SUPTM 2026: 3rd Conference on Future Challenges in Sustainable Urban Planning & Territorial Management

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Proceedings

Analysis of Urban Heat Island Intensity in Dhaka and Its Relationship with Land Use Land Cover Types

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Abstract: Bangladesh's capital, Dhaka, is one of the world's most crowded and rapidly urbanizing megacities. Its thermal environment has changed dramatically over the last three decades due to uncontrolled growth and the conversion of aquatic and vegetative areas into built-up zones, which has exacerbated the Urban Heat Island (UHI) effect. The UHI effect in Dhaka is deeply connected with its long-term spatial dynamics in relation to changes in Land cover. This study examines urban heat island (UHI) patterns in Dhaka from 1990 to 2025 utilizing multi-temporal satellite-derived Land Surface Temperature (LST) data and Land use Land cover (LULC) classification. he intensity of UHI was classified into Very High, High, Moderate, Low, and Very Low categories, and spatial change detection was utilized. Statistical metrics, including mean and standard deviation, were computed to assess changes over time. Due to thick, impermeable, unplanned urbanization with little green space, South Dhaka, and especially Old Dhaka areas like Gendaria, Gulistan, Motijheel, and Chawkbazar, exhibit the highest UHI intensities, according to the results. On the other hand, because of their greater vegetation cover and lower levels of urbanization, North Dhaka neighborhoods like Uttarkhan and Dakshin Khan have low to very low UHI. According to LULC study, densely populated areas with little vegetation have the highest UHI values, while vegetation and water bodies have the lowest. Bare ground shows moderate to high intensity. Very High UHI zones grew almost 3 times and High zones by +59.48% between 1990 and 2025, whereas Low and Very Low zones decreased by −38.37% and −49.64%, respectively. Mean UHI shifted with stable standard deviation, reflecting spatial redistribution rather than uniform warming. These results demonstrate how land cover change has a significant impact on UHI dynamics and stress the necessity of climate-sensitive planning, the preservation of green and blue areas, and focused mitigation techniques to increase Dhaka's thermal resilience.

Keywords: Dhaka; Land Use Land Cover; Land Surface Temperature; Urban Heat Island effect; Urbanization; LST; LULC; Urban Heat; UHI; Sustainable urban planning; Urban thermal environment; Spatio-temporal analysis

Citation: Lastname, F.; Lastname, F.; Lastname, F. Title. *SUPTM 2026 conference proceedings* xx. https://doi.org/ 10.31428/xxxxx

1.Introduction

Rapid urban expansion across South Asia has emerged as a major driver of land use land cover (LULC) change and urban thermal modification, with extensive remote-sensing-based research demonstrating a strong association between built-up growth and increasing land surface temperature (LST), alongside the cooling influence of vegetation and water bodies**[1]**. These processes collectively intensify the urban heat island (UHI) effect, defined as the temperature contrast between urbanized areas and their less-developed surroundings driven by land-cover change and human activities Among South Asian megacities, Dhaka Metropolitan Area exemplifies these dynamics due to sustained and largely unplanned urbanization, characterized by widespread conversion of vegetated and aquatic surfaces into dense built-up land [2]. This transformation has altered Dhaka's surface energy balance, reinforcing heat storage through impervious materials, high building density, and limited green infrastructure, and producing pronounced spatial contrasts in thermal conditions between urban cores and peripheral zones. The biophysical mechanisms underlying UHI formation in Dhaka are well documented, with empirical studies consistently reporting positive relationships between built-up land-cover indices and LST and negative associations between vegetation cover and surface temperature**[3]**. However, despite a growing body of literature, many studies focus on short-term or generalized urban–rural comparisons, offering limited insight into the long-term spatial redistribution of UHI intensity levels within the city **[4]**In particular, fewer studies systematically classify UHI intensity into multiple categories and assess how these categories evolve spatially in response to changing LULC types over extended periods **[5]**Addressing this gap, the present study analyzes the spatio-temporal evolution of UHI intensity in Dhaka and its relationship with LULC using multi-temporal satellite-derived LST data, providing a long-term, spatially explicit assessment to support climate-sensitive urban planning and heat-mitigation strategies in rapidly urbanizing megacities.

2. Study Area

Dhaka, the capital and largest city of Bangladesh. Dhaka Metropolitan Area (Figure1) is one of the world's most densely populated urban regions and a globally significant hotspot of rapid, unplanned urbanization [3]. Ranked as the seventh most densely populated city worldwide, extreme population density and accelerated spatial expansion make it an ideal case for thermal variability driven by intense land-cover transformation[3].

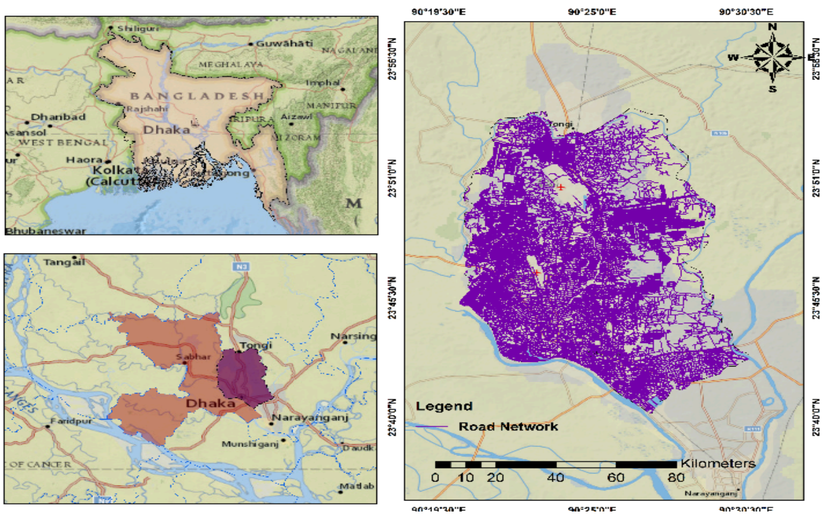


Figure 1. Study Area Map

3. Methodology

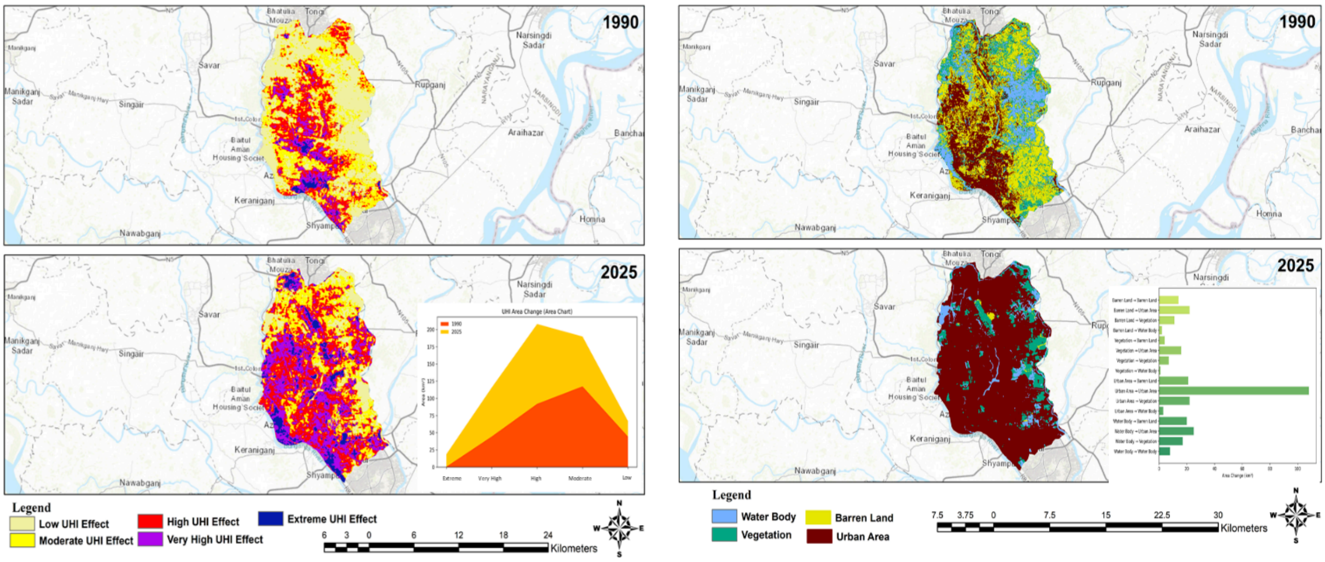
UHI intensity was calculated using LST derived from satellite thermal data, with all processing performed in ArcGIS Pro. Thermal bands were radiometrically calibrated, atmospherically and emissivity corrected, and reprojected to a uniform coordinate system before LST retrieval. Mean LST values were extracted for urban and surrounding non-urban areas, and UHI intensity was derived from spatial LST variation. UHI intensity was classified using the Natural Breaks (Jenks) method to capture spatial heterogeneity in urban thermal conditions. LULC classification was conducted using supervised classification of multispectral imagery in ArcGIS Pro. Representative training samples were selected for major LULC classes, including built-up areas, vegetation, water bodies, agricultural land, and bare land. The resulting LULC maps were used to examine the relationship between LULC patterns and LST-based UHI distribution**[5,6]**

4. Results

The results show a rapid increase in urbanization over the last 35 years, with extensive expansion of built-up areas and reduction of vegetated land. This land transformation resulted in a clear rise in LST and a pronounced increase in UHI intensity, with high-intensity UHI zones expanding significantly in recent years.

UHI Intensity	**Area (km²) in 1990**	**Area (km²) in 1990**
Extreme	0.58	17.92
Very High	44.53	71.02
High	92.03	115.98
Moderate	117.47	72.40
Low	44.50	22.41

The analysis reveals a pronounced shift toward higher UHI intensity over time. The Extreme UHI category increased by nearly 3000%, indicating the rapid development of severe thermal hotspots. Similarly, Very High and High UHI areas expanded by about 59.5% and 26.0%, respectively, reflecting escalating urban thermal stress. In contrast, Moderate and Low UHI zones declined sharply by 38.4% and 49.6%, suggesting a loss of relatively cooler urban surfaces, systematic intensification of UHI conditions, underscoring growing thermal vulnerability.



(**a**) (**b**)

Figure 2. Spartio-temporal Distribution of UHI and LULC

Figures 2(a) and 2(b) indicate substantial LULC transformation in the Dhaka Metropolitan Area from 1990 to 2025, characterized by extensive conversion of vegetation, agricultural land, and wetlands into built-up areas. This change is most evident in core urban zones such as Mirpur, Uttara, Gulshan, and Banani, as well as in peripheral areas like Savar and Keraniganj. Correspondingly, UHI patterns show a marked increase in high to extreme heat zones, expanding from the urban core into newly developed areas. The Pearson’s correlation results show a clear relationship between land cover and UHI intensity. Vegetation and water bodies are negatively correlated with UHI, indicating their strong cooling effect and role in reducing thermal stress. In contrast, urban areas exhibit a positive correlation with UHI, confirming that dense built-up surfaces and impervious materials intensify heat accumulation. Barren land shows a weaker positive relationship, suggesting moderate heat contribution compared to fully urbanized areas. Overall, the results confirm that natural land covers mitigate UHI, while built-up surfaces amplify it.

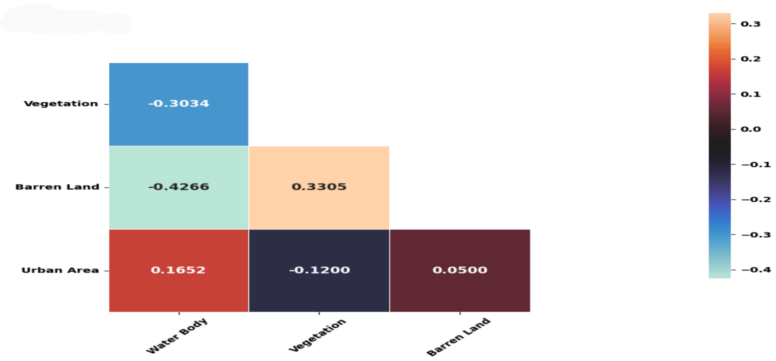


Figure 3. Correlation between UHI and different LULC.

6. Conclusion

This study provides clear evidence that rapid and largely unplanned urbanization has intensified the UHI effect in Dhaka through substantial LULC transformation. The progressive expansion of built-up areas at the expense of vegetation and water bodies has driven a marked shift toward higher UHI intensity zones, particularly within dense urban cores and newly developed areas. The strong spatial coupling between land surface temperature and LULC patterns confirms land-cover change as a dominant driver of urban thermal stress. These findings highlight the critical need for climate-sensitive urban planning and the protection of green and blue infrastructure to enhance thermal resilience in Dhaka.

Funding: This research received no external funding

Conflicts of Interest: The author declares no conflict of interest.

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