Integrated RS and GIS to Analysis Land use Land cover: Qaladze City as Case Study

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Abstract

This research investigated the changes in Land Use Land Cover (LULC) in Qaladze city which is located in the Northeast of the Kurdistan Region Government (KRG) of Iraq, within the Sulaymaniyah Governorate, over the past twenty years. The study research aims to utilize both GIS and RS techniques for evaluating changes that occurred in LULC within Qaladze city . The data analysis based on various Satellite images LE07_L1TP 2003, LC08_L2SP 2013 and LC09_L1TP 2023 were freely downloaded from the (USGS) website. The maximum likelihood algorism of supervised classification and Normalized Difference Vegetation Index (NDVI) methods were applied to generate LULC maps. The results reveal significant agricultural land and vegetation decreasing dramatically from 2003 to 2023, while the area occupied by built-up or settlement areas in 2003 more than doubled by 2023. The research highlights the need for sustainable urban planning and land management strategies to mitigate the adverse impacts of such rapid changes on the environment and agricultural resources.

Keywords: LULC, Environment change, Satellite Imagery, GIS, RS, Supervised Classification, NDVI.

Recieved: 3/9/2024
Accepted: 26/9/2024

1. INTRODUCTION

Land use is described as the actions undertaken by individuals to carry out economic activities on the landscape environment including built up, agriculture, commerce, and recreation. Land cover on the other hand, represents the physical features on the ground surface such as crops, water bodies, soil, structures, grasslands or forests (Rai et al., 2017). In this regard, knowledge about LULC change becomes an emerging issue for optimal selection, planning, restoration, and conservation of natural resources.

Human activities significantly impact the Earth's surface, environmental quality, and natural resources. To mitigate these negative effects, it is necessary to monitor both human activities and environmental changes (Rimal, 2012). Rapid population growth poses a severe threat to the future of nations, particularly due to the loss of agricultural land. The expansion of urban areas has emerged as a critical issue, especially since the latter half of the 20th century, drawing significant attention from various academic disciplines, particularly geography. Urban growth drives changes in LULC patterns and is closely associated with the increasing shift from rural to urban living, which poses considerable environmental impacts (Duran, 2012).

Satellite imagery has become highly suitable and valuable for assessing LULC transitions. Combining remote sensing with Geographic Information Systems (GIS) enables a better understanding of environmental processes and facilitates the analysis of large volumes of spatial data (Milla et al., 2005). Satellite Image offers significant advantages over traditional ground survey methods due to its extensive coverage and effectiveness in mapping isolated or data-scarce regions (Rahman & Rahman, 2021). When it comes to analyzing landform changes quickly, cost-effectively and with greater precision, GIS and RS techniques are becoming more efficient than conventional methods due to their ability to provide high-resolution, detailed, accurate and current information. (Belal and Moghanm, 2011). In order to study of environment changes or LULC changes the GIS and RS tools are the most powerful in timely interpretation and analysis of the Landsat images.

In the past 20 years, Qaladze city has experienced significant transformation due to population growth and several diverse factors such as planning and establishment of industrial zones, and the influx of people into the city. This was why this area was selected for study. Thus, this research aims to utilized GIS and RS for evaluating changes that occur in LULC within Qaladze city. The aim of the research will be achieved through three key objectives: -

1. To identify LULC changes in Qaladze City.
2. To evaluate loss the agricultural lands due to urban expansion.
3. To highlight the effectiveness of both GIS and RS techniques and examine the advantages of different Landsat image data types and various remote sensing approaches.

2. Methodology and Materials

2.1 Study Area

Qaladze is geographically situated in the Northeast of the Kurdistan Region Government (KRG) of Iraq, within the Sulaymaniyah Governorate. It is a border city located 28.5 kilometers west of Iran. The study area is the center of the Pshder district, which includes six subdistricts: Qaladze, Sangasar, Zharawa, Halsho, Hero, and Easewa. The study area covers approximately 31.18 square kilometers. According to the Raparin Statistical Directorate (2023), the total population of the study area is about 100,102 people. The astronomical location of the study area is between longitudes 45°05′20” to 45°10′00” East and latitudes 36°09′20” to 36°12′00” North (Fig.1).

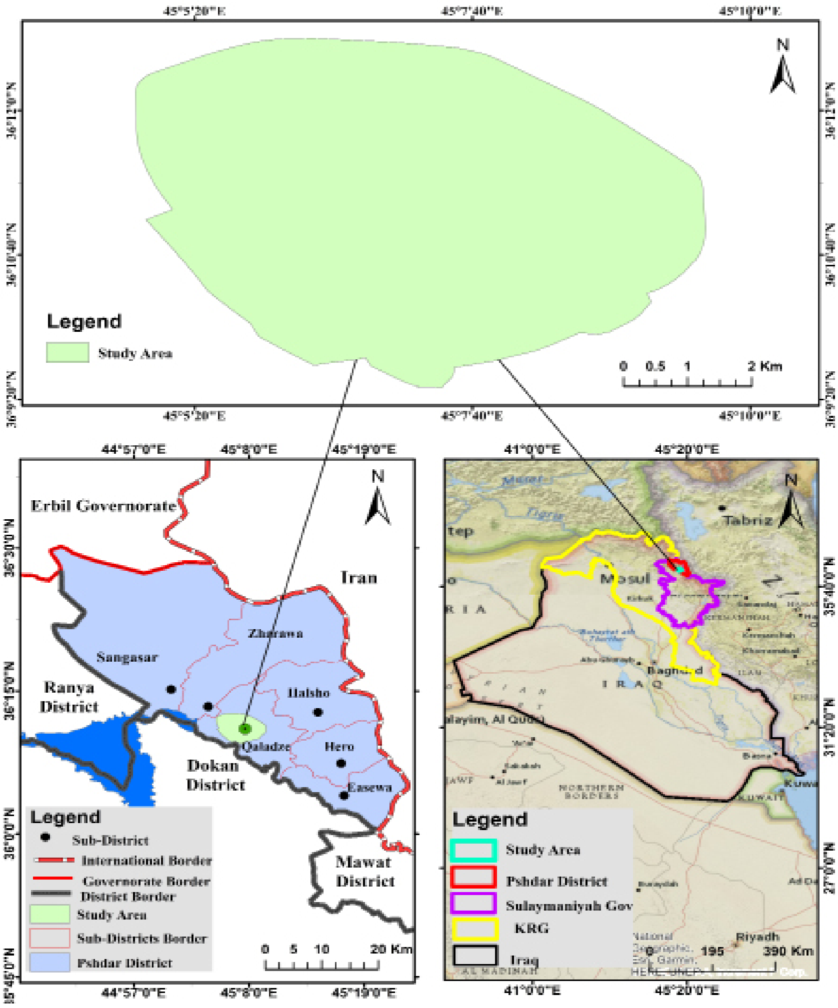


Figure 1: Location of the study area.

2.2 Data Types and Sources

For the present research, various Satellite images were freely downloaded from the United States Geological Survey (USGS) website. These images include Landsat 7 Level 1 Terrain Precision (LE07_L1TP) captured in May 2003, Landsat 8 Level 2 Surface Reflectance Product (LC08_L2SP) captured in April 2013, and Landsat 9 Level 1 Terrain Precision (LC09_L1TP) captured in May 2023, respectively (Table 3.1). All satellite images were projected onto UTM (Universal Transverse Mercator) coordinate system with datum WGS 1984, Zone 38 North of Hampshire (Table1).

2.3 Image Processing

2.3.1 Layer Stacking

Layer stacking is the process of combining bands of the same image into a single file format. Each Landsat image consists of several layers, and the combination of multiple layers for each image was performed using the ERDAS Imagine software tool to display them as a single image. The output images from this process can be easily used for analysis through various software, such as GIS, ERDAS Imagine, and the Environment for

Visualizing Images (ENVI) (Fig.2).

Table1: The Landsat images used as a data source for the study.

Landsat Image ID	Capture Date	Sensor	Path	Row	Spatial Resolution
LE07_L1TP_169035-20200915	11/05/2003	LE07_L1TP	169	35	30
LC08_L2SP_169035_20200912	28/04/2013	LC08_L2SP	169	35	30
LC09_L1TP_168035_20230511_	11/05/2023	LC09_L1TP	168	35	30

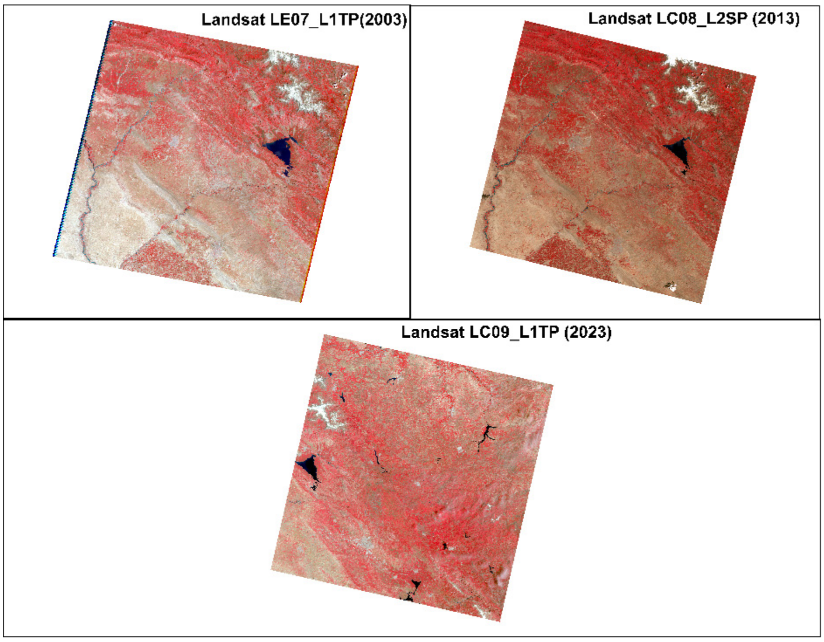


Figure 2: The Layer stacking process output of Landsat images.

٢,٤ Images Subset to Area of Interest (AOI)

The boundary of the study area, defined by the city's master plan, was provided by the Municipality of Qaladze (٢٠٢٣). Through the ERDAS imagine (٢٠١٥) soft was used to the subset or clip process. The boundary has used to clip and subset the satellite images, as the images cover a wide range of areas, while the study area itself covers small portion. According to Rahman et al. (٢٠٢٢), the subset process is utilized to delineate the target area based on specific coordinates. This method aids in the identification of ground control points on Landsat images (Fig. ٣).

Figure٣: Subset and clip the satellite images to the study area boundary.

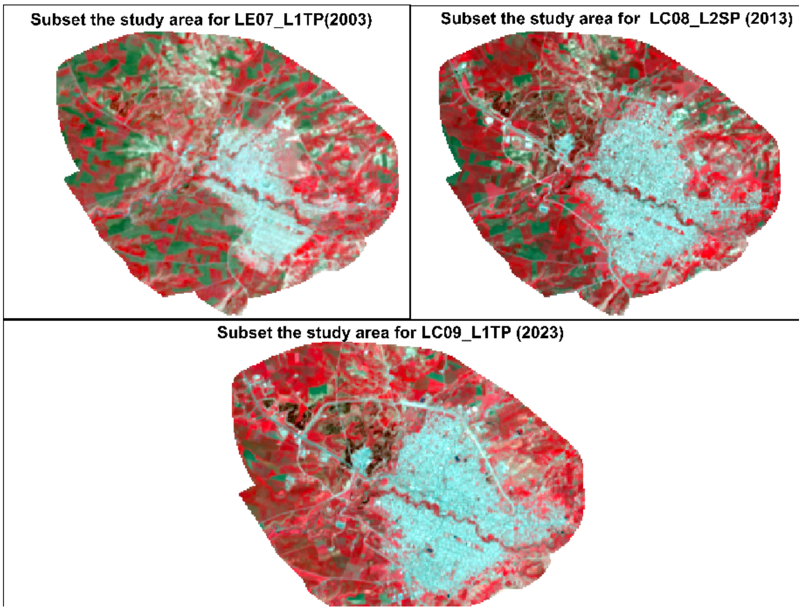


Figure٣: Subset and clip the satellite images to the study area boundary

٢,٥ Satellite Image Classification

٢,٥,١ Supervised Classification Method

The supervised classification method was applied for the Landsat images LE٠٧_L١TP ٢٠٠٣, LC٠٨_L٢SP ٢٠١٣ and LC٠٩_L١TP ٢٠٢٣ to display training date due to the spectral signature for three types of land cover classes which are (Built up, agriculture land and forest). Land cover samples are defined as training sites used to determine land cover classes across an entire image. This study employed a supervised classification approach, favored due to the availability of satellite images and the researchers› prior knowledge of the study area. Additionally, the maximum likelihood algorithm was chosen to enhance the classification results. This method remains one of the most commonly used algorithms in supervised classification process (McIver and Friedl,٢٠٠٢: Wu and Shao,٢٠٠٢).

Table ٢: LULC classes scheme, based on supervised classification.

LULC Class	Description
Built up	Residentials, commercial, industrial, roads and other manmade structures.
Agriculture land	Cultivated ،uncultivateded land and grass.
Forest	Trees and forests.

٢,٥,٢ Normalized Difference Vegetation index (NDVI)

The NDVI is employed to estimate levels of dense vegetation. For Landsat ٧, NDVI uses bands ٣ (Red) and ٤ (Near Infrared), while for Landsat ٨ and Landsat ٩, it relies on bands ٤ (Red) and ٥ (Near Infrared) (Zaitunah et al., ٢٠١٨). The NDVI, derived from a combination of red and NIR reflectance measurements as shown in Equation ١, is one of the most widely used vegetation indices globally. It has been extensively applied as a measure of Green Mass across various spatial and temporal scales (Ghorbani et al., ٢٠١٢). This index is computed based on the difference between the maximum absorption of radiation in the red spectral band and the peak reflection in the near-infrared spectral band. NDVI is a numeric indicator used for analyzing remote sensing measurements and helps establish whether an area contains live green vegetation. NDVI values range from ١- to ١+, where higher values indicate healthier, denser vegetation, while lower or negative values indicate sparsely vegetated or non-vegetated areas

such as water bodies, snow, or urban surroundings (Myneni et al., ١٩٩٥).

$$NDVI = \frac{NIR - RED}{NIR + RED}$$ Equation 1: The NDVI formula

In this study, the NDVI method was applied using the ERDAS Imagine application, and the three Landsat images were analyzed using the NDVI equation. Different bands were selected for each satellite image: for instance, Landsat (LE٢٠٠٣-٠٧) utilized Band ٣ for RED and Band ٤ for NIR, while both Landsat (LC٢٠١٣-٠٨ and LC٢٠٢٣-٠٩) used Band ٤ for RED and Band ٥ for NIR, respectively. This process displays the higher and lower values of vegetation in the study area (Fig. ٨). Additionally, to calculate the areas covered by vegetation and non-vegetation, different threshold values were assigned to collect the pixels for each Landsat image. This process was conducted using a classification method and a specialized model editor for each NDVI image. For example, for Landsat LE٢٠٠٣-٠٧, the threshold was set at NDVI < ٠,٠٢-; for Landsat LC٢٠١٣-٠٨, at NDVI < ٠,٢٥; and for Landsat LC٢٠٢٣-٠٩, at NDVI < ٠,١٣. Values greater than the threshold indicate areas with vegetation, while values below it represents areas with no vegetation (Fig.٩).

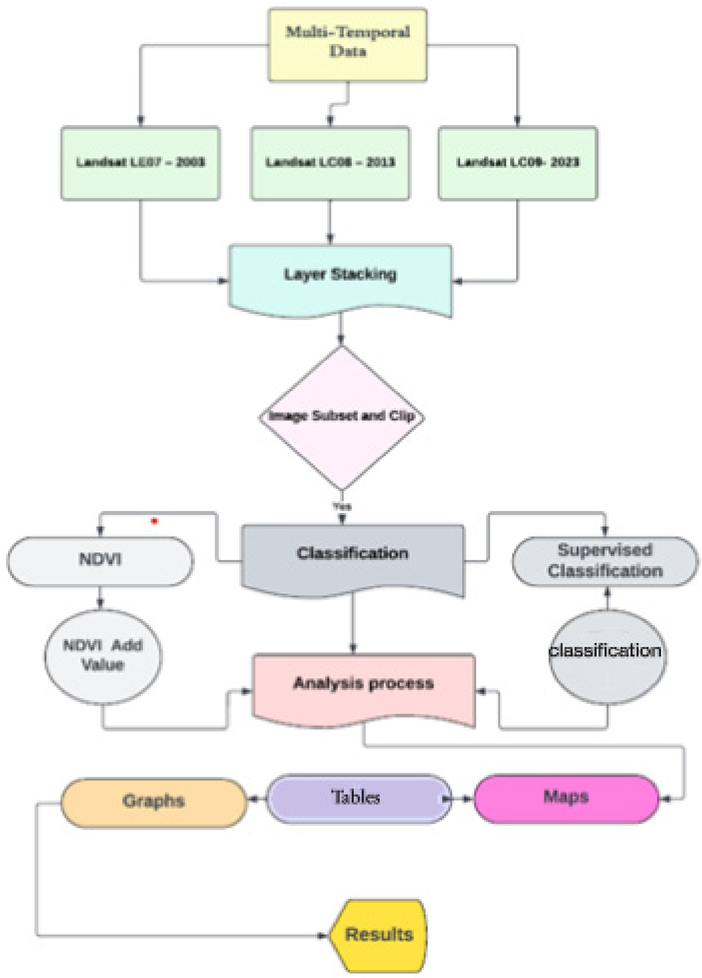


Figure٤: Flow diagram of the methodology process.

٣. Results

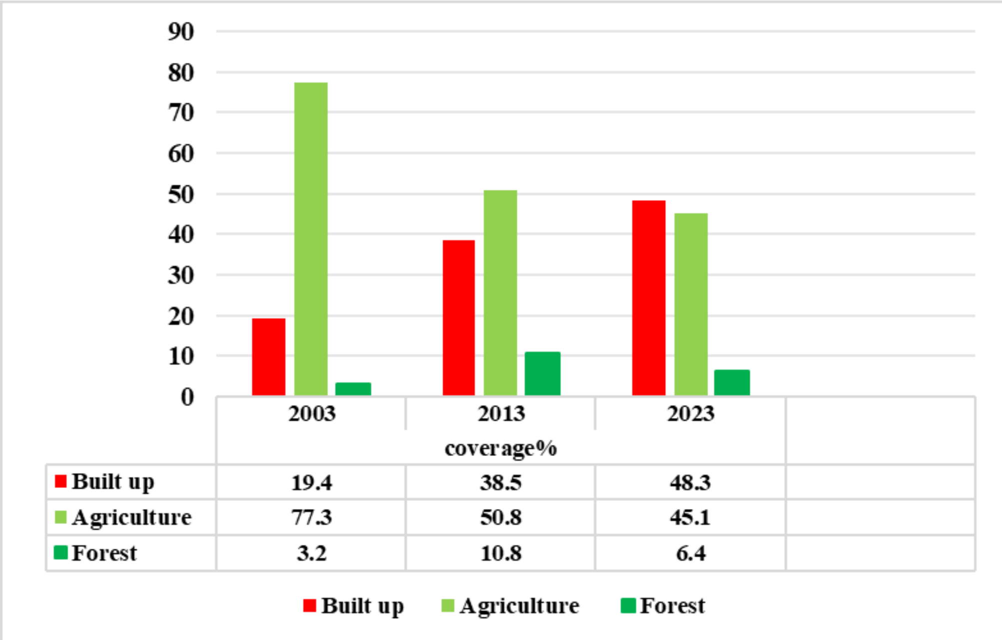
٣,١ The Supervised Classification Results

The results of the supervised classification method, based on the three different Landsat images (LE٠٧_L١TP ٢٠٠٣, LC٠٨_L٢SP ٢٠١٣, and LC٠٩_L١TP ٢٠٢٣), are presented in three different forms: tables, graphs, and maps. The statistics of this method are shown in Table ٣, which displays land cover types in square kilometers, the percentage coverage of each class, and the changes from ٢٠٠٣ to ٢٠١٣ and from ٢٠١٣ to ٢٠٢٣. The percentage coverage of each class type, represented as a column graph, can be found in Fig. ٥. Fig. ٦ shows the digital maps of the supervised classification for the years ٢٠١٣ ,٢٠٠٣, and ٢٠٢٣, respectively.

The results indicate that the built-up class increased from ٪١٩,٤ in ٢٠٠٣ to ٪٣٨,٥ by ٢٠١٣, and further to ٪٤٨,٣ by ٢٠٢٣. In contrast, a significant change was observed in the agricultural class, which decreased from ٪٧٧,٣ in ٢٠٠٣ to ٪٥٠,٨ by ٢٠١٣ and from ٪٥٠,٨ to ٪٤٥,١ by ٢٠٢٣. Meanwhile, the forest class increased from ٢٠٠٣ to ٢٠١٣, but decreased from ٢٠١٣ to ٢٠٢٣ (Table ٣, Fig. ٥, and Fig. ٦).

Table٣: The statistics of area calculation land cover types based on supervised classification process.

Land Cover type	Area in sq.km			Coverage %			Chang% 2003-2013	Chang% 2013-2023
	2003	2013	2023	2003	2013	2023		
Built up	6.6	12.01	15.07	19.4	38.5	48.3	19.1+	9.8+
Agriculture	24.3	15.87	14.1	77.3	50.8	45.1	26.5-	5.7-
Forest	1.1	3.3	2.01	3.2	10.8	6.4	7.6	4.4-
Total	31.18	31.18	31.18	100	100	100	……	…….



	2003	2013	2023
Built up	19.4	38.5	48.3
Agriculture	77.3	50.8	45.1
Forest	3.2	10.8	6.4

Figure٥: The coverage of land cover type area statistics, based on Supervised classification process.

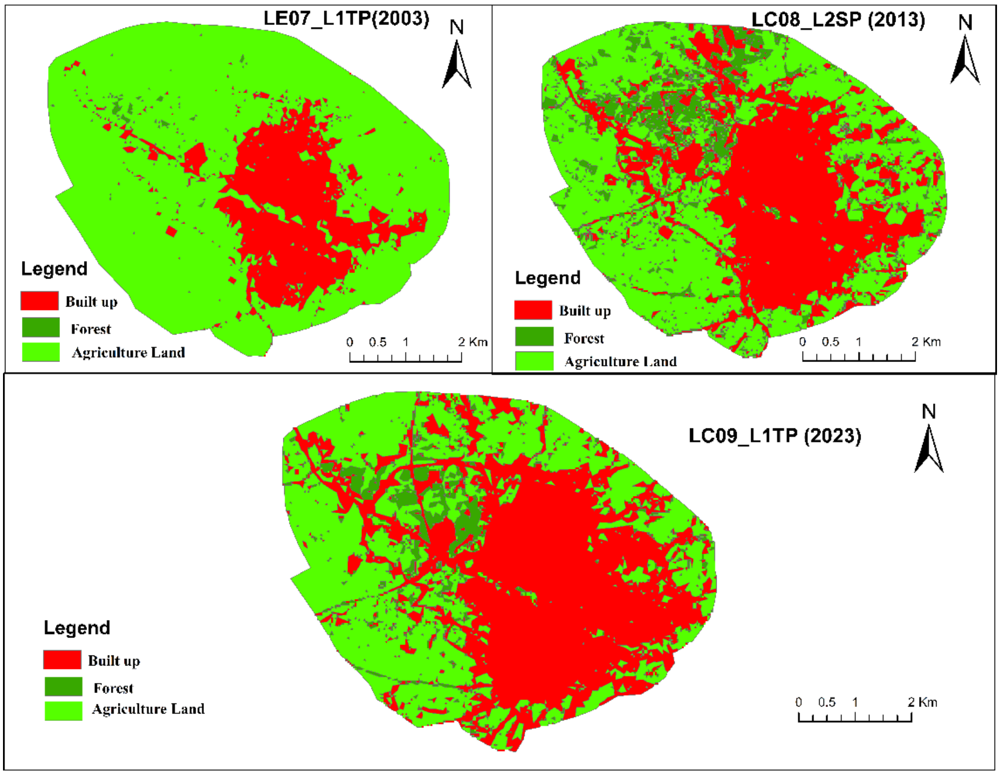


Figure٦: LULC maps depend on supervised classification among (٢٠٠٣,٢٠١٣ and٢٠٢٣).

٣,٢ The Normalized Difference Vegetation index (NDVI) Findings

The outcomes of the standard NDVI process are presented in Fig. ٨, which shows the different vegetation values for each satellite image. For example, the vegetation values for Landsat LE٠٧_L١TP ٢٠٠٣ range from ٠,٥٩+ to ٠,١٥-, while Landsat LC٠٨_L٢SP ٢٠١٣ shows values between ٠,٤٨+ and ٠,٠١٤, and Landsat LC٠٩_L١TP ٢٠٢٣ ranges from ٠,٥٥+ to ٠,٠٣٥. Values close to ١ indicate vegetation areas, whereas values near ١- correspond to barren areas (Fig. ٨).

The results of the NDVI values are displayed in Table ٤, which shows the vegetation and non-vegetation areas in square kilometers, along with the coverage percentages for LE٠٧_L١TP ٢٠٠٣, LC٠٨_L٢SP ٢٠١٣, and LC٠٩_L١TP ٢٠٢٣, and the changes that occurred between ٢٠٠٣ to ٢٠١٣ and ٢٠١٣ to ٢٠٢٣, respectively. The coverage percentages of vegetation and non-vegetation areas for the years ٢٠١٣ ,٢٠٠٣, and ٢٠٢٣ are shown in a column graph (Fig. ٧). The NDVI maps for LE٠٧_L١TP ٢٠٠٣, LC٠٨_L٢SP ٢٠١٣, and LC٠٩_L١TP ٢٠٢٣ are represented in (Fig. ٩).

The NDVI findings indicate that the vegetation cover area decreased from ٢٥,٦٣ sq. km to ٢٠,١٧ sq. km from ٢٠٠٣ to ٢٠١٣, while the non-vegetation area increased from ٥,٥٦ sq. km to ١١,٠١ sq. km. Additionally, from ٢٠١٣ to ٢٠٢٣, the vegetation area continued to decrease from ٢٠,١٧ sq. km to ١٦,٦٧ sq. km, while the non-vegetation area increased from ١١,٠١ sq. km to ١٤,٥١ sq. km, respectively (Table.٤).

Table٤: Green Mass area bases on NDVI indicator.

Land Cover type	Area in sq.km			Coverage %			Chang% 2003-2013	Chang% 2013-2023
	2003	2013	2023	2003	2013	2023		
No-Vegetation	5.56	11.01	14.51	17.8	35.4	46.5	17.6+	11.1+
Vegetation	25.62	20.17	16.67	82.2	64.6	53.5	17.6-	11.1-
Total	31.18	31.18	31.18	100	100	100	……	…….

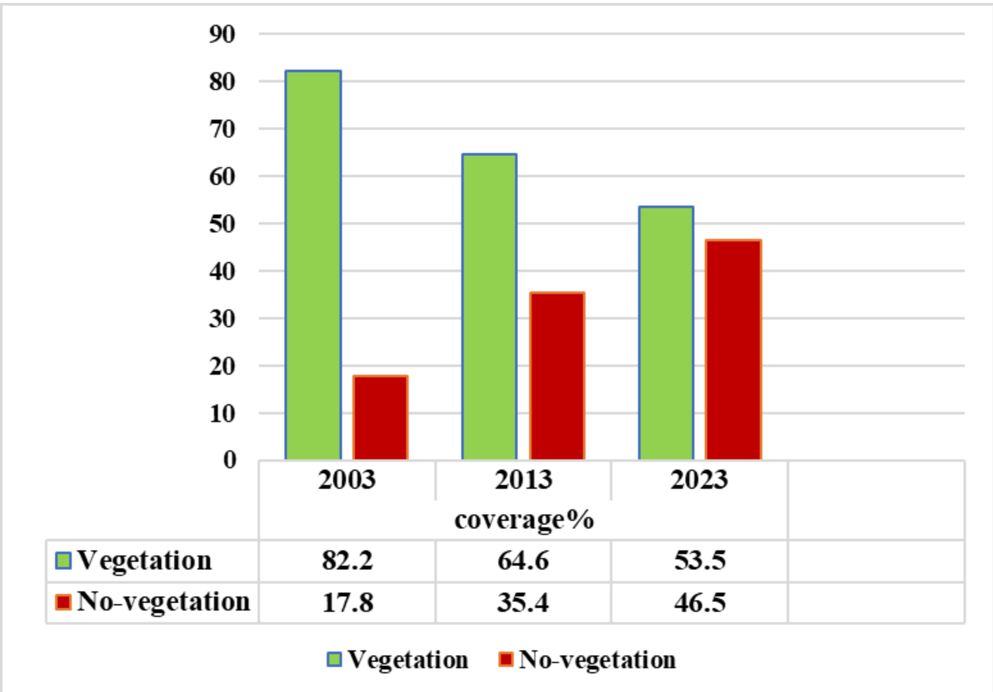


Figure٧: The coverage of vegetation and no vegetation.

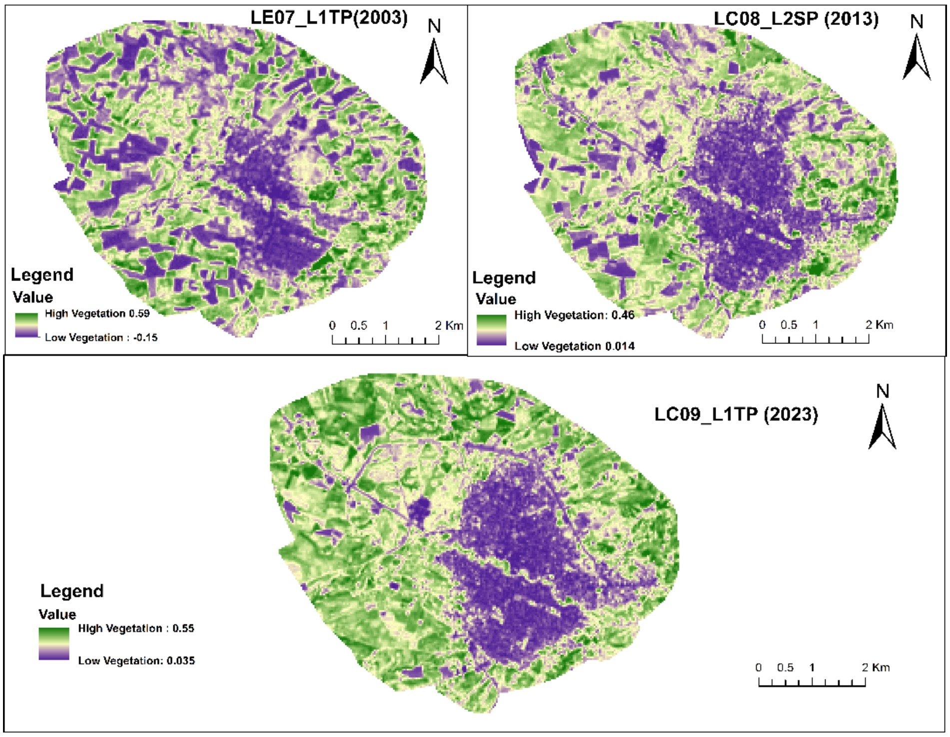


Figure٨: The NDVI maps display the Higher and Lower value of vegetation.

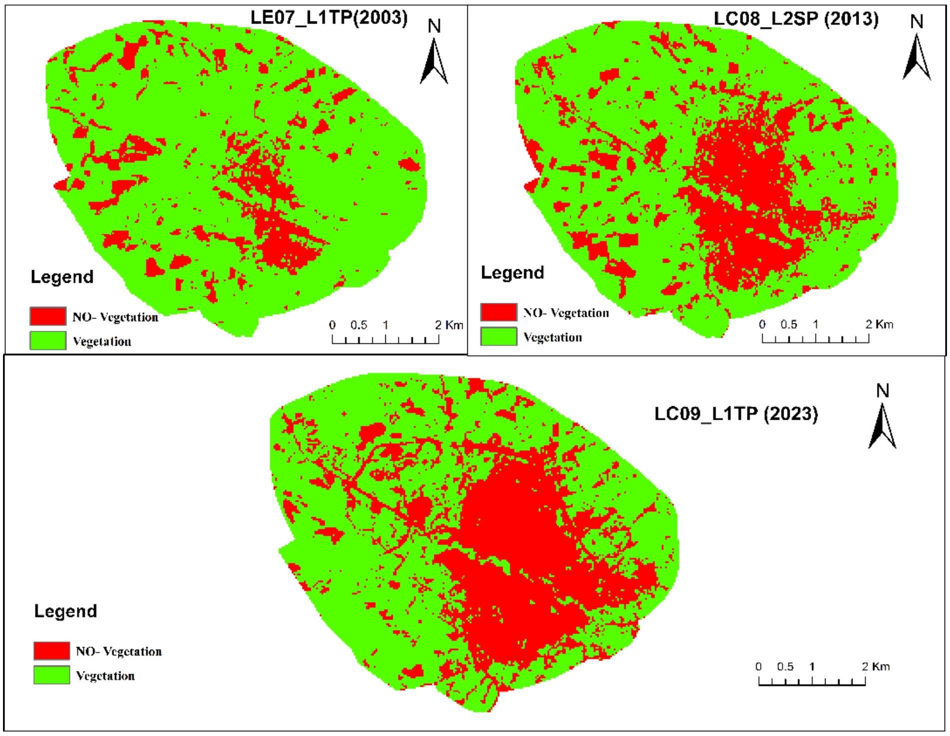


Figure٩: The NDVI maps demonstrate vegetation and no vegetation calculated areas.

٤. Discussion of Findings

The results of this research indicate a significant shift in land use and land cover over the past two decades, with most of the changes occurring in agricultural land and vegetation areas. The data shows that the agricultural land and vegetation area decreased dramatically from ٢٠٠٣ to ٢٠٢٣, while the area occupied by built-up or settlement areas in ٢٠٠٣ more than doubled by ٢٠٢٣. Therefore, settlements recorded the highest increase, while agricultural land recorded the greatest reduction (Tables ٣ and ٤). These changes in LULC can be attributed to various factors, such as population growth and urban expansion. According to the Pshdar District Mayor (٢٠٢٣) and the Raparin Statistical Directorate (٢٠٢٣), the population of the study area increased from ٤٤,٥٠٤ in ٢٠٠٣ to ١٠٠,١٠٢ in ٢٠٢٣ Additionally, after ٢٠٠٣, more than ١٠٠٠ people who had migrated to Iran before ١٩٩١, returned to Qaladze, alongside population growth du to increased in birth rate and also continuous migration from villages to the city.

٥. Conclusions

In conclusion, this research highlights a substantial transformation in land use and land cover in Qaladze over the past two decades, particularly in the reduction of agricultural land and vegetation areas and the expansion of built-up or settlement areas. The findings demonstrate a marked decrease in agricultural land, which corresponds with a significant increase in settlement areas, reflecting the highest rate of land cover change. These changes are primarily attributed to factors such as population growth, urban expansion, and the return of families previously displaced to Iran, along with ongoing migration from rural villages to the city. This study underscores the need for sustainable urban planning and land management strategies to mitigate the adverse impacts of such rapid changes on the environment and agricultural resources.

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