Employing Remote Sensing Technologies in Greenbelt Design and Combating Desertification: A Case Study of Baqubah District

Raad W. Al-zuhairi[1*], Abdulrahman B. Ali[2], Myasar R. Zaman[1], Ghassan Kamil khorsheed[3]

[1]Department of Horticulture and Landscape, College of Agriculture, University of Diyala, Iraq.
[2]Remote Sensing Unit, College of Science, University of Baghdad, Baghdad, Iraq.
[3]College of Science, University of Diyala, Iraq.

*Corresponding author: raadalzuhairi@uodiyala.edu.iq

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Abstract

Urban expansion and climate change in semi-arid regions have exacerbated environmental degradation in many cities. Baqubah, a city in eastern Iraq, like other areas in the country, has experienced changes in land use and a decline in vegetation cover. This study aims to identify optimal locations and technical requirements for establishing a sustainable greenbelt system in Baqubah District using an integrated geospatial approach. Vegetation dynamics were evaluated using the Normalized Difference Vegetation Index (NDVI), while thermal conditions were assessed through Land Surface Temperature (LST). Land use/land cover (LULC) was classified into five types using the maximum likelihood algorithm. Agricultural land is concentrated around watercourses in the central and northeastern regions, covering 74 square kilometers. Arable land appears in the southwest and east, covering 47 square kilometers, indicating its potential for development within the Green Belt project. Climatic variables were spatially fitted using the Inverse Distance Weighting (IDW) method. A spatial fit model was developed using the Analysis Hierarchy Process (AHP) and weighted superposition analysis. Land surface temperature was calculated from a thermal range of 29.8°C to 41.3°C, with the highest values (above 40°C) concentrated in urban and exposed areas. Areas with dense vegetation recorded relatively low temperatures (below 34°C), reflecting the effect of vegetation in reducing surface temperature. A spatial suitability map for establishing a green belt in the northern and northeastern areas of Baqubah district has been identified, characterized by favorable conditions including heavy rainfall (>170 mm), moderate humidity (>50%), low temperatures (<41°C), and high vegetation cover index values.

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Introduction

With a major number of arid and semi-arid regions facing problems of land degradation and desertification on the face of the earth, land degradation and desertification are some of the most pressing issues of environmental concern, these processes are a complex interaction between the climate variability, decreasing water resource, booming population growth and unsustainable land-use activities (Liu *et al.,* 2014; Phiri *et al.,* 2018). These changes in the environment are not only making the land less productive, but also causing ecological disequilibrium, loss of biodiversity and socioeconomic turmoil. In dry regions, vegetation is very important in ensuring stability in the ecosystem. Reduction in precipitation, increase in temperature and the rate of evapotranspiration in most instances result in drastic vegetation degradation and soil erosion. Such conditions often lead to more severe dust storms and a decrease in the productivity of agriculture (Dikici and Aksel, 2021).

Over the last few decades, climate change, water scarcity, land mismanagement practices have led to the further degradation of the environment in the Middle East and Iraq specifically (Hamad *et al.,* 2022). These environmental pressures have been increased further through urbanization. Increased land use has also led to drastic changes in land use in most cities as a result of rapid population increase and growing infrastructure. The growth of the urban areas in some Iraqi cities has taken place, which causes the disappearance of agricultural lands and natural vegetation (Fazaa *et al.,* 2022; Jasim *et al.,* 2020). Urban greenery is very important in enhancing the environmental status in urban areas. Green infrastructure will be able to enhance air quality, minimize dust levels, and control urban microclimates. The effect of vegetation cover on urban heat islands is demonstrated by a variety of studies that conclude that it can alleviate the problem of land surface temperatures, which occurs due to the evapotranspiration and shading of vegetation cover (Zhou *et al.,* 2018). These plans have been made the key elements of the global sustainable urban planning policies. Environmental change can only be monitored and appropriate sites taken where ecological restoration can be achieved through the use of sophisticated analytical tools that are able to measure spatial and temporal environmental processes. Remote sensing tools offer useful data that can help a researcher to track the vegetation dynamics, identify the land-use change, and examine the environmental degradation in a vast area (Phiri *et al.,* 2018). The vegetation indicators gathered with the help of satellite observations include the Normalized Difference Vegetation Index (NDVI), which has become one of the most popular techniques to measure vegetation health and distinguish dense vegetation, stressed vegetation, and bare land surfaces (Dikici and Aksel, 2021) Multi-temporal satellite images, especially Landsat and Sentinel images, are reliable in providing information on long-term information of land-cover and environmental trends. Satellite-based global observations have shown a substantial alteration in vegetation dynamics, which is the result of climate variability and human actions (Peng *et al.,* 2022). Based on the foregoing, remote sensing technology is a crucial tool for monitoring environmental changes and ensuring sustainable land management. For example, land surface temperature (LST) analysis contributes to the analysis of urban climatic conditions. Studying vegetation density using the NDVI and correlating it with ground surface temperature highlights the importance of implementing vegetation-based planning solutions to mitigate urban heat stress. Improvements in land use and coverage mapping have been further enhanced by the development of supporting vector machine algorithms (SVMs) and machine learning algorithms, including Maximum likelihood classification (MLC), (Peiman, 2011; Thakkar *et al.,* 2017).

The Analysis Hierarchy Process (AHP) and weighted overlay analysis are examples of analytical methods that have been prevalently used to determine the best sites to plan ecological restoration and green infrastructure. There is an enhancement of remote sensing and Geographic Information Systems (GIS) application in analyzing environmental change, the degradation of vegetation, and urban expansion in Iraq. A number of studies have been able to find the application of the geospatial technologies as useful to perform environmental monitoring and land management in Iraqi cities (Al-Ramahi *et al.,* 2024). More recently, applied research studies have been conducted on the integration of sustainability assessment frameworks and spatial planning methods in an attempt to support environmentally responsible urban development (Jasim and Al-Zuhairi, 2025). Equally, GIS-based spatial analysis has been applied to determine the appropriate green space in the urban development strategy in the Iraqi cities (Nassif *et al.,* 2020). Most available studies focus on environmental monitoring rather than developing accurate spatial planning models that consider environmental indicators, climate variables, and land-use dynamics. This research paper will employ an integrated geospatial framework combining remote sensing and GIS analysis to assist in planning sustainable Green Belt in Baqubah District. Specifically, examine the spatial and temporal changes in vegetation cover and will identify optimal locations for the creation of the green belt through multi-criteria spatial analysis, can provide a framework to support decision-making regarding climate-resilient Green Belt planning and sustainable environmental management in arid and semi-arid urban environments.

Materials and Methods

1. Research framework

This paper adopted a combined geospatial modelling framework in determining the best sites to develop a sustainable greenbelt in Baqubah District, Diyala Governorate, Iraq. It is a mixture of the remote sensing analysis, climatic modelling, spatial statistics and multi-criteria decision analysis (MCDA) using the AHP. The process involved six major steps: Data acquisition Image preprocessing Obtaining environmental indicators (NDVI, LST, and Land use/land cover (LULC)). Interpolation of climatic data. AHP standardization and weighting of criteria. Spatial suitability modelling and validation. All the spatial analyses were done by ArcGIS 10.8 and ENVI 5.3 in a single spatial reference system (WGS 84, UTM Zone 38N).

2. Greenbelt tree selection criteria

The most suitable selection of trees for greenbelts in semi-arid regions like Iraq, to achieve the goals of storm mitigation, air purification from dust and pollutants, and climate improvement, depends on several criteria, most importantly environmental and climatic criteria. These criteria include the ability to withstand water scarcity, high summer temperatures, and soil salinity (Khudair *et al.,* 2025). Furthermore, the trees must have deep taproots to ensure stability and protection from dust storms, along with a strong structure that can withstand strong winds. Maintenance and operational criteria, such as growth rate, must also be considered. Fast- to medium-growth trees are preferred to establish the greenbelt in a shorter time (Ali *et al.,* 2026). Water consumption: Low or moderate water consumption plants should be selected to suit available resources and drip irrigation systems.

The computer software CorelDRAW Graphics Suite 2021 was used to depict how effective wind breaks would be on the basis of wind speed, wind direction, and tree height during the last phase of map creation. The computer software CorelDRAW Graphics Suite is a vector graphic design software produced by the Corel Corporation in 1989. The eleven different versions of the computer software include features that can improve the readability of drawing objects.

3. Study area description

The study area falls under the category of semi-arid, with hot summers and cold winters, accompanied by large variations in the temperatures of both seasons. The summer is very hot at temperatures above 45°C, whereas the winter is cold, sometimes having temperatures below 5°C. July and August represent the hottest months, while January and February constitute the coldest months. Regarding precipitation, there are large variations in the annual rainfall, falling between 150 and 300 mm in the year and mainly occurring during the winter season, which includes the period from November to March. It means that the rain-fed agricultural system depends on such rains to a small degree. Furthermore, the region suffers from strong northerly winds that blow in summer, increasing evaporation levels. Additionally, it experiences easterly winds and sandstorms in spring and autumn. Topographically, the study area lies within the undulating plain region of Iraq and is characterized by a nearly flat surface, with some slight variations in elevation, as the terrain slopes from the northeast to the southwest. The general elevation of the region ranges from 40 to 150 meters above sea level. Most of Baqubah's lands are silty clayey, making them suitable for agriculture. However, some areas suffer from soil salinity and poor drainage, especially in areas close to water bodies or with limited slopes. The Diyala River also runs through the region from the northeast to the southwest, constituting an important water resource for agricultural activity, despite its fluctuations in flow due to climate change and weak water releases from the source. These climatic and topographical characteristics directly impact the deterioration of vegetation cover and the increased fragility of the region's ecosystem, making it vulnerable to desertification. Therefore, understanding these determinants is essential for developing sustainable strategies for planning and establishing Green Belt and identifying the area's most in need of environmental intervention.as showing in Figure 1.

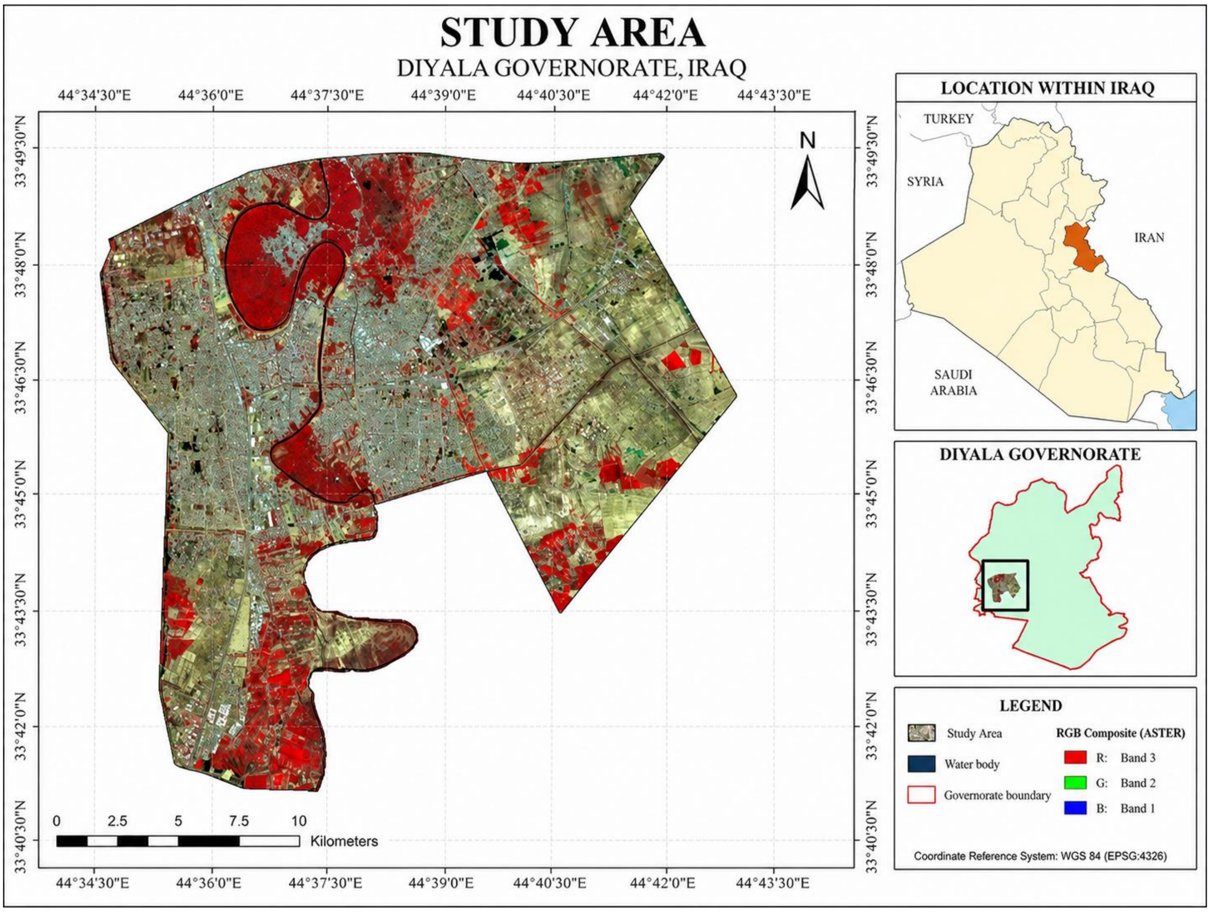

Figure 1. The study area located in Diyala Governorate, eastern Iraq

4. Data Sources

4.1. Remote sensing data

The ASTER satellite imagery (July 2023) was employed because it is the most appropriate for identifying the highest intensity of vegetation stress and thermal difference in summer. The information in the dataset is multi-spectral and their spatial resolutions are: Visible and Near-Infrared VNIR: 15 m SWIR: 30 m TIR: 90 m. The chosen scene can be taken as a source of the highest levels of environmental stress, which allows determining damaged and overheated areas that can be used in greenbelt planning.

4.2. Climatic data

NASA Giovanni (NASA GES DISC) was used to get long-term climatic data (1994-2024). The climatic variables that were extracted were: Maximum temperature Minimum temperature Rainfall Relative humidity Wind speed the spatial climatic variability affecting vegetation growth and environmental suitability was evaluated using these variables.

5. Image pre-processing

To guarantee accuracy and comparability of data, the pre-processing of satellite imagery took into account a number of standard uses. These included radiometric calibration to transform the digital numbers to spectral radiance, atmospheric correction based on the FLAASH model and geometric correction so as to get the imagery aligned with geographic coordinates. All data sets were transformed to the surface reflectance values and resampled to a uniform 30 m square spatial resolution through bilinear interpolation to ensure spatial concordance amongst raster layers. The Land Use/Land cover Classification was developed to classify the land as either residential or non-residential land. The supervised classification algorithm was the Maximum Likelihood Classification (MLC) to classify the LULC. There were five major land cover classes that were identified: Urban areas Agricultural land Water bodies Arable land Bare or abandoned land The accuracy of classification was checked with the 120 validation points based on high-resolution satellite images and on-site observations. Its outcome showed the overall classification accuracy of 89.3%, and Kappa coefficient of 0.86, which confirmed that the classified and reference data were in strong agreement.

6. Vegetation analysis

The conditions of vegetation were measured by the NDVI which was computed as, (Ali *et al.,* 2026):

$$NDVI = \frac{(\rho NIR - \rho RED)}{(\rho NIR + \rho RED)} \ldots . (1)$$

NDVI values range from -1 to +1, with negative values indicating non-vegetated surfaces such as water bodies and urban areas. Values between 0.2 and 0.5 represent poor to moderate vegetation cover, and values above 0.5 indicate dense and healthy vegetation. In this study, ASTER satellite imagery was used to calculate NDVI across Baqubah District. This aims to identify environmentally degraded areas with declining vegetation density. This helps in developing a preliminary map to identify areas requiring urgent environmental intervention and select the most suitable sites for establishing Green Belt.

7. Land Surface Temperature (LST)

In this study, land surface temperature was analyzed using ASTER satellite images, which provide high-resolution thermal bands used to calculate LST at appropriate spatial resolution. The ASTER thermal infrared subsystem consists of five bands, ranging from Band 10 to Band 14, with a spatial resolution of 90 m. These bands cover the spectral range from 8.125 to 11.65 µm and are commonly used for retrieving land surface temperature and analyzing surface thermal characteristics. The results were also correlated with field and climatological data to identify the areas most affected by heat stress within Baqubah District.

LST is calculated by analyzing satellite temperature bands, after performing a series of radiative and spectral transformations, starting from raw digital numbers (DN) and ending with the actual temperature in °C. The equations used vary depending on the satellite type, but the general principles remain similar and are applied as follows, (Ali *et al.,* 2026):

$$\boldsymbol{S_T} = \frac{T_B}{1 + \left(\frac{\lambda \times T_B}{\rho}\right) \times Ln\ \varepsilon} - 273.15 \ldots\ldots (2)$$

Where:
S_T= land surface temperature in °C.
T_B= brightness temperature in Kelvin.
λ= wavelength of the thermal band.
ρ= physical constant.
ε= land surface emissivity.

8. Climatic Data Interpolation

Climatic Data Interpolation Data interpolation is a technique applied when the inexperienced climatologists carry out research, which necessitates the estimation of the missing data points. The Inverse Distance Weighting (IDW) tool was used to perform spatial interpolation of the climatic variables. This method estimates unknown values using a weighted effect of surrounding points of observation with the near points having higher effects as compared to distant ones. The IDW method has been extensively applied in environmental modelling owing to its efficiency in representing the spatial variability of climatic parameters.

9. Criteria Standardization

The environmental layers were standardized into four levels of suitability scale to make evaluation across multi-criteria possible: Suitability Level Class Highly suitable 1 Moderately suitable 2 Marginally suitable 3 Unsuitable 4 The classification boundaries were established based on environmental conditions of soil ecology that are favourable to the growth of vegetation in semi-arid conditions. 2.9 AHP weighting and Multi-Criteria Modelling. The method used to measure the relative importance of each criterion was the AHP suggested by Saaty (1980) which uses pairwise comparison matrices to calculate the importance of the various criteria. Criteria Weights Criterion Weight NDVI 0.28 LST 0.22 Rainfall 0.18 LULC 0.15 Relative Humidity 0.09 Wind Speed 0.08 The ratio of consistency of the pairwise comparison matrix was CR = 0.07 (< 0.1), which reveals that it has acceptable logical consistency. The last suitability index was done by a weighted overlay model, (Ali *et al.,* 2026):

$$S = \sum_{i=1}^{n} (W_i \times X_i) \ \ldots . (3)$$

where:
S= suitability index.
W_i= weight of criterion i.
X_i= standardized score of criteria i.
n= total number of criteria.

10. Spatial Statistical Analysis

The spatial statistical analysis is concerned with issues of clustering, association, and causation, among others. To measure the patterns of space suitability zones, spatial statistical measures were implemented. The analysis included: Mean Center Standard Distance Elipse of Standards Deviation. The spatial autocorrelation of space as given by Moran spatial autocorrelation, according to the criteria and relative weights, the most important of which are the Feature to convert linear data into Euclidean Distance Raster, Reclassify or Standardize - Structural Model, Weighted Overlay, Standardization Model Builder. All layers were standardized according to the raster grid system at a uniform spatial resolution, and then the Weighted Overlay method was applied using the Analytical Hierarchy Model (AHM), equation 3, (Ali *et al.,* 2026), method to determine the relative importance of each factor according to its impact on vegetation growth and combating desertification.

$$W_i = \frac{\sum_{i=1}^{n} z\,(x_i) \times d_{ij}^{-p}}{\sum_{i=1}^{n} d_{ij}^{-p}} \dots\dots\dots (4)$$

The suitability levels were defined into four categories (high, medium, weak, unsuitable) based on the synthetic output of the model.

Results and Discussion

1. Spatial analysis of climatic factors

In order to assess the climatic features of Baqubah District, the long-term climatic data were accessed via the NASA GES DISC database that offers climatic data collected by satellites on the whole globe over the timeframe (1994-2024). The climatic variables under analysis were four major variables, including maximum temperature, minimum temperature, rainfall, and relative humidity. These variables were analyzed in a GIS-based environment by the IDW interpolation method to create a spatial distribution of the variables, which allowed spatial climatic gradients in the study region to be identified. The spatial distribution of climatic variables is depicted in Figure 2 as a result.

Figure 2A indicates the distribution of average maximum temperature over space, with the highest temperature of over 44 °C in the eastern and southeastern regions of the study area. The feature of these areas is low vegetation cover and vast open areas, which adds to the augmentation of heat and the impact of urban heat islands. Conversely, lower temperatures (less than 41 °C) are found in the northwestern regions, which are indications of the relatively mild environmental conditions with a high vegetation cover.

On the same note, the minimum temperature spatial distribution Figure 2B has minimum temperatures of 15.9 °C to 19.5 °C and cooler regions are in the western and southwestern sections of the district. There is better ventilation in these areas and reduced urban density. The increase in minimum temperatures is also localized in the east sectors, implying that there is local accumulation of nocturnal heat with urban growth.

The distribution of precipitation is 112.5mm- 207.9mm Figure 2C with large amounts of 112.5mm and 207.9mm found in the eastern and northeastern sectors respectively. Such regions are good environments where vegetations can be established and hence, it is a good area to develop greenbelts. On the other hand, the central and southern regions have rather smaller rainfall amount which is associated with semi-arid conditions which might necessitate additional irrigation to support vegetation prosperity.

Relative humidity distribution Figure 2D ranges with values of 44.3 and 57.4 with most humidity concentration being in the south east and north west sectors of the study area. These relatively wet micro climates offer more favorable environments to support the growth of vegetation in comparison with the drier central and eastern parts.

These climatic layers were then included in the multi-criteria spatial suitability model that was developed in this study. In the framework of the AHP, the rainfall, relative humidity, and temperature were regarded as the most important environmental factors affecting the possibility to grow vegetation in semi-arid environments. All climatic variables were made standard and given a relative weight on the basis of their ecological importance.

After being weighted, the climatic layers were then integrated into other environmental factors, like NDVI, LST, and LULC, to come up with the final spatial layers for the assessment of greenbelt suitability. As shown in Figure 7, the results of greenbelt suitability have shown that the northern and northeastern parts of the Baqubah District will become the best suitable areas for greenbelt development. This is due to the fact that these locations are characterized by ideal climatic factors, greater vegetation potentials, and minimal thermal stress levels.

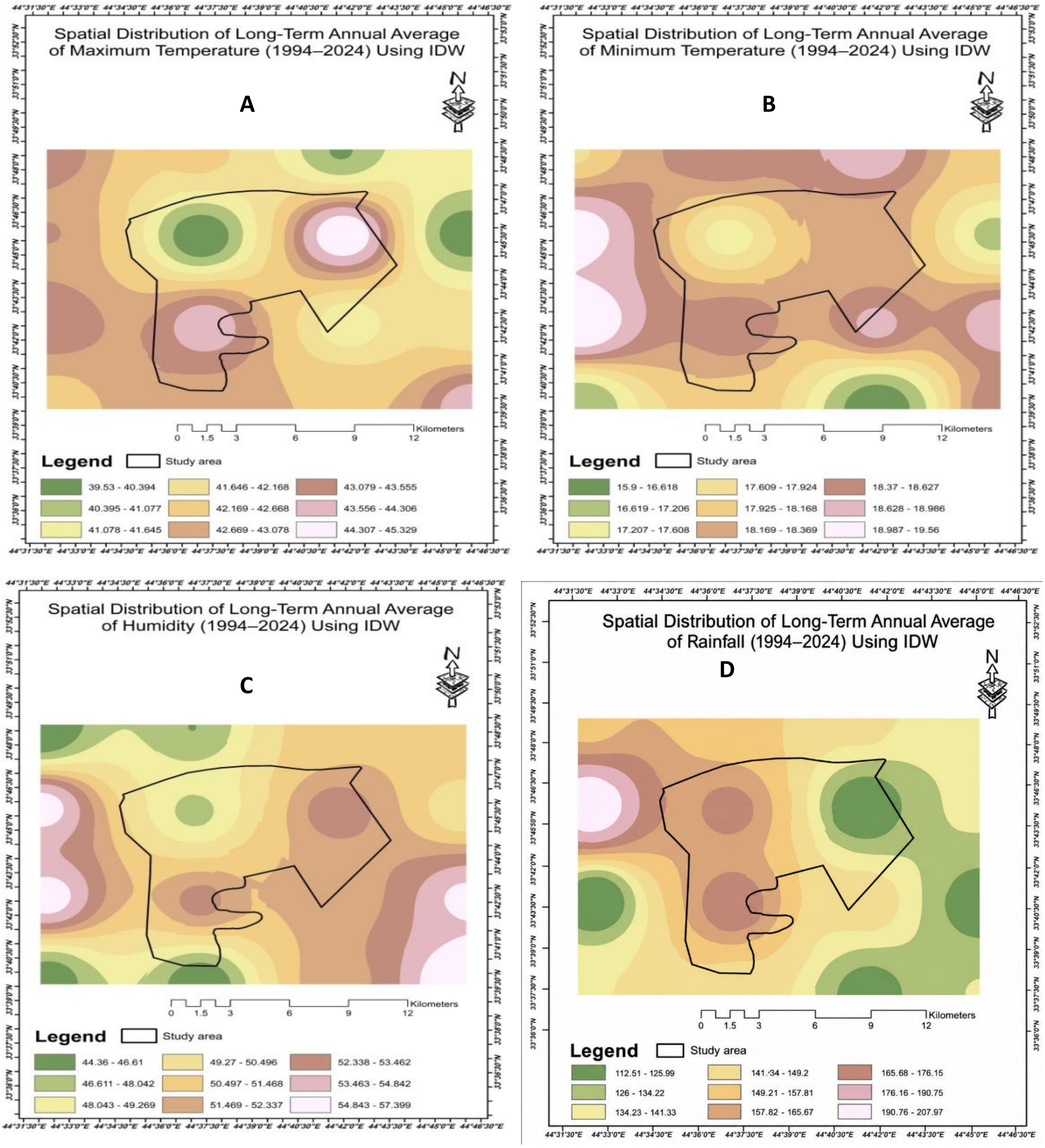

Figure 2. Spatial Analysis of Climatic Variables in Baqubah District (1994–2024) Using IDW Interpolation

A- Spatial Distribution of Long-Term Annual Average of Maximum Temperature. B- Spatial Distribution of Long-Term Annual Average of Minimum Temperature. C- Spatial Distribution of Long-Term Annual Average of Relative Humidity. D- Spatial Distribution of Long-Term Annual Average of Rainfall. These maps provide a comprehensive spatial understanding of the climatic conditions in Baqubah, which are critical for guiding ecological planning and greenbelt development.

The polar diagram (Wind Rose) in Figure 3 shows the wind directions in Baqubah District. The prevailing winds during the period under study originated primarily from the northern (N) and northeastern (NE) sectors, recording the highest relative frequency compared to the other directions. Wind frequencies, however, are significantly lower in the southern and western directions, indicating the dominance of a relatively regular wind pattern from north to south. In light of these results, wind direction is a crucial factor in selecting the optimal location for the Green Belt. Establishing the belt opposite the prevailing wind direction achieves an important protective environmental function by intercepting winds laden with dust and pollutants, repelling sand encroachment, and reducing the impact of dust storms on urban and agricultural areas. Therefore, the northern and northeastern parts of Baqubah District are the most suitable areas for establishing the Green Belt, as they will form a natural protective vegetation barrier that isolates the city from sources of pollution and dry winds coming from the north. This contributes to improving air quality, reducing wind erosion, and minimizing the negative environmental impacts resulting from desertification or unplanned urbanization. When these results are combined with spatial analysis of environmental indicators (NDVI, LST, LULC) and climatic factors (humidity, rain, temperature), it becomes possible to define a precise and scientific spatial scale for establishing an effective and sustainable Green Belt.

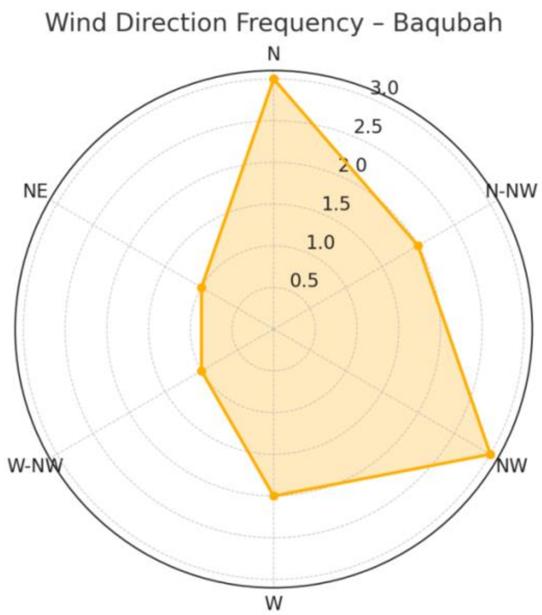

Figure 3. Prevailing Wind Direction Frequency in Baqubah District (1994–2024)

2. Spectral analysis of remote sensing indices (NDVI, LULC and LST)

The spectral and spatial indices were examined in order to find out the environmental features of the investigated land using the NDVI, LULC, and LST. They played an important part in determining the degree of impact on the process of desertification and vegetation deterioration. Their assessment is important for the analysis of surface environmental dynamics and selection of Green Belt locations.

As shown in Figure 4, the NDVI values in Baqubah District were classified by an undirected method and varied between -0.26 and +0.71 and included five classes. Low NDVI values are depicted in red/yellow colors (NDVI<0.15). These low values refer to urbanized, exposed, and environmentally degraded land that occupies most areas of the center and south of the investigated area. High NDVI values (>0.4) are marked in dark green and cover the eastern and southwestern parts of the district; they refer to orchards and irrigated agriculture. Such data indicate vegetation poverty in large areas of the district.

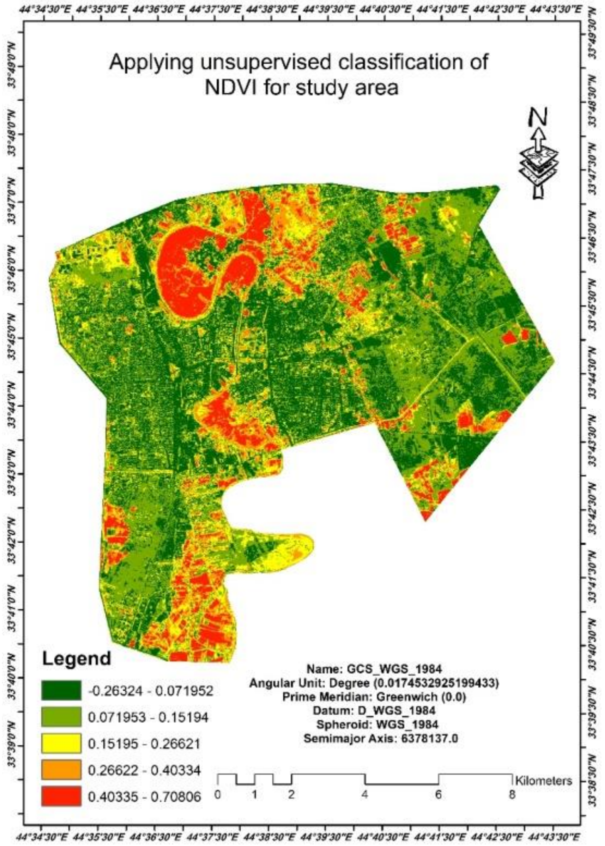

Figure. 4. Unsupervised Classification of NDVI for Baqubah District: Spatial Assessment of Vegetation Cover

Land uses within Baqubah District were classified using MLC into five main types: Agricultural Land, Urban Areas, Water Bodies, Arable Land, and Bare and Abandoned Land. As illustrated in Figure 5, urban areas (red) represent the dominant land cover, especially in the central and north-western parts of the study area, with an extent of approximately 142 km², reflecting substantial urban expansion. Agricultural lands (light green) are concentrated around waterways in the center and northeast, where they constitute 74 km^2, reflecting the dependence of agriculture on proximity to water sources, which constitute 22 km^2. Arable lands (orange) appear in the southwest and east, which constitute 47 km2, indicating the potential for development within the Green Belt Project. Abandoned lands (yellow/brown) are spread across many areas, forming 104 km2, and are a major target for environmental reclamation and a pivotal objective in the Green Belt strategy.

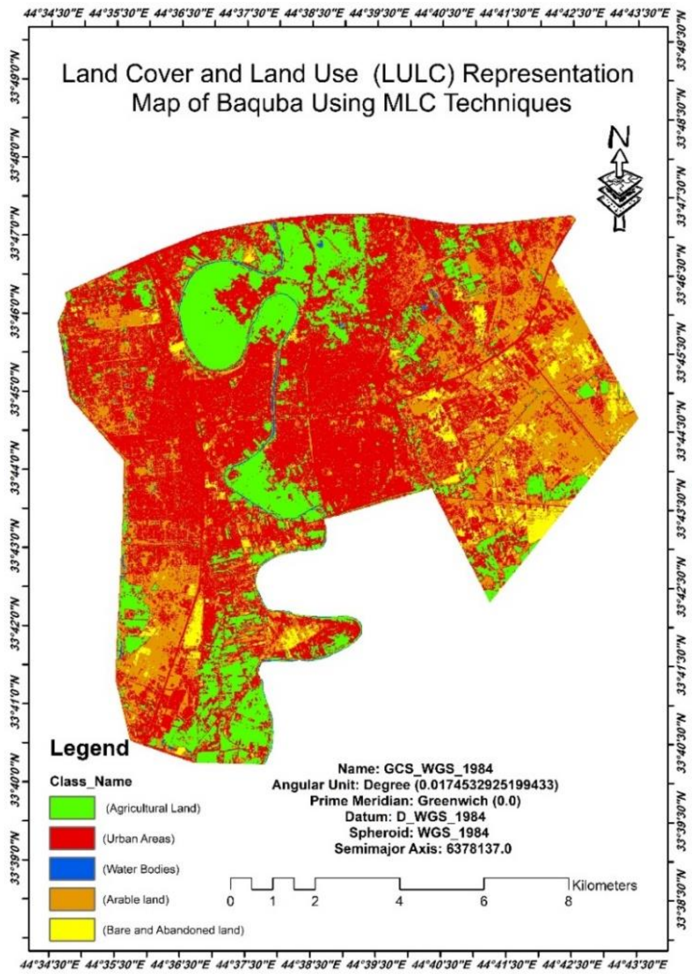

Figure 5. Land Use and Land Cover (LULC) Classification Map of Baqubah District Using Maximum Likelihood Classification (MLC)

For thermal analysis, the land surface temperature was calculated from the satellite image's thermal band. The LST map Figure 6 showed that the thermal values ranged between 29.8°C and 41.3°C, with the highest values (>40°C) being concentrated in urban and exposed areas. This corresponds to the urban and exposed areas, as seen in the NDVI and LULC maps. Areas with dense vegetation cover showed relatively lower temperatures (<34°C), reflecting the effect of vegetation in reducing surface temperature. This analysis confirms the inverse relationship between NDVI and LST, with temperatures increasing in locations lacking vegetation.

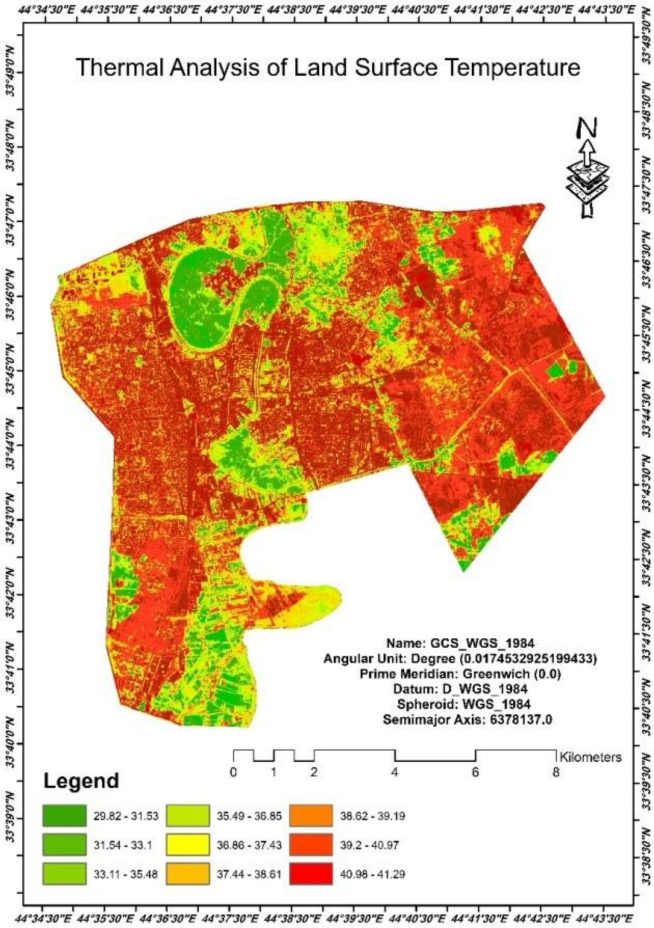

Figure 6. Land Surface Temperature (LST) Map of Baqubah District: Thermal Analysis Using Remote Sensing Data

3. Spatial Suitability Model for Green Belt Locations

The development of an integrated spatial suitability model was done through the Weighted Overlay method in a GIS environment on the basis of AHP to ascertain the relative significance of climatic and spectral environmental factors. The model included these factors maximum and minimum temperature, rainfall, relative humidity, wind speed, NDVI, LULC and LST. The variables were all standardized and turned into similar raster layers and then incorporated into the multi-criteria spatial analysis.

The resultant suitability map identified four categories of the study area namely highly suitable, moderately suitable, marginally suitable, and unsuitable areas as presented in Figure 7. The regions of high suitability are predominantly located in the northern and northeastern regions of the Baqubah District, and the favorable conditions that exist there are a higher rainfall (>170 mm), moderate humidity (>50%), lower temperatures (<41 o °C), and high NDVI values. On the contrary, moderate and marginal suitability areas are found in the central and southern regions and are usually connected with degraded agricultural lands or growing cities. The inappropriate areas are clustered at the southwestern part, which is highly surface temperature, with low humidity and vegetation cover.

The spatial analysis of statistics based on Global Moran I showed a value of 0.41 ($p < 0.05$) which means that there is a significant clustered spatial presence of high-suitability regions (Moran, 1950; ESRI, 2024). This validates that the power centers of greenbelt development are spatially clustered especially in the north and northeastern parts of the district.

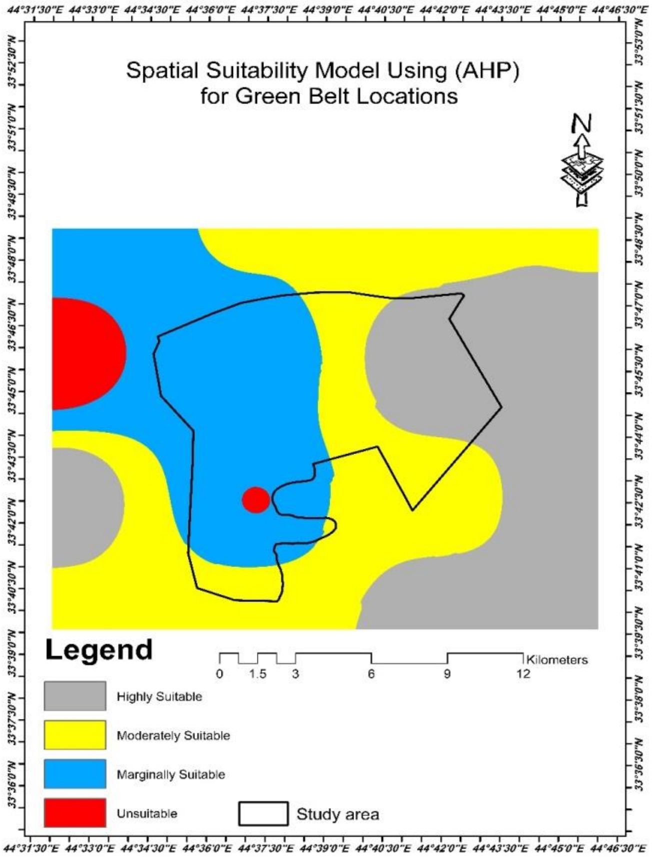

Figure 7. Spatial Suitability Model for Green Belt Development in Baqubah District Using AHP and Weighted Overlay

The Table 1 shows the suggested vegetative species that can be used to develop the Baqubah greenbelt. The chosen species are highly adjusted to semi-arid types of climatic conditions and they have different degrees of drought and salinity resistance that are the main environmental limitations in the Diyala Governorate. These species are tall trees, medium trees, shrubs, and ground cover plants which have a combined effect on protecting the wind, stabilizing the soil, and restoring the ecology.

According to the designed greenbelt as showing in Figure 8, the planting requirements were approximated (i.e., the length of the belt was about 20 km) whereby tall trees had a spacing of 3m, medium trees had a spacing of 4m and the shrubs had a spacing of 1.5m. Under these assumptions, it can be estimated that the total size of woody plants needed would be between 57,000 to 67,500 plants without taking into consideration service corridors and 63,000 to 75,000 plants with modifications as indicated in Table 1.

It is hoped that these species choices will help to optimize windbreak performance, stabilize the soil, and increase the ecological integrity, which will promote the sustainability of the proposed greenbelt system in the long run.

Table 1. Proposed Plant Species Suitable for Baqubah Greenbelt

Category	Scientific Name	Common Name	Height (m)	Salinity Tolerance	Drought Tolerance	Primary Function
Tall trees	*Eucalyptus camaldulensis*	River Red Gum	15–25	Moderate	High	Primary windbreak
Tall trees	*Tamarix aphylla*	Tamarisk	10–18	High	Very High	Salinity resistance

Tall trees	*Casuarina equisetifolia*	Casuarina	12–20	Moderate	High	Wind stabilization
Medium trees	*Melia azedarach*	Chinaberry	8–12	Moderate	Moderate	Shade provision
Medium trees	*Ziziphus spina-christi*	Christ's Thorn Jujube	6–10	High	High	Ecological & economic value
Shrubs	*Atriplex halimus*	Saltbush	1–2	Very High	Very High	Soil stabilization
Shrubs	*Nerium oleander*	Oleander	2–4	Moderate	Moderate	Visual barrier
Ground cover	*Cynodon dactylon*	Bermuda Grass	<1	Moderate	Moderate	Soil fixation

The quality standards in irrigation water were established according to the FAO standards on the use of agricultural water (Ayers and Westcot, 1985). Electrical conductivity (ECw), total dissolved solids (TDS), was used to determine salinity hazard but sodium adsorption ratio (SAR) and Residual sodium carbonate (RSC) was used to measure sodicity and structural degradation in soils. Strict limits can be imposed on semi-arid regions such as Baqubah District where the minimum allowed ECw of the irrigation water should be 3.0 dS/m or SAR exceeds 9 such that only salt resistant species can be deployed, drainage system should be enhanced and crops should be leached periodically as Table 2 shows.

Other ion-specific parameters such as sodium (Na^+), chloride (Cl^-) and boron (B) were included because they have a direct impact on phytotoxicity of woody species used in shelterbelt systems. These parameters are specific and specifically monitored when the treated wastewater or marginal-quality water sources are observed as irrigation sources. With these standards in place, there will be proper alignment between the long-term sustainability of greenbelts and internationally established standards of irrigation management (Ayers and Westcot, 1985).

Table 2. Recommended irrigation water parameters

Parameter	Acceptable Range	Critical Threshold	Recommendation
EC (dS/m)	1–3	>4	Preferably <3
pH	6.5–8.0	>8.5	Adjustment if necessary
SAR	<6	>9	Monitor sodicity risk
TDS (ppm)	<2000	>3000	Monitor salinity
Bicarbonate (meq/L)	<3	>5	Risk of precipitation

Soil suitability criteria were defined according to internationally recognized guidelines for irrigated and afforestation systems (FAO, 1990; USDA-NRCS, 2014). Sandy loam to loam textures were identified as optimal due to their balanced water-holding capacity and aeration properties, which are essential for root development in shelterbelt species. Soil electrical conductivity (ECe) values below 4 dS/m were considered acceptable for most moderately salt-tolerant tree species, while higher values require leaching and drainage interventions to mitigate salinity stress (FAO, 1990).

Soil pH values between 6.8 and 8.2 were deemed suitable for nutrient availability and microbial activity. Slight alkalinity is typical of soils in Baqubah District; however, pH levels exceeding 8.5 may limit phosphorus and micronutrient availability. Adequate effective soil depth (>80 cm) is critical for root anchorage and drought resilience, particularly in windbreak systems exposed to strong seasonal winds (USDA-NRCS, 2014). Organic matter content above 1% enhances soil structure, infiltration, and long-term fertility, supporting sustainable greenbelt establishment, as Table.3.

Table 3. Recommended Soil Properties for Greenbelt Establishment

Property	Suitable Range	Remarks
Texture	Sandy loam – Loam	Optimal aeration
pH	7.0–8.2	Slight alkalinity typical of Baqubah soils
EC (dS/m)	<4	Leaching required if higher
Organic Matter	>1%	Compost addition recommended
Soil Depth	>80 cm	Suitable for tree root systems
Permeability	Moderate	Avoid poor drainage

Sources: FAO (1990); USDA-NRCS (2014).

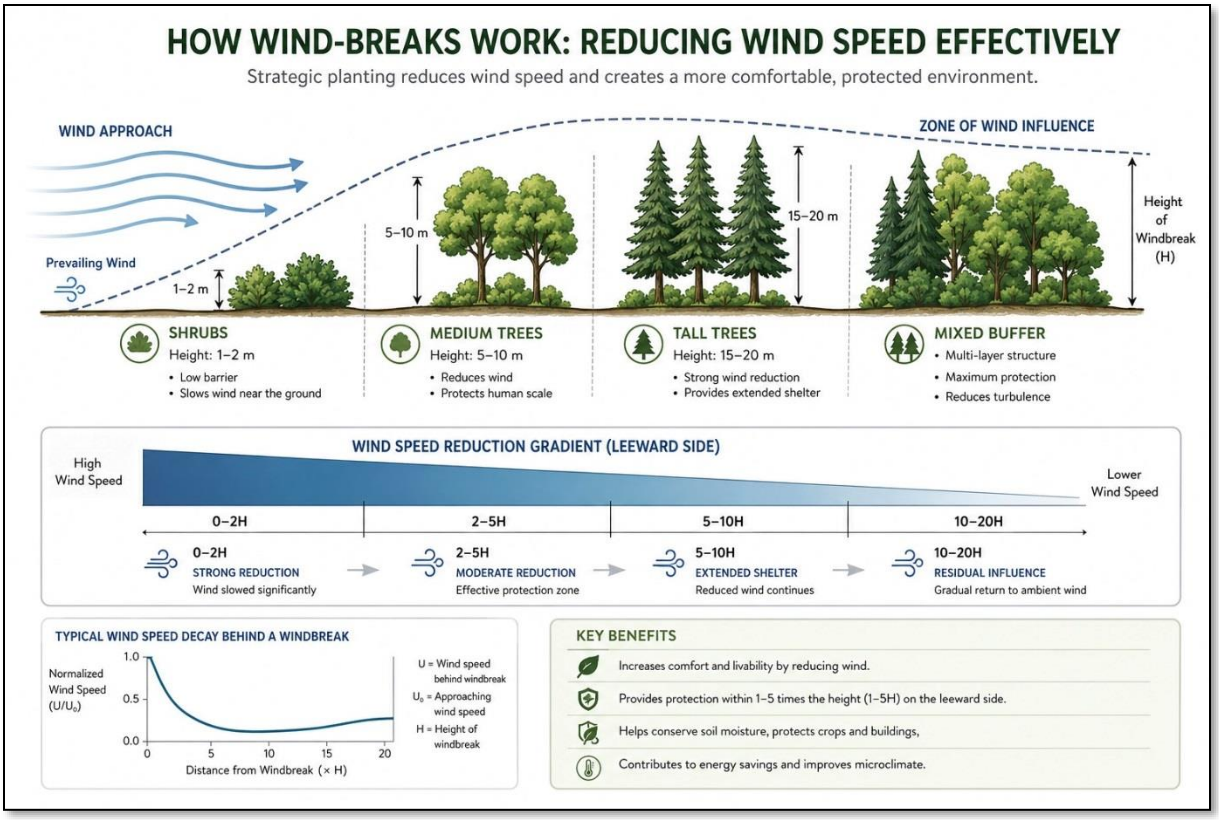

Figure 8. Diagram created using CorelDRAW software to illustrate the effectiveness of windbreaks based on tree height, wind speed, and direction

Conclusions

The environmental analysis of the area using the climatic indicators resulted in noticeable environmental differences between various sectors of Baquba. The north and northeast sectors emerged as the best-suited locations for green belt establishment due to more favorable conditions, such as higher humidity levels, moderate temperatures, and agreement with wind direction. As for the results of spectral analysis of the environmental characteristics utilized, a positive relationship between NDVI values and the temperature of the earth surface was established. High NDVI is associated with cooling of the earth surface, which proves the relevance of implementing the suggested idea of green belt to counteract climate changes. Spatial suitability models based on AHP provided efficient identification of the optimal locations for implementation of the green belt based on integration of climatic, spectral, and land use criteria within one model. The proposed green belt is intended to be 20 km long with a width between 120 m and 180 m; its installation can bring several environmental advantages, including decreased wind velocity, dust storms, cooling, and soil erosion prevention. The long-term effectiveness of the project depends on sustainable soil and water management practices, the selection of drought and salinity-resistant species, and the implementation of an effective irrigation system.

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Conflict of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper .

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Author Contribution

R. W. Al-zuhairi and A. B. Ali, write the original draft, M. R. Zaman and G. K. khorsheed, assisted in gathering in gathering official information from official departments. author edit and finalize the manuscript. All authors read and agree to the submission of the manuscript to the journal.

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