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Research Paper

Relationship between vegetation cover and land surface temperature in Basra, Iraq

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ABSTRACT

This study aims to assess the changes in vegetation cover and its relationship with land surface temperature from 1990 to 2024 in Basra Governorate, southern Iraq. Satellite images from Landsat 5 and 8, in addition to remote sensing and GIS tools, were used to analyze the changes in vegetation cover and their effects on land surface temperature (LST). Non-supervisory classification based on normalized difference vegetation index (NDVI) threshold values was used to classify vegetation cover into four classes. The results showed a significant decrease in dense vegetation cover from 4.8% in 1990 to 1.0% in 2024. It was also noted that non-vegetation areas increased, rising from 67.4% in 1990 to 79.3% in 2024. In winter, dense vegetation decreased from 4.5% in 1990 to 0.8% in 2024, and non-vegetation areas increased from 67.5% to 79.7%. In addition, the coefficient of determination decreased from 0.11 in 1990 to 0.06 in 2024, indicating a decline in the effect of vegetation cover on the surface temperature of the earth due to rapid urban expansion, which contributes to climate change. The study emphasizes the need .to develop strategies to preserve the environment and reduce the effects of desertification and climate change in Basra

Keywords: NDVI, Vegetation cover, Land surface temperature, Climate change, Iraq

Climatic conditions are closely associated with plant development and adaptation and thereby ecosystem. Climate change is a major cause of vegetation change. Vegetation responses to climate change vary widely across locations and seasons (Khalil *et al.,* 2023; Sajan *et al.,* 2023). As an indicator of vegetation cover, the Normalized Differential Vegetation Index (NDVI) is widely used because it provides an accurate assessment of vegetation growth, biomass, photosynthetic activity, and cover (Al-Salihi *et al.,* 2013; Jayasree *et al.,* 2013). Remote sensing imagery is widely used for monitoring vegetation changes due to its ability to provide calibrated, objective, and repeatable data across large areas (Bhavsar and Patel, 2016; Al-Yasiry *et al.,* 2023). This technology enables efficient tracking of vegetation dynamics using various satellite imagery and indices such as NDVI (Al-Malikey, 2019). Szabo *et al.,* (2016) analyzed Landsat 7 data from Hungary (1999) to classify vegetation using NDVI, NDWI, and MNDWI indices. Tuoku *et al*. (2024) studied the effects of solar radiation and rainfall as key factors on vegetation in China (1982–2020), while carbon dioxide and humidity showed limited influences. Sur *et al.,* (2018) related rainfall with vegetation cover in Gujarat and Rajasthan India while Sajan *et al.,* (2023) related LST with NDVI in Bihar, India. The relation between land surface temperature (LST) and vegetation cover index in Babylon, Iraq has been reported by Al-Aarajy and Hassan (2023).

Urban and environmental changes in vegetation systems over time provide crucial insights into the impacts of climate change and desertification. Hence, this study was proposed to understand the dynamics of vegetation cover and land surface temperature over Basra Province of Iraq from 1990 to 2024.

MATERIALS AND METHODS

Study area

The research area chosen was Basra province, Iraq (Lat. 31° 16″N; Long. 46° 34″E; Elevation 5 m). With a monsoon climate and a desert-like terrain, Basra province has extremely hot summers, particularly in July and August, with mean temperatures of 37.4 ^{0}C and highs of 45 ^{0}C. While the average annual rainfall is less than 100 mm, the average potential evapotranspiration exceeds 2,450 mm, the region features a level topography, ranging from a few meters to under 50 meters above sea level, along with the existence of oil fields. The climate is characterized as a dry and hot summer (Nemah *et al.,* 2019). The mean humidity from May to October is below

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50%. This correlates with less precipitation throughout the majority of months, heightened soil erosion, and the occurrence of dust storms. The peak temperature exceeds 45 ^{0}C throughout the warmer months, indicating that the research region is subject to an arid environment, and brief winters with minimal seasonal precipitation. The predominant rainfall occurs from October to March (Halos and Mahdi, 2021).

Data sources

According to data availability, picture quality, and land cloud cover (under 10%), the USGS website (https://earthexplorer.usgs.gov) yielded a total of 22 photos using path/row 166/069 in July and December months. The initial images from 1990-2001 were obtained by Landsat 5, while the photos from 2013 - 2024 were obtained with Landsat 8. The pictures were acquired with the TM sensor on Landsat 5 and the OLI sensor on Landsat 8. The satellite photos were analyzed using GIS 10.8 software to depict surface temperature, and cover vegetation.

Normalized difference vegetation index (NDVI)

NDVI was calculated using B4: NIR, B3: RED in Landsat 5, and B5: RED in Landsat8. Based on this information, the NDVI images were classified into four categories using the NDVI threshold bands in ArcGIS. The NDVI values for sparse vegetation are between 0.2 and 0.4; moderate vegetation values range from 0.4 to 0.6, while NDVI values for dense vegetation range from 0.6 to 1. NDVI values less than 0.2 represent water bodies and areas without vegetation.

$$\mathrm{NDVI} = \frac{\mathrm{NIR - RE}}{\mathrm{NIR + RE}}$$

Land surface temperature (LST)

The land surface temperature (LST) is extracted from a satellite picture using band 6 of the Landsat 5 satellite with the TM sensor and band 10 of the Landsat 8 satellite with the OLI sensor.

$$L_\lambda = \left(\frac{L_{max\lambda} - L_{min\lambda}}{QCal_{max} - QCal_{min}}\right) * (QCal - QCal_{min}) + L_{min\lambda}$$

$$L_\lambda = M_L * QCal + A_L$$

QCal represents the quantized calibrated pixel value in digital numbers (DN), radiance value ($L_{max\lambda}$, $L_{min\lambda}$) was derived using metadata parameters G, and brightness temperature (T) in °C via the conversion formula provided below.

$$T = K_2 * \left[\ln\left(\frac{K_1}{L_\lambda} + 1\right)\right]^{-1}$$

K1 and K2 are the calibration constants for thermal bands; for Landsat 5,607.76, and 1260.56, respectively, whereas for Landsat 8, 774.8853 and 1321.0789, respectively. ε = emissivity of the Earth's surface as determined by the equation:

$$\varepsilon = 0.004 * Pv + 0.986$$

Pv = proportional vegetation derived from (NDVI) as written

$$Pv = \left[\frac{(NDVI - NDVI_{min})}{(NDVI_{max} - NDVI_{min})}\right]^2$$

$NDVI_{min}$, $NDVI_{max}$ = the maximum and minimum NDVI. Finally, LST was computed by the equation

$$LST = \frac{T}{1 + \left(\frac{\lambda * T}{\rho}\right) * \ln\varepsilon} - 273.15$$

where λ = the average wavelength of the emitted radiation (=11.457 and 10.8 µm for Landsat 5 and 8, respectively) and ρ =1.438x10^{-34} J.s (constant value).

RESULTS AND DISCUSSIONS

Distribution of vegetation cover over the period

Based on the NDVI values, the vegetation cover across Basra province were classified into four categories for all the years (1990 to 2024) and percent area under each category are presented in Table 1. The result show that the period saw significant and progressive changes in vegetation cover across Basra province. The dense vegetation cover area which was more than 4% before 2000, decreased to less than 2% after 2022. The non-vegetation area which was less than 70% before 2000, increased to more than 75% after 2022. The data highlights a persistent trend of vegetation degradation, particularly in dense and moderate vegetation classes, while sparse vegetation demonstrated notable temporal fluctuations. For example, sparse vegetation increased during the late 1990s and early 2000s but experienced a declining trend thereafter. These variations reflect a complex interplay of factors, including urban expansion, agricultural practices, and water resource availability. The progressive rise in non-vegetation areas and the corresponding decline in vegetated zones can be attributed to both environmental and anthropogenic drivers. Desertification, water scarcity, and rapid urbanization have reshaped the landscape, with urbanized areas like Al-Zubair and Al-Qurna experiencing the greatest loss of vegetation due to infrastructure development and reduced agricultural activity. Additionally, the impact of climate change—manifested in elevated temperatures and declining rainfall—has accelerated vegetation loss, further contributing to landscape transformation. These alarming trends emphasize the need for urgent intervention through effective environmental policies and sustainable land management practices. Strategic measures such as reforestation, efficient water usage, and urban green space planning are vital for mitigating the adverse impacts of vegetation loss on the region's ecosystem and climate

Relationship between NDVI and LST

The relationship between the normalized difference vegetation index (NDVI) and land surface temperature (LST) in Basra Province underwent notable shifts between 1990 and 2024. Over this period, the decline in vegetation cover—particularly in dense and moderate vegetation categories—correlated with a reduced capacity of vegetation to regulate surface temperatures. This trend is evident in the decreasing coefficient of determination (R^2), which dropped from 0.1124 in 1990 to 0.0633 in 2022 (Fig. 1). The results indicate a clear inverse relationship between NDVI and

Table 1: Percentage area under different vegetation categories as per NDVI

Year	Month	Percentage area under vegetation categories			
		Dense (NDVI:0.6-1.0)	Moderate (NDVI:0.4-0.6)	Sparse (NDVI:0.2-0.4)	Others (NDVI:<0.2)
1990	July	4.8	13.3	14.5	67.4
	December	4.5	15.1	12.9	67.5
1993	July	5.4	6.1	20.3	68.1
	December	6.7	9.9	16.2	67.2
1996	July	5.7	8.8	22.8	62.7
	December	4.1	9.9	23.5	62.5
1999	July	4.7	2.2	23.5	69.7
	December	5.5	8.9	17.8	67.8
2000	July	4.6	7.8	26.8	60.8
	December	4.2	12.8	17.7	65.3
2001	July	4.7	9.4	32.9	52.9
	December	3.1	6.1	24.7	76.4
2013	July	3.2	15.5	9.7	71.6
	December	3.2	10.4	10.0	53.8
2016	July	3.0	10.2	14.5	72.3
	December	3.2	11.2	16.4	69.2
2019	July	3.0	5.6	19.0	72.4
	December	2.6	14.2	8.8	74.4
2022	July	1.8	8.4	11.3	78.6
	December	1.2	10.7	11.3	76.8
2024	July	1.0	3.0	16.8	79.3
	December	0.8	9.2	10.3	79.7

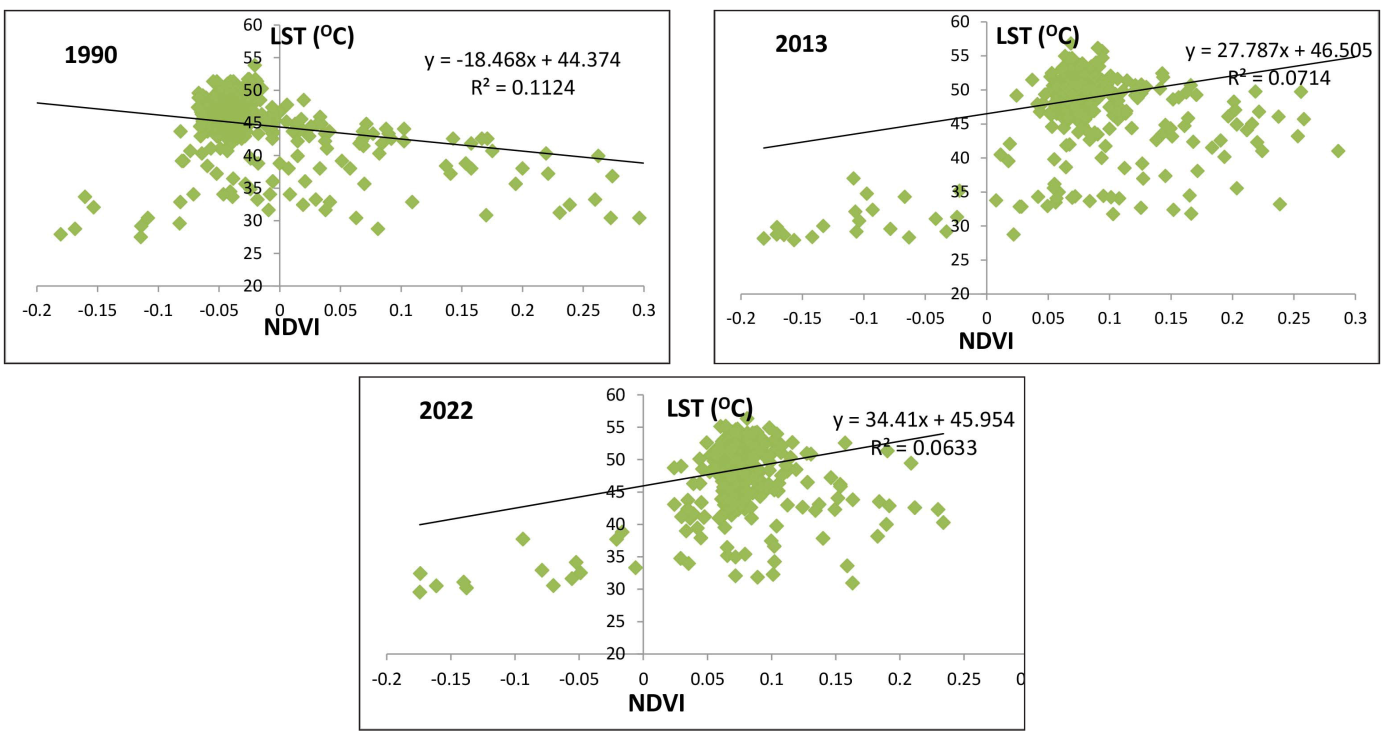

Fig. 1: Relationship between NDVI and LST during 1990, 2013 and 2022

LST, where areas with higher vegetation density (reflected in higher NDVI values) exhibited lower surface temperatures. In 1990, the relatively higher proportion of dense vegetation exerted a moderate cooling effect, as indicated by the R^2 value. However, the decline in vegetation cover over time, significantly weakened this cooling effect, allowing urban heat islands to dominate. By 2024, with dense vegetation reduced to 0.99% and non-vegetative areas rising to 79.3%, the NDVI-LST relationship had weakened considerably, underscoring the adverse impacts of urban expansion and vegetation degradation. Several factors contributed to these changes. Urbanization, characterized by the replacement of vegetated areas with impervious surfaces like concrete and asphalt, intensified LST by absorbing and retaining greater solar radiation. Furthermore, climate change exacerbated vegetation stress through prolonged droughts and reduced precipitation, further diminishing the capacity of vegetation to mitigate surface heating. The degradation of the NDVI-LST relationship highlights the critical need for sustainable urban planning and environmental restoration initiatives. Large-scale afforestation projects, enhanced urban green spaces, and water-efficient irrigation systems are pivotal in restoring the balance between vegetation and surface temperature regulation. Continuous monitoring of NDVI and LST using satellite data is essential for evaluating the effectiveness of these interventions and mitigating the growing impacts of climate change and urban heat islands.

CONCLUSION

During the study period, Basra has undergone profound environmental changes characterized by a drastic decline in vegetation cover, particularly in dense and medium categories, and an expansion in non-vegetative areas. Dense vegetation decreased while non-vegetative areas expanded. These changes were particularly pronounced in urbanized regions such as Al-Zubair and Al-Qurna, driven by rapid urbanization, desertification, and climatic shifts. The study revealed that the relationship between vegetation cover and land surface temperature (LST) has significantly weakened over the years. This reduction highlights the growing dominance of urban heat islands, reduced vegetation resilience, and intensified climate change effects in the region. These findings underline the urgent need for strategic interventions, including large-scale afforestation, sustainable urban planning, and public awareness campaigns about energy efficiency and environmental preservation. Regular monitoring of vegetation and temperature patterns is also essential to mitigate the escalating impacts of urbanization and Climate change, ensuring a sustainable future for Basra.

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***Conflict of Interest*:** The authors declare no conflict of interest.

***Data Availability*:** The data used in this study were obtained from the publicly accessible USGS platform (https://earthexplorer.usgs.gov).

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