Research Article

Vegetation Analysis Using Remote Sensing

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Abstract | This study examines the dynamics of land cover in the city of Al-Khalis, Iraq, and the surrounding areas between 2013, 2016, 2019, and 2022. Through remote sensing and Geographic Information System (GIS) techniques, the study aims to monitor changes in land use and assess vegetation health from NDVI (Normalized Difference Vegetation Index) values. Landsat 8 satellite images were employed to classify the region into three broad categories: Water, vegetation, and non-vegetation, which offered a clear insight into the land cover dynamics of the region.

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Introduction

Land cover change detection is a crucial method utilized for effective land planning and management. With the rapid advancement of technology, Geographic Information Systems (GIS) and remote sensing are now essential tools to track and study changes in land cover over a time frame. Among the various datasets at hand, satellite imagery has proved extremely valuable in obtaining detailed information on land cover dynamics. Landsat imagery, in particular, is a choice of preference due to its availability and reliability in land use and cover analysis (Muhsin, 2016; Al-Waeli, 2020). Normalized Difference Vegetation Index (NDVI) is among the best techniques for tracking vegetation change. NDVI is an usual index of vegetation coverage for multiple periods and areas. NDVI is especially useful in the detection of human-induced effects like urbanization and infrastructure development and in the cognition of spatio-temporal pattern of vegetation. NDVI technique operates through examining the reflected and absorbed Earth's surface energy ratio, which is calculated from the Red and Near-Infrared (NIR) bands of satellite sensors (Mašková *et al*., 2008; Frimpong *et al*., 2023; Taha *et al*., 2024). Its basis is healthy plants reflect the visible spectrum in low amounts as a result of chlorophyll absorption primarily. Different research studies have utilized NDVI to determine vegetation cover and study the effects of environmental factors like desertification, drought, and erosion.

Tucker *et al.* (1991) showed the application of NDVI in climate change research, in this case, for the growth of the Sahara desert between 1980 and 1990 using NDVI values as a rainfall surrogate. NDVI has also been linked to biomass production, canopy photosynthesis, stomatal resistance, and evapotranspiration and thus proves extremely valuable in environmental and climatic studies. Efforts have evolved towards production of global coverage NDVI data sets to inform land surface model processes for application in climate research. Geerken *et al.* (2005) offered supervised time series NDVI classification methods, and they are applicable for vegetation cover and types extraction. Bhandari *et al.* (2012) showed that NDVI has the potential to improve the study of satellite images through integration of multispectral remote sensing and various analysis techniques. The applications of NDVI go beyond monitoring vegetation. Ahmad *et al.* (2014) examined urban sprawl and green space development in Malaysia's Klang-Langat valley, illustrating how NDVI can be used to evaluate the changes in urban green space. Further studies in China's Xishuangbanna also employed phenology-based vegetation index differencing to quickly and accurately map rubber plantations. Such varied applications illustrate the versatility and importance of NDVI in land cover and vegetation dynamics research.

This study examines and classifies the drivers of land cover and land use changes in Al-Khalis during four years: 2013, 2016, 2019, and 2022. The research seeks to offer an extensive overview of how the drivers have evolved over time and their impact on the urban and natural landscape of the city.

Area of study and data description

Al-Khalis city was selected as a research site in this research paper. The city is situated in the north of Diyala Governorate, around 55 km north of Iraq's capital city, Baghdad. Figure 1 illustrates more of Al-Khalis city's location. The geographic coordinates of Al-Khalis city are longitude (44.5219807° E) and latitude (33.8430542° N), as shown in Figure 2. Satellite images from Landsat 8 were employed as a data source of the study area in 2013, 2016, 2019 and 2022 with a spatial resolution of 30 meters. Landsat 8 images were utilized due to their high spatial and high spectral resolution, making them a rich source of data in land use/land cover change monitoring.

Figure 1: *Diyala orchards in the district of Khalis city.*

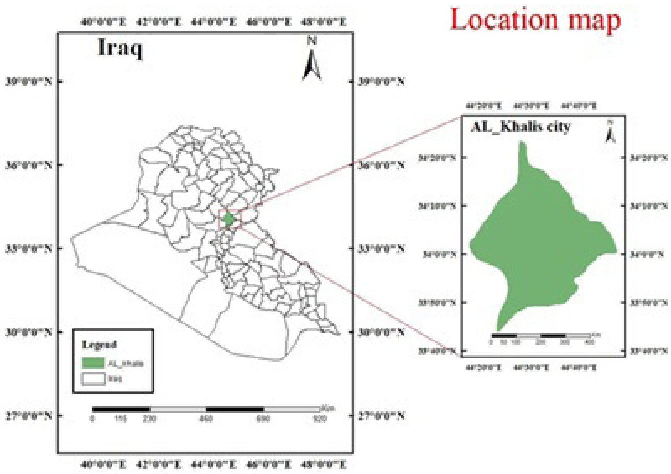

Figure 2: *Location of the study area.*

Materials and Methods

To ensure satellite data reliability and accuracy, each Landsat 8 image was geometrically corrected to fit coordinates of the actual world. This way, spatial distortions were reduced and year-to-year comparability enhanced. Radiometric calibration was subsequently performed to convert raw Digital Number (DN) values to at-sensor spectral radiance using the following formula:

$$L_\lambda = M_L \times Q_{cal} + A_L$$

Where; M_L is the band-specific multiplicative rescaling factor, A_L is the additive rescaling factor, and Q_{cal} is the initial DN value of the pixel. This is done so that the reflectance values are standard, thus the data is prepared for any subsequent analysis.

To calculate vegetation cover and temporal change, the Normalized Difference Vegetation Index (NDVI) was calculated for all data sets. NDVI is a common remote sensing index that measures vegetation health by comparing the reflectance of red and near-infrared (NIR) light. It is calculated as:

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

Where the red band (0.64-0.67 μm) and the NIR band (0.85-0.88 μm) from Landsat 8 are utilized. NDVI ranges from -1 to +1, where high values for healthy vegetation and low values for bare land, urban areas, or water. Through the monitoring of NDVI values over multiple years (2013, 2016, 2019, and 2022), the study establishes significant trends in land cover change. For classifying land cover classes, an unsupervised classification algorithm based on the ISO Cluster classification algorithm was employed. This method groups pixels with similar spectral characteristics into different groups, such that initial discrimination of vegetation, water bodies, barren areas, and urban areas is obtained. Classification was then more accurately done by utilizing the application of NDVI thresholds to enhance the accuracy of identifying vegetation-covered areas.

Time-series analysis of NDVI was carried out to establish changes in vegetation, loss or gain, with proof of the environmental and human-induced changes taking place in Al-Khalis over time. The overall study process from data preprocessing to NDVI calculation, classification, and analysis is illustrated in Figure 3 with an explicit flowchart of the methodology. Apart from this, statistical tests were conducted in order to measure vegetation changes and evaluate land cover changes over the research period.

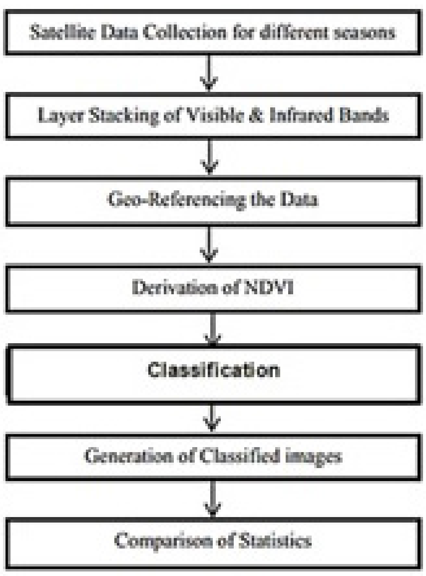

Figure 3: *Illustrates the flowchart of the methodology.*

Results

Bands combination

Multispectral satellite imagery is a convenient method of land cover analysis in that it is capable of recording beyond visible spectrum to allow more accurate analysis of different properties of a surface. In this study, (6, 5, 2) Landsat 8 band combination was utilized to estimate agriculture areas, bodies of water, and areas of non-vegetation in Al-Khalis city to better discriminate different land cover classes. The combination consists of Band 6 (1560–1660 nm Short-Wave Infrared 1), of high utility in soil moisture detection and in differentiating vegetation and exposed soil; Band 5 (845–885 nm Near-Infrared), of high sensitivity to vegetation health and vegetation density, in that healthy vegetation is highly reflective in infrared range; and Band 2 (Blue, 450–515 nm), of utility in better identification of bodies of water and in enhancing contrasts between different land surfaces. The application of this band combination is of high utility in agricultural crop monitoring, in that agricultural crops appear in vivid green, exposed soil in magenta, and vegetation that is not agricultural in shades of green. Such spectral contrasts allow identification of patterns of land cover over time, providing useful details in environmental and agricultural analysis. The Figure 4a, b, c, d presented below illustrate the (6, 5, 2) band combination applied to Al-Khalis city for the years 2013, 2016, 2019, and 2022, highlighting notable transformations in vegetation cover, urban expansion, and overall land use dynamics.

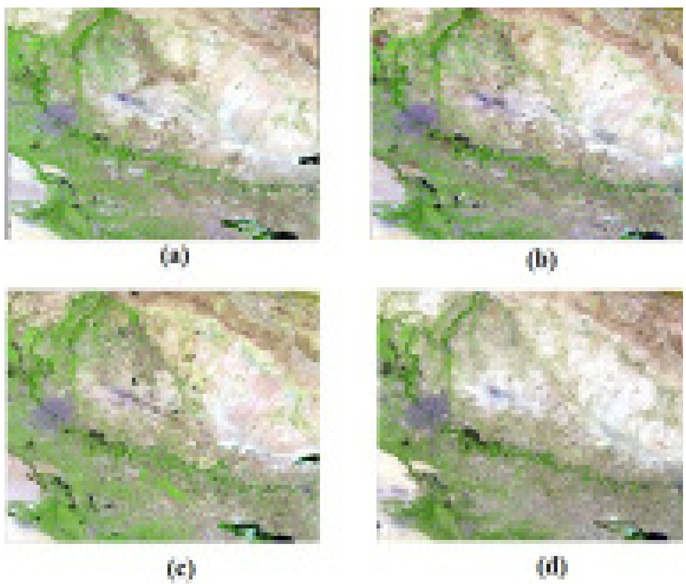

Figure 4: *Landsat image for Al-Khalis city in (a) 2013, (b) 2016, (c) 2019 and (d) 2022 with (6,5,2) band combination technique.*

Image classification

Image classification is crucial in fields like remote sensing, image analysis, and pattern recognition. Sometimes, the classification process itself is analyzed, particularly when creating a land-use map from remotely sensed data, which ultimately results in a map-like image. Thus, image classification serves as a vital tool for examining digital images. Researchers today employ various image classification methods for different objectives. With the increased accessibility and abundance of remote sensing technologies over the past decade, remote sensing images have become widely utilized for classifying urban areas and detecting changes. Applications of image classification include crop monitoring, soil mapping, forest cover analysis, land cover change detection, natural disaster assessments, water resource management, wetland mapping, environmental inventories, urban and regional planning, and other observable objects using remote sensing data.

After performing geometric and radiometric corrections and eliminating cloud effects, an image classification was conducted on three satellite images of Al-Khalis city from the years 2013, 2016, 2019, and 2022. The ground covers in Khalis were categorized into four types: Urban areas, vegetation, water, and barren land. Consequently, four maps were produced, illustrating the four types of land cover for Al-Khalis city during these years, as depicted in (Figure 5a, b, c, d).

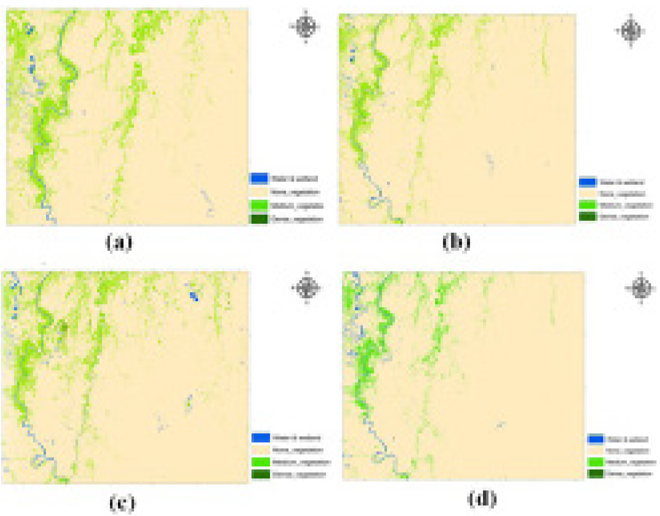

Figure 5: *Image classification for Al-Khalis city in (a) 2013, (b) 2016, (c) 2019 and (d) 2022.*

Change detection in land cover types

After finishing satellite image classification, a thorough analysis was conducted in order to determine how much each kind of land cover occupies in terms of space. To accomplish this, ArcMap software was utilized, and it calculated each kind of land cover's overall area through a count of its pixels and then multiplied it with one pixel's area, and one pixel is 900 m^2 in area. With this, we can calculate approximately how types of land cover have changed over years. We can view significant trends and trends in Al-Khalis city's land use and land cover changes over years through comparing these values for two regions.

The values for areas in terms of how much significant types of land cover have changed over years, such as urban expansion, change in vegetation, change in water, and increased bare land, were examined.

Analyzing this, we can view what is responsible for these types of changes, such as urban expansion, agricultural activities, environmental factors, and human actions.

What we obtain through calculation is significant changes in cover, and such changes can impact a lot in terms of how we utilize land in a sustainable manner, utilize resources, and save the environment.

To understand why land cover change occurs, we must examine how land use changed in 2013, 2016, 2019, and 2022, as seen in (Figure 6a, b, c). These graphs present information regarding land use trends, including how city expansion, flora, water, and spaces develop over time. Identifying these trends assists in making sound decisions regarding city planning, conservation, and wise use of resources. Monitoring these trends also enables one to view how city expansion, agriculture, deforestation, and climate shifts impact land. All of this information is useful in developing future change prediction models and enables decision-makers to prepare for future challenges and develop strategies for minimizing potential future environmental concerns. With such information, one can closely monitor land use trends and make sound policies, guiding development in a healthy, not destructive, manner. Ultimately, such an analysis enables a healthy balance between development and conservation, and healthy and strong cities result.

Normalized difference vegetation index

NDVI values may vary due to numerous factors, such as clouds, atmospheric changes, varying light conditions, and direction of observation. All these can render the information ambiguous. In order to interpret the information appropriately, ArcMap 10.8 software was utilized to extract and classify cover types in the study area, placing them in various densities for various cover types. Figures 7a, b, c, d indicate processed images that visually depict these categories. NDVI values range from –1 to 1. High values near 1 indicate healthy and dense cover, while values near –1 indicate uncovered areas, such as water, bare ground, and buildings. With this classification, valuable information regarding cover and its relationship to environmental changes and land use can be derived over time.

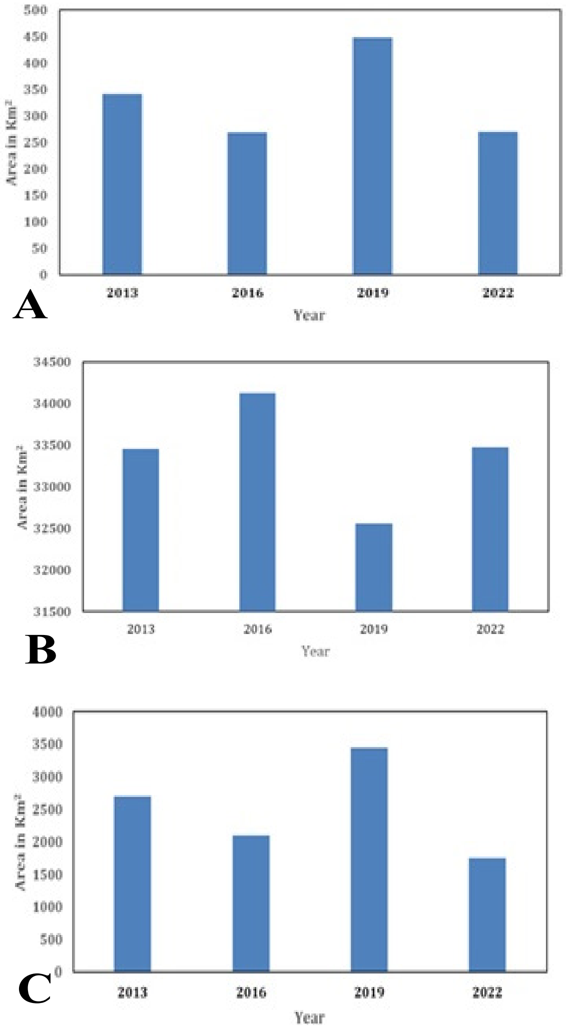

Figure 6: *Change in water and wetland (A), non-vegetation (B) and vegetation (C).*

Discussion

The observation of NDVI values over the years presented in the study reveals significant changes in cover in the region. As indicated in Figure 7a, c, NDVI values increased in 2013 and 2019, with significant cover increase in both years. Figures 7b, d, on the other hand, indicate a decline in NDVI values in 2016 and 2022, with reduced cover in comparison to the previous years. These changes occurred due to numerous factors, such as weather, changing seasons, human activities associated with urban growth, urban migration, and agricultural activities.

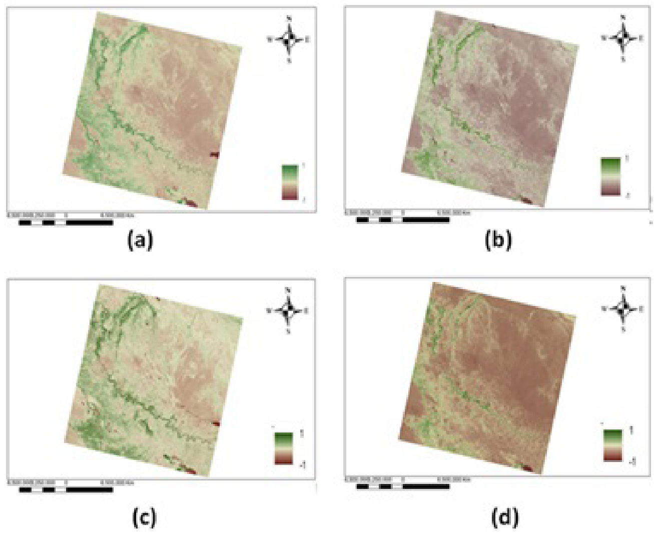

Figure 7: *a, b, c, d image classification using NDVI in 2013, 2016, 2019 and 2022.*

The largest cause of these changes was the impacts of conflicts in the nation, particularly the war against ISIS, which significantly destroyed the environment. Destruction of buildings and infrastructure resulted in a loss in urban areas, impacting land cover. There was a significant reduction in water bodies except in 2019 most likely due to variations in water management and issues with water supply systems, as indicated in Figure 6a. There was a significant loss of cover in 2016, with more bare land appearing. All these factors disrupted the balance of the environment, resulting in a significant change in the climate of the region.

One important consequence of having less cover is an increased number of dust storms. With less cover, the ground erodes, and big chunks can simply blow off in the wind. That creates a larger number of dust storms, and these can hurt the environment and humans' health in surrounding regions. Learning about these trends can contribute towards planning for utilizing the land and minimizing future damage to the environment.

Acknowledgement

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Novelty Statement

This study employs remote sensing techniques to examine vegetation cover in the city of Al-Khalis. It conducts a new assessment of temporal vegetation change and provides valuable insights to inform local environmental planning and sustainable land use.

Author’s Contribution

Israa Abdulqasim Mohammed Ali: Writing review and editing, formal analysis, data curation, supervision, investigation.
ALZahraa Haider Hasan: Data curation and investigation.
Raghda Ihsan Lafta, Murad Musaab Adel and Ali M. Mozan Al-Koaerji: Investigation, validation.

Summary
The Normalized Difference Vegetation Index is a commonly used tool for evaluating land surface greenness, as it shows a positive relationship with the density of green vegetation in a specific pixel area. This study utilized Landsat-based NDVI data from remote sensing imagery to estimate vegetation cover in Al-Khalis city for the years 2013, 2016, 2019, and 2022. The results reveal that vegetation cover peaked in 2013, indicating an increase in green areas. However, by 2022, there was a notable decrease in vegetation, resulting in more barren and exposed land. These changes underscore the dynamic nature of land cover alterations over time, shaped by both natural and human influences.

Conflict of interest
The authors have declared no conflict of interest.

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