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Spatial Analysis of Urban Heat Island Indicator in Wasit-Iraq Based on Land Surface Temperature Retrieval from Landsat-8 Imagery

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Abstract

Remote sensing and GIS techniques are very effective for monitoring urban heat island dynamics, providing useful information for sustainable urban planning and environmental management in Wasit. Urban Heat Island (UHI) is one of the major environmental challenges associated with urban expansion and land cover change in modern cities. This study investigates the spatial variation of Land Surface Temperature (LST) and urban heat island (UHI) intensity in Wasit governorate of Iraq, using Landsat-8 images acquired in July 2025. Land Surface Temperature was retrieved from the thermal infrared band, while the Normalized Difference Vegetation Index (NDVI) was calculated to evaluate vegetation cover and its relationship with surface temperature. The results showed that vegetation rate is about 0.142 % and the mean LST was 41.73 ^{O}C. Urban and built-up areas recorded the highest LST values, while agricultural lands and areas near the Tigris River showed lower surface temperatures. The NDVI–LST relationship showed a negative correlation, with correlation coefficient values of (0.009) that indicate that vegetation cover plays an important role in reducing urban thermal stress.

Keywords: Urban Heat Island, Land Surface Temperature, Landsat 8, Remote Sensing, LST.

1. Introduction

Urbanization is considered one of the most significant forms of land use transformation affecting environmental conditions in cities worldwide. Rapid urban growth leads to the replacement of natural surfaces and vegetation with impervious materials such as asphalt, concrete, and buildings. These surfaces absorb and retain solar radiation, resulting in higher temperatures in urban areas compared with surrounding rural regions. This phenomenon is commonly known as the Urban Heat Island (UHI) effect [1].

Urban heat islands have become a major environmental concern because of their negative impacts on climate, energy consumption, environmental quality, and human health [2].

Increased urban temperatures may lead to higher cooling energy demand, deterioration of air quality, thermal discomfort, and increased environmental stress, particularly during summer seasons in arid and semi-arid regions [3]. Remote sensing and Geographic Information System (GIS) techniques provide effective tools for monitoring and analyzing thermal environmental conditions over large geographic areas [3, 4].

Landsat satellite imagery is widely used in environmental and climate studies because it provides multispectral and thermal infrared data suitable for Land Surface Temperature (LST) retrieval and land cover analysis [5]. Land Surface Temperature represents one of the most important indicators used to investigate urban thermal characteristics and urban heat island intensity.

Surface temperature distribution is strongly influenced by land cover types, vegetation density, water bodies, and built-up areas. Vegetation can reduce temperature through evapotranspiration and shading processes, while urban materials such as asphalt and concrete contribute to heat accumulation [2, 6]. The Normalized Difference Vegetation Index (NDVI) is commonly used to evaluate vegetation conditions and examine their relationship with surface temperature distribution. Previous studies have demonstrated a strong negative relationship between NDVI and LST, where areas with dense vegetation usually exhibit lower temperatures than densely urbanized areas [7].

Wasit Governorate, located in eastern Iraq, has experienced significant urban expansion during recent years [8]. Population growth, increasing infrastructure development, and a reduction in vegetation cover may contribute to rising surface temperatures and intensification of urban heat island effects. Furthermore, the climatic conditions of the region, characterized by extremely hot summers and limited rainfall, make Wasit vulnerable to thermal environmental stress [8, 9].

Although several studies have investigated urban heat island phenomena in different cities worldwide, limited research has focused on the thermal environment of Wasit using recent Landsat observations. Therefore, this study aims to analyze the spatial dynamics of Land Surface Temperature and urban heat island intensity in Wasit using Landsat imagery acquired during the summer season. The study specifically analyzed Landsat 8 image thermal infrared data acquired in July 2025 to identify spatial distribution in thermal patterns associated with urban growth and land cover transformation, and evaluate the relationship between vegetation cover and land surface temperature using the LST index.

2. Study Area

Wasit governorate covers an area of about 17753 km², which represents 4% of Iraq's total area (437072 Km^2). Wasit is located in eastern Iraq, or the southern part of the central region of Iraq. The city is situated along the Tigris River and is considered one of the important urban centers in central Iraq. Geographically, it is located approximately between Longitude 46°17' 60.00"E, Latitude 32° 13' 60.00"N. The climate of the study area is characterized as arid to semi-arid, with extremely hot summers and mild winters [8,9]. Summer temperatures frequently exceed 45°C especially during July and August. Rainfall is limited and occurs mainly during the winter months. It contains different land cover types, including urban residential areas, transportation networks, agricultural lands, bare soil, and water bodies associated with the Tigris River.

During recent years, Wasit has experienced rapid urban expansion due to population growth and infrastructure development, which may contribute to increased land surface temperature and

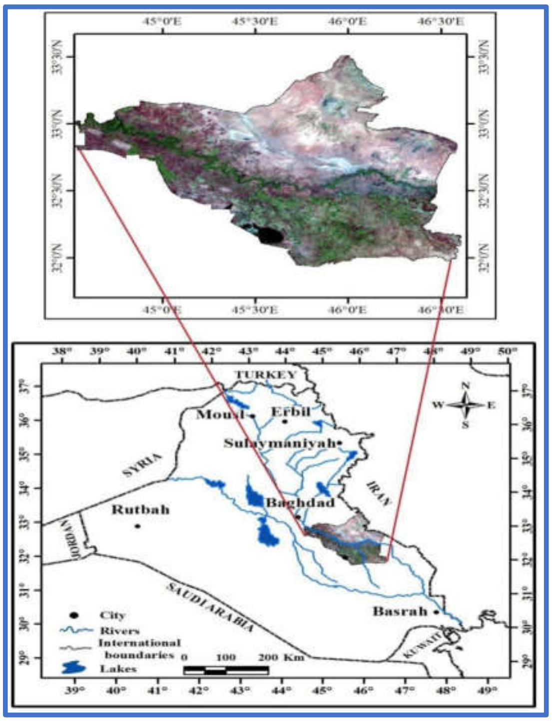

Figure 1: Wasit Governorate Landsat-8 map.

urban heat island intensity [10]. Vegetation cover is mainly concentrated in agricultural lands and riverbanks, whereas densely built-up urban regions contain limited green areas [8].

Table 1: Images of the Landsat 8 (OLI/TIRS) satellite of Wasit.

No.	Satellite	Acquisition Date	Path/ row
1	Landsat 8	2025/07/20	167/37
2	Landsat 8	2025/07/20	167/38
3	Landsat 8	2025/07/11	168/37

This variation in land cover provides a suitable environment for evaluating the spatial relationship between vegetation density and thermal distribution. The importance of selecting Wasit as the study area is related to Rapid urban growth, increasing population density, High summer temperatures, Reduction in vegetation cover and Environmental sensitivity to urban heat island effects, therefore, Wasit represents an appropriate case study for investigating urban thermal environmental changes using remote sensing and GIS techniques.

3. Satellite Data Acquisition

This study is based on Landsat satellite imagery acquired during the summer season in July to investigate urban heat island dynamics and Land Surface Temperature distribution in Wasit governorate. The satellite images downloaded from the USGS Earth Explorer platform, that geo-registered to the same Universal Transversal Mercator (WGS-1984t-UTM - Zone 38N) coordinate system using the nearest neighbor resampling method, utilizing the WGS- 84 datum and UTM _Zone 38N projection [11]. Landsat imagery was selected due to its availability, moderate spatial resolution, and thermal infrared capability suitable for environmental and climate studies [3, 11].

Three Landsat 8 geo-referenced images showed in table (1) were used in this study with ground resolution of 30 m. Landsat 8 carries Operational land image (OLI/ TIRS) sensors from collection two C2 level one L1. Cloud free data was selected to avoid cloud effects with Similar atmospheric conditions.

Landsat 8 has a thermal infrared sensor (TIRS) with a resolution of 100 m give thermal infrared Band 10 was used for Land Surface Temperature LST retrieval, while optical bands were used to calculate the Normalized Difference Vegetation Index (NDVI), fig (2) showed the image of Wasit Governorate captured in July 2025 with a ground resolution of 30 m from the sensor clipped by a shapefile represents the administrative boundaries [12].

The study area boundary was extracted and used for clipping satellite imagery prior to thermal analysis. The software QGIS 3.40.8 is used for spatial analysis and map production. Remote sensing and GIS techniques were employed to process satellite imagery, retrieve land surface temperature, classify thermal zones, and analyse spatial thermal variations within the study area.

4. Methodology

The methodological framework of this study consists of several sequential steps to generate NDVI map, retrieve Land Surface Temperature (LST) and evaluate urban heat island UHI characteristics in

Wasit using corrected Landsat images. The overall workflow of the study in fig. (3) below:

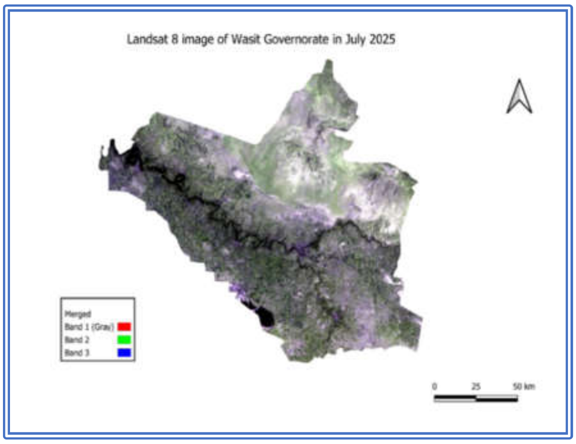

Figure 2: Landsat 8 image of Wasit Governorate in July 2025.

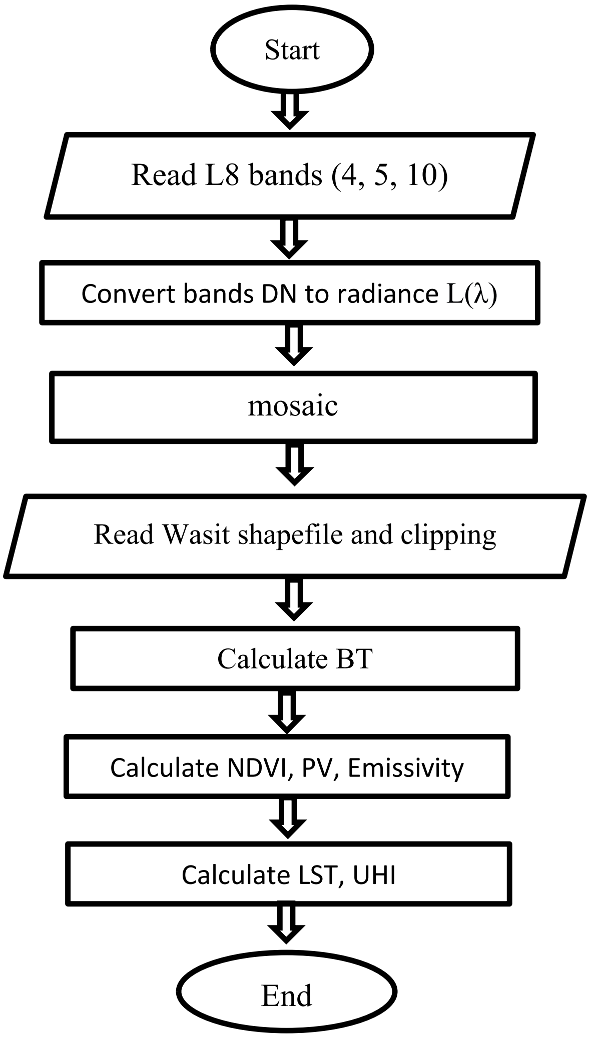

Figure 3: Preprocessing and steps of the study.

4.1 Image Preprocessing

Landsat satellite images that were downloaded from the USGS Earth Explorer platform were geometrically and radiometrically corrected by the data provider. Summer images acquired during July 2025 were selected because urban heat island intensity becomes more pronounced during hot seasons. After downloading, the images were clipped according to the boundary of Wasit to focus the analysis on the study area.

4.1.1 Conversion of Digital Number to Spectral Radiance

In remote sensing analysis the atmospheric correction for solar radiation is important; its necessity depends on the objectives of the study. Finding of the ground reflectance starts with converting the value of the pixels to spectral radiance. Landsat-8 OLI/TIRS bands can be converted to TOA spectral radiance using the radiance rescaling factors provided in the metadata of images; equation (1) represents the conversion:

$$L_\lambda = M_L \times Q_{cal} + A_L \quad .... (1)$$

Where:

L_λ = TOA spectral radiance at sensor aperture.

M_L = multiplicative rescaling factor.

A_L = additive rescaling factor.

Q_{cal} = quantized calibrated standard product pixel value (DN).

The radiometric rescaling factors were obtained from the metadata file of each Landsat image [5,7].

4.1.2 Conversion to Brightness Temperature

Brightness Temperature (BT) is the spectral brightness temperature measured by the satellite at the top of the atmosphere, and it can be calculated using Equation (2):

$$BT = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda}+1\right)} - 273.15 \quad \text{........ (2)}$$

Where:

BT = brightness temperature in °C

K_1 , K_2 = Thermal calibration constants equal to 774.8853 and 1321.0789

L_λ = TOA spectral radiance at sensor aperture [5, 7].

4.2 NDVI index

The Normalized Difference Vegetation Index (NDVI) was calculated to evaluate vegetation density and health based on reflectivity of the earth surface to near-infrared and red light and investigate its relationship with land surface temperature distribution [12]. NDVI was calculated using the following equation (3):

$$NDVI = \frac{NIR-Red}{NIR+Red} \quad \text{.......... (3)}$$

Where:

NIR = Near Infrared band (Band 5 in Landsat 8)

Red = Red band (Band 4 in Landsat 8)

NDVI values range from −1 to +1. High positive values indicate dense vegetation cover, while low or negative values indicate built-up land, bare soil, or water surfaces [13].

4.3. The percentage of Vegetation PV

The percentage of vegetation PV used to get land surface thermal radiation, it's between 0 and 1 indicating the vegetation density in a pixel. PV is calculated from equation (4):

$$PV = \frac{NDVI - \mathrm{NDVI_{min}}}{\mathrm{NDVI_{max}} - \mathrm{NDVI_{min}}} \quad \text{......... (4)}$$

where:

NDVI: the vegetation index value calculated for each pixel.

NDVI $_{max}$: The highest NDVI close to 1 for dense vegetation.

NDVI $_{min}$: The lowest NDVI value, usually close to 0 or negative for bare soil and water. PV values were calculated by normalizing NDVI values from 0 to 1 for each pixel and determining the density of vegetation in the pixel.

The resulting value was squared to indicate whether an area had dense or sparse vegetation within it. If the NDVI value is near the upper limit of its range the PV value is therefore near 1 meaning the pixel has dense vegetation; if it is near the lower limit then the PV will be close to 0 meaning that the pixel is either covered with soil or has surface water. This value also provides the input needed to calculate LSE (land surface emissivity) which will improve our estimates of LST (land surface temperature) in climate and agricultural research. [14].

4.4 Estimation of Land Surface Emissivity

Land Surface Emissivity (LSE) was estimated based on NDVI values to account for surface characteristics and vegetation conditions. Vegetated areas generally exhibit higher emissivity values than built-up and barren surfaces. It is a measure of surface that emits h eat radiation compared to an ideal black body at the same temperature. LSE improves the accuracy of LST calculations. It is determined based on vegetation cover using the NDVI index, where PV is first calculated by normalizing the NDVI between its maximum and minimum values, and by using Equation (5), the value of E is calculated [5, 7].

$$E = 0.004 \times PV + 0.986 \ldots (5)$$

Different surfaces reflect different radiances, with water and dry soil having low radiances (~ 0.92) while dense vegetation has high radiances (~0.98). LSE is essential for accurate LST calculations, especially in climate studies, drought analysis, and UHI, as it helps correct the effects of different land surface characteristics on satellite-measured temperatures [5, 7].

4.5 Land Surface Temperature LST

Land Surface Temperature was retrieved from the thermal infrared band 10 of Landsat imagery using standard thermal remote sensing procedures. Equation (6) is used to calculate LST measured in Kelvin or Celsius [7]:

$$LST = \frac{BT}{\ln(E) \times \left(\frac{\lambda \times BT}{\rho}\right) + 1} \quad \ldots\ldots (6)$$

Where:

LST = Land surface temperature.

BT = Brightness temperature.

λ = Wave length of the thermal radiation equal to 10 .8 µm.

ρ = Thermal irradiance constant equal to (14388) mK.

E = Land Surface Emissivity.

λ and BT are calculated for band 10. The resulting LST values were classified into temperature classes for visualization and analysis.

4.6 Urban Heat Island Analysis UHI

Urban heat island intensity was evaluated by comparing the average temperature of urban areas with surrounding rural or vegetated areas. Urban Heat Island intensity was calculated using the equation:

$$UHI = \frac{LST - LST_m}{LST_{sd}} \; \ldots\ldots\ldots\ldots (7)$$

Where:

LST_m: mean of land surface temperature,

LST_{sd}: standard deviation. Areas with significantly high temperatures were identified as urban heat island zones [7].

4.5 Statistical Analysis

Statistical analysis was conducted to evaluate land surface temperature and the relationship between NDVI and LST. The statistical parameters were calculated Minimum LST, Maximum LST, Mean LST and Correlation coefficient between NDVI and LST. The correlation analysis was used to determine the relationship between vegetation density and surface temperature.

5. Results and Discussion

5.1 NDVI Analysis

The NDVI analysis revealed substantial spatial variation in vegetation density across the study area. Agricultural lands and riverbank regions recorded relatively high NDVI values, whereas densely urbanized and barren areas exhibited low NDVI values. The results indicate low rate in vegetation density in several urban regions. This reduction in vegetation cover may contribute significantly to increasing land surface temperature and urban heat island intensity. Fig (4) illustrates that the total area of dense and moderate vegetation class was 24.5997 Km^2 from the total area of Wasit (17753 Km$^{2)}$, and the vegetation percentage is about 0.142 %.

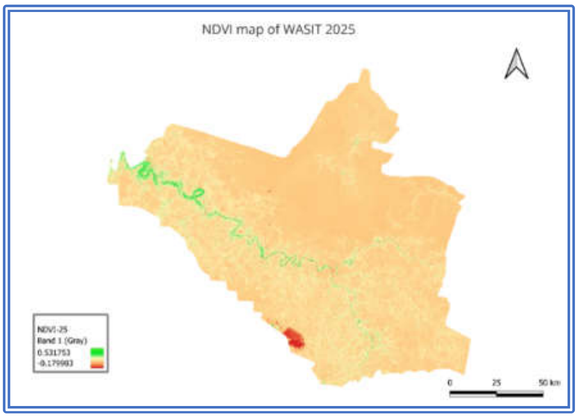

Figure 4: Normalized Difference Vegetation Index of Wasit, July 2025.

5.2 Spatial Distribution of Land Surface Temperature

The retrieved Land Surface Temperature (LST) maps revealed clear spatial variation in surface temperature in Wasit during the study period. High temperature values were mainly concentrated in densely built-up urban areas and barren lands. In contrast, lower temperatures were observed near vegetated regions and water bodies associated with the Tigris River. The thermal distribution maps for 2025 demonstrated noticeable differences in the spatial extent of high-temperature zones.

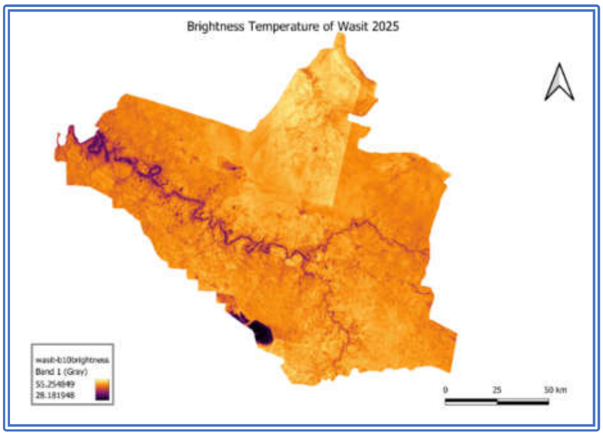

Figure 5: Brightness temperature (BT) of Wasit July 2025**.**

The minimum, maximum, and mean LST values extracted from the analyzed Landsat images are presented in Table 2. The results indicate that the maximum land surface temperature in 2025 was 55.28 **°C**, and the minimum value was 28.19 **°C**. This increase in thermal stress within the urban environment may be associated with rapid urban expansion, increasing impervious surfaces, and a reduction in vegetation cover.

5.3 Relationship Between NDVI and LST

A spatial comparison between NDVI and LST maps showed a strong inverse relationship between vegetation density and land surface temperature. Areas characterized by high NDVI values generally exhibited lower temperatures, while areas with sparse vegetation and dense urban structures recorded higher temperatures.

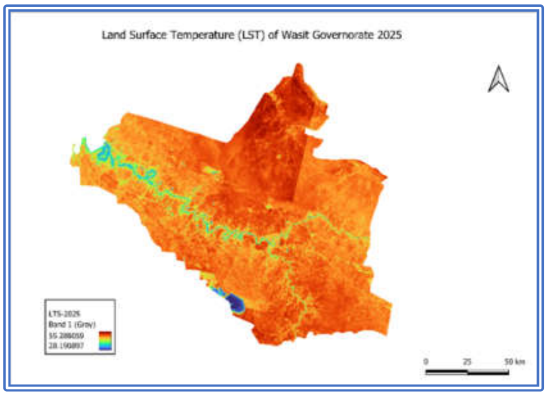

Figure 6: Map of Land Surface Temperature (LST) of Wasit, July 2025.

In 2025, the correlation coefficient R between NDVI and LST was (-0.009), the negative sign meaning that LST increases as NDVI values decrease, and increasing vegetation cover contributes to reducing surface temperature. The correlation coefficient indicates that vegetation plays an important role in reducing thermal intensity and improving environmental conditions within the urban area.

5.4 Urban Heat Island Intensity UHI

Urban Heat Island (UHI) intensity was estimated by comparing the average land surface temperature of urban regions with surrounding rural and vegetated areas.

The results indicate that urban heat island intensity and land surface temperature increased in about 9º difference from the vegetated regions. This increase reflects the impact of urbanization, infrastructure expansion, and vegetation reduction on the thermal environment of Wasit, fig (7) shows the index map.

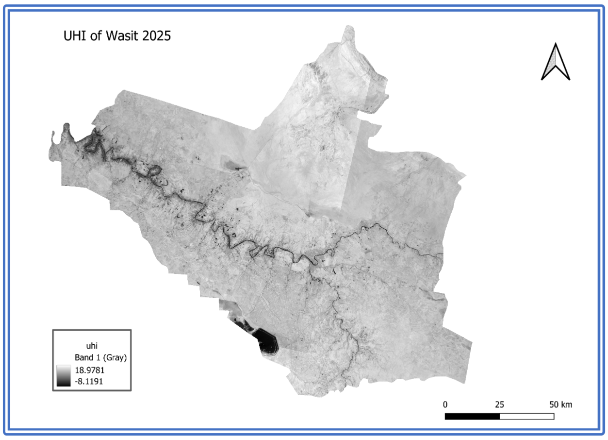

Figure 7: UHI index of Wasit Governorate for July 2025.

The correlation between LST and UHI is 1, which means high-intensity urban heat island UHI zones were mainly concentrated in Dense residential districts, main transportation corridors, and bare and undeveloped lands. In contrast, lower values were observed in agricultural lands and areas located near the Tigris River due to the cooling effects of vegetation and water bodies.

5. Discussion

The findings of this study confirm the significant influence of land cover characteristics on spatial temperature distribution in Wasit Governorate. Urban regions characterized by impervious surfaces such as concrete and asphalt recorded higher temperatures because these materials absorb and store solar radiation efficiently. In contrast, vegetated areas exhibited lower temperatures due to evapotranspiration and shading effects.

Table (2): Indices values measured by QGIS of Wasit Governorate for 2025.

Index	Minimum	Maximum	Mean
NDVI	-0.1799830	0.5317531	0.1758850
LST (°C)	28.190896	55.288059	41.7394781
UHI	-8.1191034	18.978059	5.4294781

Images from July 2025 show that urban regions have intensified thermal environmental conditions in the study area. Reduction in vegetation cover and conversion of agricultural lands into urban land uses appear to be the main contributors to increasing urban heat island intensity.

The negative correlation between NDVI and LST found in this study is consistent with results reported in other remote sensing studies conducted in arid and semi-arid urban regions.

The results highlight the need to activate appropriate urban planning strategies, including increasing urban green spaces, protecting agricultural lands, enhancing vegetation cover, and implementing environmentally sustainable infrastructure. Such measures may help mitigate urban heat island effects and improve thermal environmental quality in Wasit Governorate.

6. Conclusion

The study investigated the spatial characteristics of the Urban Heat Island (UHI) phenomenon in Wasit/ Iraq, using Landsat 8 satellite imagery and Land Surface Temperature (LST) retrieval techniques, and reached these conclusions:

There is a considerable spatial variation in the temperature of the surface in the study area. Urban and regions are densely built-up, giving the highest LST values, but agricultural lands and areas located near the Tigris River recorded lower temperatures due to the cooling effects of vegetation and water bodies.

The correlation analysis confirmed a negative relationship between NDVI and LST, where areas with dense vegetation generally exhibited lower temperatures compared with densely urbanized regions.

The results suggest that built-up urban areas, increasing impervious surfaces, and a reduction in vegetation cover are major factors contributing to the intensification of urban heat island effects Wasit.

The study demonstrates the effectiveness of remote sensing and GIS techniques for monitoring urban thermal environments and identifying thermal hot spots. The findings may assist urban planners and environmental decision-makers in developing sustainable strategies to reduce urban heat island impacts and improve environmental quality in the study area.

Images demonstrated a noticeable increase in land surface temperature and urban heat island intensity in the urban class, about 9^{o} difference from the vegetated regions. The solution to minimize the effects of urban heat islands is to expand vegetation cover, which is a strategy for achieving urban sustainability.

7. Future plans

Future studies are recommended to incorporate higher spatial resolution satellite imagery, seasonal thermal analysis with the entire climate effects, and long-term urban growth assessment; these approaches may provide a more comprehensive understanding of urban thermal dynamics in Iraqi cities.

References

1. Voogt, J. A., & Oke, T. R. (2003). Thermal remote sensing of urban climates. Remote Sensing of Environment, 86(3), 370–384.
2. Weng, Q. (2009). Thermal infrared remote sensing for urban climate and environmental studies: Methods, applications, and trends. ISPRS Journal of Photogrammetry and Remote Sensing, 64(4), 335–344.
3. U.S. Geological Survey. (2019). Landsat 8 data users handbook (Version 5.0). Department of the Interior, U.S. Geological Survey.
4. Jamaludin, N. J., Abdullah, A. F., Muhadi, N. A., & Aimrun, W. (2025). Assessment and enhancement of Landsat 8 land surface temperature retrieval using mono window algorithm and machine learning approaches. Journal of Atmospheric and Solar-Terrestrial Physics, 276.
5. Kumar, D., Soni, A. P., & Kumar, M. (2022). Retrieval of land surface temperature from Landsat-8 thermal infrared sensor data. Journal of Human, Earth, and Future, 3(2).
6. U.S. Geological Survey. (2024). Landsat Collection 2 surface temperature product guide (Version 6).
7. Li, X., Zhou, Y., Asrar, G. R., Zhu, Z., & Li, X. (2017). The surface urban heat island response to urban expansion: A panel analysis for the conterminous United States. Science of the Total Environment, 605–606, 426–435.
8. Shahad, H. S., Malik, M. I., & Al-Dabbagh, H. A. (2023). Land use and land cover study of Al-Kut City, Iraq using Sentinel-2 images by supervised classification techniques. AIP Conference Proceedings, 2834(1), 050021.
9. Abdulkareem, M. K., & Jaber, H. S. (2025). Desertification change detection in Wasit Province, Iraq using remote sensing and GIS. IOP Conference Series: Earth and Environmental Science, 1545(1),012087.
10. Qin, Z., Karnieli, A., & Berliner, P. (2001). A mono-window algorithm for retrieving land surface temperature from Landsat TM data and its application to the Israel–Egypt border region. International Journal of Remote Sensing, 22(18), 3719–3746.
11. Sobrino, J. A., Jiménez-Muñoz, J. C., & Paolini, L. (2004). Land surface temperature retrieval from Landsat TM 5. Remote Sensing of Environment, 90(4),434–440.

12. Rasul, A., Balzter, H., & Smith, C. (2015). Spatial variation of the daytime surface urban cool island during the dry season in Erbil, Iraqi Kurdistan. Urban Climate, 14, 176–186. https://doi.org/10.1016/j.uclim.2015.09.001
13. U.S. Geological Survey. (n.d.). Earth Explorer. https.usgs.gov/
14. United Nations. (n.d.). UN GeoHub. https://geohub.un.org/webapps/geohub/
15. Al-Azzawi, T. M. F., & Al-Zirgany, A. A. S. (2018). Change detection for some land cover types of Wasit Province (Eastern Iraq) using remote sensing and GIS techniques for years 1989–2017. Indian Journal of Natural Sciences, 9(51), 15441–15449.
16. Hartoyo, A. P. P., et al. (2021). Normalized Difference Vegetation Index (NDVI) analysis for vegetation cover in Leuser Ecosystem Area, Sumatra, Indonesia. Biodiversitas, 22(3),1160–1171.
17. Su, W., Jin, X., & Jin, Y. (2025). Remote sensing of photovoltaic panel impacts on NDVI and vegetation drought adaptation in the Qinghai–Tibetan Plateau. Remote Sensing Applications: Society and Environment, 40, 101783.
18. Oke, T. R. (1982). The energetic basis of the urban heat island. Quarterly Journal of the Royal Meteorological Society,108(455),1–24.
19. Roy, D. P., et al. (2014). Landsat-8: Science and product vision for terrestrial global change research. Remote Sensing of Environment,145,154–172.
20. Tsou, J., Zhuang, J., Li, Y., & Zhang, Y. (2017). Urban heat island assessment using Landsat 8 data: A case study in Shenzhen and Hong Kong. Urban Science,1(1).
21. Dutta, K., Basu, D., & Agrawal, S. (2014). Temporal and spatial analysis of urban heat island using Landsat satellite data: Two Indian case studies. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XL-8, 65–71. https://doi.org/10.5194/isprsarchives-XL-8-65-2014