



International Journal for Research in Climate Change and Earth Science

SPATIOTEMPORAL ANALYSIS OF LAND SURFACE TEMPERATURE AND VEGETATION CHANGE UNDER CHANGING CLIMATIC CONDITIONS

Published By:
Green Publications Services Private LTD.

Volume 01 Issue 03 September
2026
DOI: 10.53555/cces.v1i3.2581

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Article History:
Article Type: Research

Received Date: 15/06/2026
Acceptance Date: 05/09/2026

Revised Date: 10/08/2026
Published Date: 25/09/2026

Abstract

The rising trend of urbanization and climate change has increased concern about the alteration of land surface temperature (LST) and vegetation in the rapidly developing metropolitan areas. This study aims to understand the spatiotemporal variations in LST and vegetation greenness over the Dhaka Metropolitan Region from 1990 to 2025. The satellite-derived environmental indicators analyzed had the Normalized Difference Vegetation Index (NDVI), the Normalized Difference Built-up Index (NDBI), and the Modified Normalized Difference Water Index (MNDWI), which were compared in time and space via Pearson correlation and through fixed-effects panel regression. The mean LST was found to be increased by 4.70 °C, and mean NDVI increased by 0.0434 on an overall basis. Nearly 94.96% of spatial grid cells were found to have higher surface temperature while 62.49% of spatial grid cells had greater vegetation greenness. The correlation analysis revealed that as LST increased, NDVI decreased, and that NDBI had a consistently positive correlation with the surface temperature. The panel regression also showed that NDVI had a negative correlation with LST, MNDWI had a negative correlation with LST, and NDBI had a positive correlation with LST. All these results indicate complex relations between vegetation, built-up features and thermal conditions in the city. The research findings can inform integrated green infrastructure planning and spatially targeted approaches to environmental resilience planning in Dhaka in the face of urban change.

Keywords: Land Surface Temperature; Normalized Difference Vegetation Index; Urban Heat Island; Spatiotemporal Analysis; Dhaka Metropolitan Region

1. Introduction

Surface temperature variations, vegetation changes and environmental sustainability have become important concerns in metropolitan areas due to rapid urbanization and altering climatic conditions. Covering natural landscapes with impervious surfaces changes surface energy balances, decreases evapotranspiration and affects local thermal environments. Such processes are related to urban heat island formation, adding environmental pressures to highly populated cities. The increasing temperatures and extreme weather events due to climate change further aggravate urban thermal conditions, making integrated environmental assessment (EEA) crucial (Lee et al., 2023). The complex interactions between urban heat islands and heatwaves in the atmosphere and on the surface have been stressed in recent studies and emphasize the need for integrated approaches to understand the spatial and temporal characteristics of these events (Cheval et al., 2024).

The land surface temperature (LST) is one of critical parameters for assessing the thermal environment of urban areas, and also one of the parameters that describe the land cover-vegetation-energy exchange interactions. Satellite remote sensing can provide a consistent spatial view over large geographical areas, which can help identify thermal hotspots and environmental changes. With the help of the development of thermal remote sensing, the intensity, the spatial heterogeneity and the correlation between surface temperature and urban development of the UHI could be well evaluated. Prospects in thermal remote sensing have enhanced the intensity assessment, the spatial heterogeneity and the surface temperature and urban development correlation of UHI (Shi et al., 2021). Combining LST with spectral indices provides possibilities to explore the changes in the environment in terms of measurable relationships between vegetation greenness, built-up characteristics and surface water condition (Galalizadeh et al., 2024).

Vegetation is an integral part of urban thermal modification, which includes shade, evapotranspiration, and surface radiation changes (Liu et al., 2021). The ability of urban green spaces to cool surfaces also depends on the biophysical properties of the vegetation, the urban morphology and geographical location (Wong et al., 2021; Cuthbert et al., 2022). The results of the global assessment show that urban greenery offers significant cooling effects, which are unequally distributed among cities and socioeconomic contexts (Li et al., 2024). Tree-related cooling benefits also have been shown to be especially significant in disadvantaged neighbourhoods, highlighting the importance of vegetation management for equitable urban adaptation (Gilligan, 2023). Beyond the local level, urban trees play a wider role in environmental regulation, which is relevant to green infrastructure in sustainable urban planning (Fu et al., 2022; Simpkins, 2023).

However, the distribution of vegetation and the thermal conditions do not always have a simple relationship. The alterations in vegetation cover can be caused by urban expansion, infrastructure development, and changes in land management that also affect local temperatures. Results show that significant vegetation loss is likely to occur in locations with marked exposure to urban heat, which could further make them more vulnerable to environmental impacts. Thus, when studying vegetation dynamics, such as the relationship with surface temperature, the regional scale must be considered along with the local environmental relationships. The NDVI is a reliable indicator

of the greenness of vegetation on Earth, and the Normalized Difference Built-up Index and Modified Normalized Difference Water Index are used to describe other aspects of urban surface conditions.

The study of these relations is of particular interest in Dhaka, Bangladesh, due to the city's high population density, rapid urbanization, and environmental stresses. Seasonal variations in land cover indices and land surface temperatures have been shown in previous remote sensing studies in Dhaka, suggesting that the time of observation affects land surface temperature assessments (Sresto et al., 2022). Studies exploring the urban heat island characteristics have also revealed urban-urban heatwave interactions, highlighting the importance of metropolitan heat exposure (Tabassum et al., 2024). Recently, the use of explainable geospatial AI in a study of spatiotemporal patterns of the urban heat environment in Dhaka highlights the significance of sophisticated analytic techniques in comprehending the urban heat environment.

While these advances have been made, further research is required to describe long-term trends in surface temperature and vegetation greenness, taking into account spatial heterogeneity and associated land surface features. There may be significant differences between the individual urban locations represented by regional averages, as well as differences between relationships for specific years and successive time periods. A combination of temporal comparisons and spatial mapping, correlation analysis and panel regression can then provide a more comprehensive picture of the changes in the environment. This is especially applicable if considering vegetation-associated cooling relationships in the context of more general changes in urban surface characteristics. Cautions are important for any analysis of satellite-derived temperature differences as the timing of acquisition, seasonal differences and atmospheric conditions could affect the patterns that are observed.

Objectives:

1. To objectively measure LST and vegetation greenness changes with time in the selected observation years.
2. To analyze the difference and correlation of the spatial distribution of LST, NDVI, NDBI, and MNDWI.
3. To test for correlations between land surface parameters and LST by correlation and spatial panel regression methods.

2. Materials and Methods

2.1. Study Area and Research Design

The present study is quantitative, retro-active and geospatial in nature to find out the spatiotemporal variations of land surface temperature (LST) and vegetation dynamics in Dhaka Metropolitan Region (DMR), Bangladesh for the period 1990-2025. The area has high urbanisation, land cover mosaic and environmental variability. The variations in surface temperature, vegetation greenness, built-up characteristics and water-related surface conditions were investigated for 5 observation years: 1990, 2000, 2010, 2020 and 2025 using a longitudinal spatial panel approach. The analytical unit was the individual spatial grid cell which allowed geographical comparisons over time.

2.2. Data Sources and Dataset Characteristics

The Multi-temporal Gridded Panel Dataset of NDVI, NDBI, MNDWI and Land Surface Temperature for Dhaka Metropolitan Region (DMR) (1990-2025) was used for the study which is publicly available from the Mendeley Data repository. This analytical dataset consisted of 32135 observations across six 427 spatial grid cells having five observations each. The following variables were used: grid identification, observation year, spatial coordinates, mean LST, LST standard deviation, Normalized Difference Vegetation Index (NDVI), Normalized Difference Built-up Index (NDBI), and Modified Normalized Difference Water Index (MNDWI). These variables were used to explore the surface thermal conditions and vegetation change with respect to urban environmental variables (Sifat & Novo, 2026).

2.3. Data Preprocessing and Quality Assessment

Data Preprocessing: Completeness, consistency and structural integrity of spatial panel checked. Records were examined for missing observations, duplicate grid-year combinations and consistency of observations over time. No missing values or multiple grid-year observations in data, so panel of 6,427 grid cells observed across 5 years selected. The spatial coordinates were not altered for geographical mapping but the numerical environmental indicators were kept as is. Two descriptive screenings were performed to locate possible extreme observations and examine the distributions of the variables. No satellite image correction or spectral-index retrieval was performed on the data set as previously processed images from the satellite were provided.

2.4. Land Surface Temperature and Vegetation Assessment

Grid-level mean LST was used as a proxy for LST over the land surface and LST standard deviation was used as a proxy for within-grid thermal variability. Assessment of vegetation characteristics was made by measuring the NDVI which indicates vegetation greenness based on the difference of near infrared and red reflectance. The following is a typical expression of NDVI:

$$NDVI = \frac{I - e}{I + e}$$

where NIR and Red are the near-infrared and red reflectance, respectively. Generally, the higher the NDVI, the greener the vegetation. NDBI and MNDWI were also added to represent the built-up and water body surface states. The existing grid-level indices were adopted without any recalculation from satellite images.

2.5. Spatiotemporal Change Detection

Spatiotemporal variations of LST and vegetation were evaluated by comparing among the five observation years. The differences between the two periods and between the overall 1990-2025 were calculated to determine the changes in thermal and vegetation conditions. The changes in the grid were stated as:

$$\Delta = .2 - .1$$

where X_i represents LST or NDVI for grid cell i and t_1 and t_2 denote the initial and final observation years. Positive LST differences showed the warming trend, while negative differences showed the cooling trend. Likewise, the difference between positive and negative NDVI values indicated an increase in green vegetation and a decrease, respectively. The change for annualized change was determined by dividing the differences by the number of years. A series of spatial change maps were suggested for the purpose of spatial identification of concentrations of warming and vegetation change.

2.6. Statistical Analysis of LST and Land-Surface Relationships

To explore relationships between LST and land-surface characteristics, descriptive statistics, correlation analysis and multivariable panel regression were specified. Linear relationships were assessed using Pearson's correlation coefficient; when the data was not normally distributed or was not monotonic, Spearman's correlation was used. A fixed-effects panel regression model was set up as:

$$S = \alpha_i + \beta_1 DI + \beta_2 DI + \beta_3 DI + \epsilon_{it}$$

where LST_{it} represents surface temperature for grid cell i in year t , α_i denotes grid-specific effects, λ_t represents year effects, β_1 – β_3 indicate regression coefficients, and ϵ_{it} represents random error. Statistical significance was evaluated at $p < 0.05$, with confidence intervals and model diagnostics considered during interpretation. Associations were interpreted without assuming causality.

2.7. Climatic Variability and Environmental Interpretation

Observed changes in LST and vegetation characteristics were driven by climatic variability. The temporal variation of surface temperatures and NDVI was analyzed in addition to NDBI and MNDWI, to determine the relationships between surface thermal conditions, vegetation greenness, urban development and water-related characteristics. Climatic influences were not independently quantified as the data set lacked direct measurements of air temperature, precipitation and humidity. For investigating climatic drivers statistically, supplementary meteorological observations from various sources like ERA5-Land and CHIRPS would be needed. For this reason, the analysis was oriented towards observed spatiotemporal associations, rather than towards the direct attribution of environmental changes to climatic conditions.

2.8. Reliability, Limitations, and Ethical Considerations

The balanced panel structure, the full observations, the consistent spatial identifiers and availability of multiple environmental indicators were helpful to the reliability of the analytical framework. However, the five years of observation selected were not suitable for continuous trend analysis in time and season and the processed satellite-derived data suffered from the limitation of only being suitable for independent verification of the original retrieval procedures. The lack of direct meteorological variables further reduced climatic attribution. The study involved secondary geospatial data which were publicly available, but did not involve human participants, animals, or personally identifiable information. Thus, informed institutional ethics approval was not typically necessary. Research transparency was accomplished by citing the

source of the original data and by reporting analytical processes.

3. Results

3.1. Descriptive Characteristics of Land Surface Temperature and Environmental Indices

The analysis was based on 32,135 observations from 6,427 spatial grid cells in 5 observation years (1990-2025) in the Dhaka Metropolitan Region. Table 1 shows that there is a significant amount of variation in land surface temperature (LST) and environmental indices. Mean LST increased from 26.37 °C in 1990 to 31.07 °C in 2025, representing an overall difference of 4.70 °C. The lowest mean LST was recorded in 2020 (25.53 °C), and the mean Normalized Difference Vegetation Index (NDVI) ranged from 0.3583 to 0.4358, and the mean Normalized Difference Built-up Index (NDBI) and mean Modified Normalized Difference Water Index (MNDWI) also showed variation in observation years. The results suggest significant temporal variations in thermal conditions, vegetation greenness and land-surface features.

Table 1. Descriptive statistics of land surface temperature and environmental indices during 1990–2025

Year	Mean LST (°C)	LST SD (°C)	Mean NDVI	Mean NDBI	Mean MNDWI
1990	26.37	1.89	0.3924	−0.1656	−0.2463
2000	29.19	1.36	0.3925	−0.1942	−0.2128
2010	27.54	1.67	0.3583	−0.1522	−0.2536
2020	25.53	1.47	0.4008	−0.1372	−0.2470
2025	31.07	2.06	0.4358	−0.1342	−0.3003

Note: LST SD represents the standard deviation of grid-level mean LST within each observation year.

3.2. Temporal Variation in Land Surface Temperature

The LST variability over the study period was found to be non-monotonic, based on the temporal analysis. The mean LST showed a general increasing trend from 1990 to 2000, but showed a decreasing trend from 2000 to 2010 and from 2010 to 2020 as shown in Figure 1. There was also a significant rise in the period 2020 to 2025. The results show that the maximum increase in temperature, 5.55 °C, happened in the 2020-2025 period as indicated in Table 2. The mean LST increased by 4.70 °C over the entire 1990-2025 period, which averaged to the annualized endpoint difference of ~0.134 °C/year. This is due to the changing pattern in the surface thermal conditions between the observation years, as represented by the changing temperature pattern.

Table 2. Temporal changes in land surface temperature across observation periods

Observation period	Mean LST change (°C)	Annualized change (°C/year)
1990–2000	+2.82	+0.282
2000–2010	−1.66	−0.166
2010–2020	−2.01	−0.201
2020–2025	+5.55	+1.110
1990–2025	+4.70	+0.134

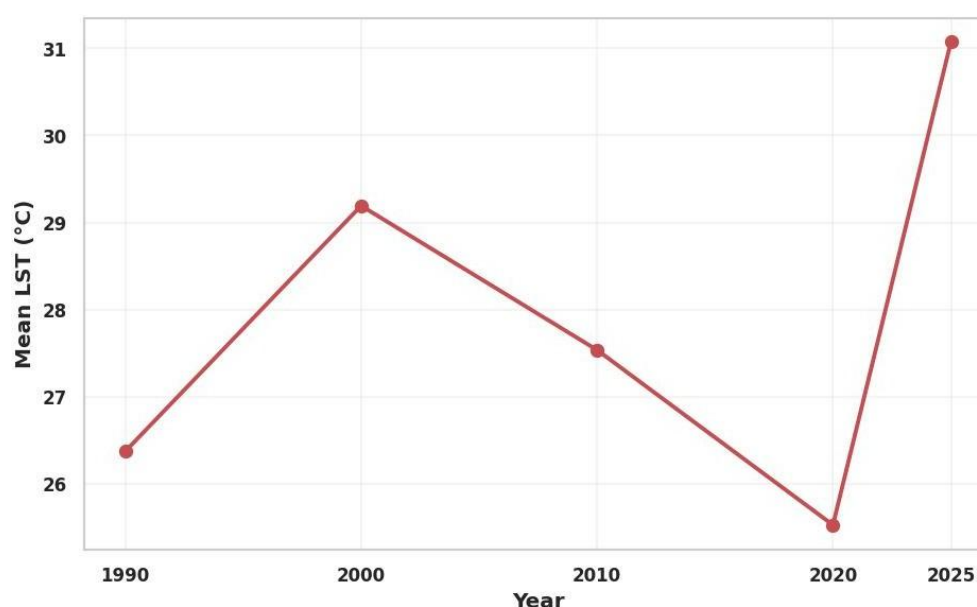


Figure 1. Temporal variation in mean land surface temperature across the Dhaka Metropolitan Region during the selected observation years from 1990 to 2025

3.3. Spatiotemporal Changes in Vegetation Greenness

There was significant variation in vegetation dynamics over the five years of observations. As shown in Table 3, the mean NDVI is almost unchanged from 1990 to 2000 and then decreased by 0.0342 from 2000 to 2010. Subsequent increases of 0.0425 and 0.0350 were recorded during 2010–2020 and 2020–2025, respectively. The difference in NDVI between 1990 and 2025 was about +0.0434, which means that the mean NDVI of the vegetation was greening at the end of the period. The temporal fluctuations are presented in Figure 2, with the lowest NDVI value in

2010 and the highest in 2025. Interestingly, the NDVI and LST were not consistently found to be inversely related over time, as both showed an increase over the final observation interval.

Table 3. Changes in vegetation greenness across observation periods

Observation period	Mean NDVI change	Annualized NDVI change
1990–2000	+0.0001	+0.00001
2000–2010	−0.0342	−0.00342
2010–2020	+0.0425	+0.00425
2020–2025	+0.0350	+0.00700
1990–2025	+0.0434	+0.00124

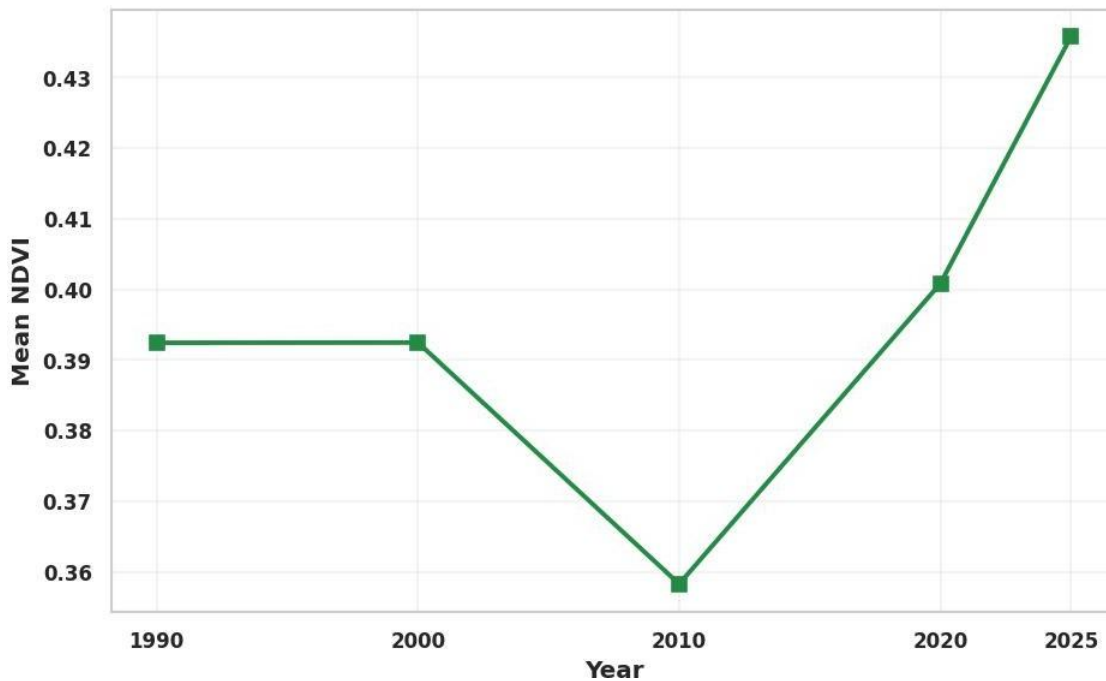


Figure 2. Temporal variation in mean Normalized Difference Vegetation Index across the Dhaka Metropolitan Region during 1990–2025

3.4. Spatial Distribution of Land Surface Temperature

The spatial analysis identified spatial variations of thermal conditions over the Dhaka Metropolitan Region. The spatial distribution shown in Fig. 3 shows the differences in grid-level LST between the 1990 and 2025 average, with more positive mean temperatures in 2025 than in

1990 in the region. The entire dataset showed significant spatial temperature variations from a low of around 20.79 °C to a high of 39.15 °C at the grid level. The spatial patterns show that the thermal condition varied between geographic locations, suggesting that surface characteristics may also affect the thermal condition. The change in the geographical distribution of relatively warmer and cooler surfaces is also suggested by the comparison of the endpoint years.

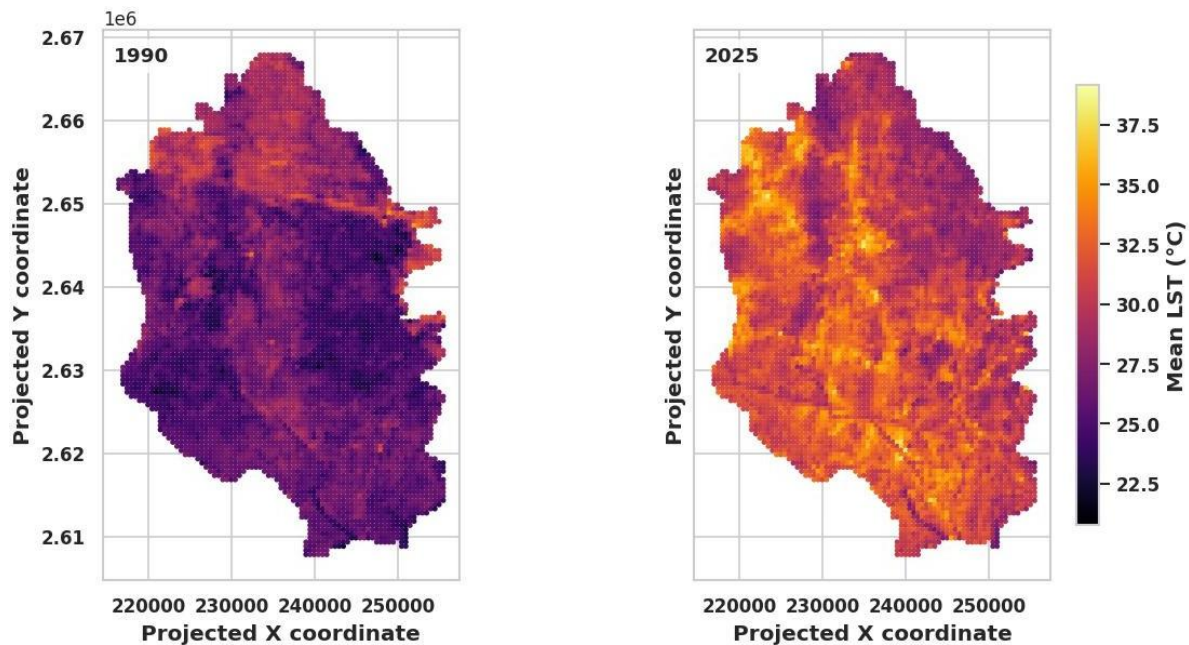


Figure 3. Spatial distribution of grid-level mean land surface temperature across the Dhaka Metropolitan Region in 1990 and 2025

3.5. Relationships Between Land Surface Temperature and Vegetation Characteristics

The Pearson correlation analysis showed that the relationships between LST and environmental indices were significantly different in time. The NDVI-LST correlation underwent a shift from negative in 1990 to a much stronger negative association in 2025, as shown in Table 4. On the other hand, NDBI had consistently positive correlation with LST, which has increased from 0.3757 in 1990 to 0.8006 in 2025. The trend of negative relationships between MNDWI and LST was observed for the entire time period. The links between LST and NDVI for 1990 and 2025 are shown in Figure 4, in which only a slight correlation is evident in the first year and a moderate negative correlation in the last year.

Table 4. Year-specific Pearson correlation coefficients between LST and environmental indices

Year	LST–NDVI	LST–NDBI	LST–MNDWI
1990	–0.0068	0.3757	–0.3241

2000	0.0731	0.5901	-0.3529
2010	-0.3144	0.7505	-0.3220
2020	-0.4082	0.7365	-0.2869
2025	-0.5449	0.8006	-0.1952

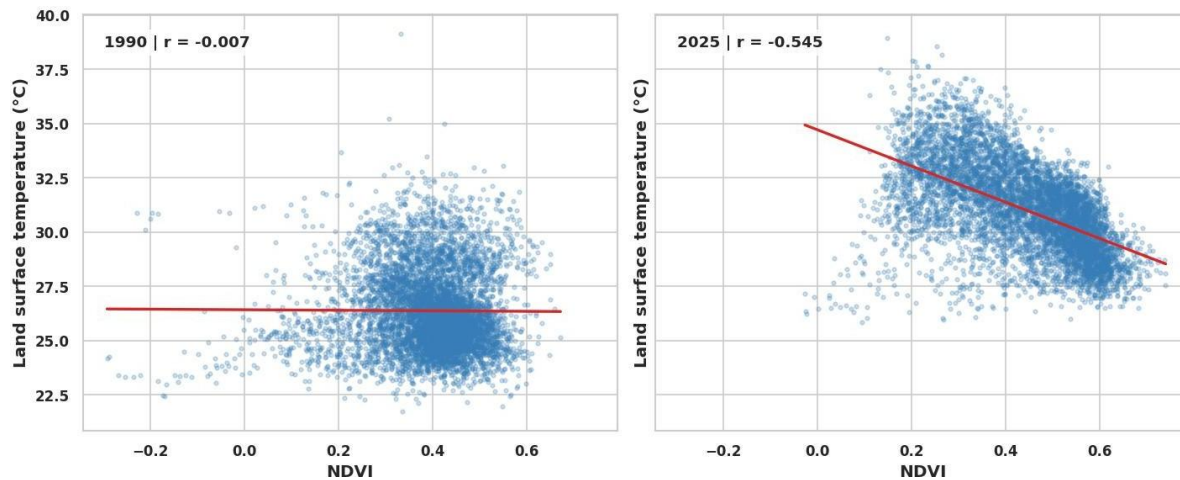


Figure 4. Relationships between land surface temperature and Normalized Difference Vegetation Index in 1990 and 2025, showing grid-level observations and fitted linear regression lines

3.6. Multivariable Relationships Between Land Surface Temperature and Environmental Indices

The correlation between LST and NDVI was performed for all 32,135 observations and showed a weak negative correlation ($r = -0.0845$, $p < 0.001$). The relationships between LST and NDBI were found to be moderately positive ($r = 0.4019$, while the MNDWI had a negative value of -0.2381). The correlation structure of all environmental indices are shown in Figure 5 with differences noted in the direction and magnitude of the relationship between each environmental index. A two-way fixed-effects panel regression was used to compare the relationships between LST and land surface characteristics while controlling for the effects of grid and year. As shown in Table 5, none of the three indices was shown to be statistically significant in their relationship with LST, but were found to be statistically significant with negative relationships to LST for NDVI and MNDWI, while NDBI showed a statistically significant positive relationship to LST. The coefficient of NDVI was found to be -6.6028 , which means that for every 0.1-unit increase in vegetation greenness, LST would drop by 0.660°C while the other explanatory variables and fixed effects were held constant. Likewise, for every one unit increase in NDBI, LST increased by about 0.331°C and for every one unit increase in MNDWI, LST decreased by about 0.517°C . This within-transformed model accounted for about 23.10% of the variation after removing the effects of grid and year.

Table 5. Two-way fixed-effects panel regression results for land surface temperature

Predictor	Coefficient	Clustered SE	95% confidence interval	p-value
NDVI	−6.6028	0.2915	−7.174 to −6.031	<0.001
NDBI	3.3114	0.3676	2.591 to 4.032	<0.001
MNDWI	−5.1666	0.2951	−5.745 to −4.588	<0.001

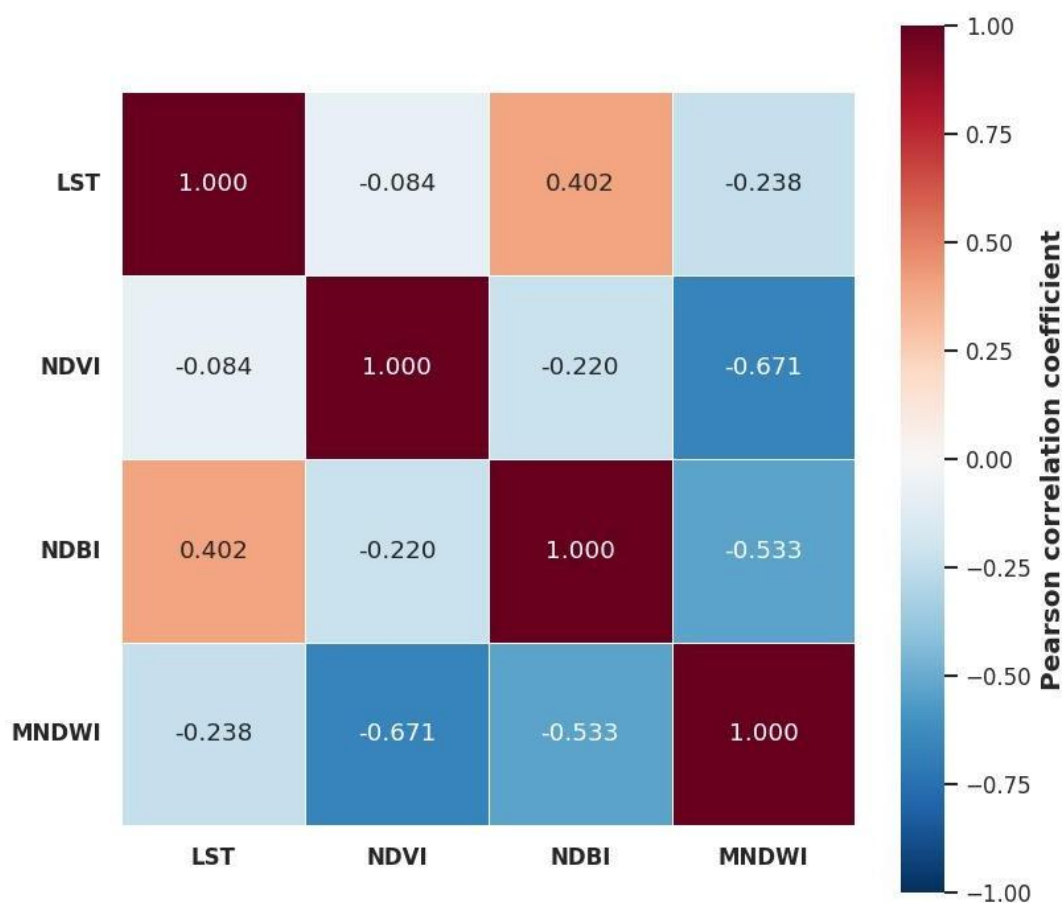


Figure 5. Pearson correlation matrix illustrating the relationships among land surface temperature, NDVI, NDBI, and MNDWI across all observation years

3.7. Integrated Spatiotemporal Assessment of Surface Temperature and Vegetation Change

The spatiotemporal assessment embedded revealed that the patterns of change in surface temperature and vegetation greenness were different between 1990 and 2025. Grid level

comparisons showed that LST increased in 2025 compared to 1990 in approximately 94.96% of the spatial units and increased NDVI for 62.49% of the spatial units. These results show that the changes in surface temperature and greenness of the vegetation were simultaneous for large areas of the study area. Figure 6 shows spatial variation of the differences in LST between the endpoint years, showing geographical variations of temperature changes. The results from correlation and regression analysis show that vegetation greenness and water-related variables were negatively correlated with LST while built-up surface variables were positively correlated with LST. However, direct attribution to climate was not possible at the time since there were no independent measurements of air temperature, precipitation or humidity in the dataset.

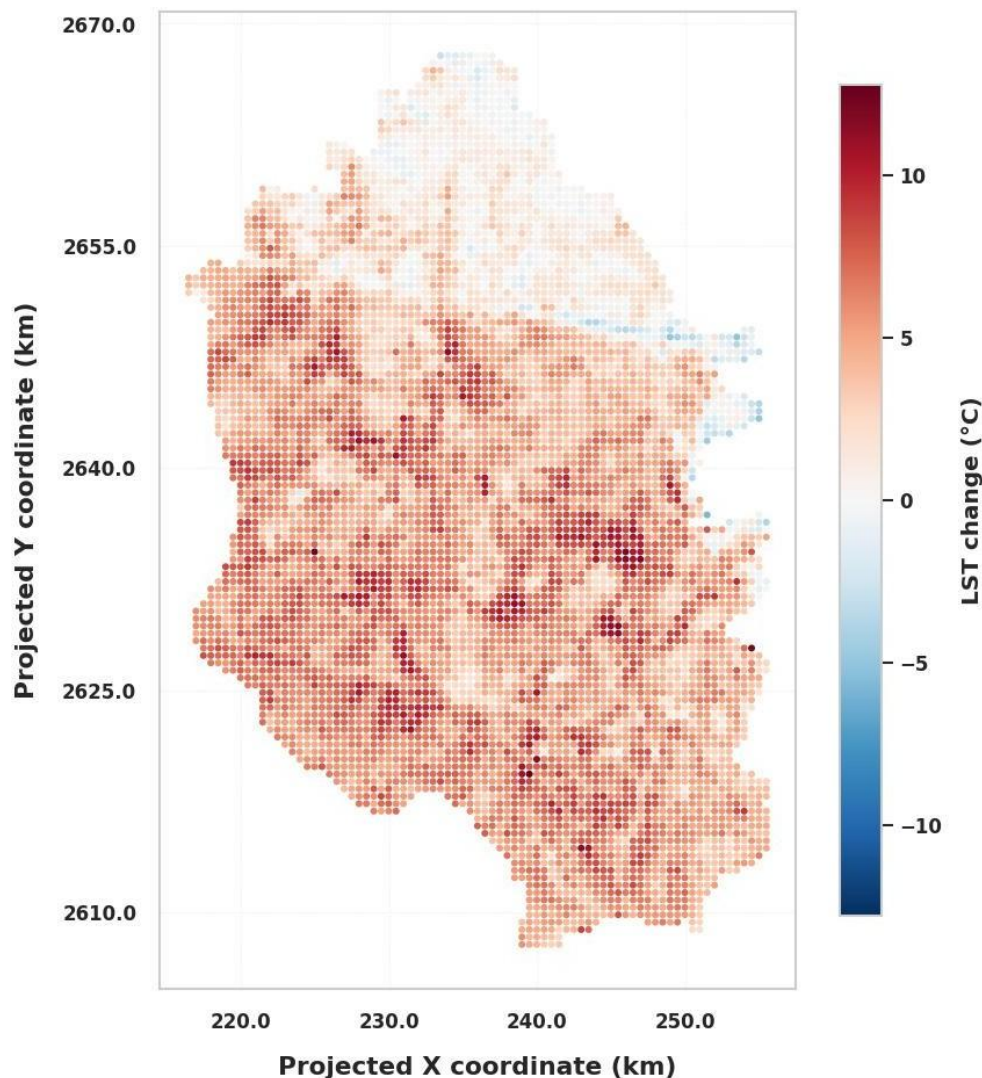


Figure 6. Spatial distribution of grid-level land surface temperature changes between 1990 and 2025 across the Dhaka Metropolitan Region

3.8. Summary of Key Findings

It was found that there are significant land surface temperature (LST) and vegetation greenness changes at both spatial and temporal scales in Dhaka Metropolitan Region (DMR) for the period

1990-2025. The mean LST has increased by 4.70 °C during the study period and mean NDVI has increased during the study period by 0.0434. The percentage of spatial grid cells with enhanced LST were about 94.96% of the total, while 62.49% showed enhanced vegetation greenness. The significant negative associations obtained in the correlation and regression analysis between LST and NDVI, MNDWI were observed, whereas NDBI showed positive association. These results show the correlations between surface thermal conditions and land surface properties. But the effect of climate on the observed changes could not be assessed directly due to a lack of meteorological observations.

4. Discussion

In the present study, the mapping spatiotemporal variations of land surface temperature (LST) and vegetation greenness were observed over the Dhaka Metropolitan Region (DMR) during 1990-2025. There was a net increase in mean LST of 4.70 °C, but there was significant inter-annual variability. Widespread surface thermal changes were noted with temperatures increasing in about 94.96% of spatial grid cells, respectively, in 2025 compared to 1990. The results are consistent with earlier studies that reported on the existing spatial variation of urban temperatures in Dhaka and the need for spatially variable heat evaluation (Hussain et al., 2023). Research on urban environmental indices also focused on their significance to understand surface temperature changes and plan cities.

This nonmonotonic pattern of temperature indicates that progressive urban expansion is not the only driver of surface thermal conditions. Observed temperatures could be affected by differences in Land Cover, conditions during the satellite acquisition and seasonal characteristics. Past studies conducted in the greater Dhaka showed the relationship between climatic variability, land use dynamics and satellite-derived environmental indices (Kulsum & Moniruzzaman, 2022). The results of similar studies in Chattogram indicated that urbanization is linked to urban surface temperature variations and thus reflected the wider applicability of land change in urban areas in Bangladesh (Roy et al., 2020). However, the regional temperature differences are not necessarily the same as urban and rural heat island differences and should be properly compared (Wang et al., 2023).

Though there were fluctuations between the two times, the overall increase in NDVI in the vegetation analysis was found to be 0.0434 from 1990 to 2025. Importantly, the rise in regional vegetation greenness was associated with an increase in mean LST in the last observation interval. The apparent discrepancy suggests that the distribution of vegetation is not the only explanation for the regional thermal conditions. Past Landsat research showed that spatial variability of LST–NDVI relationships exist in both temporal and spatial dimensions (Guha et al., 2020; Zaitunah et al., 2022). Moreover, vegetation cooling is related to canopy structure, moisture availability and local atmospheric conditions. More recently, it has been shown that urban vegetation can have more complex thermal responses in humid conditions, where it is not straightforward that the greener, the lower the temperature.

The correlation analysis showed that the relationship between LST and NDVI has become more negative from almost nonexistent in 1990 to moderately negative in 2025. Another significant negative coefficient for NDVI was confirmed in the fixed effects regression, where the

vegetation index was reduced in the warmer grid cells after removing the spatial and temporal effects. These results confirm that research works have been conducted that reveal the cooling effect of the configurations of vegetation and the surrounding urban morphology. Research using spatial causal inference has also highlighted the potential role of vegetation and surface reflectivity in urban heat mitigation (Shah et al., 2021; Calhoun et al., 2024). But the current observed associations should not be taken as a cause-and-effect estimate of vegetation cooling.

The built-up characteristics showed consistently positive relation with LST, the highest annual correlation being in 2025. The positive regression coefficient for NDBI also suggests an increase in built up spectral features with increasing surface temperature. A similar relationship between LST and NDBI has been found from multiseason Landsat data (Guha et al., 2021). Similar studies using CA and ANN techniques in Dhaka also showed that land cover changes play a crucial role in comprehending the patterns of surface temperature (Kafy et al., 2021). Furthermore, urban morphology could also have an influence on the cooling efficiency of green space, highlighting the importance of considering urban morphology in addition to vegetation indicators (Chen et al. 2025).

The LST was negatively correlated with MNDWI, indicating that water related surface characteristics played a role in the temperature difference. Spatial heterogeneity also suggests that local environmental conditions could have different effects on exposure to heat in metropolitan areas. Recent estimates of environmental livability in Dhaka further highlight the need to consider several spatial indicators to assess urban environmental conditions (Huang et al., 2025). Therefore, context specific combinations of protection of vegetation, permeable surfaces and planning for water should be a priority in interventions (Massaro et al., 2023). Improving the local thermal conditions could be one potential solution for terrace gardens (Visvanathan et al., 2024), and periurban agricultural landscape may have other potential for mitigating summer heat. There are some restrictions that should be considered. Trend interpretation was limited by using five selected years for the analysis rather than annual observations. In addition, detailed land cover classifications, meteorological measurements and timing of acquisition from the satellite were not available for independent climatic attribution. Future studies should combine atmospheric observations, seasonal controls and spatially explicit urban morphology to differentiate between climatic variability and land transformation effects. The results show the need for integrated thermal and vegetation studies for sustainable metropolitan planning and target-oriented adaptation measures.

5. Conclusion

This study focused on spatiotemporal trends of land surface temperature (LST), vegetation greenness and environmental parameters in Dhaka metropolitan region during 1990-2025. The results indicated that the average LST had risen by 4.70 °C over a period of study while the mean Normalized Difference Vegetation Index (NDVI) had increased by 0.0434. The surface temperature of 94.96% of the spatial grid cells has increased, and that of 62.49% of them has improved the greenness of vegetation. The contrasting patterns show the complexity of urban thermal dynamics and suggest that the regional temperature variations cannot be explained by vegetation changes alone. LST was found to have significant negative correlation with both NDVI and Modified Normalized Difference Water Index, and a positive correlation with

Normalized Difference Built-up Index, in fixed-effects regression. The fixed-effects regression analyses showed significant negative correlations between LST and NDVI, LST and Modified Normalized Difference Water Index, and a positive correlation between LST and Normalized Difference Built-up Index. The results highlight the need to preserve vegetation, to pursue sustainable urban development and water sensitive planning to manage the surface thermal conditions. Climatic attribution and continuous trend assessment is however limited by the short number of observation years, and by the lack of direct meteorological measurements. Further research could include more detailed land cover classifications, climatic variables, and future satellite observations to better support environmental interpretation. In general, the present study offers an important spatial evidence to understand the spatial variation of the surface temperature in the urban area and it would be helpful to develop integrated strategies to build environmental resilience and sustainable urban planning in Dhaka in a location-specific way.

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