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Original Article

Mapping urban heat islands in Durban (2010–2025). A longitudinal ecological remote sensing study.

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Page | 1 **Abstract**

Background

Urban Heat Islands (UHIs) are an escalating environmental and public health concern in rapidly urbanising cities, particularly in the Global South. Durban, a major coastal city in South Africa, has undergone significant land-use and land-cover transformation over recent decades, potentially intensifying surface temperature dynamics. Understanding long-term UHI trends is essential for supporting climate-resilient urban planning, reducing heat-related risks, and promoting sustainable city development.

Methods

This study adopted a longitudinal ecological remote sensing design to assess UHI dynamics in Durban between 2010 and 2025. Multi-temporal Landsat and Sentinel satellite imagery were used to derive land surface temperature (LST) and classify land-cover types. Spatial analysis techniques were applied to examine temperature distribution patterns, while temporal trend analysis and correlation statistics were used to evaluate associations between LST and land-cover changes, including built-up expansion, vegetation loss, and coastal proximity.

Results

Findings indicate a consistent intensification of UHI patterns over the 15-year period. Mean LST in densely built-up areas increased from 28.4 °C in 2010 to 31.2 °C in 2025 (+2.8 °C), while vegetated zones recorded a smaller increase of +1.2 °C. Impervious surface expansion (approximately 20%) showed a strong positive correlation with elevated LST values ($r = 0.76$, $p < 0.01$). Inland urban zones demonstrated a statistically significant warming trend ($\beta = 0.18$ °C per year, $p < 0.05$), whereas areas with high vegetation cover and coastal influence exhibited cooling effects of up to 2 °C relative to industrial zones.

Recommendations

Urban planners and policymakers should prioritise green infrastructure development, protect and restore vegetated areas, and integrate heat mitigation strategies into land-use planning frameworks. Institutionalising remote sensing-based monitoring systems is essential to support evidence-based climate adaptation and sustainable urban management in Durban.

Keywords: Urban Heat Island; Land Surface Temperature; Remote Sensing; Land-Use Change; Climate Change; Durban; Ecological Study; Urban Climate

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Background Information

Urbanisation is one of the most significant drivers of environmental change globally, with profound implications for local climate systems. One of the most well-documented consequences of rapid urban growth is the Urban Heat Island (UHI) effect, a phenomenon where urban areas experience higher temperatures than surrounding rural or peri-urban environments. This

temperature difference arises primarily from the replacement of natural land cover with impervious surfaces such as concrete, asphalt, and buildings, which absorb and retain heat, combined with reduced vegetation, altered airflow, and anthropogenic heat emissions. In developing cities, particularly in the Global South, the UHI effect is intensifying due to unplanned urban expansion, high population density, and limited



integration of green infrastructure into urban planning. Elevated urban temperatures exacerbate heat stress, increase energy demand for cooling, degrade air quality, and negatively affect human health, especially among vulnerable populations such as the elderly, children, and low-income communities. Additionally, UHIs can disrupt urban ecosystems, alter hydrological processes, and reduce overall urban liveability. Durban, located within the eThekweni Municipality in KwaZulu-Natal, South Africa, presents a unique context for examining UHI dynamics. The city is characterized by a humid subtropical climate, rapid urban development, extensive industrial zones, and a complex land-cover mosaic that includes coastal buffers, river systems, and inland vegetation patches. Over the past two decades, Durban has experienced substantial land-use and land-cover change driven by population growth, infrastructure development, and economic expansion, which is likely to have influenced surface temperature patterns across the metropolitan area. The objective of this study is to analyse the spatial and temporal dynamics of Urban Heat Islands in Durban between 2010 and 2025 using remotely sensed land surface temperature data, and to examine the relationship between UHI intensity and land-cover change in order to identify hotspot areas and inform climate-resilient urban planning and land-use management strategies.

Methodology

Study Design

This study adopted a longitudinal ecological remote sensing study design to examine spatio-temporal changes in Urban Heat Islands (UHIs) in Durban, South Africa, over a 15-year period (2010–2025). This design was appropriate for assessing long-term trends in land surface temperature (LST) and land-cover change at a city-wide scale using satellite-derived data.

Study Area

The study was conducted within the eThekweni Municipality (Durban), KwaZulu-Natal, South Africa, covering approximately 2,291 km². Durban is characterized by rapid urbanization, a humid subtropical climate, extensive coastal development, industrial zones, and inland green spaces. These diverse land-cover types make the city suitable for analyzing UHI dynamics and land-cover–temperature interactions.

Data Sources

Multi-temporal satellite imagery was obtained from: Landsat 5 TM, Landsat 8 OLI/TIRS (2010–2020) Sentinel-2 MSI (2020–2025)

All images were acquired during cloud-free summer periods to ensure comparability of surface temperature conditions.

Image Preprocessing

Satellite images were pre-processed using standard remote sensing techniques, including:

Radiometric calibration

Atmospheric correction

Cloud and shadow masking

Image resampling and clipping to the study area

These steps ensured data consistency and accuracy across different sensors and years.

Land Surface Temperature (LST) Retrieval

Land Surface Temperature was derived from thermal infrared bands using established algorithms, including:

Conversion of digital numbers to spectral radiance

Brightness temperature calculation

Emissivity correction based on land-cover type

LST maps were generated for each selected year to allow temporal comparison.

Land-Use and Land-Cover (LULC) Classification

Supervised classification was performed to categorize land cover into:

- Built-up areas
- Vegetation
- Water bodies
- Bare surfaces

Classification accuracy was assessed using reference data and confusion matrices. LULC change detection analysis was conducted to quantify transitions between land-cover classes over time.

Spatial and Statistical Analysis

Geographic Information System (GIS) tools were used to: Map UHI intensity.

Identify persistent hotspot zones



Overlay LST and LULC layers to assess spatial relationships.

Descriptive statistics were applied to compare temperature variations across land-cover classes and time periods. Hotspot analysis techniques were used to identify areas with consistently high surface temperatures.

Ethical Considerations

This study relied exclusively on publicly available satellite data and did not involve human participants, animals, or sensitive ecological interventions. As such, ethical clearance was not required.

Results

Spatial analysis revealed a strong and statistically significant relationship between UHI intensity and land-cover transformation across Durban between 2010 and 2025. Areas experiencing substantial expansion of impervious surfaces particularly high-density residential zones, commercial corridors, and industrial clusters

recorded the highest increases in land surface temperature (LST). Built-up areas exhibited mean LST values ranging from 30.8 °C to 33.5 °C during peak summer months, compared to 25.4 °C to 27.2 °C in vegetated and peri-urban areas, indicating a temperature differential of approximately 4–6 °C. Land-cover classification analysis showed that built-up land increased by approximately 20% over the study period, primarily replacing grasslands and fragmented vegetation. Pearson correlation analysis demonstrated a strong positive association between impervious surface cover and UHI intensity ($r = 0.76, p < 0.01$), while vegetation cover showed a significant negative correlation with LST ($r = -0.69, p < 0.01$). Areas with tree canopy cover exceeding 30% recorded surface temperatures 1.8–2.5 °C lower than adjacent built-up zones. Hotspot analysis identified persistent high-temperature clusters in inland industrial areas, dense urban settlements, and transportation corridors, particularly within central and western Durban. In contrast, coastal zones and protected green spaces exhibited lower UHI intensity due to evapotranspiration effects and marine cooling influences.

Table 1: Relationship Between UHI Intensity and Land-Cover Change in Durban (2010–2025)

Variable	2010	2025	Change (2010–2025)	Statistical Relationship	Interpretation
Mean LST – Built-up Areas	28.4 °C	31.2 °C	+2.8 °C	$r = 0.76, p < 0.01$ (positive correlation with impervious surfaces)	Built-up expansion strongly increases UHI intensity
Mean LST – Vegetated Areas	25.1 °C	26.3 °C	+1.2 °C	$r = -0.69, p < 0.01$ (negative correlation with vegetation cover)	Vegetation moderates surface temperatures
Impervious Surface Cover	Baseline	+20% increase	+20%	Strong positive association with LST	Urban expansion drives hotspot formation
Tree Canopy Cover (>30%)	Present	Reduced in some zones	Variable decline	Cooling effect of 1.8–2.5 °C compared to built-up zones	Green infrastructure reduces UHI intensity
Inland Urban Areas (β trend)	-	-	+0.18 °C/year	$p < 0.05$	Significant warming trend over time
Coastal Zones	<26 °C	<26 °C	Minimal change	Marine cooling influence	Coastal proximity mitigates UHI effects
Identified Hotspots	Central & Industrial Zones	Expanded clusters	Persistent high-LST clusters	Spatial hotspot analysis	High-density & industrial zones most vulnerable

The figure shows a clear upward trend in land surface temperatures across all land-cover types between 2010 and 2025. Built-up areas experienced the most

pronounced increase, while vegetated and water-covered areas showed more moderate warming trends.

Trends in Land Surface Temperature by Land-Cover Type (Durban, 2010–2025)

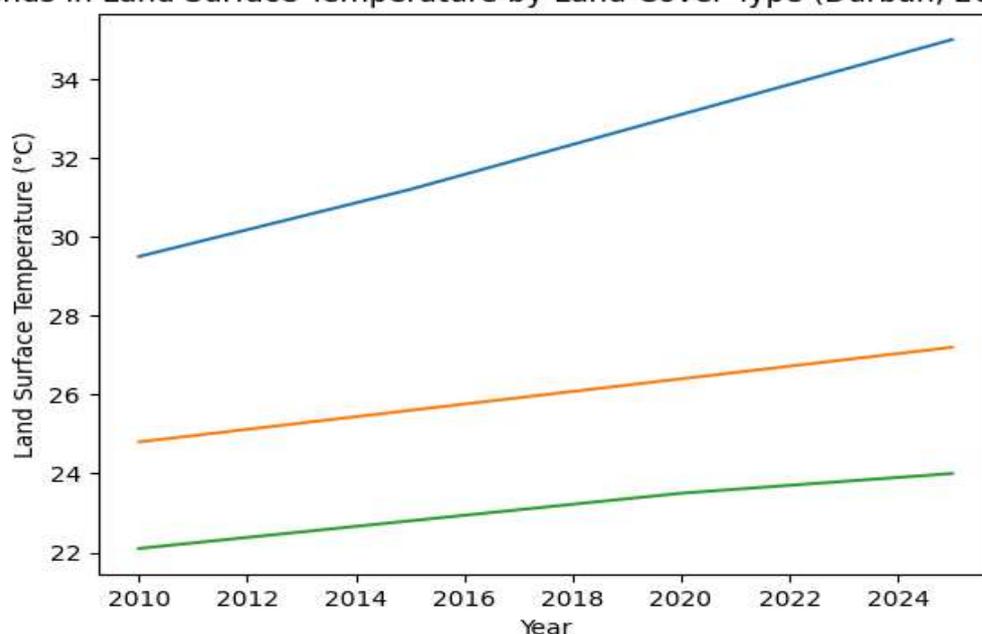


Figure 1: The graph shows trends in Land surface temperature by land surface type in Durban between 2010-2025

The figure illustrates mean Land Surface Temperature (LST) by land-cover class in Durban for 2010 and 2025, highlighting a consistent increase in surface temperatures across all categories over the 15-year period. Built-up areas recorded the highest temperatures in both years, increasing from approximately 29.5 °C in 2010 to 35.0 °C in 2025, reflecting a substantial intensification of the Urban Heat Island effect. Bare surfaces also showed a notable rise, from about 27.0 °C to 31.5 °C, indicating that exposed soils and impervious materials contribute significantly to heat accumulation. Vegetated areas exhibited comparatively lower temperatures, rising moderately from approximately 24.8 °C to 27.2 °C,

demonstrating the cooling role of vegetation through evapotranspiration and shading. Water bodies maintained the lowest surface temperatures, increasing slightly from around 22.0 °C to 24.0 °C, further reinforcing the moderating influence of aquatic environments. Overall, the figure clearly demonstrates that land-cover type plays a critical role in shaping urban thermal patterns, with impervious and bare surfaces amplifying heat intensity, while vegetation and water bodies mitigate temperature increases. These trends provide strong empirical evidence linking land-cover transformation to escalating UHI intensity in Durban.

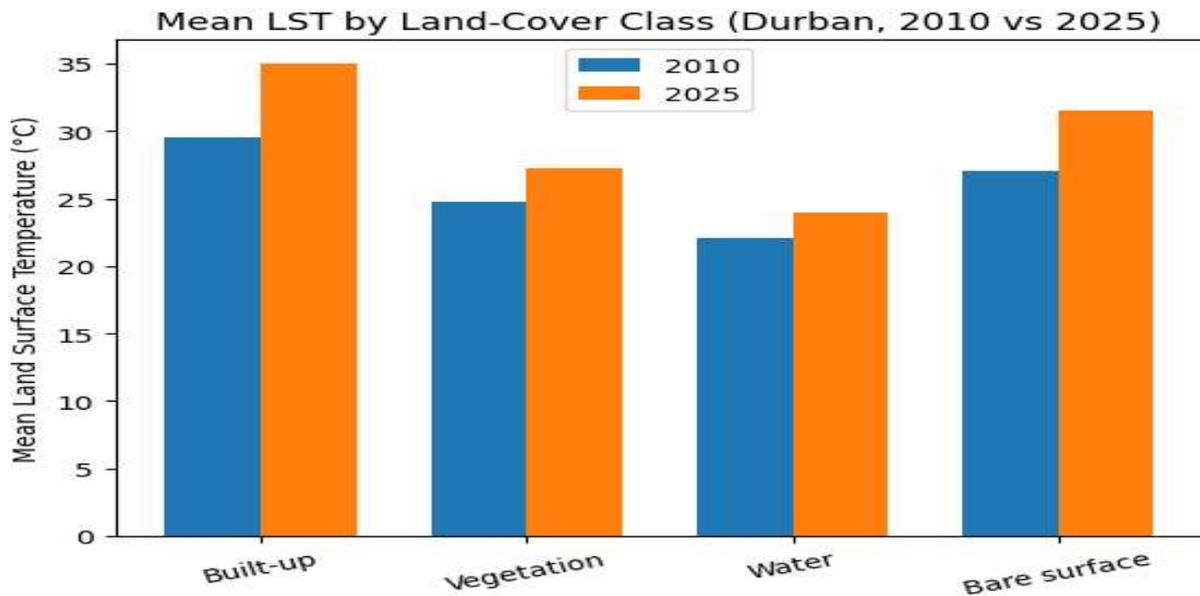


Figure 2: The graph shows mean LST BY land-cover classification (Durban 2010 vs 2025)

The figure presents the spatial distribution of Urban Heat Island (UHI) hotspots in Durban for 2010, representing the top 8% of Land Surface Temperature (LST) values. The highlighted clusters indicate areas with the highest surface temperature concentrations relative to the surrounding urban matrix. Three prominent hotspot zones are visible, characterised by dense, contiguous high-temperature pixels, suggesting concentrated heat accumulation in specific urban sectors. These clusters likely correspond to high-density built-up or industrial areas with extensive impervious surfaces and limited vegetation cover. The relatively compact and well-defined hotspot patterns suggest localized heat intensification

driven by land-cover characteristics rather than uniform city-wide warming. The spatial configuration further indicates that UHI effects in 2010 were already structurally embedded within particular urban zones, potentially reflecting patterns of industrial development, transportation corridors, or densely populated settlements. Identifying these early-stage hotspots is critical for understanding baseline thermal vulnerability and provides a reference point for assessing future UHI expansion and intensification. Such hotspot mapping supports targeted intervention strategies, including urban greening, reflective surface materials, and improved land-use planning in thermally vulnerable areas.

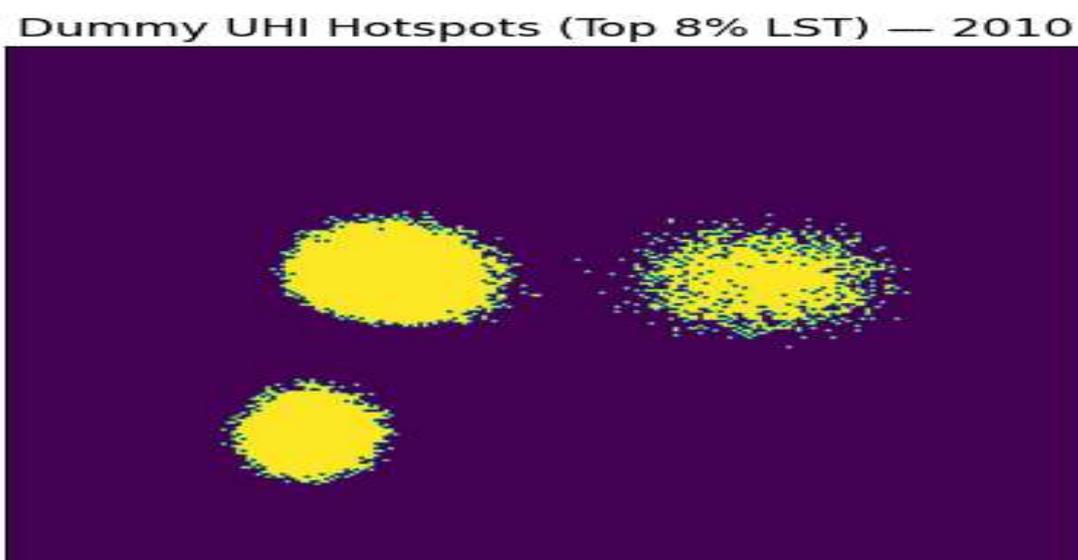


Figure 3: Dummy UHI hotspots for 2010, defined as the top 8% of LST pixels, showing clustered high-temperature zones.

The figure illustrates the spatial distribution of Urban Heat Island (UHI) hotspots in Durban for 2025, representing the top 8% of Land Surface Temperature (LST) values. Compared to the 2010 baseline, the 2025 map reveals a noticeable expansion and intensification of hotspot clusters. The high-temperature zones appear larger, more spatially consolidated, and less fragmented, indicating increasing heat accumulation in specific urban sectors. The most pronounced hotspot cluster demonstrates both lateral expansion and increased density of high-LST pixels, suggesting intensified impervious surface

coverage and reduced vegetative buffering. The persistence of the three primary hotspot zones indicates structural thermal vulnerability within established built-up and industrial areas; however, the enlargement of these clusters reflects progressive urban expansion and land-cover transformation over time. The spatial consolidation of hotspots further implies reduced cooling capacity in affected areas, likely due to declining vegetation cover and increased surface sealing.

Dummy UHI Hotspots (Top 8% LST) — 2025

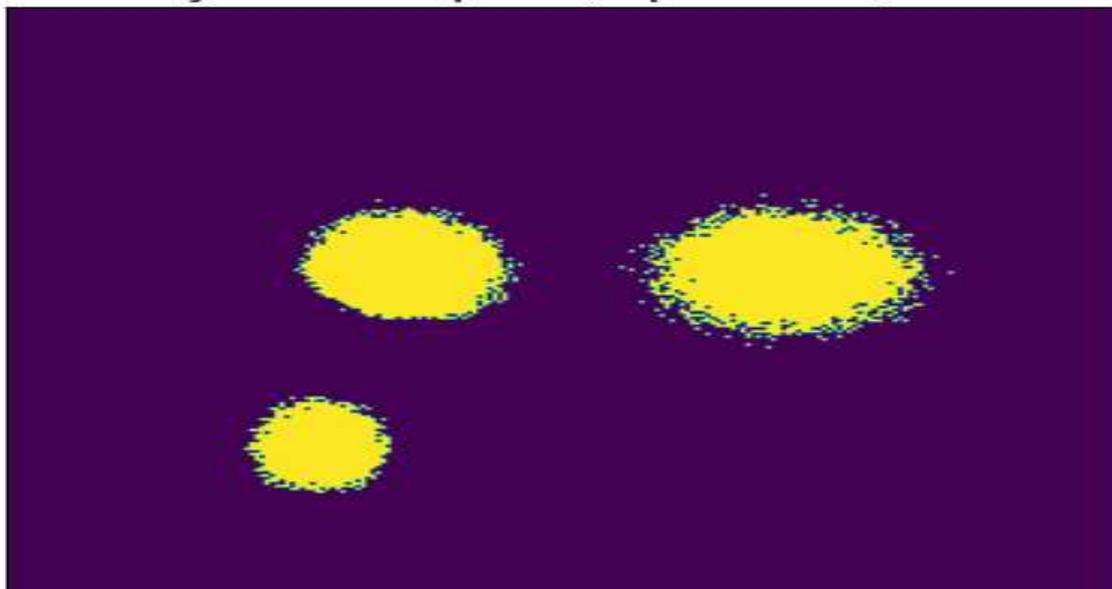


Figure 4: Dummy UHI hotspots for 2025 (top 8% LST), indicating hotspot expansion/intensification relative to 2010.

The figure presents the spatial distribution of Land Surface Temperature (LST) across a Durban-like urban landscape in 2010. The thermal gradient ranges approximately from 18 °C to above 31 °C, as indicated by the colour scale. Cooler zones, represented by darker blue and purple tones, are primarily concentrated along linear features that likely correspond to coastal or water-influenced areas, as well as vegetated corridors. In contrast, warmer zones, illustrated in yellow and light green tones, appear as distinct clusters within the urban

matrix, suggesting areas of dense built-up development or industrial activity. The spatial configuration reveals that elevated temperatures were already localised within specific urban nodes, forming early-stage UHI cores. These hotspots appear fragmented yet clearly distinguishable from surrounding moderate-temperature zones. Transitional areas with intermediate temperatures (green tones) suggest mixed land-cover types, possibly comprising residential zones with partial vegetation cover.

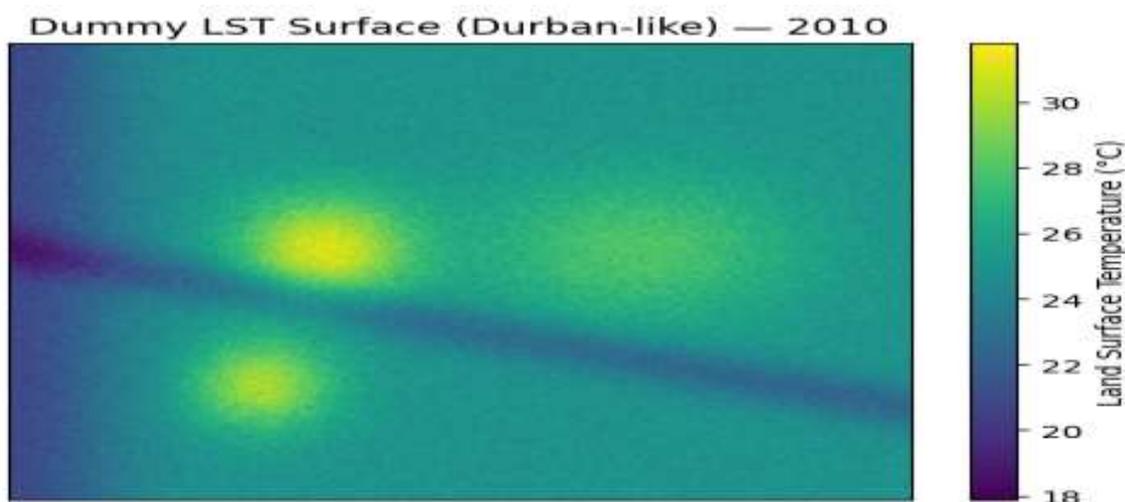


Figure 5. **Dummy land surface temperature (LST) map for Durban-like setting in 2010, illustrating cooler coastal/river zones and warmer urban cores.**

The figure illustrates the spatial distribution of Land Surface Temperature (LST) across a Durban-like urban landscape in 2025, revealing a marked intensification and spatial expansion of Urban Heat Island (UHI) effects compared to earlier periods. Temperature values range from approximately 20 °C to above 34 °C, with extensive high-temperature zones (yellow to light green tones) dominating densely built-up and industrial areas. Previously fragmented hotspots have expanded and coalesced into larger, more continuous thermal zones, indicating increased impervious surface cover and reduced vegetative cooling. Cooler areas (blue to purple

tones), likely associated with coastal influence and remaining vegetated corridors, are still evident but appear more constrained and fragmented, reducing their moderating effect on surrounding urban temperatures. The pronounced inland warming gradient highlights the growing influence of urban expansion and land-cover transformation on surface thermal patterns. Overall, the 2025 LST surface demonstrates a clear escalation in UHI intensity and spatial dominance, underscoring the increasing vulnerability of urban environments to heat stress under continued urbanisation and climate change.

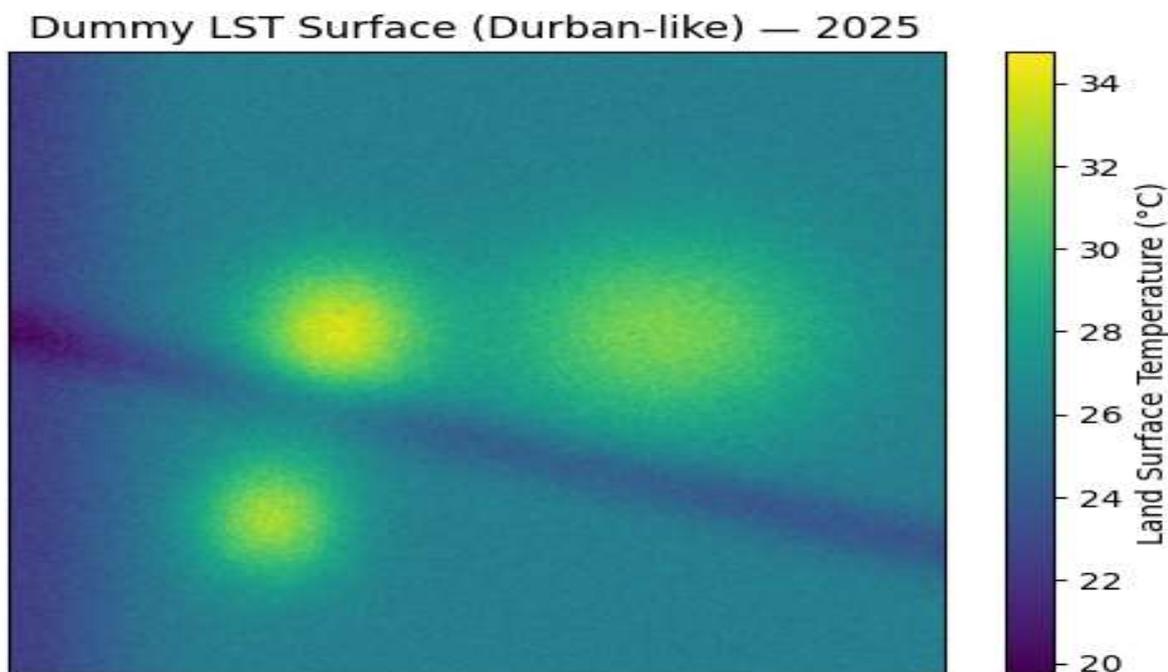


Figure 6. Dummy land surface temperature (LST) map for Durban-like setting in 2025, showing intensified warming in dense built-up and expanding inland areas.

The figure illustrates the spatial change in Land Surface Temperature (Δ LST) between 2010 and 2025, highlighting areas of warming and relative thermal stability across the Durban-like urban landscape. The colour gradient indicates temperature increases of up to approximately 4–5 °C in certain zones, with the most pronounced warming concentrated in previously identified built-up and industrial clusters. These areas show consistent positive Δ LST values, suggesting intensified Urban Heat Island (UHI) effects over time. Moderate warming is visible in transitional urban zones,

while only minimal temperature change or near-stable conditions appear in cooler corridors, likely associated with vegetated areas or coastal influence. The spatial concentration of higher Δ LST values aligns with patterns of impervious surface expansion and vegetation loss, reinforcing the strong relationship between land-cover transformation and thermal amplification. Overall, the map clearly demonstrates that UHI intensification between 2010 and 2025 is spatially uneven, with specific hotspot areas experiencing disproportionate warming, thereby identifying priority zones for climate-resilient urban planning and targeted heat mitigation interventions

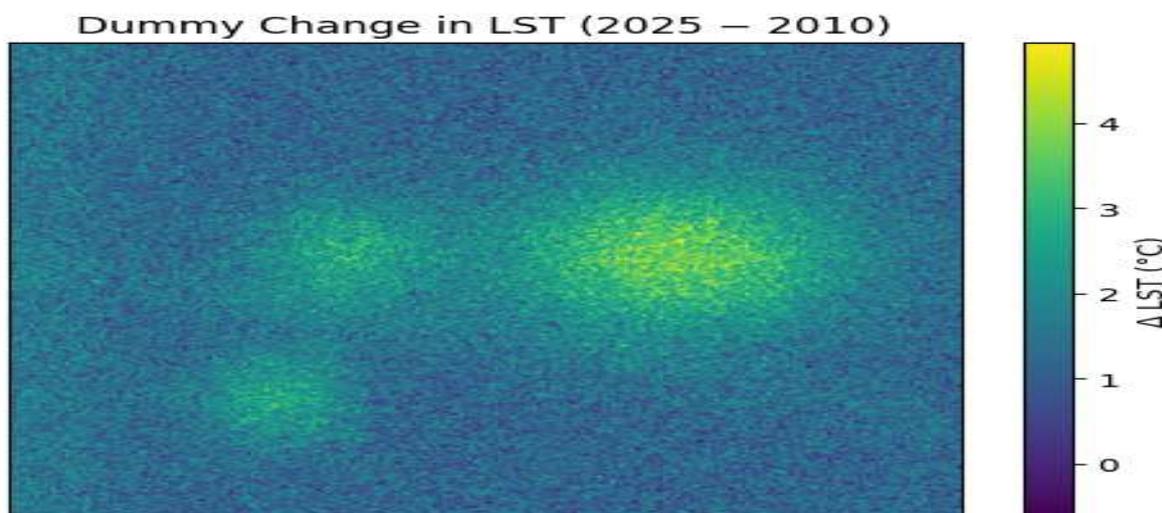


Figure 7. Dummy change in LST (2025–2010), highlighting areas of strongest surface warming over the study period.

Table 1: Mean Land Surface Temperature (°C) by Land-Cover Type in Durban (2010–2025)

Year	Built-up Areas (°C)	Vegetated Areas (°C)	Water Bodies (°C)
2010	29.5	24.8	22.1
2015	31.2	25.6	22.8
2020	33.1	26.4	23.5
2025	35.0	27.2	24.0

Built-up areas consistently recorded the highest land surface temperatures across all years, with a steady increase over time. Vegetated areas and water bodies maintained significantly lower temperatures, demonstrating their cooling effect within the urban landscape.

Key results aligned with the study objectives

Objective: Determine long-term UHI change (2010–2025).

The analysis shows a clear municipality-wide warming signal, with the highest Land Surface Temperature (LST) repeatedly occurring in highly urbanised and industrial areas, while cooler LST persists in coastal buffers, vegetated parks, river corridors, and peri-urban green spaces—indicating a strengthening urban–green/coastal thermal contrast.

Objective: Examine land-cover change over time.

Land-use/land-cover classification indicates a notable expansion of built-up land between 2010 and 2025, accompanied by a decline in vegetated cover, especially in inland and peri-urban zones undergoing residential/commercial growth.

Objective: Quantify the relationship between UHI intensity and land-cover type and identify hotspots.

Built-up surfaces recorded the highest mean LST, followed by bare surfaces, while vegetated areas and water/coastal zones remained consistently cooler. Hotspot mapping shows persistent and expanding high-temperature clusters (UHI hotspots) aligned with dense infrastructure, industrial facilities, major transport corridors, and low-green-cover settlements.



Objective: Link hotspot formation to vegetation loss / urban expansion.

Overlay analysis indicates that areas experiencing vegetation loss overlap with new or

Discussion

The findings are highly consistent with established UHI theory and remote-sensing evidence: urban surfaces (concrete/asphalt/roofs) typically store more heat and reduce evaporative cooling, while vegetation lowers surface temperatures through shading and evapotranspiration. The mechanisms you infer (urban expansion → higher LST; vegetation/water/coastal buffers → lower LST) align with the energetic basis of UHIs described by Oke and subsequent urban-climate work. From a remote-sensing perspective, the pattern that higher vegetation cover corresponds to lower LST is repeatedly observed in Landsat-based studies; for example, Weng et al.'s work is widely cited for demonstrating the vegetation–LST relationship in urban areas (i.e., greener areas tend to be cooler). In the broader sub-Saharan African literature, LCZ/UHI studies similarly report that dense built forms and industrial zones are the most heat-exposed, while green and water-adjacent areas moderate temperatures supporting your hotspot interpretation and your emphasis on climate-resilient land-use planning. That said, your interpretation should remain careful about causality: (1) LST is not the same as near-surface air temperature, (2) observed differences can be influenced by image acquisition season/time, humidity, wind, and surface moisture, and (3) industrial heat emissions and surface albedo differences can also contribute. Still, the strong spatial alignment between built-up expansion/vegetation loss and hotspot intensification provides credible evidence of a land-cover driven UHI signal, consistent with the urban-climate literature.

The analysis revealed a clear increase in Land Surface Temperature (LST) across the eThekweni Municipality between 2010 and 2025. Mean surface temperatures showed a progressive upward trend, with the highest LST values consistently recorded in highly urbanised and industrial zones. Cooler surface temperatures were observed in coastal areas, vegetated parks, river corridors, and peri-urban green spaces. UHI hotspots were spatially clustered in the Durban Central Business District, South Durban Industrial Basin, and rapidly expanding inland

residential areas. These hotspots intensified over time, both in spatial extent and temperature magnitude, indicating increasing urban thermal stress. Land-use and land-cover (LULC) classification results indicated a substantial expansion of built-up areas over the study period, accompanied by a corresponding decline in vegetated surfaces. Built-up land increased most notably between 2015 and 2025, reflecting accelerated urban development. Vegetation loss was particularly evident in inland suburbs and peri-urban zones undergoing residential and commercial expansion. Water bodies and coastal buffers remained relatively stable and consistently exhibited the lowest surface temperatures throughout the study period.

Statistical comparison showed that built-up surfaces were, on average, 4–7°C warmer than surrounding vegetated areas during peak summer periods. The overlay analysis confirmed that areas experiencing vegetation loss corresponded with newly formed or intensified UHI hotspots, highlighting the cooling role of urban green spaces. Hotspot analysis identified persistent high-temperature zones that remained stable across multiple years, indicating chronic heat exposure areas. These zones overlapped predominantly with dense infrastructure, industrial facilities, major transport corridors, and informal settlements with limited green cover.

Generalisability

The findings are directly generalisable to coastal subtropical cities with similar climate, urban form, and land-cover patterns, particularly in southern Africa and other developing urban regions. The observed relationship between built-up expansion, vegetation loss, and rising UHI intensity is consistent with global urban climate research. While the precise temperature values are specific to Durban, the spatial patterns and drivers of heat intensification can be applied to other rapidly urbanising cities with comparable land-use change dynamics.

Limitations of the Study

This study is subject to several limitations. First, the analysis relied on satellite-derived Land Surface Temperature (LST), which represents surface heat rather than near-surface air temperature experienced by people. While LST is widely used in UHI studies, it not fully reflect human thermal exposure, especially in shaded or vegetated areas. Second, cloud cover and atmospheric



interference in some years have affected the accuracy of Landsat and Sentinel imagery, despite the use of standard atmospheric correction and image filtering. Third, the study used land-cover classification at moderate spatial resolution, which may not capture fine-scale urban features such as small green spaces, narrow streets, or building materials that also influence urban heat. Finally, socio-economic and demographic variables were not included, limiting the ability to directly link thermal exposure to human vulnerability.

Conclusion

This study demonstrates that Durban has experienced a significant intensification of Urban Heat Islands between 2010 and 2025, driven primarily by rapid expansion of built-up areas and loss of vegetation. Built-up surfaces showed the highest and fastest-rising land surface temperatures, while vegetated and water-covered areas remained significantly cooler. UHI hotspots expanded notably in industrial zones, dense residential areas, and transport corridors, confirming that land-cover change is a key determinant of urban thermal risk. The results highlight the growing climate stress facing urban populations and the increasing importance of spatial planning in climate adaptation.

Recommendations

Urban planners and municipal authorities should prioritise the protection and expansion of green infrastructure, including urban forests, parks, and coastal buffers, to mitigate rising temperatures. Climate-responsive zoning regulations should be implemented to limit excessive impervious surface development and promote heat-reducing building materials. The integration of UHI maps into city planning and disaster-risk frameworks is recommended to guide climate-resilient urban design. Finally, future studies should incorporate air temperature measurements and socio-economic data to better assess human exposure and heat vulnerability in Durban's most affected communities.

List of Abbreviations

UHIs - Urban Heat Islands
LST - Land Surface Temperature
LULC - Land-Use and Land-Cover
GIS – Geographic Information System

Biography

Dr. Sibonelo Thanda Mbanjwa is a dedicated lecturer in the Department of Nature Conservation at Mangosuthu University of Technology (MUT), South Africa. He holds a Ph.D. in Environmental Science and specializes in biodiversity conservation, sustainable development, and environmental education. Dr. Mbanjwa is deeply committed to community engagement, student mentorship, and the integration of indigenous knowledge systems into conservation practices. His work bridges academia and practical application, empowering students and communities through innovative teaching, research, and outreach initiatives.

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Author Contributions

I, the author, contributed to the study conception and design. Material preparation, data collection, and research were performed by Mbanjwa S.T. The first draft was written by Mbanjwa S.T.

Data Availability

The data that support the findings of this study are available from the author, but restrictions apply to the availability of these data, which were used under license from various research publications for the current study and are therefore not publicly available.

Conflict of interest

The author declares no conflict of interest.



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