P-ISSN: 1996-983X
E-ISSN: 2960-1908

مجلة المخطط والتنمية

Journal of planner and development

Vol 30 Issue 3 2025/12 /7

Change detection analysis of urban areas in Baghdad City using remote sensing and GIS

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Abstract

Urban expansion has been identified as a causative factor for numerous environmental issues in urban areas, such as diminished air quality, elevated local temperatures, and poor water quality. This research aims to detect change in urban areas in Baghdad over a period of approximately 30 years, spanning from 1993 to 2023. The Landsat (TM5, ETM+7, and OLI8) images were used in this research. After performing image pre-processing, a supervised classification was used by the Support Vector Machine (SVM) to classify the images into five land cover classes, namely urban areas, water bodies, vegetation, soil, and wetlands. The classifications' accuracy assessment for the years 1993, 2003, 2013, and 2023 were 89%, 91%, 92%, and 90%, respectively. The results indicate that there has been a notable increase in urban areas over the specified time intervals. Specifically, the data shows that the urban areas experienced growth of 1.34%, 1.62%, 1.98%, and 4.54% during the time periods of 1993–2003, 2003–2013, 2013–2023, and 1993–2023, respectively.

Keywords: GIS, remote sensing, change detection, LULC

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Journal of planner and development

Vol 30 Issue 3 2025/12 /7

P-ISSN: 1996-983X

E-ISSN: 2960-1908

تحليل كشف التغيير للمناطق الحضرية في مدينة بغداد باستخدام التحسس النائي ونظم المعلومات الجغرافية

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المستخلص

تم تحديد التوسع الحضري كعامل مسبب للعديد من القضايا البيئية في المناطق الحضرية، مثل انخفاض جودة الهواء، وارتفاع درجات الحرارة المحلية، وسوء نوعية المياه. يهدف هذا البحث إلى الكشف عن التغير في المناطق الحضرية في بغداد خلال فترة ٣٠ سنة تقريباً، تمتد من عام ١٩٩٣ إلى عام ٢٠٢٣. تم استخدام صور القمر الصناعي لاندسات (TM5، ETM+7، وOLI8) في هذا البحث. وبعد إجراء المعالجة المسبقة للصور ، تم استخدام تصنيف خاضع للإشراف بواسطة خوارزمية جهاز ناقل الدعم (SVM) لتصنيف الصور إلى خمس فئات من الغطاء الأرضي، وهي المناطق الحضرية، والمسطحات المائية، والغطاء النباتي، والتربة، والأراضي الرطبة. وبلغت نسبة دقة التصنيفات للأعوام ١٩٩٣ و٢٠٠٣ و٢٠١٣ و٢٠٢٣ ٨٩% و٩١% و٩٢% و٩٠% على التوالي. تشير نتائج تحليل كشف التغير إلى وجود زيادة ملحوظة في المناطق الحضرية خلال الفترات الزمنية المحددة. وعلى وجه التحديد، تظهر البيانات أن المناطق الحضرية شهدت نمواً بنسبة ٣٤.١%، و١,٦٢%، و١,٩٨%، و٤,٥٤% خلال الفترات الزمنية ١٩٩٣-٢٠٠٣، ٢٠٠٣-٢٠١٣، ٢٠١٣-٢٠٢٣ و١٩٩٣-٢٠٢٣ على التوالي.

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E-ISSN: 2960-1908

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1. Introduction

The pressure to handle land use and land cover issues has been heightened due to the decline in environmental quality, challenges associated with uncontrolled growth, and the depletion of critical wetland ecosystems (Aly et al., 2016). The degradation of both agricultural land and urban areas has been observed over an extended period (Aguirre et al., 2012).Enhanced scrutiny of the mechanisms governing land cover and land use is necessary in order to comprehensively comprehend the ramifications of alterations in Earth use on worldwide ecosystems (Faraj & Mahmood, 2018). The modification of the natural environment by human actions results in changes to the physical features of the land, hence amplifying the demand for fundamental resources such as fresh water, food, energy, and shelter ((Ali & Jaber, 2020). Land use is often determined by economic and societal reasons. This study examines the enduring trends in land development across different climatic, political, and demographic contexts. The influence of these factors on land use and land cover is often observed to have an immediate impact (Villarreal et al., 2011). The acts of people not only contribute to the acceleration of land use and land cover (LULC) dynamics and exert control over important processes, but they also generate alterations that have consequences for human populations (Buyantuyev et al., 2010).

In order to comprehend the underlying mechanisms that contribute to environmental issues or devise strategies for their amelioration, it is imperative to possess precise and reliable data about land use (Congalton et al., 2014). The acquisition of precise landuse data is important for the administrative and scientific objectives of modern society. It constitutes an essential component of both regional and international systems. According to (Dibs et al., 2022) the economic system shows the regularity of the establishment of different occurrences on the ground. Effective planning can help prevent the construction of residential properties in floodplains or locations adjacent to heavy industries, provided that planners possess precise and up-to-date information regarding these areas. It is imperative to establish a clear differentiation between the concepts of land use and land cover (Hashim et al., 2021). The term "land use" pertains to the practical activities that occur on a specific parcel of land, whereas "land cover" pertains to the physical characteristics that define the environment in which these activities occur (Hussein & Fakhri Merzah, 2020). Landscaping, urban development, sports fields, and golf courses exemplify various ways in which land can be effectively utilized (Abdul et al., 2023).

The term "land cover" pertains to the observable characteristics of the Earth's surface, including vegetation or exposed ground, which can be either natural or impacted by human activities (Jasem & AL-Hamadani, 2020).

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The modification of landuse/landcover has been demonstrated to have extensive implications for biodiversity and the well-being of ecosystems, as well as for the accessibility and convenience of human-produced commodities and services. The extensive nature of remote sensing data facilitates a full analysis of land cover and land use. This study detects and analyses the change in urban areas and the affection of Urban Expansion on land cover. The modification in landcover due to landuse does not inevitably indicate land degradation. However, certain land use practices influenced by societal factors may contribute to land degradation (Vasuki et al., 2019). The alteration of land use has a substantial impact on a range of factors, including biodiversity, radiation, water, and the release of gases. Moreover, urban Expansion has the potential to impact various activities, including the biosphere and the worldwide climate (Basheer et al., 2022).

Land cover alterations can be caused by various environmental phenomena, including but not limited to weather patterns, flooding, wildfires, fluctuations in ecosystem dynamics, and climate variations (Erb et al., 2007).land use experiences substantial alterations on a daily basis, primarily due to agricultural and livestock practices, forest management and harvesting techniques, and urbanization. The transformation of land use can be ascribed to two overarching categories of change: cumulative and systemic. Anthropogenic activities have led to a cumulative alteration of the environment, which is a commonly observed phenomenon. Urban activity has been the primary cause of cumulative environmental alterations, which encompass the transformation of various ecosystems such as grasslands, landscapes, wetlands, and croplands (Li et al., 2018). The notion of systematic change pertains to the intentional manipulation of biochemical processes to maintain the sustainability of the biosphere. The intervention under consideration possesses the capacity to initiate alterations on a worldwide level, with the extent of these changes being contingent upon the scope of the intervention (Avci et al., 2021).

The objective of this study is to identify alterations in the urban area of Baghdad spanning a duration of roughly three decades. The significance of this research lies in its potential to furnish valuable insights into the prospects for judicious utilization of resources, thereby enabling informed decision-making, devising effective strategies, and implementing land use systems that are indispensable for mitigating the mounting pressures of urban sprawl and human activities.

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2. Material and method

2.1. Study area

As depicted in Figure (1), Baghdad serves as the economic hub and capital city of Iraq. From a geographical standpoint, Baghdad is situated at the heart of the nation. Presently, the city is considered one of the most significant and expansive urban centers in the Middle East. It boasts a highly advanced infrastructure, including prominent institutions of higher education, educational establishments, amenities, and expansive sports arenas. In recent times, Baghdad has experienced high Urban Expansion. The urban center of Baghdad is situated in the central region of Iraq, spanning across both banks of the Tigris River. Its precise geographic location can be identified by the following coordinates: latitude ranging from (33˚25´46″ to 33˚24´21″) N, and longitude ranging from (44˚15´55″ to 44˚17´38″) E and the area of Baghdad is (5060 km^2)(Faraj & Mahmood, 2018).

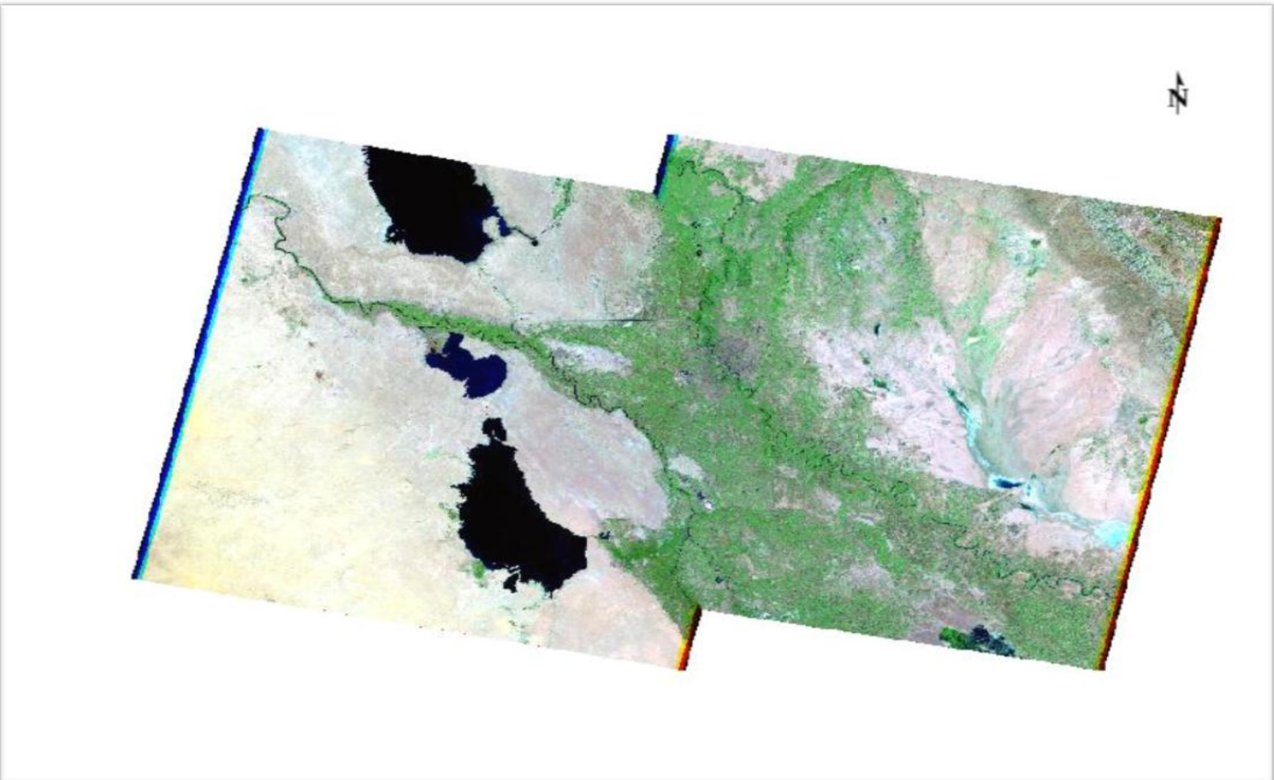

Figure (1) image of study

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2.2. Data used in this study

The present study involved the acquisition of satellite imagery from the United States Geological Survey (USGS), spanning a period of three decades from 1993 to 2023. Table (1) provides an explanation of the satellite images captured. The table presents a discernible pattern wherein satellite images captured during distinct years correspond to varying seasons, thereby facilitating a straightforward distinction between land cover and land use. The datasets have been projected using the Universal Transverse Mercator (UTM) projection, specifically with zone number 38N, and have been referenced to the World Geodetic System 1984 (WGS 84) datum. The Mosaic was devised with the intention of encompassing the entirety of the designated area.

Table (1) Landsat Satellite Data (USGS)

Images	dated	Landsat satellite	Band used	Spatial resolution
Image 1	13/3/,20/3/1993	TM 5	6	30m
Image 2	7/3,2/3 ,2003	ETM+7	6	30m
Image 3	13/3,19/3/2013	TM 5	6	30m
Image 4	1/3,10/3/2023	OLI 8	6	30m

2.3. Image pre-processing

The objective of the research to detect changes in the urban areas of Baghdad through the utilization of multi-temporal satellite imagery. The pre-processing stage involved the utilization of the Environment for Visualizing Images (ENVI) software which is image analysis software that allows for the extraction of meaningful data from visual input, hence enhancing decision-making procedures in the realm of digital image processing, including geometric correction and radiometric correction (Faraj & Mahmood, 2018). Landsat satellite images were utilized to detect changes in the region of interest, which started with radiometric correction by the removal of noise from all the Landsat images. Utilizing a topographic map of Baghdad, we conducted geometric correction of the images to mitigate distortions resulting from variations in orientation sensor parameters and sensor noise. The satellite image of 2023 was regarded as the base data. Subsequently, images from the years 1993, 2003, and 2013 were registered relative to image 2023 image. Subsequently, a mosaic was produced from images, which were clipped to conform to the study area's boundary. The ultimate cartographic representation is depicted in Figure (2).

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E-ISSN: 2960-1908

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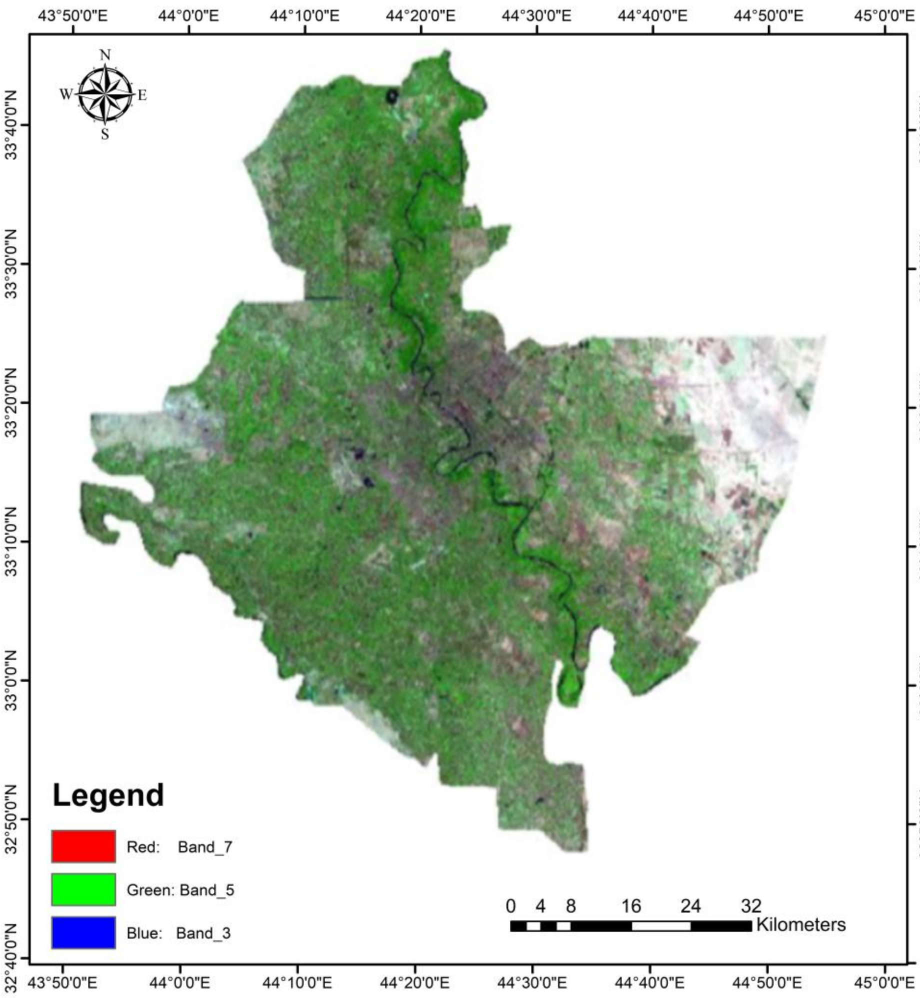

Figure (2) Final image of study area of Baghdad

2.4. Image Processing

2.4.1. Classification

The interest area of the four maps was classified into five distinct classes. At the classification stage, a Support Vector Machine (SVM) approach was employed for each image to produce a thematic map and change detection between 1993 and 2023. The process of supervised classification was executed utilizing the (GIS 10.3) software. Over (200) training samples were compiled for each category. Following the classification process, the accuracy of the classifications was determined using the confusion matrix, and validation was conducted by collecting certain sample locations. The thematic maps depicting land cover for the years 1993, 2003, 2013, and 2023 are presented in (Figures 3,4,5, and 6) respectively.

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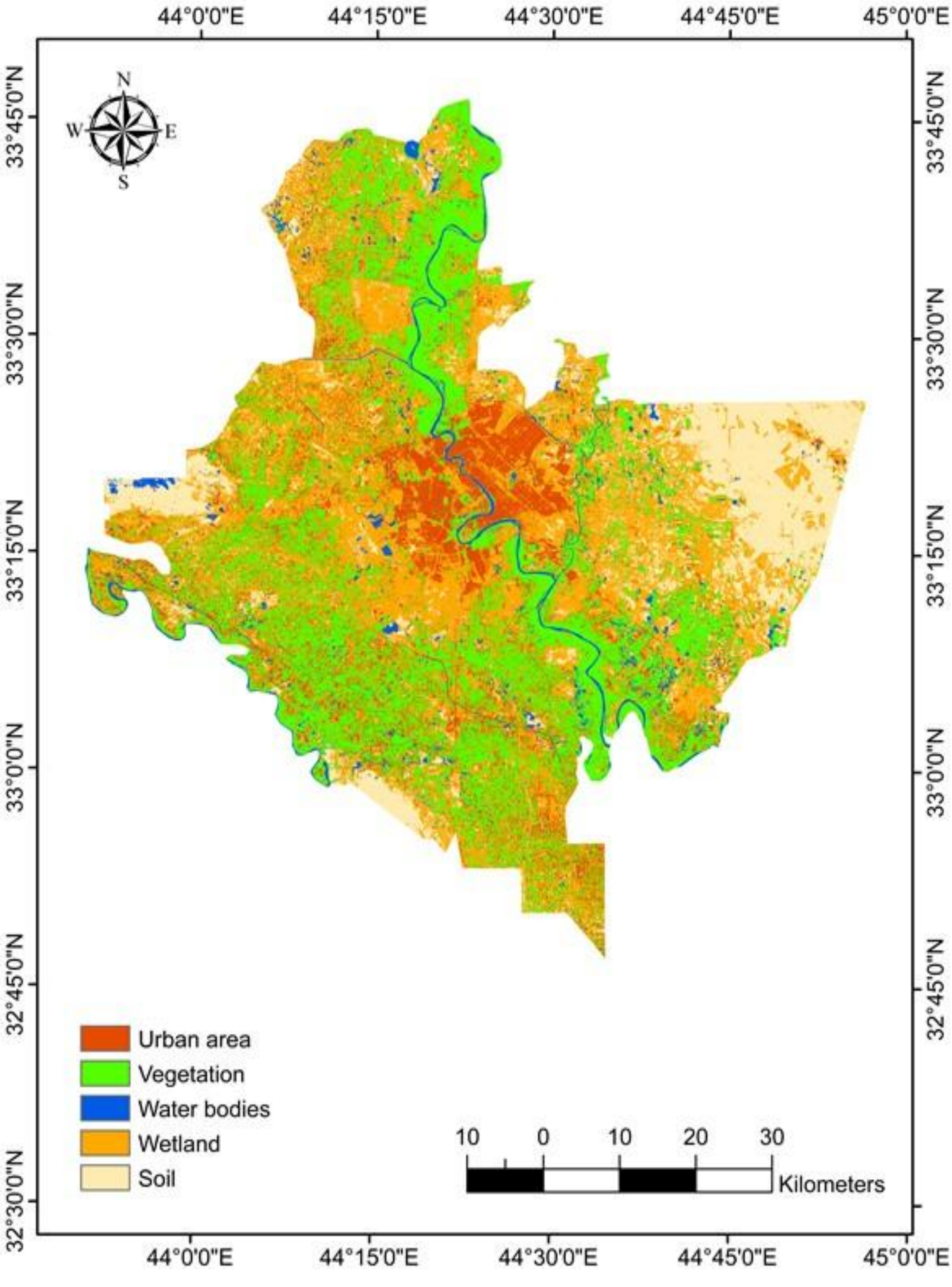

Figure (3) Thematic map for Baghdad 1993

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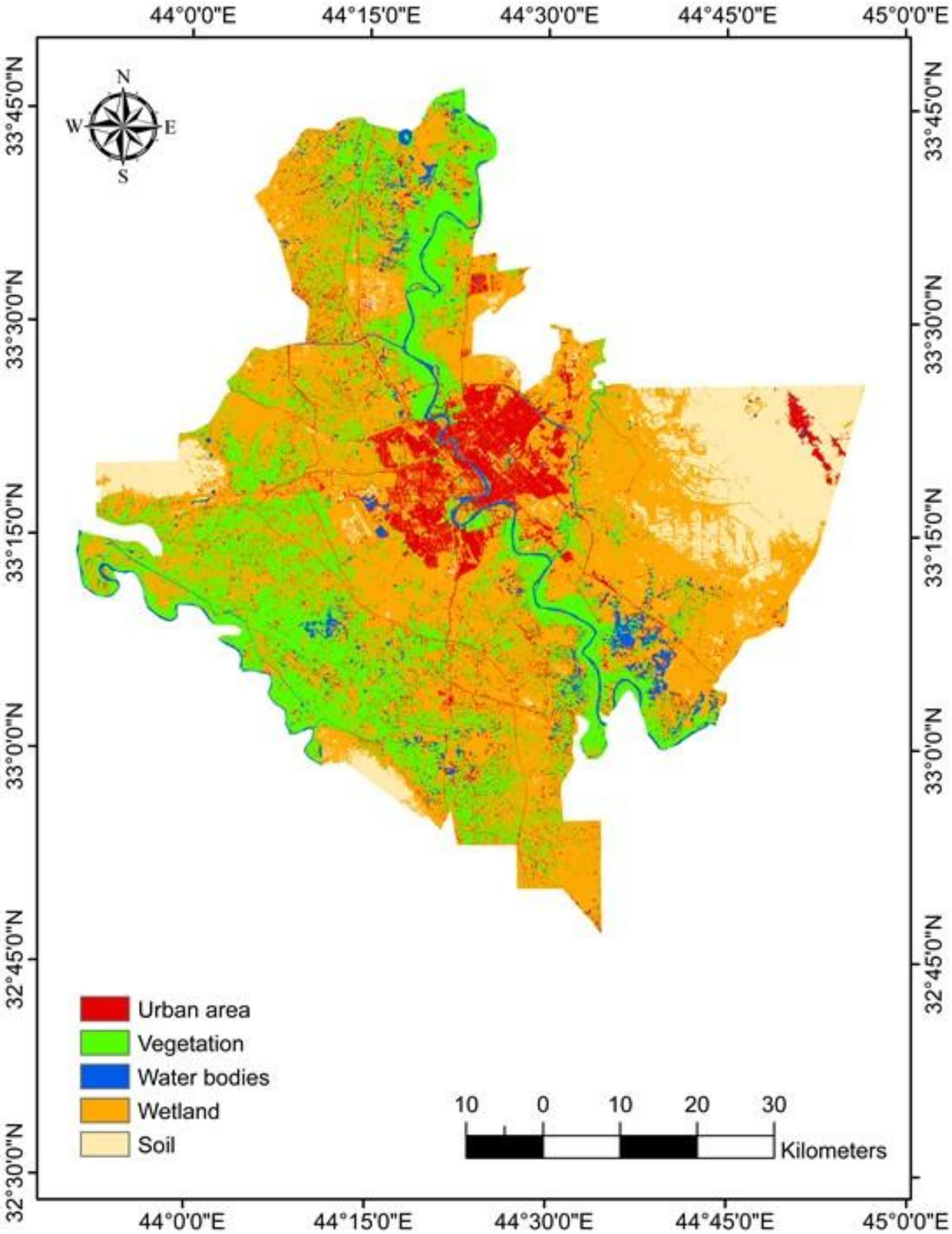

Figure (4) Thematic map for Baghdad 2003

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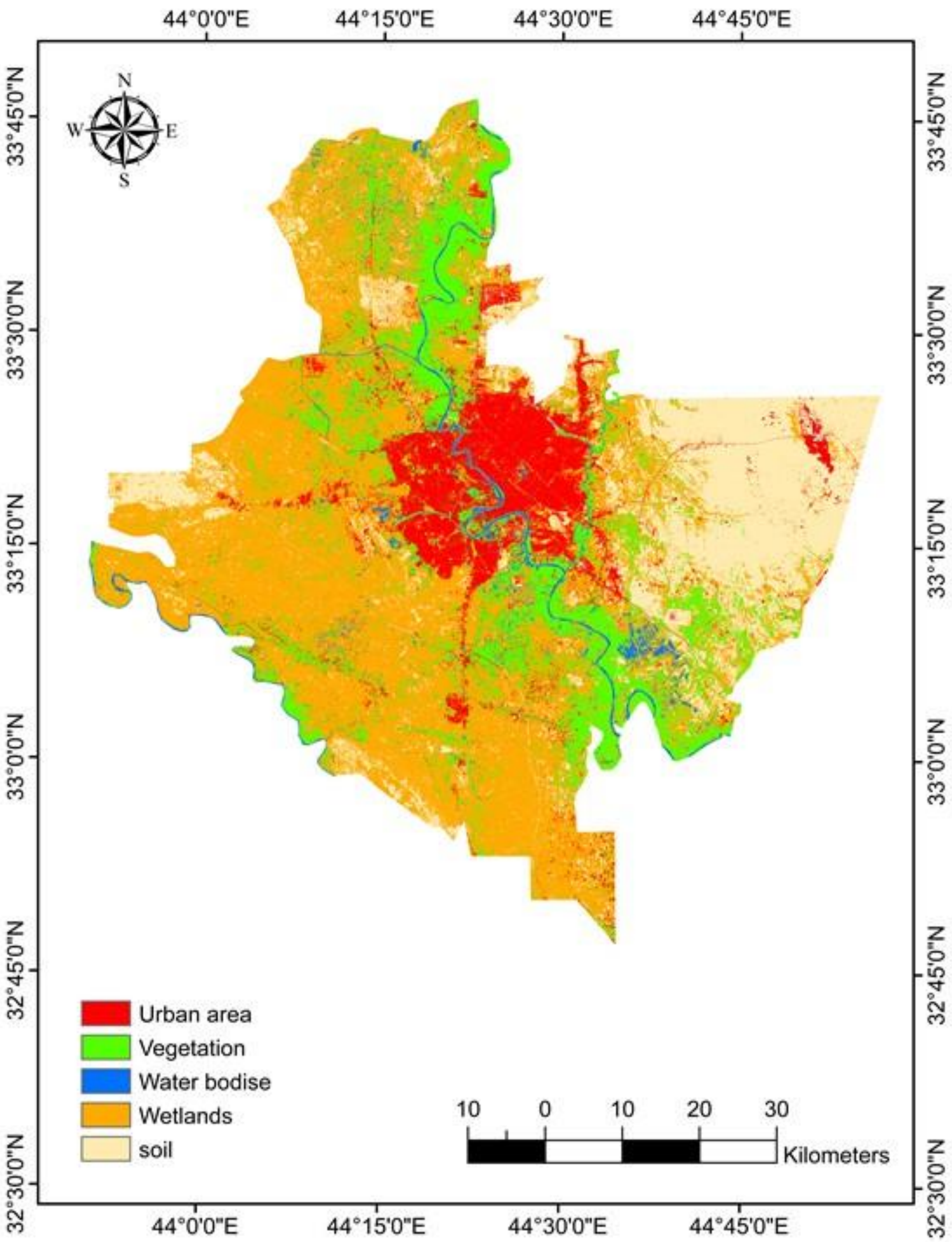

Figure (5) Thematic map for Baghdad 2013

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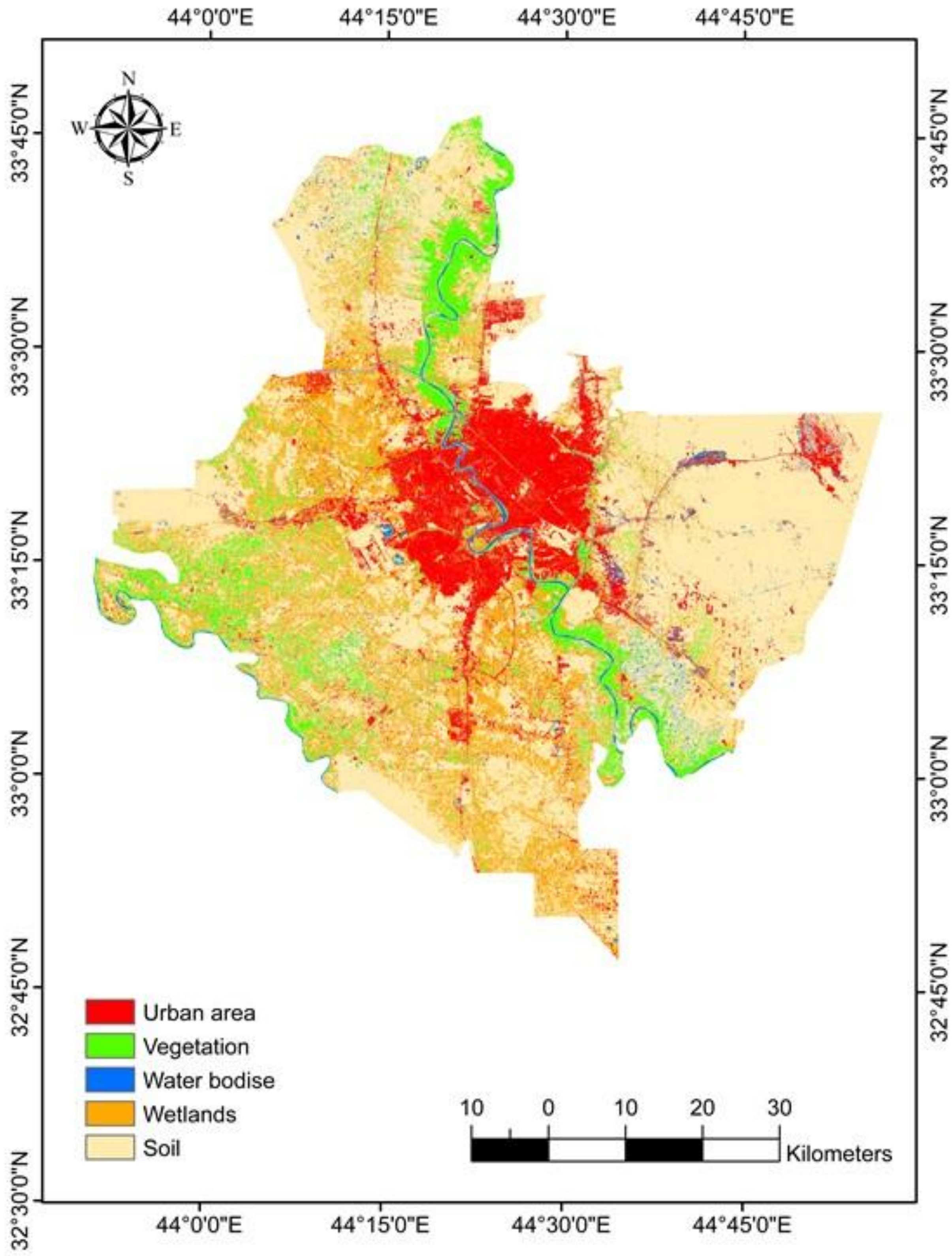

Figure (6) Thematic map for Baghdad 2023

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2.5. Image post-processing

In order to assess the accuracy of the classification, each map depicting land cover was cross-referenced with a corresponding data source. The source data was established through the utilization of historical data from Google Earth and topographic maps, with a focus on randomly selected sample points, using Equation (1) and Equation (2) to calculate accuracy assessment and kappa value (Faraj et al., 2018). The classifications accuracy assessment for the years 1993, 2003, 2013, and 2023 were 92%, 91%, 92%, and 93%, respectively. Table (2) displays a kappa statistic exceeding 60% for the examined years, indicating that the maps classification from 1993 to 2023 is dependable and trustworthy for the formulation of future plans (Faraj et al., 2018).

$$Overall\ accuracy = \frac{X_{1,1} + X_{2,2} + X_{3,3} + X_{k,k}}{N} \qquad \text{(1)}$$

$$Kappa\ value = \frac{N \sum_{i=1}^{k} X_{ii} - \sum_{1=1}^{k}(X_{i+} * X_{+i})}{N^2 - \sum_{1=1}^{k}(X_{i+} * X_{+i})} \qquad \text{(2)}$$

Where:

k: is the number of raw (e.g., land-cover classes) in the matrix.

X_{ii}: is the number of observations in row i and column i.

X_{i+} and X_{+i}: are the marginal totals for row I and column i.

N: is the total number of observations.

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Table (2) accuracy assessment and Kappa value

Classification	Overall accuracy	kappa statistic
Thematic map 1993	89%	86%
Thematic map 2003	91%	88%
Thematic map 2013	92%	89%
Thematic map 2023	90%	87%

3. Analysis Results and Discussion

The identification of urban area change in this study was conducted through statistical analysis of thematic maps of Baghdad city. Figure (7) depicts the temporal changes in urban areas from (1993 to 2023). The urban land area of the study area was measured at (349 km^2) in (1993) and experienced a subsequent expansion to (417 km^2) in (2003), indicating a (1.3%) growth rate. During the decade spanning from (2013 to 2023), there was a significant expansion of urban land, with an increase from (481 km^2 to 531 km^2). The principal driver behind the growth of urban regions is the increase in population. Table (3) displays the urban areas change detection over the years.

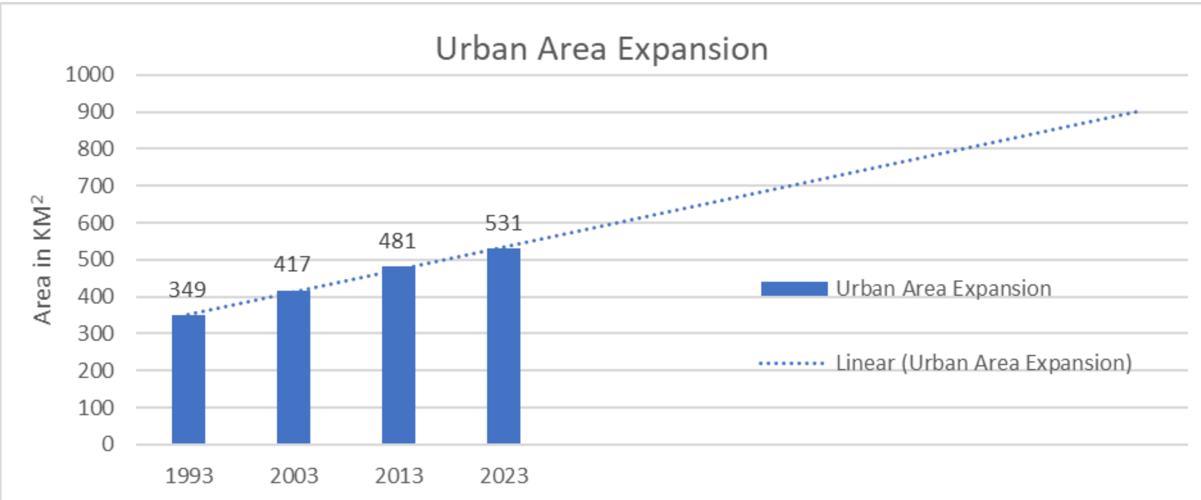

Figure (7) urban area Expansion

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Table (3) Change detection results

Change detection	Area km^2	Percentage %
Change detection Between (1993-2003)	68	+1.34%
Change detection Between (2003-2013)	64	+1.62%
Change detection Between (2013-2023)	50	+1.98%
Change detection Between (1993-2023)	182	+4.54%

(+): areas increasing indicator

4. Conclusion

The objective of this study is to conduct an analysis of the variations in urban areas between the years 1993 and 2023. Remote sensing has the capability to detect and monitor changes in data obtained from satellite imagery. The present study acquired data from the (USGS), which included Landsat imagery of the city of Baghdad. The image sensors were 1993 TM, 2003 ETM+, 2013 TM, and 2023 OLI, respectively. The images were subjected to supervised classification using the Support Vector Machine (SVM) method, with five distinct classes: vegetation, urban area, water bodies, soil, and wetlands. The classification accuracy for the years 1993, 2003, 2013, and 2023 is 89%, 91%, 92%, and 90%, respectively. The change detection reveals that the urban areas have experienced an increase of 1.34%, 1.62%, 1.98%, and 4.54% during the time intervals of (1993-2003), (2003-2013), (2013-2023), and (1993-2023), respectively. Access to information regarding opportunities for optimal utilization is crucial for making informed decisions, strategizing, and implementing land use systems that are necessary to address the escalating pressures of urban expansion and human activities.

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5. Recommendation

It is recommended that the techniques used in this research be generalized for other areas of Iraq and provide a significant tool for the surveillance and measurement of changes in the (LULC). Also, it is recommended to enhance the dataset by increasing the classes studied to account for more diverse terrain detection.

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