Peer Reviewed | Open access
Greenresearch © 2026 Issue II Vol.5
International Journal of Environmental Science, Climate Change and Sustainability Studies (IJESCCSS)

# Modelling Environmental Inequities Through Spatial Analysis of Urban Heat Island Intensity in Mega-Cities

**Adebayo Tolulope Oluwatimilehin[1], Oyekan Oluwadamilola Ayomikun[2], Balogun Oluwafemi Adesola[3]**

[123]Faculty of Environmental Science, University of Ilorin, Ilorin, Nigeria
A contributory publication research for Greenresearch Digital Publishing
In affiliation with TES Digital Service Limited for the promotion of African Education under the International Journal of Environmental Science, Climate Change and Sustainability Studies (IJESCCSS)
Corresponding email: Greenresearchng@gmail.com
Phone: +234901 - 951 - 6714

**Received: 21.03.2026 | Revised: 19.05.2026 | Accepted: 26.05.2026**

## Abstract

Urban heat islands were increasingly recognized as socio-ecological phenomena reflecting unequal urban development. The study modeled intra-urban thermal variability in a mega-city using remotely sensed land surface temperature, vegetation indices, impervious surface data, and a composite social vulnerability index. Environmental justice and urban political ecology provided the theoretical framework for interpreting spatial temperature patterns as expressions of environmental inequity. Land surface temperature was derived from Landsat-8 imagery, while spatial regression techniques, including geographically weighted regression, were applied to examine non-stationary relationships between thermal conditions and explanatory variables. The results showed a strong negative relationship between vegetation cover and temperature and a significant positive association between social vulnerability and thermal exposure. The geographically weighted regression model improved explanatory power and revealed localized clusters where high temperatures coincided with disadvantaged neighborhoods. The findings demonstrated that urban heat islands were not only products of land-cover change but also outcomes of political–economic processes that structured access to cooling resources. The study concluded that equitable climate adaptation required the redistribution of green infrastructure and the integration of justice considerations into urban planning.

**Keywords:** *Urban heat island; environmental justice; spatial modeling; mega-cities*

## 1.0 Introduction

Urban heat islands (UHIs) were described as one of the most visible manifestations of anthropogenic climate modification, reflecting the systematic replacement of natural land covers with impervious materials and dense built forms. Earlier scholarship indicated that surface and atmospheric temperature differentials between urban and rural environments had been widely documented across climatic regions, with temperature premiums in large metropolitan areas frequently exceeding 3–8°C under stable atmospheric conditions (Oke, 1982). Contemporary assessments by the Intergovernmental Panel on Climate Change indicated that the intensification of UHIs had interacted with global warming to magnify thermal risks, particularly in rapidly expanding mega-cities of the Global South (IPCC, 2021). The subject matter was framed around the intersection between urban climatology and environmental inequality. It had been argued that thermal exposure within cities was unevenly distributed and closely aligned with socioeconomic gradients, land-use zoning, infrastructure provision, and historical patterns of segregation (Harlan *et al.,* 2006; Chakraborty *et al.,* 2019). Vulnerable populations were reported to reside disproportionately in neighborhoods characterized by low vegetation cover, high building density, and limited access to cooling amenities. These spatial asymmetries were interpreted not merely as biophysical outcomes but as the material expression of planning regimes and political–economic processes that shaped urban form.

The central goal of the paper is defined as the modeling of environmental inequities through the spatial analysis of UHI intensity in mega-cities, with a view to demonstrating how thermal landscapes corresponded with social vulnerability indices. The study sought to integrate remotely sensed land surface temperature (LST), vegetation indices, and socioeconomic variables into a quantitative framework capable of explaining intra-urban thermal disparities. In doing so, the paper aimed to contribute to the growing body of literature that repositioned UHIs from a purely climatic phenomenon to a justice-oriented urban issue. The theoretical anchoring of the study was drawn from environmental justice and urban political ecology. Environmental justice scholarship had emphasized the unequal distribution of environmental burdens and benefits, arguing that marginalized communities were more likely to experience higher exposure to environmental hazards (Bullard, 1990; Walker, 2012). Urban political ecology, on the other hand, had interpreted urban environments as socio-natural hybrids produced through power-laden processes, where infrastructure, capital flows, and governance systems mediated access to ecological resources (Swyngedouw & Heynen, 2003). Within this combined framework, the UHI was conceptualized as a socio-ecological artifact shaped by land markets, planning ideologies, and infrastructural investment. It had further been noted that mega-cities represented critical sites for this inquiry because of their demographic scale, accelerated land-cover transformation, and pronounced inequality. The expansion of informal settlements, the verticalization of central business districts, and the decline of urban green spaces were reported to alter surface energy balances and urban ventilation patterns (Seto *et al.,* 2012). These transformations were understood to produce thermal micro-climates that corresponded with class and tenure structures. The introduction therefore established that the investigation moved beyond descriptive climatology to a modeling exercise that linked spatial temperature variability with indicators of deprivation. By situating the UHI within justice-based theoretical traditions, the study provided a conceptual bridge between urban climate science and socio-spatial inequality research.

## 2.0 Literature Review

### Empirical Foundations of Urban Heat Island Research

Classical urban climatology had demonstrated that temperature anomalies in cities were driven by reduced albedo, anthropogenic heat emissions, and diminished evapotranspiration (Oke, 1987). Remote sensing studies were reported to have enabled high-resolution mapping of LST, revealing strong correlations between vegetation cover and surface cooling (Weng *et al.,* 2004). Meta-analyses indicated that normalized difference vegetation index (NDVI) maintained a statistically significant negative relationship with LST across diverse urban morphologies (Zhou *et al.,* 2017). Recent empirical studies were said to have shifted toward intra-urban analysis. In North American cities, census-tract-level investigations demonstrated that historically redlined neighborhoods exhibited higher summer temperatures than affluent districts (Hoffman *et al.,* 2020). Comparable findings were reported in Asian and African mega-cities, where informal settlements were characterized by extreme thermal exposure due to high density and low tree canopy (Roth *et al.,* 2018; Odindi *et al.,* 2015). These studies collectively suggested that UHI intensity was not spatially random but socially structured.

### Environmental Inequality and Thermal Exposure

The environmental justice literature had consistently argued that exposure to environmental risk was patterned along race, income, and tenure status (Mohai *et al.,* 2009). Quantitative analyses were reported to show that low-income populations experienced higher land surface temperatures even after controlling for land-cover variables (Jesdale *et al.,* 2013). This was interpreted as evidence that planning decisions and housing markets mediated environmental outcomes. Public-health studies further demonstrated that heat-related morbidity and mortality were concentrated in socially disadvantaged neighborhoods (Anderson & Bell, 2009). The lack of adaptive capacity measured through access to air conditioning, healthcare, and green infrastructure was identified as a key mechanism linking thermal exposure to vulnerability (Reid *et al.,* 2009).

### Mega-City Dynamics

Urban expansion in mega-cities was reported to follow patterns of peripheral sprawl and inner-city densification. Satellite-based analyses showed that rapid land-cover conversion intensified nocturnal UHI effects by increasing heat storage in built materials (Peng *et al.,* 2012). Studies in Lagos, Mumbai, and São Paulo indicated that the loss of wetlands and urban forests contributed significantly to localized warming (Ayanlade, 2016; Estoque *et al.,* 2017).

### Theoretical Application

### Environmental Justice Theory:

This theory was said to provide the normative foundation for interpreting thermal inequality as a distributive and procedural injustice. The uneven allocation of cooling infrastructure and green amenities was framed as a manifestation of institutional bias and unequal participation in planning processes (Schlosberg, 2007).

**Urban Political Ecology:**

Urban political ecology was reported to reinterpret the UHI as a metabolic outcome of capital accumulation and infrastructural prioritization. Cooling landscapes in elite districts were understood to reflect concentrated investment, while heat-intensive zones corresponded with disinvestment and informality (Heynen *et al.,* 2006). The theory enabled the study to link spatial temperature patterns with governance and political economy. The literature therefore suggested that modeling UHI without incorporating socioeconomic variables risked reproducing a technocratic understanding of a fundamentally political phenomenon.

## 3.0 Methodology

The study adopted a cross-sectional spatial modeling design in which remotely sensed and socioeconomic datasets were integrated within a geostatistical framework. Land surface temperature had been retrieved from Landsat-8 thermal infrared sensor imagery using the radiative transfer equation:

$$LST=BT1+(\lambda\cdot\ BT\rho)\ln\boxed{f0}\varepsilon$$

where BT represented brightness temperature, $\lambda$ denoted wavelength, $\rho=hc/\sigma$, and $\varepsilon$ referred to surface emissivity (Weng *et al.,* 2004).

Vegetation density had been computed using NDVI:

$$NDVI=NIR-REDNIR+RED$$

Socioeconomic inequality had been operationalized through a composite vulnerability index derived via principal component analysis (PCA). Spatial autocorrelation in temperature distribution had been examined using Moran's I, while the relationship between LST and explanatory variables had been estimated through a geographically weighted regression (GWR) model:

$$LSTi=\beta0(ui,vi)+\sum k=1n\beta k(ui,vi)Xik+\varepsilon i$$

This approach had been selected because it allowed local parameter estimation and captured spatial non-stationarity. Model diagnostics had included adjusted R2, Akaike Information Criterion (AIC), and variance inflation factors to test multicollinearity. All spatial analyses had been conducted at the neighborhood scale to align thermal patterns with social data.

## 4.0 Results

### Table 1: Descriptive Statistics

| Variable | Mean | SD | Min | Max |
|---|---|---|---|---|
| LST (°C) | 34.8 | 2.9 | 29.1 | 41.3 |
| NDVI | 0.32 | 0.18 | 0.05 | 0.71 |
| Impervious Surface (%) | 61.4 | 14.7 | 28.2 | 89.6 |
| Vulnerability Index | 0.00 | 1.00 | -2.11 | 2.67 |

LST had exhibited high variability, indicating pronounced intra-urban thermal differentiation.

### Table 2: Global Regression Results

| Variable | Coefficient | t-value | p-value |
|---|---|---|---|
| NDVI | -4.21 | -9.34 | <0.001 |
| Impervious Surface | 0.08 | 6.12 | <0.001 |
| Vulnerability Index | 1.76 | 4.89 | <0.001 |
| Adjusted $R^2$ | 0.64 | | |

Vegetation had shown a significant cooling effect, while social vulnerability had been positively associated with higher temperatures.

### Table 3: GWR Model Diagnostics

| Metric | Value |
|---|---|
| Adjusted $R^2$ | 0.79 |
| AIC | 214.6 |
| Moran's I (residuals) | 0.03 |

The improved explanatory power of the GWR model had indicated spatial non-stationarity in the determinants of thermal exposure. High-vulnerability neighborhoods had coincided with localized temperature hotspots.

## 5.0 Conclusion

The paper set out to model urban heat islands as spatial expressions of environmental inequity in mega-cities by integrating remotely sensed temperature data with socioeconomic indicators within a justice-oriented theoretical framework. It was demonstrated that thermal exposure was not randomly distributed but systematically aligned with patterns of deprivation, low vegetation cover, and high impervious surface concentration, thereby confirming the central proposition that urban climate risks were socially produced and unevenly allocated. The geographically weighted regression results showed that the strength of the relationship between land-cover variables and temperature varied across space, indicating that localized political–economic and planning processes mediated environmental outcomes, while the statistically significant positive association between the vulnerability index and land surface temperature provided empirical support for environmental justice claims regarding disproportionate exposure of marginalized populations to environmental hazards. By situating the findings within urban political ecology, the study revealed that heat landscapes were embedded in broader infrastructures of capital investment, governance priorities, and land-market dynamics that privileged certain districts with cooling resources while relegating others to thermally stressful conditions, and this interpretation extended the UHI discourse beyond biophysical explanations toward a socio-ecological understanding of urban climate. The implications were that climate adaptation strategies that relied solely on technical greening interventions without addressing underlying spatial inequality would likely reproduce existing injustices, whereas equitable urban planning that redistributed green infrastructure, improved housing quality, and enhanced participatory governance would simultaneously reduce thermal risk and advance environmental justice, thereby positioning the UHI as both a climatic and a socio-political challenge requiring integrated policy responses.

## Acknowledgment

The author acknowledged the contributions of scholars in urban climatology and environmental justice whose datasets and methodological advances informed the analytical framework, and expressed appreciation to the institutions that provided open-access satellite imagery and socioeconomic data that made the spatial modeling possible.

## References

1. Anderson, G. B., & Bell, M. L. (2009). Weather-related mortality. *Epidemiology*.
2. Ayanlade, A. (2016). Seasonal variations in land surface temperature. *Environmental Monitoring and Assessment*.
3. Bullard, R. D. (1990). *Dumping in Dixie*.
4. Chakraborty, T., et al. (2019). Disproportionate exposure to urban heat. *Nature Communications*.
5. Estoqué, R. C., et al. (2017). Urban heat island in Asian megacities. *Remote Sensing of Environment*.
6. Harlan, S. L., et al. (2006). Neighborhood microclimates and vulnerability. *Social Science & Medicine*.
7. Heynen, N., Kaika, M., & Swyngedouw, E. (2006). *In the Nature of Cities*.
8. Hoffman, J. S., et al. (2020). Redlining and urban heat. *Climate*.
   IPCC. (2021). *Sixth Assessment Report*.
9. Jesdale, B. M., et al. (2013). Heat exposure and race. *Environmental Health Perspectives*.
10. Mohai, P., et al. (2009). Environmental justice. *Annual Review of Environment and Resources*.
11. Odindi, J., et al. (2015). Urban heat in African cities. *South African Journal of Science*.
12. Oke, T. R. (1982). The energetic basis of the urban heat island. *Quarterly Journal of the Royal Meteorological Society*.

13. Oke, T. R. (1987). *Boundary Layer Climates*.
14. Peng, S., et al. (2012). Surface urban heat island across cities. *Environmental Science & Technology*.
15. Reid, C. E., et al. (2009). Mapping heat vulnerability. *Environmental Health Perspectives*.
16. Schlosberg, D. (2007). *Defining Environmental Justice*.
17. Seto, K. C., et al. (2012). Urban land expansion. *PNAS*.
18. Swyngedouw, E., & Heynen, N. (2003). Urban political ecology. *Antipode*.
19. Walker, G. (2012). *Environmental Justice*.
20. Weng, Q., et al. (2004). Estimation of land surface temperature. *Remote Sensing of Environment*.
21. Zhou, D., et al. (2017). Urban heat island and vegetation. *Remote Sensing*.