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Assessing Vegetation Cover Changes in the Eastern and Western Regions of the Tigris River Using GIS and Remote Sensing

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Abstract

Monitoring vegetation change is essential to monitoring natural and human factors affecting vegetation area and land use. The research aims to detect the change in vegetation cover during 2008, 2010, 2013, 2015, 2018, 2019, and 2023 in the eastern and western parts of the Tigris River in Baghdad, Iraq. Landsat 5 (Thematic Mapper) and 8 (Operational Land) satellite images were used. They were classified using the NDVI index (Normalized Difference Vegetation Index) to detect changes in vegetation and the NBI index (New Urbanism Index) to detect urban expansion using ArcMap 10.8. The results showed that the largest vegetation cover area was 77.69 km^2 in 2013, followed by 2023, which was 68.58 km2; then, in 2018, it was 68.36 km^2. In 2008, 2010, 2015, and 2019, there was a significant decrease in the vegetation cover areas, reaching 61.92 km^2 in 2008, 60.62 km^2 in 2010, 46.14 km^2 in 2015, and 46.04 km^2 in 2019. The vegetation cover area decreased from 77.69 km^2 in 2013 to 46.14 km^2 in 2015 due to the decrease in annual rainfall rates from 296.7 mm to 190.9 mm. In addition, there was a significant increase in building areas for 2008-2023 from 156.26 km^2 to 173.5 km^2 due to the increased population density and urban expansion in Baghdad. Because plants are the home of living organisms, reducing green spaces threatens biodiversity and poses health risks, as plants contribute to purifying the air.

Keywords: Remote sensing, GIS, NDVI, NBI, Satellite Image, Vegetation Cover, Changes Detection, Tigris River, Assessment.

"تقييم تغيرات الغطاء النباتي في المناطق الشرقية والغربية لنهر دجلة باستخدام نظم المعلومات الجغرافية والاستشعار عن بعد"

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الخلاصة

تعتبر عملية رصد التغير في الغطاء النباتي مهمة لرصد العوامل الطبيعية والبشرية التي تؤثر على مساحة الغطاء النباتي وكذلك استخدامات الأراضي. ويهدف البحث إلى الكشف عن التغير في الغطاء النباتي خلال الأعوام (2008,2010,2013,2015,2018,2019,2023). في الأجزاء الشرقية والغربية من نهر دجلة في مدينة بغداد. تم استخدام الصور الفضائية (Landsat 5 (Thematic Mapper و(Landsat 8(Operational Land خلال فترة الدراسة ,تم تصنيفها باستخدام مؤشر NDVI (مؤشر الفرق الطبيعي للغطاء النباتي) لكشف التغيرات في الغطاء النباتي ومؤشر NBI (مؤشر العمران الجديد) لكشف التوسع العمراني, استخدم برنامج Arcmap10.8 في منهج البحث.وأظهرت النتائج أن أكبر مساحة للغطاء النباتي بلغت (77.69 كم2) في عام 2013، تليها عام 2023، حيث بلغت المساحة النباتية (68.58 كم2)، ثم في عام 2018 بلغت مساحة الغطاء النباتي (68.36 كم2)، وفي الأعوام 2015،2010،2008، و2019 حدث انخفاض كبير في مساحات الغطاء النباتي، إذ بلغت (61.92 كم2) عام 2008، (60.62 كم2) عام 2010، (46.14 كم2) عام 2015، و (46.04 كم2) عام 2019. انخفاض مساحة الغطاء النباتي من (77.69 كم2) عام 2013 إلى (46.14 كم2) عام 2015 نتيجة لانخفاض المعدلات السنوية لهطول الأمطار من (296.702 ملم) إلى (190.9 ملم). بالإضافة إلى عوامل أخرى مثل الارتفاع الكبير في مساحات الأبنية للفترة 2008–2023 من (156.26 كم2) الى (173.5كم2) نتيجة زيادة الكثافة السكانية والتوسع العمراني في مدينة بغداد. ولأن النباتات هي موطن الكائنات الحية، فإن تقليل المساحات الخضراء يهدد التنوع البيولوجي ويشكل مخاطر صحية، حيث تساهم النباتات في تنقية الهواء .

1. Introduction

The study and application of multispectral remote sensing involves collecting spatial, spectral, and temporal information about particular objects, regions, or phenomena, like vegetation, land cover classification, urban areas, agricultural land, and water resources, without a physical connection [1]. Remote Sensing data is available as digital maps or photographs and offers details on land use, land cover, soil properties, and other features of the Earth's surface [2]. Satellite images (Remote Sensing data) are made up of mini squares arranged in rows and columns next to each other. Referring to it as the pixel or cell, every cell contains a number indicating how much radiation is reflected off the portion of the Earth's surface. Specialized sensors gather information through many spectral bands [3]. The basis for the use of remote sensing in the detection of variance is that changes in ground cover result from changes in radiation values received by the sensor [4]. Additionally, the satellite imagery dataset, which represents each pixel (the smallest item in the picture) as a spectrum texture for a feature in a raster grid, was used to compute the area of each feature [5].

Monitoring changes in land cover (LC) requires satellite data to detect and determine the changes that may occur in exploiting and managing natural resources and other human activities. The change in the land cover is detected through the difference in the digital reflectivity values of the features recorded by airborne sensors or in space [6]. Many researches and surveys involving the environment and monitoring employ remote sensing techniques [7]. Over 40 years ago, satellite data was first used in practice to monitor crop distribution and vegetation [8]. Most vegetation worldwide is land cover (LC), and as plants preserve the natural equilibrium of rapidly changing environments brought about by deliberate and accidental human usage, they are receiving more attention [9]. Using geo-registered multi-temporal remote sensing data, change detection is a method that assists in identifying changes related to land use and land cover attributes [10]. Assessment of the vegetation cover changes is becoming increasingly crucial for researching the interactions between natural and human settings [11]. Therefore, knowledge of plant cover changes over time is crucial for land planning and management [12].

Thematic maps extracted from satellite data may be compared using GIS to find changes [13]; GIS is a beneficial tool for determining various criterion values. To help with the modeling of spatial, GIS is a system that can manage, modify, display, and analyze spatial information. Geospatial technologies, such as satellite images, aerial photography, and geographic information systems (GIS), hold considerable potential for enhancing information on patterns in deterioration across broad regions and facilitating more efficient information administration [14]. Moreover, farmers may use this information to make well-informed operations decisions and adjust to changing circumstances [15]. In areas where food security is at risk, it is essential to anticipate crop output for decision-makers and sustain an adequate crop production level [16,17]. Remote sensing and GIS have recently been used extensively in agriculture applications, including precision agriculture, yield prediction, soil mapping, and crop monitoring. Using these instruments, farmers can maximize crop management techniques while cutting expenses and raising yields [18,19].

Because of the variety of plant types and their spread, vegetation monitoring is a crucial remote sensing application [46]. In a remote sensing scene, vegetation areas can be identified using a variety of indicators. NDVI (Normalized Difference Vegetation Index) is a popular and often-used index [20]. NDVI makes it possible to easily compare data over time and space and monitor photosynthesis in vegetation [21]. NDVI, a measure of vegetation growth and coverage, is frequently used to characterize the spatiotemporal features of land use and land cover, including the percentage of vegetation covered [22]. One of the advantages of using remote sensing techniques to evaluate natural resources is the ability to analyze changes in the vegetation. Plants respond to energy in different ways.

Healthy vegetation absorbs visible light for remote sensing and reflects infrared wavelengths that are unnecessary for photosynthesis. The Quantitative Vegetation Cover Index, or NDVI, defines this differential spectral property [23]. (Hon Ross), the Center for Remote Sensing director at the University of Texas was the first to submit an official report on NDVI in 1973, as developed the difference ratio between red and near-infrared radiation [24]. The difference between the observed canopy reflectance in the red and near-infrared bands used to compute the NDVI [25]. The vegetation cover change classification technique uses each pixel as a labeled class to produce classed pictures [26]. Using vegetation indexes aids in extracting certain vegetation classes from a region and normalizing the effects of differential lighting of features in the area [27].

Indicators were examined to see how useful they were for detecting changes in the vegetation and land cover. Of the three groups of vegetation indices in this study, the NDVI group was least impacted by topographic considerations. The vegetation indices in various categories exhibited statistically distinct features, and only the NDVI group had normal distribution histograms. Based on laboratory and field data, comparisons of different approaches revealed that the NDVI difference methodology showed the best vegetation change detection [28]. The range of NDVI values ranges from 1^{+} to 1^{-}. A positive result implies that the cell has a dense vegetation covering; the greater the positive value, the more green the plant and the more dense the cover, and vice versa. The vegetative difference index distinguishes between healthy and unhealthy plants since negative values reflect the absence of thick vegetation cover [29]. Rainfall and NDVI have a significant correlation [30]. The amount of water on arable land directly correlates with its high and low density [5].

Remote sensing and GIS can be used to monitor and predict the impact of environmental factors on agriculture, such as changes in weather patterns and climate [31]. The climate of any region is linked to fixed natural factors such as geographical location, proximity, and distance from bodies of water, as well as the influence of the region's topography, and to moving natural factors represented by the distributions of pressure, temperature, and wind [32]. The environment, human habitation, biodiversity, and the ability of agriculture and natural resources to withstand the effects of extreme weather events are all predicted to suffer due to climate change [33]. The predominant wind direction influences climate forecasts [34]. The relationship between plant cover and climate change may serve as a model for future environmental enhancement and vegetation restoration in areas with comparable features. Without the introduction of engineering and agricultural mechanization, plowing, haphazard watering, urban encroachment, and excessive exploitation of available resources were among the processes of land degradation that were rich in agriculture and contributed to the gradual loss of vegetation cover. Furthermore, military operations and wars caused the labor force to be displaced from agriculture [35]. The ArcGIS software package can help the decision-maker take the measures necessary to avoid the problems caused by emergency events [45].
Many factors contribute to the decline in agricultural activity, and one of the essential human factors is the erosion of residential use at the expense of agricultural and arable land. The deliberate conversion of areas of agricultural land for residential purposes, whether by governmental decisions or personal efforts by residents, takes advantage of the low prices of agricultural land in exchange for land designated for housing [36]. Vegetation cover changes according to human activities and environmental activities. Some changes affect the vegetation cover negatively, which may result from the excessive cutting of forest trees, as well as problems of environmental deterioration of the vegetation cover, in addition to the presence of urban expansion, which negatively affects the vegetation cover. This often occurs when the city grows rapidly, allowing room for the urban sprawl phenomenon, which manifests in irregular expansion and expansion [37]. The most notable changes in LC were brought about by constant urban growth on agricultural land over the years, leading to land degradation, and most LC changes were caused by human activity [38]. Global ecosystems and agricultural changes are primarily caused by anthropogenic activity and natural climate change [39]. Using the R, NIR, and MIR bands, NBI (New Built-up Index) was suggested. The primary idea behind this built-up index is that, in the R band, bare land has a higher spectral response than built-up areas, which have a bigger spectral response than other land use land cover classifications [40].

Previous related works: research has shown (A. S. Mahdi, 2022) that from 2000 to 2017, an increase or extension of metropolitan areas was built on vegetative regions, leading to several environmental issues [41]. A study pointed out an increase in vegetation cover in 1990 by 980.68 km^2 and from 1420.35 km^2 in 2003 to 2072.98 km^2 in 2016, while the annual water bodies were about 185.95 km^2 in 1990, they decreased to 68.27 km^2 in 2003, and they increased to 180.23 km^2 in 2016 [42]. A study demonstrated the decline in agricultural productivity rate, which fell from 56.57% in 2010 to 43.43% in 2019. Climate change is assumed to contribute to this degradation, along with other elements such as water scarcity, 0.52 and 0.44 [43]. This study aims to study the variation in vegetation area during 2008, 2010, 2013, 2015, 2018, 2019, and 2023. Knowing how much climatic and human factors affect the vegetation cover area is essential.

2. Study area

The study area is located in Baghdad Governorate in Iraq and includes areas east and west of the Tigris River, which are located between longitudes 33.425118 north and 33.173764 south and latitudes 44.529771 east and 44.298897 west. The total area of the study area was 247.2 km^2, Figure 1. The areas adjacent to the Tigris River in Baghdad, in particular, and Iraq, in general, were affected by water scarcity and climate change, which was reflected in the area of vegetation cover in the city, in addition to urban sprawl, which led to a decrease in areas of vegetation cover during recent years and a change in the gender of the lands adjacent to the river to service and urban projects.

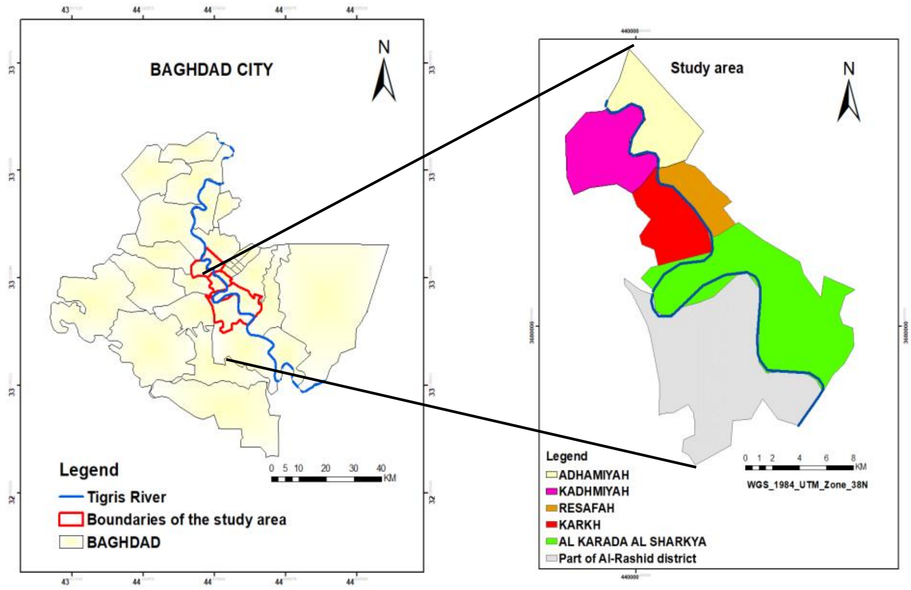

Figure 1: Study area

3. Methodology

3.1 Data acquisition

Landsat images were collected from the USGS Earth Explorer platform (http://earthexolorer.usgs.gov) for 2008, 2010, 2013, 2015, 2018, 2019, and 2023. The 2008 and 2010 Landsat 5 (Thematic Mapper) images were taken in November, and the 2013, 2015, 2018, 2019, and 2023 Landsat-8 (Operational Land Imager) images were obtained in September. Rainfall data for Baghdad city stations for 2008, 2010, 2013, 2015, 2018, 2019, and 2023 were obtained from (Ministry of Transport, Meteorological and Seismic Monitoring Authority).

3.2 Software used

- ArcMap software was used to classify and analyze satellite images.
- Microsoft Excel was used to perform mathematical calculations.

3.3 Data processing

The image processing included:

- Removing noise and atmospheric effects for Landsat 5 images only.
- The study area was deducted from the administrative boundaries.
- The study area was extracted from images using (Extract by Mask)

The steps for processing and analyzing data are shown in Figure 2.

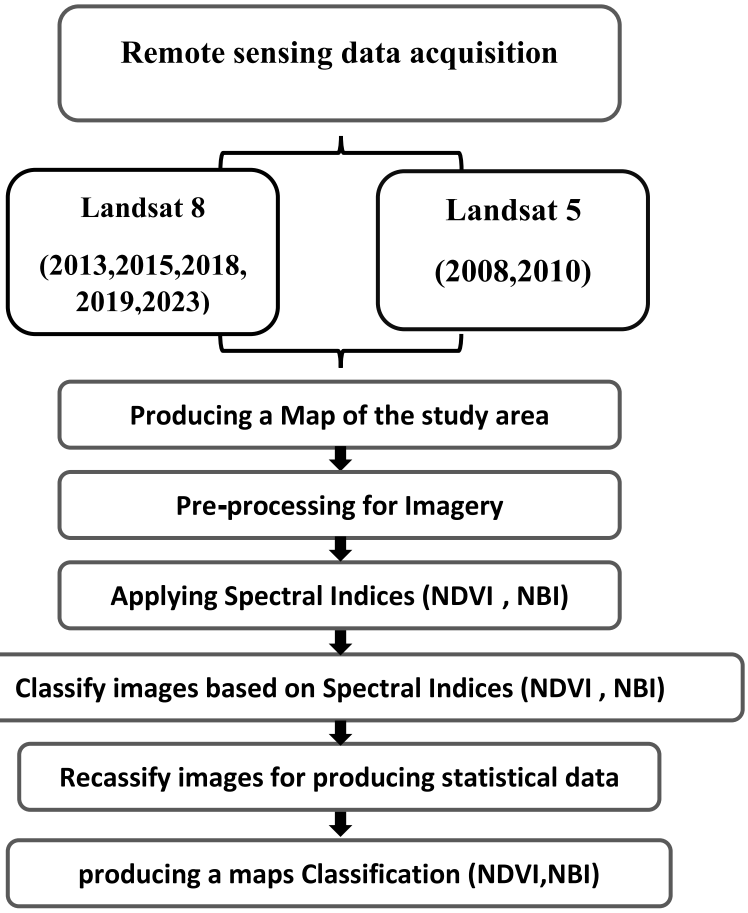

Figure 2: The flowchart of the processing and analyzing data.

3.4 Classify Image Based on Spectral Indices

A series of spectral bands were used by indices to compute certain values that aid in differentiating between various categories of land cover. The NDVI index (Normal Difference Vegetation Index) was used to detect changes in vegetation cover, and the NBI index (New Urbanism Index) to detect urban expansion.

3.4.1 Normalized Difference Vegetation Index(NDVI)

The index was used to estimate vegetative growth and green density in plants. NDVI is an effective tool in soil classification and environmental analysis. NDVI values are helpful in the spectral classification of soil, as different plant species and varieties can be identified and differentiated by the variation in NDVI values used. NDVI analysis techniques were applied to determine vegetation cover, classify cultivated areas, monitor environmental and soil changes, and identify drought areas and other environmental and agricultural uses. NDVI values range between $^{-}1$ and $^{+}1$ [44]. Negative or shallow values represent areas that are not vegetated, such as clouds, water, or ice. Positive and high NDVI values indicate the presence of dense, abundant vegetation. NDVI was calculated according to the Equation (1) :

$$NDVI = (BNIR-RED)/ (BNIR-RED) \qquad (1)$$

Where B_{NIR}= Reflection of the near-infrared spectrum, B_{RED}= reflectance range of the red spectrum

For Landsat 8 (Red = Band 4 , NIR = Band 5) , For Landsat 5 (Red = Band 3 , NIR = Band 4), Table1 .

3.4.2 New Built-up Index (NBI)

Based on the fact that the spectral response of bare land is higher than that of other land covers in the bands before it, the index as formula (2):

$$NBI = (B_{RED} * B_{SWIR1}) / B_{NIR} \quad (2)$$

Where: $B_{RED=}$reflectance range of the red spectrum, $B_{SWIR1=}$ reflectance range of the first shortwave Infrared, B_{NIR}=Reflection of the near-infrared spectrum.
For Landsat 8 (Red= Band 4, NIR= Band 5, SWIR1= Band 6), for Landsat 5 (Red= Band 3, NIR= Band 4, SWIR1= Band 5), Table1 .

Table 1: Landsat Bands from National Aeronautics and Space Administration (NASA), available online;
http: //arset.gsfc.nasa.gov

Wavelengths	Landsat 8 Bands	Landsat 5 Bands
Coastal aerosol	Band 1	
Blue	Band 2	Band 1
Green	Band 3	Band 2
Red	**Band 4**	**Band 3**
Near- Infrared	**Band 5**	**Band 4**
SWIR 1	**Band 6**	**Band 5**
SWIR 2	Band 7	Band 7
Panchromatic	Band 8	Band 8 (L7)
Cirrus	Band 9	
Thermal Infrared 1	Band 10	Band 6
Thermal Infrared 2	Band 11	
Spatial Resolution (m)	15m for panchromatic band 8 30 m for bands 2,3,4,5,6,7,9 100m for bands 10,11.	
The month of image capture	September	November

3.5 Excel Forecast function

Using linear regression, the forecast function predicts a future value based on existing values.

4. Results and Discussion

Vegetation cover maps were derived from Landsat image data using NDVI classification for years 2008, 2013, 2018, and 2023, Figure 3

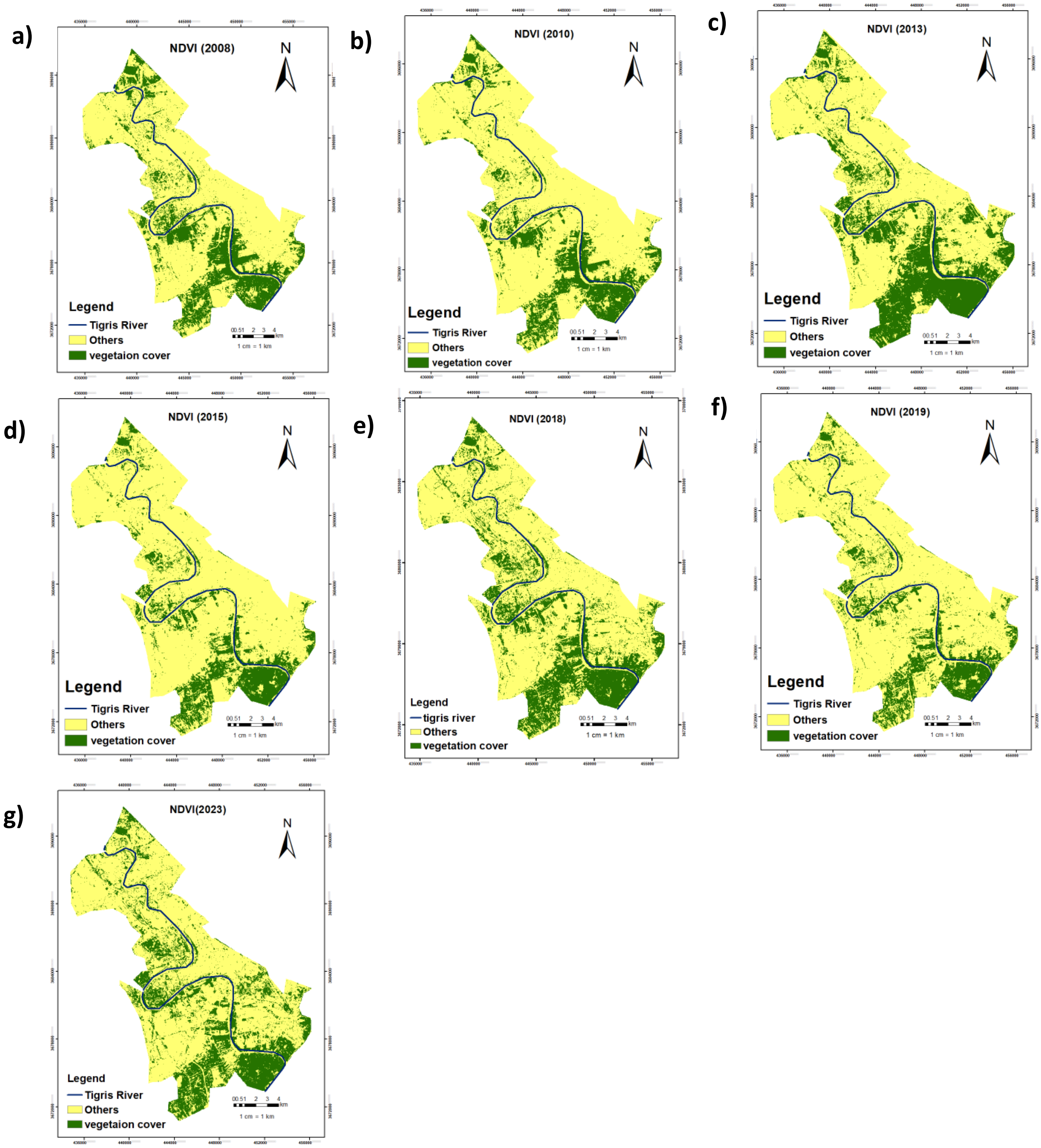

Figure 3: NDVI classification maps of study area where a) in 2008 b) in 2010 c) in 2013 d) in 2015 e) in 2018 f) in 2019 g) in 2023

Tables 2 and 3 show the area and percentage of vegetation cover maps derived from Landsat images for 2008, 2010, 2013, 2015, 2018, 2019, and 2023.

Classes	2008	2010	2013	2015	2018	2019	2023
vegetation cover	61.92	60.62	77.69	46.14	68.36	46.04	68.58
Others	185.24	186.54	169.47	201.03	178.8	201.13	178.58
Total area	**247.2**	**247.2**	**247.2**	**247.2**	**247.2**	**247.2**	**247.2**

Table 2: Area of vegetation cover (km^2)**.**

Table 3: Percentage of vegetation cover**.**

Classes	2008	2010	2013	2015	2018	2019	2023
vegetation cover	25.05%	24.53%	31.43%	18.67%	27.66%	18.63%	27.75%
Others	74.95%	75.47%	68.57%	81.33%	72.34%	81.37%	72.25%
Total area	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Figure 6: Variation in vegetation cover over 2008, 2010, 2013, 2015, 2018, 2019, and 2023; it was drawn based on data from Table 3.

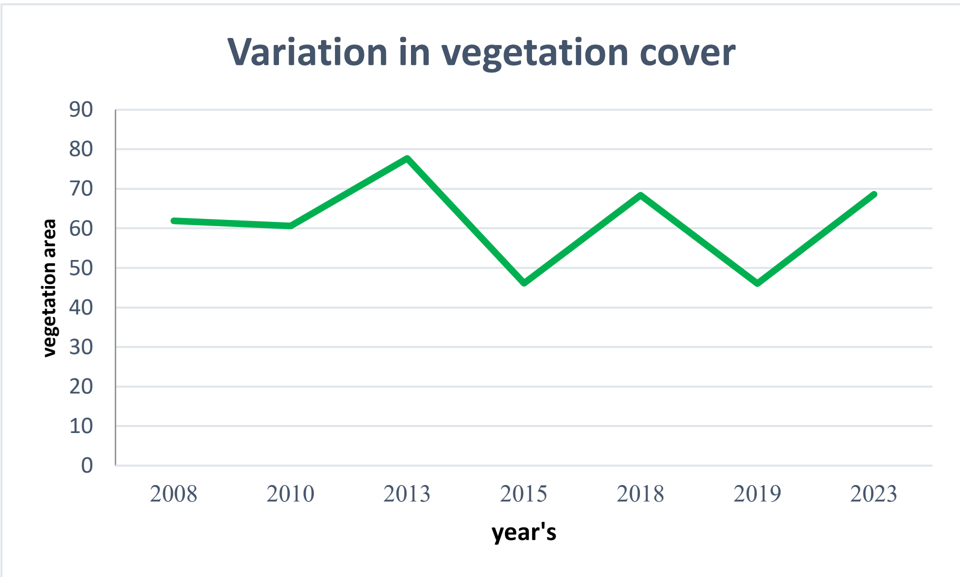

Figure 4: Variation in vegetation cover over 2008, 2010, 2013, 2015, 2018, 2019, and 2023

Built-up maps were derived from Landsat image data using NBI classification for 2008, 2010, 2013, 2015, 2018, 2019, and 2023, Figure 5.

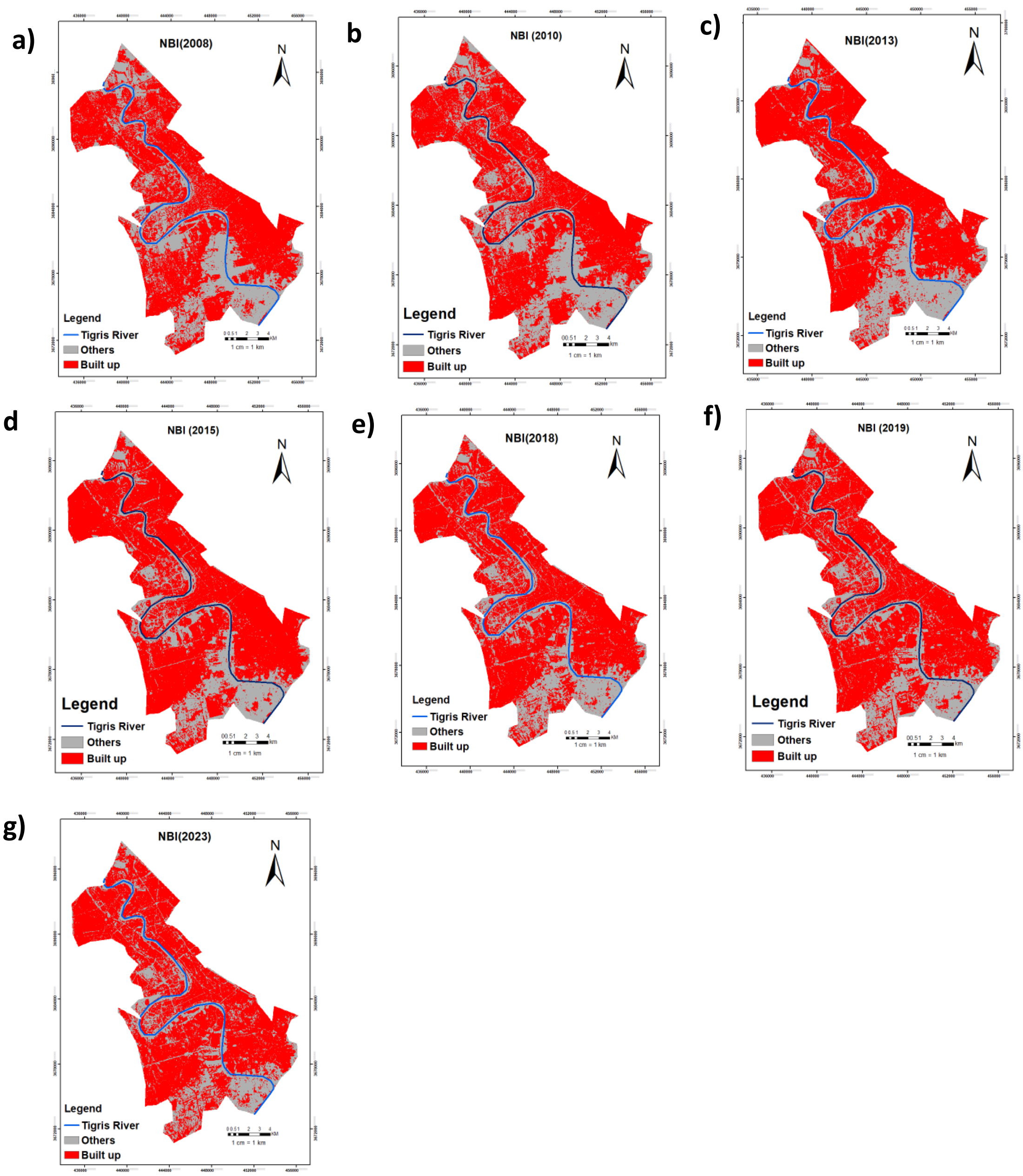

Figure 5: NBI classification maps of the study area where: a) in 2008, b) in 2010, c) in 2013, d) in 2015, e) in 2018, f) in 2019, g) in 2023

Tables 4 and 5: the area and percentage of the Built-up maps derived from Landsat images for 2008,2010, 2013,2015, 2018, 2019, and 2023

Table 4: Area of Built-up cover(Km^2)

Classes	2008	2010	2013	2015	2018	2019	2023
Others	90.9	89.6	80.57	69.73	76.59	77.35	73.67
Built up	156.26	157.57	166.59	177.43	170.57	169.81	173.5
Total area	**247.2**	**247.2**	**247.2**	**247.2**	**247.2**	**247.2**	**247.2**

Table 5: Percentage of Built-up cover

Classes	2008	2010	2013	2015	2018	2019	2023
Others	36.78%	36.25%	32.60%	28.21%	30.99%	31.30%	29.80%
Built up	63.22%	63.75%	67.40%	71.79%	69.01%	68.70%	70.20%
Total area	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Figure 6: Growth in buildings over 2008, 2010, 2013, 2015, 2018, 2019, and 2023; it was drawn based on data from Table 5.

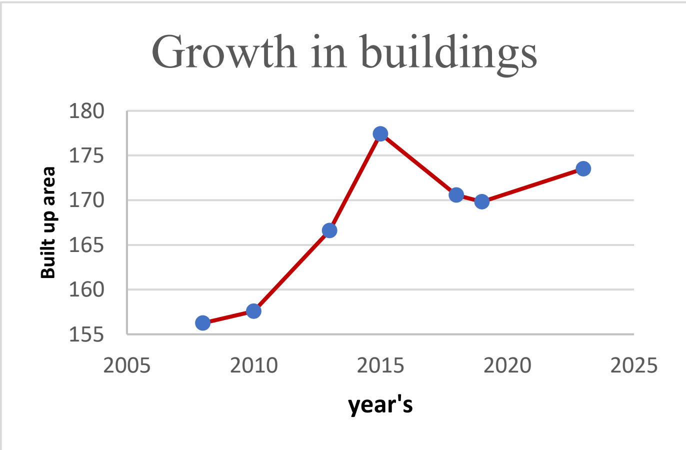

Figure 6: Growth in buildings over 2008, 2010, 2013, 2015, 2018, 2019 and 2023

Table 7: Rainfall data for Baghdad city stations were obtained from (the Ministry of Transport/Meteorological and Seismic Monitoring Authority) for 2008, 2010, 2013, 2015, 2018, 2019, and 2023.

Table 6: Rainfall amounts for years 2008, 2010, 2013, 2015, 2018, 2019, 2023

year	rainfall (mm)
2008	59.113
2010	92.5
2013	296.702
2015	190.9
2018	284.2
2019	146.9
2023	194.409

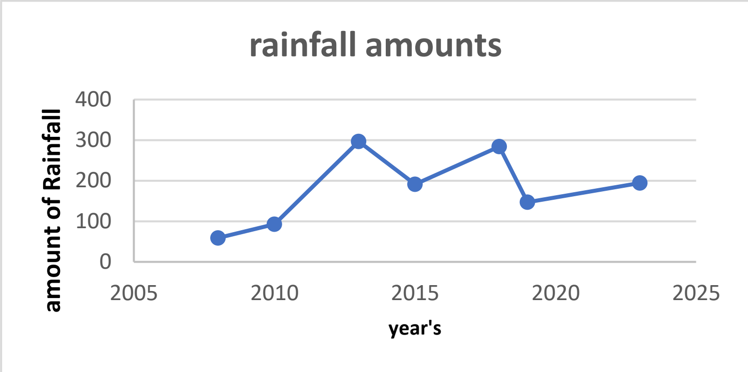

Figure 7: Rainfall amounts for years 2008, 2010, 2013, 2015, 2018, 2019, and 2023

The results obtained from the process of analyzing the satellite images for the years 2008, 2010, 2013, 2015, 2018, 2019, and 2023 showed a large contrast in green areas within the study area, where the results indicated that the largest area of the vegetation reached 77.69 km^2 in 2013, followed in 2023 when the vegetation area reached 68.58 km^2, then in 2018 it reached 68.36 km^2. In 2008, 2010, 2015, and 2019, there was a great decrease in the vegetation spaces, reaching 61.92 km2 in 2008, 60.62 km^2 in 2010, 46.14 km^2 in 2015, and 46.04 km^2 in 2019: table 2 and Figure 4.

By analyzing the above data, it was noticed that the study area, in particular, and Baghdad, in general, are affected by several factors, the most important of which are climatic factors, which change the amounts of rain to 77.69 km^2. At the same time, in other years, there was a great decrease in the amount of rain in the study area, with annual rates of 59.113 mm in 2008, 92.5mm in 2010, 190.9 mm in 2015, 284.2mm in 2018, 146.9mm in 2019, 194.409mm in 2023, Table 6 and Figure 7.

This led to a decrease in the vegetation areas, and the decrease in the vegetation from 77.69 km^2 in 2013 to 46.14 km^2 in 2015 was due to the decrease in the annual rain rates from 296.702 mm to 190.9 mm.

In addition to other factors such as the large rise in temperatures and the increase in buildings for 2008-2023 from 156.26 km^2 to 173.5 km^2 due to the increase in population density and urban expansion in Baghdad, Table 4 and Figure 6. With these climatic and human conditions, the vegetation spaces are expected to be 59.05 km^2 and buildings 196.69 km^2 in 2040, Figure 8.

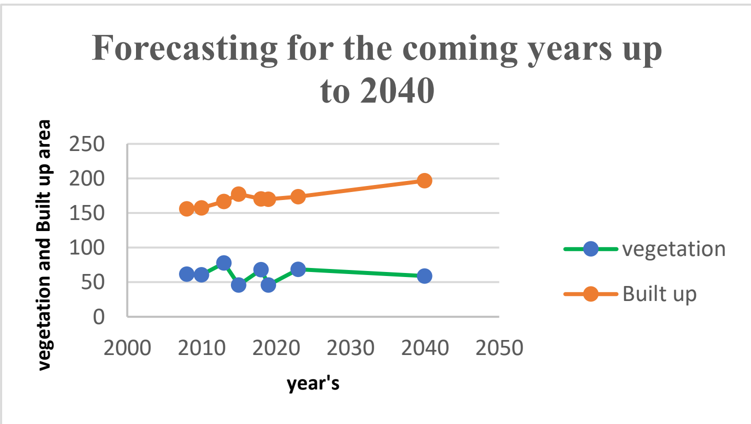

Figure 8: Forecasting for the coming years up to 2040 for vegetation cover and growth in buildings

When comparing satellite data with ground truth, accuracy was 88% for NDVI and 76% for NBI.

5. Conclusion

Climate change causes a change in the areas of vegetation cover, and the increase in rainfall amounts of 296,702 mm in 2013 caused an increase in vegetation areas of 77.69 km^2, and the decrease in rainfall amounts in other years caused a decrease in vegetation areas. It was noted that vegetation cover decreased from 2013 to 2023 from 77.69 km^2 to 68.58 km^2, affected by increasing urban expansion. In addition to urban expansion, population growth increased in Baghdad, the type of agricultural land changed to residential or commercial, and migration from the countryside to the city. Increased urbanization may influence climate change, leading to changes in precipitation and higher temperatures, negatively impacting vegetation growth and health. Because plants are the home of living organisms, reducing green spaces threatens biodiversity. Decreased vegetation cover poses health risks, as plants contribute to purifying the air. Therefore, remote sensing technology helps monitor temporal changes in vegetation cover and provides good results for analysis and interpretation by using remote sensing data such as satellite images. GIS technology helps choose the best place for agriculture, monitor the factors affecting the plant, and know and estimate the plant's needs for fertilizer, water, etc.

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