and temporal changes occurring in the study area over the period (1993-2023AD). These tools were an effective and rapid tool for obtaining the best results with the least time, least effort, and least cost.
3. The region has experienced a notable transformation in recent years, driven in part by climate change. This transformation has had a positive impact on the area, contributing to an increase in agricultural land, natural vegetation, water bodies, and urban development. In contrast, barren lands and rocky deposits have significantly decreased, highlighting a shift towards more productive and developed land uses.
4. The region has experienced a significant boom due to climate change in recent years, which has had a positive impact on the area, resulting in an increase in the areas of agricultural land, natural vegetation, water cover, and residential land, while significantly decreasing the areas of barren land and rocky deposits.
5. The study showed that the magnitude of changes occurring in the studied area, in terms of the Normalized Difference Vegetation Index (NDVI), reached its peak in 2023 AD, with areas with little vegetation increasing significantly, occupying 21.15% of the area. In 1993 AD, this decreased to 9.5%. This suggests a significant decline in large categories of plants.
6. The study found a significant decline in marshlands and sandy sedimentary lands from 1993 to 2023. This change was attributed to both natural factors and human

activities that positively influenced the study area, including urbanization, agricultural expansion, and water management practices.

#### Recommendations:

1. Rely on satellite imagery and geographic information systems to monitor the deterioration in land cover in Iraq in general and northern Kirkuk Governorate in particular.
2. Use spectral indices to monitor land cover, as these indices reflect the characteristics of land cover. We can generalize this method to different regions of Iraq and compare it to previous years to determine the extent of land cover change.
3. The results reached by the study constitute a starting point for building a knowledge information database and monitoring changes in land cover in the study area, following up on those changes, identifying their causes and predicting them in the future.

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