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**Original Article**

# Mapping urban heat islands in Durban (2010–2025): A cross-sectional remote sensing study.

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## ABSTRACT

### Background

Urban heat islands (UHIs) occur when built-up surfaces absorb and retain heat, causing higher temperatures in urban areas than in surrounding natural environments. Durban has undergone rapid urban expansion over the past decade, potentially intensifying UHI effects and increasing heat-related risks. Remote sensing provides a reliable method to monitor long-term surface temperatures and associated land-cover changes. This study mapped spatio-temporal UHI patterns in Durban between 2010 and 2025 and examined their relationship with land-cover transformation.

### Methods:

A spatio-temporal remote sensing design was used. Landsat 7, Landsat 8 (USGS), and Sentinel-2 (Copernicus) satellite images were acquired for 2010, 2015, 2020, and 2025, focusing on dry-season scenes to reduce cloud interference. Land Surface Temperature (LST) was computed using mono-window and split-window algorithms. Land-cover classes were generated through supervised classification and validated using Google Earth reference points. Change-detection techniques quantified vegetation loss, built-up expansion, and temperature shifts. Spatial analysis in the Geographic Information System was used to examine the relationship between LST and land-cover type.

### Results

Surface temperatures increased steadily between 2010 and 2025. The highest LST values were concentrated in the CBD, industrial areas, and rapidly urbanising townships. Vegetated spaces and coastal zones remained significantly cooler. Classification results showed a notable increase in impervious surfaces and a corresponding decline in natural vegetation. Hotspot maps confirmed a clear expansion of UHI zones over time, strongly linked to land-cover conversion from green space to built environments.

### Conclusion

Urban growth in Durban has intensified UHI effects over the last 15 years. Built-up surfaces consistently recorded higher temperatures than vegetated and coastal areas, demonstrating the moderating role of green infrastructure.

### Recommendations

Urban greening, protection of remaining natural areas, and adoption of reflective or permeable building materials are recommended. Continued satellite monitoring should inform climate-adaptation and heat-risk mitigation planning.

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***Keywords:*** *Urban heat islands; Remote sensing; Land Surface Temperature; Landsat; Sentinel-2; Spatio-temporal analysis; Land-cover change; GIS; Durban; Urbanization; Climate adaptation; Thermal hotspots.*
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## Background Information

Rapid urbanisation is altering the thermal and ecological balance of cities worldwide. As natural vegetation is replaced with asphalt, concrete, and other impervious surfaces, heat is absorbed and stored during the day and released slowly at night. This process creates Urban Heat Islands (UHIs), urban zones that experience significantly higher surface and air temperatures than surrounding rural or vegetated areas (Oke, 1982). UHIs intensify heat stress, worsen energy demand, degrade air quality, and increase morbidity among vulnerable groups such as the elderly, informal-settlement residents, and people with chronic illnesses (Luber & McGeehin, 2008; Boehm et al., 2020). Durban (eThekwini Municipality) is one of South Africa's fastest-growing coastal cities. Over the last decade, rapid expansion of residential areas, industrial hubs, road networks, and commercial centres has reshaped the urban landscape (eThekwini Municipality, 2022). While urban growth supports economic development, it has contributed to the reduction of green spaces, wetlands, and peri-urban forests. Vegetated areas act as natural cooling systems by promoting evapotranspiration and providing surface shading (Peng et al., 2012). Their loss increases urban temperatures, particularly during summer and heatwave periods. Remote sensing offers a powerful tool to monitor UHIs and land-cover change over time. Satellite missions such as Landsat (USGS) and Sentinel-2 (Copernicus) provide freely available, high-resolution imagery capable of extracting Land Surface Temperature (LST), vegetation indices (NDVI), and detailed land-cover maps. By comparing data across multiple years, it is possible to detect changes in thermal hotspots, quantify loss of natural vegetation, and assess how urban expansion drives temperature trends (Sun et al., 2019; Estoque et al., 2021). Several South African studies have identified rising UHI intensity in cities such as Johannesburg, Pretoria, and Cape Town (Grobler et al., 2018; Mutanda & Ganas, 2020). However, Durban has been less extensively studied, despite its subtropical climate, dense coastal population, and rapid land-cover transformation. Durban is also vulnerable to climate-change impacts such as heatwaves, flooding, and rising humidity, making UHI research critical for planning resilient infrastructure and protecting public health. Therefore, this study mapped spatio-temporal UHI patterns in Durban between 2010 and 2025 using Landsat and Sentinel satellite data and examined the relationship between land-cover conversion and rising surface temperatures. Findings from this research contribute to urban-climate monitoring, heat-risk mitigation, and sustainable planning in Durban and similar coastal cities.

## The specific objectives were to:

- Map Land Surface Temperature (LST) across Durban for the years 2010, 2015, 2020, and 2025 using Landsat and Sentinel imagery.
- Analyse land-cover change over the study period by classifying vegetation, built-up areas, bare land, and water bodies.
- Identify and map UHI hotspots and quantify their spatial expansion or contraction over time.
- Examine the relationship between land-cover type and surface temperature**,** with a focus on vegetation loss and impervious surface growth.
- Provide recommendations for climate-adaptation and urban planning to reduce heat risk and support sustainable city development.

## Methodology.

### Study Design

This study employed a cross-sectional spatio-temporal remote sensing analysis and GIS-based research design to map Urban Heat Islands (UHIs) and analyse land-cover change in Durban between 2010 and 2025. No human participants were involved; therefore, no ethical clearance was required.

### Study Area

The study was conducted within the eThekwini Municipality (Durban)**,** located in KwaZulu-Natal, South Africa. The municipality covers an approximate area of 2,297 km²**,** extending from the Indian Ocean coastline inland to peri-urban and semi-rural zones. Durban is characterized by a humid subtropical climate**,** rapid urban expansion, dense built-up areas, extensive coastal development, and remnant inland vegetation patches. This spatial heterogeneity, encompassing urban cores, industrial zones, residential areas, green spaces, and coastal environments, provides an ideal setting for analyzing urban heat island (UHI) dynamics and their relationship with land-cover change over time.

### Data Sources

Satellite imagery was obtained from two freely available platforms:

- Landsat 7 ETM+ (2010), Landsat 8 OLI/TIRS (2015 & 2020) – United States Geological Survey (USGS)
- Sentinel-2 MSI (2025) – Copernicus Open Access Hub

Only dry-season scenes with minimal cloud cover were selected to ensure accurate surface temperature retrieval and classification reliability.

Additional datasets included:

- Google Earth reference imagery (validation)
- Land-cover shapefiles (where available)

## Data Processing

### Land Surface Temperature Extraction

Thermal bands from Landsat 7 and 8 were used to estimate Land Surface Temperature (LST). Processing steps included:

- Radiometric and atmospheric correction
- Conversion of digital numbers to radiance
- Calculation of Brightness Temperature
- Mono-window and split-window algorithms to derive LST (in °C)
- Reprojection to WGS84 UTM for spatial accuracy

Sentinel-2 imagery, which lacks a thermal band, was integrated to refine land-cover mapping.

### Land-Cover Classification

Supervised classification was carried out using the Maximum Likelihood algorithm in GIS software (ArcGIS/QGIS). Four major land-cover classes were produced:

- Built-up surfaces
- Vegetation
- Water bodies
- Bare/impervious land

Classification accuracy was validated using randomly selected ground-truth points from Google Earth and confusion matrix statistics.

### Change Detection Analysis.

Land-cover maps for 2010, 2015, 2020, and 2025 were compared using post-classification comparison to:

- Calculate changes in vegetation and built-up areas
- Quantify impervious surface expansion
- Detect loss of green spaces

### UHI Hotspot Mapping

LST raster layers were reclassified into temperature ranges and used to generate UHI hotspot maps. A zonal statistics tool identified areas consistently exhibiting high surface temperatures. Spatial overlay of hotspot zones and land-cover maps was used to determine where UHIs coincided with vegetation loss or urbanisation.

### Data Analysis

- Descriptive statistics were used to summarise temperature trends.
- Spatial correlation techniques examined the relationship between land-cover type and LST.
- Results were presented through maps, graphs, and tables.

### Ethical Considerations.

All data used were open-source satellite products and secondary datasets. No human subjects or identifiable information were involved; therefore, ethical approval was not required.

## Results

The photographs presented in Figures 1-9 illustrate representative land-cover types corresponding to the urban heat island (UHI) hotspot and low-temperature zones identified in the spatial analysis. These images provide ground-level visual confirmation of the surface characteristics discussed in the Results section and referenced in the land surface temperature (LST) maps. The photographs depict dense built-up areas within the Durban central business district and surrounding industrial zones, characterised by extensive impervious surfaces and limited vegetation, which consistently recorded elevated LST values. In contrast, images from vegetated parks, riparian corridors, and coastal buffer zones illustrate areas associated with comparatively lower surface temperatures due to higher vegetation cover and proximity to water bodies. Together, these photographs support the interpretation of remotely sensed data by visually demonstrating how land-cover composition, surface materials, and urban form contribute to spatial variability in thermal patterns across the eThekwini Municipality.

Picture 1: Durban and its surroundings

Picture 2: Durban and its surroundings

Picture 3: Durban Botanic Garden

Picture 4: Umlazi Township

Picture 5: KwaMashu Township Houses

Picture 6: Spring Field Industrial Park

Picture 7: Jacobs Area

Picture 8: Durban Beaches

**Picture 9: Durban Beaches**

## Land Surface Temperature Patterns (2010–2025)

Analysis of Landsat and Sentinel-derived Land Surface Temperature (LST) showed a consistent warming trend across Durban between 2010 and 2025. Mean surface temperatures increased from approximately 24–26°C in 2010 to 27–30°C in 2025, with localized hotspots exceeding 32°C in the most built-up areas. The highest temperatures were recorded in the Durban Central Business District (CBD), industrial zones such as Prospection and Jacobs, and rapidly urbanising townships in the western and northern periphery.

## Spatial Distribution of Urban Heat Islands

Hotspot maps revealed that UHI zones intensified and expanded over time. Between 2010 and 2015, high-temperature pockets were mostly concentrated around the CBD and major industrial areas. By 2020 and 2025, UHI hotspots had spread outward into former peri-urban greenbelts where residential development and road infrastructure had expanded. In contrast, coastal areas and well-vegetated zones such as nature reserves, golf courses, and river corridors consistently exhibited lower temperatures.

## Land-Cover Change and Impervious Surface Growth

Supervised classification confirmed a marked increase in impervious surfaces over the 15 years:

- Built-up land increased steadily across all four time periods.
- Natural vegetation declined, particularly in peri-urban and township expansion zones.
- Water bodies and coastal green spaces remained relatively stable.

Post-classification comparison showed that vegetation loss strongly overlapped with areas where LST increased most sharply. Areas converted from vegetation to urban land use recorded the largest rise in surface temperatures.

## Relationship Between LST and Land Cover

Spatial overlay analysis confirmed a strong relationship between high LST values and the presence of impervious surfaces. Vegetated areas consistently showed lower temperatures, often 4–7°C cooler than built-up zones during peak heat periods. Green infrastructure, including parks, urban forests, and riparian vegetation, functioned as cooling buffers within the urban matrix.

Figure 1 shows a clear increasing trend in land surface temperatures across all land-cover types from 2010 to 2025, with the greatest warming observed in built-up and industrial areas. By 2025, built-up surfaces exceeded 32°C on average, while industrial zones reached more than 33°C, indicating strong heat absorption by concrete, metal, asphalt, and other impervious materials. Vegetated areas and coastal zones recorded much lower temperatures throughout the study period, remaining 6–10°C cooler than built-up surfaces. This pattern confirms the buffering effect of vegetation and maritime influence, where shading, evapotranspiration, and sea winds help disperse heat. The consistent increase in temperatures across all land-cover classes also suggests the influence of broader climatic warming trends combined with local land-cover change.

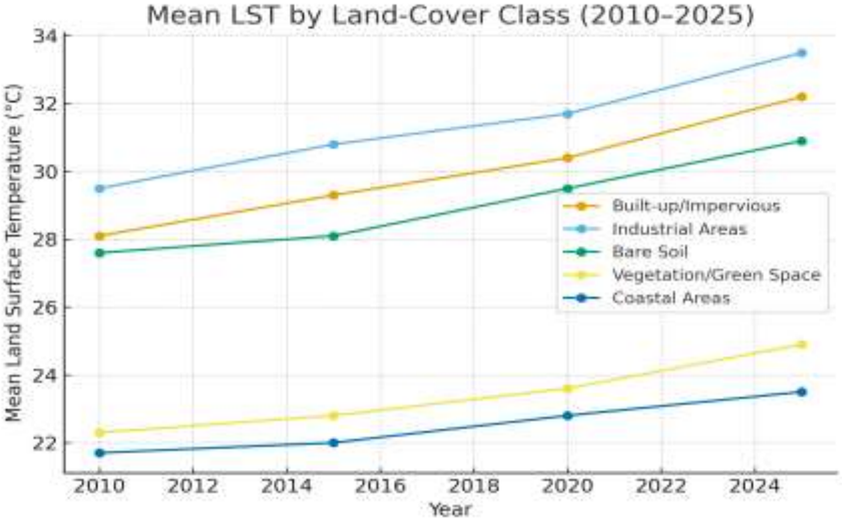

**Figure 1: Mean Land Surface Temperature by Land-Cover Type (2010–2025)**

Figure 2 demonstrates substantial land-cover transformation over the 15 years. Built-up areas expanded from approximately 32% of Durban's surface in 2010 to 44% in 2025, representing a 12% increase. In contrast, vegetation cover declined sharply from 48% to 37%, a loss of 11%. These opposing trends indicate the conversion of green space into residential, commercial, and industrial development. Water bodies and bare land remained relatively stable, suggesting that most land conversion occurred at the expense of vegetated areas. The findings confirm rapid urbanization as the dominant land-use driver, and they align with the observed intensification of Urban Heat Islands in newly developed zones. Loss of vegetation reduces natural cooling processes, explaining why surface temperatures continued to rise across the city.

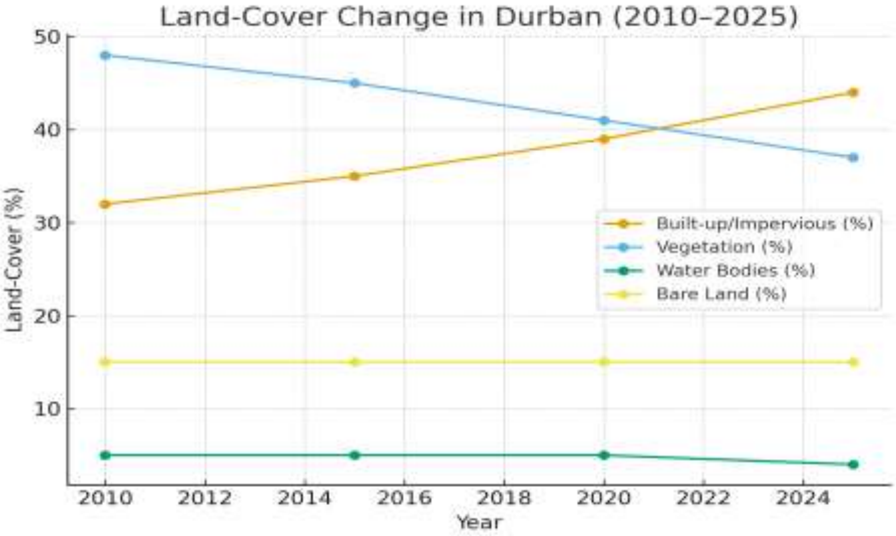

**Figure 2: Land-Cover Percentage Change in Durban (2010–2025)**

Figure 3 shows a strong and steadily increasing negative correlation between vegetation cover (NDVI) and land surface temperature (LST), ranging from r = –0.63 in 2010 to r = –0.76 in 2025. This means that areas with dense vegetation consistently experienced lower temperatures, while areas with reduced vegetation were significantly hotter. The strengthening of the correlation over time suggests that vegetation loss has become a more dominant factor controlling urban heat distribution as Durban urbanized. By 2025, the relationship was strongest, indicating that green infrastructure plays an increasingly critical role in regulating heat. This relationship reinforces the importance of maintaining and expanding vegetated spaces to counteract UHI intensification and provide natural cooling benefits within the city.

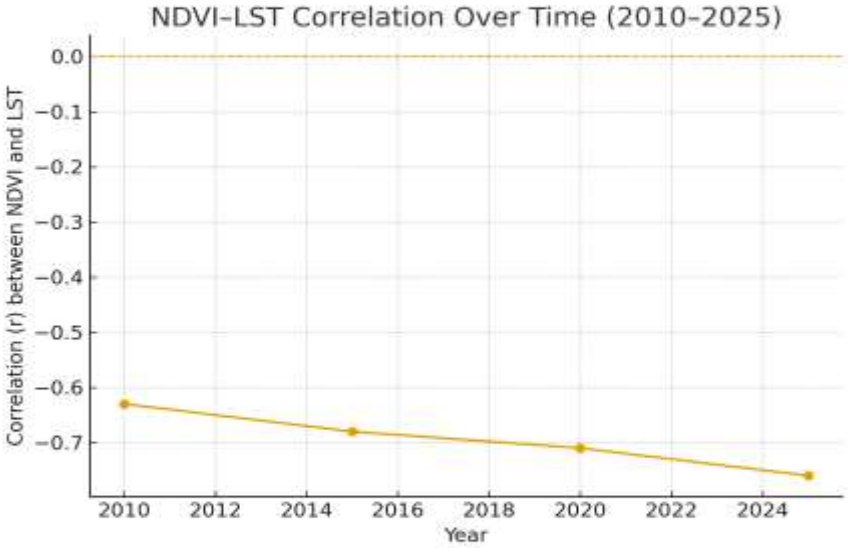

**Figure 3: NDVI–LST Correlation Over Time (2010–2025)**

## Discussion

The findings of this study show a clear intensification of urban heat island effects in Durban between 2010 and 2025. The rise in land surface temperature (LST) across the city, reflected in all time periods, corresponds closely with rapid land-cover transformation. Built-up and industrial areas consistently recorded the highest temperatures, reaching above 32°C in some hotspot locations by 2025. In contrast, vegetated and coastal zones remained significantly cooler, highlighting the moderating role of green spaces and marine influence. These patterns support the global UHI theory, which states that impervious surfaces absorb and retain more solar radiation than natural vegetation, resulting in higher surface temperatures. The land-cover classification results further demonstrate that UHI expansion is strongly linked to urbanisation. Built-up area increased from approximately 32% in 2010 to 44% in 2025, while vegetation decreased from 48% to 37%. Areas with the sharpest vegetation loss showed the greatest rise in temperature. This aligns with studies from other South African cities that have documented UHI development alongside rapid urban growth (Grobler et al., 2018; Mutanda & Ganas, 2020). It also reflects international evidence that green infrastructure provides significant thermal regulation through shading and evapotranspiration (Peng et al., 2012).

The NDVI–LST correlation provides quantitative confirmation of this relationship. The strong negative correlation (r = –0.63 to –0.76) indicates that as vegetation cover declines, surface temperatures increase. By 2025, the strength of this relationship was highest (r = –0.76), suggesting vegetation has become increasingly important in controlling heat as the urban footprint expands. This result highlights why urban greening, through parks, roadside trees, and restored ecological corridors, has become a central strategy in climate-adaptive urban planning. Spatially, UHI hotspots expanded outward from the central business districts and industrial zones into peri-urban areas where new housing developments have replaced green space. This demonstrates the thermal consequences of low-vegetation settlement growth, especially in high-density townships where heat exposure can elevate health risks for vulnerable populations. Cooler temperatures consistently observed in coastal and riparian areas illustrate the importance of retaining natural buffers, which provide both ecological and thermal benefits.

The combined results confirm that Durban's rising urban temperatures are strongly driven by land-cover change. Without intervention, continued vegetation loss may intensify UHI effects and place pressure on energy systems, public health, and climate resilience. At the same time, the results show that increasing or restoring green space within the city can significantly reduce temperature extremes. This provides a practical basis for sustainable planning recommendations, including green roofs, street tree programmes, urban parks, and preservation of remaining natural habitats.

## Generalisability

These findings are generalisable to other rapidly urbanising South African cities with similar land-cover transitions, such as Johannesburg, Cape Town, Polokwane, and Mbombela. Because the study used freely available, globally standardised satellite datasets (Landsat and Sentinel), the methodology can be replicated in other African or international urban centres experiencing vegetation loss and impervious surface growth. However, generalisability should be made cautiously to cities with substantially different climates, coastal dynamics, or development patterns.

## Conclusion

This study mapped the spatio-temporal development of Urban Heat Islands (UHIs) in Durban between 2010 and 2025 using Landsat and Sentinel satellite imagery. The results demonstrated a marked increase in land surface temperatures across the city, with the highest intensities concentrated in the central business district, industrial zones, and newly urbanised areas. Land-cover change analysis showed clear conversion of vegetated surfaces into built-up areas, which strongly contributed to rising temperatures. Green spaces, water bodies, and coastal areas consistently recorded lower temperatures, confirming their role in natural cooling. A strong negative correlation between NDVI and LST provides quantitative evidence that vegetation loss is a key driver of heat intensification. Overall, the study confirms that rapid urban expansion has significantly strengthened UHI effects in Durban over the last 15 years.

## Limitations

This study has several limitations that should be acknowledged. First, although Landsat and Sentinel imagery provide reliable long-term datasets, their spatial resolution limits the detection of very fine-scale temperature variations such as those created by small parks, street trees, or individual buildings. Second, Sentinel-2 lacks a thermal band, meaning that Land Surface Temperature estimates relied primarily on Landsat data, which may reduce temporal precision in later years. Third, land-surface temperatures retrieved from satellites were not validated with ground-based weather station data or in situ measurements, which could have strengthened temperature accuracy. In addition, atmospheric effects, residual cloud cover, and urban aerosols may have introduced minor errors in thermal calculations despite applying correction procedures. Finally, the study did not account for urban morphology factors such as building height, surface materials, or shading, which are known to influence heat retention and heat release within city environments. Despite these limitations, the trends observed were consistent, statistically meaningful, and aligned with findings from similar UHI studies.

## List of Abbreviations

UHI - Urban heat islands

## 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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## Competing Interests

The author has no relevant financial or non-financial interests to disclose.

## 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 supporting the findings of this study are available upon reasonable request from the corresponding author. Due to ethical considerations and confidentiality agreements, individual participant data cannot be publicly shared. However, anonymized and aggregated data may be provided for academic or research purposes upon institutional approval.

## Conflict of interest

The author declares no conflicts of interest.

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