Utilizing Remote Sensing Techniques to Analyze and Select the Optimal Site for Establishing a Sustainable Green Belt along the Baghdad–Karbala Pilgrims Route

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Abstract:

Green belts are an important environmental solution for combating desertification and mitigating the effects of climate change, especially in arid and semi-arid regions such as Iraq. This research aims to identify the optimal locations for establishing a sustainable green belt along the Baghdad-Karbala Road, using remote sensing, satellite, and geographic information systems (GIS) techniques. This road represents a vital axis witnessing rapid urban expansion and a major route for millions of pilgrims during the Arbaeen pilgrimage. This places significant pressure on the local environment and infrastructure, necessitating science-based planning interventions to ensure sustainable visitor services. Satellite imagery (such as Landsat 8 and Sentinel-2) from the recent period (2023–2024) was used, and a set of spectral indices, including the NDVI (Natural Color Vividness Index), the BSI (Aridity Index), and the NDMI (Natural Color Moisture Index), were applied to assess the environmental condition of the lands adjacent to the road. The terrain was also analyzed using a digital elevation model (DEM) to determine the appropriate slopes and levels for agriculture, taking into account factors such as wind direction and speed, the level of urban expansion, and nearby groundwater or surface water sources. A multi-criteria decision analysis (MCDA) methodology was adopted within a GIS environment to identify the most suitable areas, with each criterion weighted according to its environmental and logistical importance using the Analytic Hierarchy Process (AHP) method. The analysis results showed that the areas located southwest of Latifiya city and north of Alexandria are among the environmentally promising areas for establishing a green belt. These areas recorded the highest values in NDVI and the lowest in BSI, with flat terrain and relative proximity to water sources. The study also demonstrated that the areas within Babil Governorate

adjacent to the road have a high potential for transformation into green spaces if properly managed, using drought-resistant plants and low-water-consumption agricultural methods. The study recommends integrating the results of this analysis into regional sustainable development plans, particularly in light of the importance of the Million Pilgrimage Route. It also proposes involving stakeholders and local communities in the design and implementation to ensure the environmental and social sustainability of the project.

Keywords: Million-Pilgrimage Crowds - Visitor Services - Arba'een Pilgrimage - Remote Sensing and Satellites - Sustainable Development

Introduction

Green belts are among the most important sustainable environmental solutions that contribute to combating desertification, improving air quality, and mitigating the effects of climate change. This is particularly true in areas with high population density and intense human activity, such as the road linking Baghdad and Karbala, which witnesses a massive influx of people during religious occasions, particularly during the months of Muharram and Safar. This road represents a strategic axis not only from a religious and social perspective, but also in terms of its environmental and economic impact. It is a vital corridor witnessing urban expansion and increased activity, which has led to a significant deterioration of vegetation cover, increased pollution rates, and rising surface temperatures. Given the importance of this reality, the need to adopt smart environmental strategies based on sustainable development principles is essential. These strategies aim to rehabilitate the local environment by establishing a green belt extending along this road. This green belt provides a healthy and safe environment for visitors and local residents, and serves as a natural barrier to counter desertification and mitigate the impact of dust storms. In this context, remote sensing and geographic information systems (GIS) techniques have proven highly effective in analyzing environmental conditions and monitoring spatial and temporal changes in biosphere components. These technologies enable researchers to obtain accurate spatial data and analyze it using advanced tools to assess the natural and environmental characteristics of the land, such as soil type, vegetation indices (NDVI, SAVI), surface temperatures (LST), topography, slope trends, proximity to water sources, and infrastructure such as road and service networks. Selecting the optimal site for establishing a green belt is a complex process that requires the use of these advanced analytical tools to ensure a balance between environmental efficiency and economic and social feasibility. The focus on the road linking Baghdad and Karbala in particular stems from the symbolic and strategic importance of this route, as it represents a religious landmark visited by millions of visitors annually. This exposes it to increasing environmental pressures, requiring careful, scientifically based environmental planning interventions. By combining data from multispectral satellite imagery, such as Sentinel-2 and Landsat 8, with spatial analysis in a GIS environment, an integrated spatial model can be constructed to help identify the most environmentally and logistically suitable areas for green belt development, taking into account climatic, hydrological, topographic, and social factors. Spatial analysis based on overlay analysis and multi-criteria decision analysis (MCDA) techniques is an ideal method for supporting environmental planning decision-making by weighing criteria and evaluating different scenarios quantitatively. Furthermore, implementing a sustainable green belt requires not only identifying the appropriate location, but also understanding the dynamics of the surrounding ecosystem, assessing the soil's ability to support vegetation, the availability of water resources, and the types of plants suitable for the local environment, while taking into account expected long-term climate change. Hence, this research aims to build an integrated scientific basis for analyzing and selecting the best proposed sites for establishing a sustainable green belt along the pilgrims' route between Baghdad and Karbala. This research relies on remote sensing data analysis and geographic information systems, within a scientific framework that combines environmental vision and spatial planning. This is in pursuit of achieving sustainable development goals of preserving the environment, improving the urban landscape, supporting the green economy, and serving pilgrims by providing a more comfortable and safer environment along this vital route. The importance of the study also lies in the possibility of generalizing the proposed model to other Iraqi regions suffering from similar environmental conditions, making this project a pioneering experiment in employing modern technology to serve environmental and development issues in Iraq and the region.

Previous Studies

Recent years have witnessed increasing interest in the application of remote sensing and GIS technologies in the planning and implementation of environmental projects, particularly in the field of establishing green belts and combating desertification. Abdul Karim et al. (2019) highlighted the importance of integrating multispectral satellite imagery with GIS in identifying environmentally degraded areas and identifying suitable sites for expanding vegetation cover in urban and peri-urban areas. In a similar study, Hamid (2020) examined the role of the Normalized Vegetation Index (NDVI) in monitoring the degradation of agricultural lands adjacent to highways, emphasizing that changes in vegetation cover can be accurately monitored through time series analysis of satellite data. Al-Dulaimi (2021) used Sentinel-2 and Landsat 8 data to analyze land surface temperatures (LST) and identify areas most vulnerable to the urban heat island phenomenon, proposing the creation of dense vegetation strips to mitigate this phenomenon. This aligns with the objectives of green belts in peri-urban areas such as the Visitors' Road. On the other hand, Al-Shammari and Al-Hashemi (2022) presented an applied study on selecting optimal locations for green belts around the city of Najaf, using overlay analysis and hydrological analysis to identify areas with high potential for cultivation, with a focus on the availability of water resources and soil type. The study demonstrated the effectiveness of the multi-criteria data analysis (MCDA) model in supporting environmental decision-making. Youssef et al.'s (2023) study also examined the relationship between population density and the decline in environmental indicators along urban roads, noting the importance of creating buffer green spaces to improve air quality and reduce visual and noise pollution. At the regional level, Faraj et al.'s (2021) study examined the green belt project around Riyadh in Saudi Arabia. Data from topography, soil, and vegetation cover were used to construct a spatial model to select optimal locations. The study confirmed that the availability of water resources is the most influential factor in the success of these projects in arid environments. Despite the numerous studies that have addressed the topic of green belts, few have focused on vital religious corridors with intensive seasonal use, such as the pilgrims' road between Baghdad and Karbala. This gives this study its importance, as it represents the first attempt to apply remote sensing techniques to analyze the environmental characteristics of this vital road and select green belt sites based on a precise, systematic spatial analysis that takes into account the religious, social, and environmental specificities of the site.

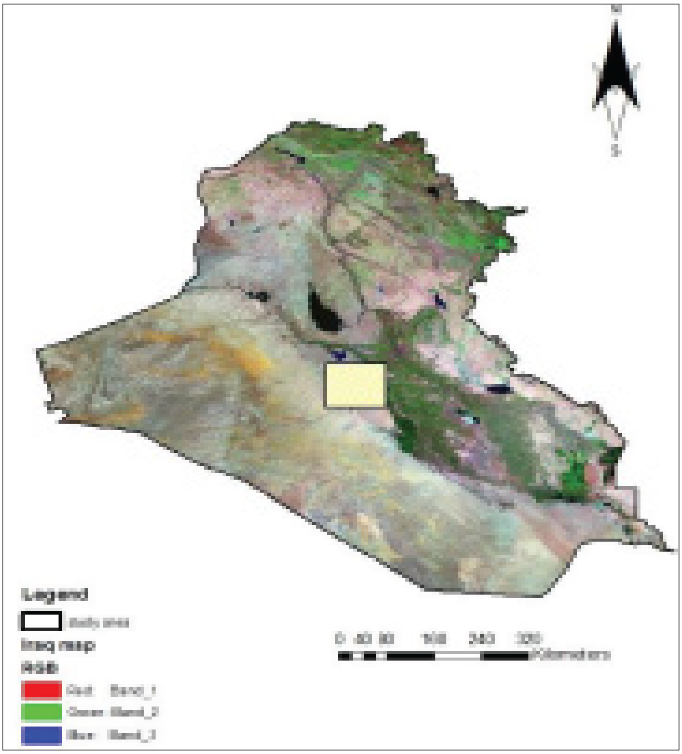
Sustainable Green Belt

The sustainable green belt is one of the most important modern environmental solutions to address the growing challenges facing the urban environment, such as deteriorating air quality, rising temperatures, desertification, and loss of biodiversity. A green belt is a planted area of trees and plants established around or within cities and along vital roads to create a natural environmental barrier that limits the negative impacts of human activities and climatic factors. The sustainability of the green belt lies in its reliance on integrated scientific planning that takes into account environmental characteristics and available resources. It is designed to ensure the long-term sustainability of its environmental function without depleting natural resources. Studies show that green belts contribute to reducing the heat island phenomenon, improving air quality by absorbing pollutants and dust, reducing noise, and stabilizing soil, as well as enhancing the psychological health of residents by providing recreational green spaces. In urban environments with arid and semi-arid climates, such as Iraq, the need for these belts increases due to the limited natural vegetation cover. To design an effective green belt, the importance of employing remote sensing and geographic information systems (GIS) techniques has emerged as key tools for analyzing and evaluating the spatial and environmental characteristics of the target area. Satellite imagery can monitor vegetation indices such as NDVI and SAVI, analyze land surface temperatures (LST), determine soil type, slopes, and topographic trends, and analyze proximity to roads and water sources. Spatial analysis techniques such as overlay and multi-criteria decomposition analysis (MCDA) can also be used to evaluate various factors and identify optimal locations for establishing the belt. With this scientific approach, it is possible to design green belts that are not limited to aesthetic functions but also play a pivotal role in enhancing urban sustainability and mitigating the effects of climate change. This makes the project to establish a sustainable green belt along the Baghdad-Karbala pilgrims' road a strategic step from the environmental, social, and economic levels.

Study Area

The study area extends along the road linking the cities of Baghdad and Karbala, known locally as the "Pilgrims' Road" due to the heavy traffic it witnesses during religious occasions, particularly the Arbaeen pilgrimage. This road is approximately 100 kilometers long, extending from the south-western suburbs of Baghdad, through the Latifiya and Musayyib districts, to the northeastern entrances to Karbala. The region is characterized by its geographical and climatic diversity, as it lies within the desert and semi-arid zone, suffering from high temperatures in the summer and low annual rain-fall rates, in addition to the increasing deterioration of natural vegetation due to human activities and uncontrolled urban expansion. The region is also located within an alluvial plain and is covered with clayey and sandy soils of varying characteristics, affected by seasonal winds and dust storms, which directly impact air quality and the health of pilgrims. The pilgrims' route is a strategic axis linking two important religious and cultural centers in Iraq. It traverses agricultural and environmentally degraded areas, making it an ide-al model for studying the impact of environmental and human factors on the selection of green belt sites. Administratively, the study area extends with-in the borders of Baghdad and Babil governorates, reaching the holy city of Karbala. It encompasses both rural and urban areas, providing a diverse environment for analyzing topographical and environmental factors using remote sensing and geographic information systems (GIS) techniques..

Figure (1): location of the study area from Iraq.



Data Source and Processing

This study adopts an integrated spatial analysis methodology that combines Remote Sensing (RS) and Geographic Information Systems (GIS) to evaluate the environmental and topographical characteristics of the study area and to identify the optimal location for establishing a sustainable green belt. The methodology begins with the acquisition of satellite imagery for different time periods covering the years 2000 to 2024, with a spatial resolution of 30 meters. These images were obtained from Landsat 5 and Landsat 8 sensors via the USGS Earth Explorer platform (http://earthexplorer.usgs.gov/), as detailed in Table (1). All imagery was selected from the spring season to minimize the effects of abandoned or uncultivated lands, which may otherwise distort classification accuracy and affect the Normalized Difference Water Index (NDWI) values. In addition to Landsat data, high-resolution Sentinel-2 MSI imagery (10-meter resolution) was utilized to extract vegetation indices (NDVI) and monitor Land Surface Temperature (LST). Furthermore, a Digital Elevation Model (DEM) with 30-meter resolution was employed to generate slope and aspect maps and conduct terrain analysis. Secondary data such as official soil maps provided by the Iraqi Ministry of Agriculture, administrative boundary layers, road networks, and surface water sources were also integrated into the GIS environment (ArcGIS Pro 3.2). These data layers were analyzed through a multi-criteria spatial model using Overlay Analysis and Multi-Criteria Decision Analysis (MCDA). A set of environmental criteria—including soil type, proximity to roads, distance from water sources, slope, aspect, NDVI, and LST—were assigned relative weights using the Analytic Hierarchy Process (AHP) based on their ecological and logistical relevance to green belt development. The weighted overlay tool was then applied to produce a spatial suitability map categorizing the area into high, moderate, and low potential zones for green belt establishment. To validate the spatial analysis, field visits were conducted at selected sites using an unmanned aerial vehicle (UAV) equipped with a multispectral camera, enabling documentation of actual vegetation cover and land conditions. The final results were reinforced through comparative analysis between recent aerial imagery and field-collected data, ensuring the reliability of the site selection process."

Table (1): Type and specification of satellite images used in the study.

Rank	Satellite type	Sensor	Date
1	Landsat-5	MSS/TM	2000/3/17
2	Landsat-8	OLI/TIRS	2024/3/11

After obtaining Landsat images many processors have been performed using GIS 10.6 like geometric correction was done using the (Map to Image) method, depending on map with known geographic coordinates, where all the features have known a projection system that is similar to the corrected map used in the debugging process and radiometric correction was performed using ERDAS Version 14.00.0. Then many bands of satellite images were composite to produce (RGB) image with false color for both sensors (TM, OLI) and the bands used for the composite are shown in table (2) then calculated of Normalized Differences Water Index to diagnose and determine the water cover from other type covers with high accuracy.

Table (2): composites bands of satellite image (RGB).

Resolution	TM	OLI/TIRS	Color
30	Band-7	Band-7	Red
30	Band-4	Band-5	Green
30	Band-2	Band-3	Blue

False colour images (RGB) that produced from the composite bands as shown in figure (2)

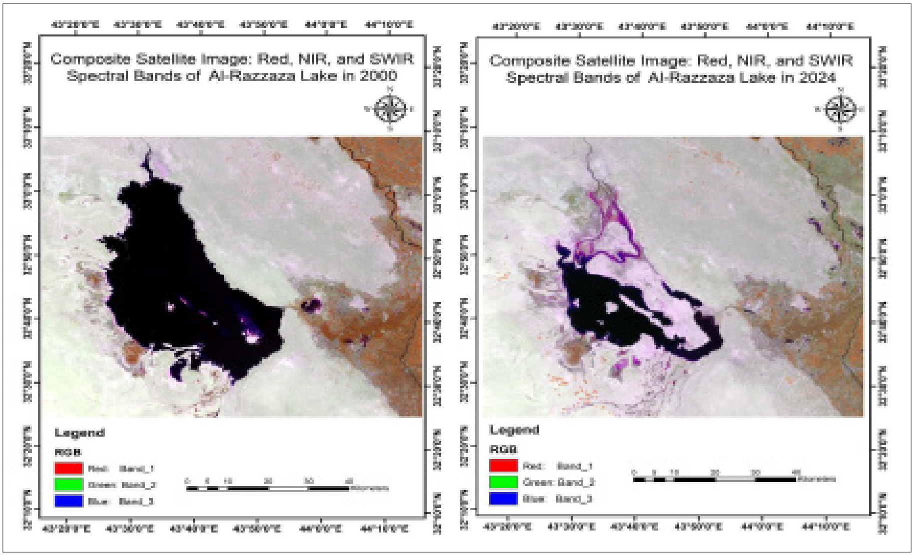


Figure 2: The pre-processed satellite images of the study area.

Result and discussion

1.Visual Interpretation:

The initial stage of image analysis involved visual interpretation of the false color composites generated from selected spectral bands. This step relied on well-established principles in remote sensing, including the interpreter's experience, the spectral properties of the satellite sensors, and the temporal context of image acquisition. In the context of the present study, visual interpretation was conducted using key image elements such as size, shape, texture, tone/color, and spatial pattern, in order to identify and distinguish land cover types and surface features relevant to the planning of the sustainable green belt along the Baghdad–Karbala pilgrim's route. This qualitative assessment facilitated the preliminary understanding of the spatial distribution of vegetation, water bodies, bare land, and anthropogenic features, thus guiding the subsequent quantitative classification phase.

2.Image Classification:

Image classification refers to the process of categorizing a digital satellite image into distinct land cover classes based on spectral similarity among ground features. In this study, both supervised and unsupervised classification techniques were evaluated; however, the supervised classification method was adopted due to its higher accuracy and reliance on ground-truth data. This method involves selecting representative training samples for each land cover type, based on field observations, high-resolution imagery from Google Earth, and expert knowledge. These training sites serve as reference points for the classification algorithm to label the entire image accordingly.

The classification process was executed using ArcGIS 10.6, where the Maximum Likelihood Classifier (MLC) was applied to Landsat satellite imagery for the years 2000 and 2024. The final classification results divided the study area into six major land cover categories: Vegetated areas, Water bodies, Bare land, Sand dunes, Gypsiferous soils, Wetlands, and Saline areas. Post-classification refinement was performed to correct misclassifications and enhance the accuracy of the outputs. Furthermore, spatial statistics were generated to quantify the area covered by each class, enabling a comparative analysis of land cover dynamics over the selected temporal window. The classified maps are presented in Figure (3) and provide crucial input for identifying degraded or potentially restorable areas suitable for green belt development.

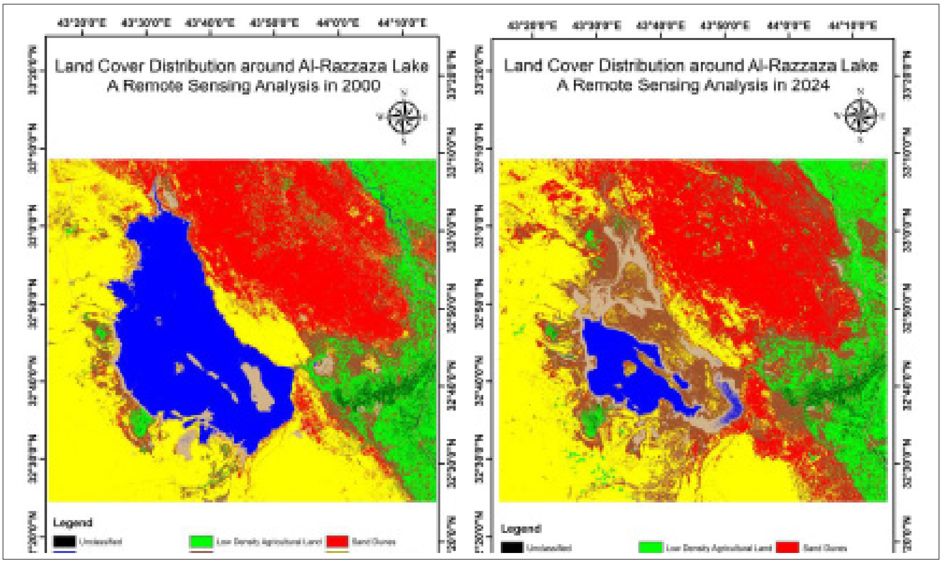


Figure 3: Image classification of land cover of TM and OLI Images 2000 on left and 2024 on right.

Table (3): Land cover areas in (Km2)

Date of image	Vegetation area	Gypsiferous	Bare land	Water bodies	Sand area	Saline area
17/03/2000	892.62	784.04	2676.73	1286.19	1748.44	279.47
11/03/2024	947.85	1727.32	2403.51	320.41	1839.15	429.26

The figure (4) The temporal variation in the land cover areas during the extended period (2000-2024) using supervised classification.

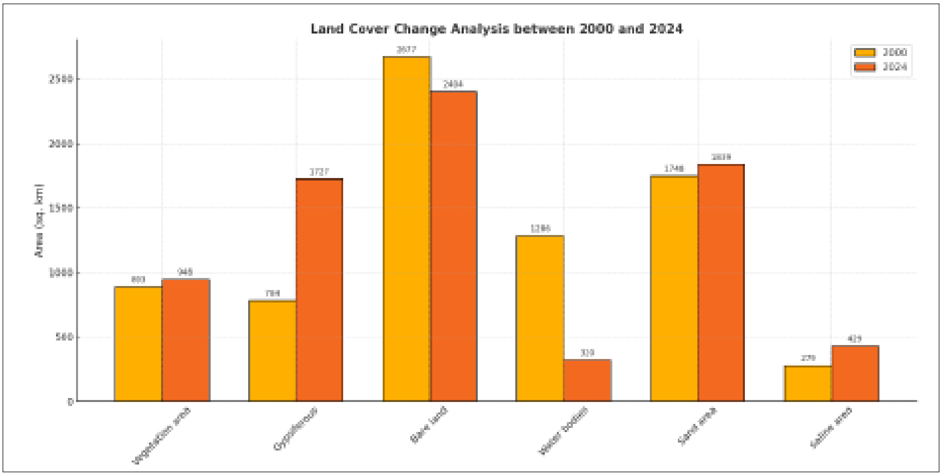


Figure (4): The changing in the land cover areas during the extended period (1985-2018).

3.Normalized Difference Water Index (NDWI):

The Normalized Difference Water Index (NDWI) is a spectral index used to detect and delineate water bodies based on their unique spectral behavior. Water surfaces exhibit strong reflectance in the green wavelength and significantly low reflectance in the near-infrared (NIR) region, which forms the foundation of the NDWI calculation. The index values generally range between –1 and +1, where positive values typically indicate the presence of surface water such as lakes, rivers, and canals, while negative values correspond to non-water features, including vegetation, bare soil, and built-up areas.

NDWI plays a critical role in isolating water bodies from adjacent land cover types, particularly in areas where spectral reflectance of water may overlap with moist soils or vegetation. It is widely applied in water body mapping, drought monitoring, and change detection studies due to its sensitivity to variations in water content over time. The index also assists in minimizing classification errors caused by spectral similarity between water and other dark features.

NDWI is calculated using the following standard formula:

$$NDWI = \frac{R\_green - R\_nir}{R\_green + R\_nir} \ldots\ldots\ldots \quad (1)$$

In this study, NDWI was computed using ArcGIS 10.6 based on Landsat imagery. The derived NDWI values were analyzed to assess the spatial and temporal distribution of water bodies across the study area. The maximum and minimum NDWI values extracted from the processed satellite images are presented in Table (4), highlighting the extent and variability of surface water features for further interpretation and mapping accuracy.

The NDWI was calculated using GIS 10.6, the highest and the lowest value for the NDWI index are shown in table (3).

Table (4): The highest and lowest NDWI values .

Date	highest value of NDWI	lowest of value NDWI
2000/3/17	0.908	-0.916
2024/3/11	0.395	-0.861

The results in the following figures show the spatial distribution of NDWI values. Unsupervised classification was applied upon NDWI and the results were shown in figure (6). It shows only the areas containing water such as the channels and Al- Razza Lak

The area of water cover was calculated in each image taken in the table (5).

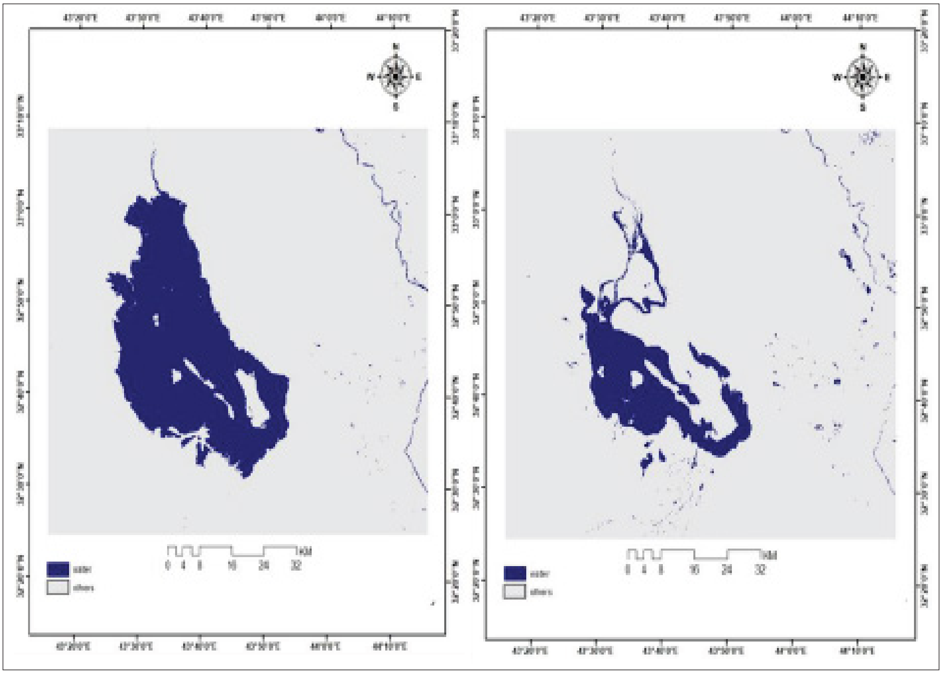


Table (5): Area of water cover extracted from NDWI in (Km2).

Date of image	Area of water cover in (Km2).
2000/3/17	1453.24
2024/3/11	502.76

Based on the outcomes of the Multi-Criteria Decision Analysis (MCDA), which integrated remote sensing data and Geographic Information Systems (GIS), several areas along the Baghdad–Karbala pilgrims route were identified as highly suitable for establishing a sustainable green belt. The spatial suitability map indicated that the most promising zones are concentrated in the central and southern sectors of the corridor, particularly between Al-Yusufiyah and Al-Musayyib districts. These areas are characterized by favorable environmental conditions, including gentle slope gradients, proximity to water sources, well-drained sandy-loamy soils, and moderately lower land surface temperatures (LST). In addition, the accessibility of these areas via the main road network makes them ideal for implementing green infrastructure projects with ease of maintenance and resource delivery.

The supervised classification of Landsat satellite imagery for the years 2000 and 2024 revealed marked changes in land cover dynamics within the study area. Six primary land cover classes were identified: Vegetation areas, Gypsiferous lands, Bare lands, Water bodies, Sand areas, and Saline soils. Quantitative analysis showed the following trends:

- Vegetation cover increased slightly from 892.62 km^2 in 2000 to 947.85 km^2 in 2024 (+55.23 km^2).
- Gypsiferous areas showed a substantial rise from 784.04 km^2 to 1727.32 km^2 (+943.28 km^2).
- Bare lands decreased from 2676.73 km^2 to 2403.51 km^2 (–273.22 km^2), suggesting a shift in surface classification likely due to erosion or surface transformation.
- Water bodies underwent a sharp decline from 1286.19 km^2 to 320.41 km^2 (–965.78 km^2), highlighting a significant reduction in surface water availability.
- Sand areas increased modestly from 1748.44 km^2 to 1839.15 km^2 (+90.71 km^2), indicating ongoing aeolian activity and sand encroachment.
- Saline soils expanded from 279.47 km^2 to 429.26 km^2 (+149.79 km^2), suggesting increasing salinization in low-lying or poorly drained zones.
- The decline in water bodies is further supported by NDWI analysis, which showed reduced positive index values, signifying diminished surface moisture. Concurrently, NDVI trends indicated only slight improvements in vegetation health, reinforcing the necessity for targeted ecological intervention.

These findings underscore the environmental vulnerability of the region and highlight the strategic importance of implementing a sustainable green belt. The green belt should be established in transitional zones between degraded and agricultural lands, where ecological restoration is feasible. It is recommended that drought- and salt-tolerant species be planted, supported by modern irrigation technologies such as drip systems and the reuse of treated water, to ensure long-term viability and maximize ecological impact.

4.Spatial Description of the Proposed Green Belt Site:

The proposed location for the sustainable green belt along the Baghdad–Karbala pilgrims route was identified through spatial suitability modeling and multi-criteria spatial analysis using remote sensing and GIS tools. The study area lies in the central region of Iraq, extending southwest from Baghdad to the city of Karbala, and intersects a range of environmental and administrative zones, including the districts of Al-Yusufiyah and Al-Musayyib. These areas were classified as highly suitable zones in the suitability map, primarily due to their favorable topographic and environmental conditions, such as low slopes, well-drained sandy to loamy soils, moderate land surface temperatures, and proximity to both surface and subsurface water resources.

The spatial framework of the proposed site also includes:

- The core alignment of the pilgrims route, which shows significant ecological stress, including vegetation degradation and signs of advancing desertification.
- High-suitability zones, highlighted in light green on the spatial map, located particularly within Al-Yusufiyah and Al-Musayyib areas, where natural conditions align well with the requirements for successful green belt establishment.

- Moderate-suitability zones, extending both north and south of the core route, offering transitional buffer areas to support ecological continuity and landscape integration.
- The main road network and identified water bodies are also illustrated on the map, emphasizing the logistical advantages for transportation, irrigation infrastructure, and future maintenance operations.

These spatial features collectively support the strategic selection of this corridor for the green belt, offering not only environmental restoration potential, but also logistical feasibility for implementation. The accessibility of the area via established roadways and its interface with degraded and agricultural lands make it an ideal candidate for an ecologically functional and socioeconomically viable green infrastructure intervention.

Conclusions and Recommendations

The results of this research demonstrate the importance of employing remote sensing and geographic information systems (GIS) techniques in analyzing environmental changes and identifying optimal locations for sustainable development projects, such as the green belt along the pilgrims' road between Baghdad and Karbala. Spatial analysis of satellite imagery during the period (2000–2024) revealed a clear decline in water bodies and the continued expansion of sandy and saline areas, with a slight improvement in vegetation cover in some areas. By applying a multi-criteria dynamics analysis (MCDA) model, high-priority areas for green belt planting were identified, particularly in the central section of the road in the Yusufiyah and Musayyib areas, where suitable environmental and logistical conditions are available. Based on the above, the research recommends the following:

1. Adopt a strategic plan for establishing a green belt based on the results of the spatial analysis, starting with the most environmentally suitable areas.
2. Use local plant species that are resistant to drought and salinity to ensure sustainable vegetation cover and reduce maintenance costs.
3. Rely on alternative water sources, such as treated wastewater or water harvesting techniques, to address the shortage of surface water.
4. Integrate the project into the National Plan to Combat Desertification and Climate Change, given its direct impact on improving air quality and reducing temperatures.
5. Expand the study to include other important routes in Iraq, especially those that witness human activity or heavy seasonal pilgrimage.
6. Adopting these recommendations will contribute to transforming this vital route into a sustainable environmental model, enhancing the social, economic, and health value of the area, and establishing a culture of smart environmental planning in Iraq.

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