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Integrating Spatio-Temporal Analysis of Landuse/Land Cover Changes and Urban Growth in Modelling Surface Temperature Variations of Asaba Metropolis, Delta State

¹ Bright Idike, ² Igbokwe Joel, ³ Idhoko Kingsley

^{1, 2, 3} Department of Surveying and Geoinformatics, Nnamdi Azikiwe University Awka, Anambra State, Nigeria

Corresponding Author: **Bright Idike**

Abstract

Rapid urbanization and land use/land cover (LULC) change have significantly altered urban thermal environments, intensifying urban heat island effects and increasing climate-related risks in developing cities. This study investigates the spatio-temporal relationship between LULC dynamics, urban growth, and land surface temperature (LST) in Asaba Metropolis, Delta State, Nigeria, over a 20-year period (2002–2022). Multi-temporal Landsat TM, ETM+, and OLI/TIRS imagery was analysed using Geographic Information Systems (GIS) and remote sensing techniques to derive LULC, Normalized Difference Vegetation Index (NDVI), and LST maps for 2002, 2012, and 2022. Supervised classification achieved overall accuracies exceeding 96%, confirming the reliability of the generated land cover maps. LST was retrieved using an NDVI-based emissivity-corrected algorithm, while statistical and spatial analyses quantified the influence of urban growth and vegetation dynamics on surface temperature patterns. Results show that built-up land increased from 19.37 km²

(5.21%) in 2002 to 56.90 km² (15.11%) in 2022, accompanied by a decline in vegetation cover from 72.99% to 67.91%. Mean LST increased from 34.24°C to 35.04°C, with the highest temperatures consistently associated with built-up and bare land surfaces. NDVI exhibited a persistent negative relationship with LST, confirming the cooling role of vegetation and the progressive intensification of the urban heat island effect. Spatial modelling further demonstrated that urban expansion and land cover transitions were the dominant drivers of increasing surface temperatures across the metropolis. This study advances understanding of urban thermal dynamics by integrating LULC change detection, urban growth analysis, NDVI assessment, and LST modelling within a unified spatio-temporal framework. The findings provide quantitative evidence to support climate-responsive urban planning, green infrastructure development, vegetation conservation, and geospatial monitoring strategies aimed at enhancing urban climate resilience in rapidly growing tropical cities.

Keywords: Land Use/Land Cover (LULC) Change, Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI), Urban Heat Island (UHI), Remote Sensing and GIS

1. Introduction

Climate change has emerged as one of the greatest environmental challenges of the twenty-first century, with far-reaching consequences for ecosystems, human health, economic development, and urban sustainability. Among its numerous manifestations, the increase in land surface temperature (LST) associated with rapid urbanization has become a major concern for cities across the world, particularly in developing countries where urban growth often occurs without adequate planning. As urban populations continue to rise, natural landscapes are increasingly transformed into built-up environments characterized by concrete structures, asphalt roads, and other impervious surfaces. These changes alter the physical properties of the Earth's surface, reduce vegetation cover, modify energy exchange processes, and ultimately contribute to increased surface temperatures and the formation of urban heat islands (UHIs).

Land Use/Land Cover (LULC) change has been widely recognized as one of the primary drivers of environmental and climatic transformations. Human activities such as urban expansion, industrial development, agricultural intensification, deforestation, and infrastructure construction significantly modify land surface characteristics, including surface albedo, evapotranspiration, soil moisture, and heat storage capacity. These alterations disrupt the natural energy balance of the environment and lead to

increased absorption and retention of solar radiation, thereby raising land surface temperatures. Consequently, cities experience higher temperatures than their surrounding rural environments, a phenomenon commonly referred to as the Urban Heat Island (UHI) effect. The increasing intensity of UHIs has implications for energy consumption, air quality, water resources, biodiversity, and public health, particularly during periods of extreme heat.

The relationship between urbanization, LULC dynamics, and surface temperature has attracted considerable research attention over the past two decades. Advances in remote sensing and Geographic Information Systems (GIS) have revolutionized environmental monitoring by providing reliable, consistent, and long-term datasets capable of capturing changes in land cover and thermal characteristics over large geographical areas. Satellite platforms such as Landsat, MODIS, and Sentinel have enabled researchers to observe historical land cover transitions, estimate vegetation conditions through vegetation indices such as the Normalized Difference Vegetation Index (NDVI), and retrieve land surface temperatures from thermal infrared imagery. These technologies have made it possible to assess how different land cover types influence temperature patterns and to monitor urban environmental changes with greater accuracy and temporal consistency.

An important approach in understanding these environmental dynamics is spatio-temporal analysis, which integrates spatial and temporal information to examine how geographical phenomena evolve over time. Unlike conventional analyses that consider only a single period or location, spatio-temporal analysis allows researchers to identify long-term trends, detect hotspots of environmental change, quantify rates of urban expansion, and evaluate the environmental consequences associated with these changes. Through this approach, it becomes possible to investigate not only where urban growth is occurring but also how rapidly it is transforming natural landscapes and influencing land surface temperatures across different time periods.

The integration of urban growth modeling with spatio-temporal analysis provides an even more comprehensive framework for evaluating the environmental consequences of urbanization. Urban growth models enable the simulation of future development scenarios, allowing planners and policymakers to predict how continued expansion may alter land use patterns and affect environmental variables such as surface temperature. These predictive capabilities are particularly valuable in the context of climate change, where understanding future risks is essential for designing resilient and sustainable cities. Such models support evidence-based planning by identifying areas that may become vulnerable to excessive heating and by evaluating the potential effectiveness of mitigation strategies before implementation. Globally, numerous studies have demonstrated a strong relationship between declining vegetation cover and increasing land surface temperature. Vegetation plays a critical role in regulating urban climates through shading, evapotranspiration, and carbon sequestration. The replacement of vegetated surfaces with impervious materials reduces these natural cooling processes, resulting in elevated temperatures across urban landscapes. Studies consistently report negative correlations between NDVI and LST, indicating that areas with higher vegetation density generally exhibit lower surface temperatures than highly urbanized regions. This understanding has strengthened the

emphasis on green infrastructure, urban forestry, and sustainable land use planning as essential strategies for mitigating the impacts of urban heat.

In many developing countries, however, rapid urbanization continues to outpace effective planning and environmental management. Cities experiencing accelerated physical expansion often witness uncontrolled conversion of forests, agricultural lands, wetlands, and open spaces into residential, commercial, and industrial developments. These transformations occur with limited consideration for their climatic implications, resulting in increasing thermal discomfort, greater energy demand for cooling, deteriorating air quality, and heightened vulnerability to climate-related hazards. Consequently, there is an urgent need for comprehensive studies that integrate land use dynamics, urban growth, and surface temperature modeling to provide scientific evidence capable of informing sustainable urban development policies.

Nigeria has experienced significant urban growth over the past few decades, driven by population increase, economic development, and rural-to-urban migration. Many of its rapidly expanding cities have undergone substantial land cover transformations that have altered their environmental and climatic conditions. Despite these developments, relatively few studies have comprehensively examined the combined effects of LULC change, urban growth, and land surface temperature within a unified spatio-temporal modeling framework. Existing investigations have largely concentrated on mapping urban expansion or analyzing individual environmental variables without integrating their interactions over extended periods.

Asaba, the capital city of Delta State, represents one of Nigeria's fastest-growing urban centers. Its strategic location, expanding commercial activities, improved transportation networks, and increasing population have accelerated urban development over the past two decades. This rapid expansion has resulted in extensive conversion of vegetated land into residential estates, commercial complexes, road infrastructure, and other built-up areas. While these developments contribute to economic growth and improved accessibility, they also modify the natural landscape and intensify surface temperature variations. The increasing use of concrete pavements, asphalt roads, and other impervious materials further enhances heat absorption and retention, thereby contributing to the development of localized urban heat islands.

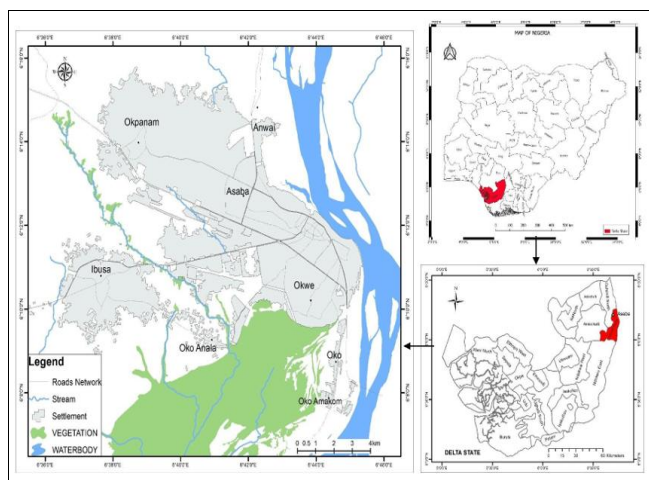
Despite these observable environmental changes, urban planning efforts within Asaba have largely focused on issues such as flood control, transportation, and infrastructure development, with comparatively little attention given to the thermal consequences of land use transformation. Existing planning approaches often lack predictive tools capable of assessing how ongoing urban growth influences surface temperature distribution and future climate risks. Furthermore, previous land use studies conducted within the metropolis have primarily emphasized urban expansion and land cover mapping without adequately investigating their direct relationship with surface temperature dynamics. This knowledge gap limits the ability of planners and decision-makers to implement effective climate-responsive development strategies.

Addressing this gap requires an integrated analytical framework that combines spatio-temporal assessment of land use and land cover changes with urban growth analysis

and land surface temperature modeling. Such an approach provides a more holistic understanding of the interactions between urbanization and climate, enabling the identification of areas most susceptible to thermal stress while supporting the formulation of sustainable mitigation measures. The integration of remote sensing, GIS, NDVI analysis, and thermal modeling offers a robust methodology for quantifying these interactions and evaluating their implications for urban resilience.

Against this background, this study investigates the integration of spatio-temporal analysis of Land Use/Land Cover changes and urban growth in modeling surface temperature variations in Asaba metropolis, Delta State, Nigeria. Using multi-temporal satellite imagery, geospatial technologies, and remote sensing techniques, the study analyzes land cover transitions over a twenty-year period, examines their relationship with land surface temperature, and models the influence of urban expansion on thermal characteristics. The findings are expected to contribute to the growing body of knowledge on urban climate studies while providing valuable information for policymakers, urban planners, environmental managers, and researchers. Ultimately, the study seeks to promote climate-responsive urban planning, encourage sustainable land use management, and support the development of resilient cities capable of adapting to the increasing challenges posed by climate change.

2. Materials and Methods



Source: Open Street Maps, Google Maps

Fig 2.1: Geographic Location of the Study Area

2.1 Study Area

The study was conducted in Asaba, the capital of Delta State, Nigeria, situated on the western bank of the lower Niger River. The city lies at approximately latitude 6°12.630'N and longitude 6°42.100'E, about 160 km north of the Niger Delta. It covers an area of roughly 300 km² and sits on undulating terrain rising up to 200 m above sea level. Asaba serves as a major transport and commercial hub, connecting western, eastern, and northern Nigeria via the Niger Bridge.

The area experiences a tropical savanna climate (Köppen: Aw), with a wet season from March to October and a dry season from November to February. Mean annual temperature is approximately 26.8°C, with annual rainfall averaging 1,331 mm. Climate dynamics are largely

governed by the Intertropical Convergence Zone (ITCZ), which drives seasonal shifts between southwesterly humid trade winds and dry northeasterly harmattan winds. The harmattan season (mid-December to February) brings dusty, dry conditions that reduce atmospheric visibility. Wind speeds peak in August (averaging 7.3 mph) and are lowest in November (4.2 mph). Cloud cover is greatest in May (85% overcast) and least in December (46% clear).

2.2 Research Design and Data Sources

The study adopted an integrated remote sensing and GIS approach to analyse land use/land cover (LULC) change and Land Surface Temperature (LST) variation across Asaba Metropolis from 2002 to 2022. The workflow encompassed data acquisition, image preprocessing, supervised classification, accuracy assessment, LST extraction, and spatial analysis using Analytical Hierarchical Process (AHP) weighting where applicable.

2.2.1 Primary Data

Primary data were collected through field surveys using a Garmin 76CSX handheld GPS receiver. Ground truth coordinates of identifiable features — including road junctions, schools, hospitals, petrol stations, and rock outcrops — were recorded for use in image geo-referencing, rectification, and classification accuracy assessment.

2.2.2 Secondary Data

Secondary data comprised the following:

- Multi-temporal, multi-spectral Landsat satellite imagery (30 m spatial resolution) acquired from the United States Geological Survey (USGS) EarthExplorer archive, with cloud cover limited to less than 20% to minimise atmospheric interference.
- Administrative boundary shapefiles for Delta State from the DIVA-GIS database.
- Road networks, rivers, and settlement data from the Mapping and Geoinformatics Department, Office of the Surveyor General of Delta State.

Three Landsat image epochs were selected to represent temporal change across the study period:

Table 2.1: Landsat Imagery Used in the Study

S. No	Satellite/Sensor	Pixel Size	Spectral Resolution	Path/Row	Date
1	Landsat 7 ETM+	30 m	Multispectral (7 bands)	189/056	Dec. 2002
2	Landsat 5 TM	30 m	Multispectral (8 bands)	189/056	Dec. 2012
3	Landsat 8 OLI/TIRS	30 m	Multispectral (11 bands)	189/056	Dec. 2022

2.2.3 Software and Hardware

Image processing and spatial analysis were performed using ArcGIS 10.5/10.8 (boundary extraction and spatial analysis), ERDAS Imagine 2015 (image preprocessing, classification, and change detection), and Microsoft Office 2023 (report writing and data charting). Hardware comprised an Intel Core i7 workstation (2.50 GHz, 12 GB RAM, 1 TB SSD) running Windows 11 Pro, supported by an A3 printer and external storage for data backup.

2.3 Image Processing and Classification

2.3.1 Preprocessing

Downloaded Landsat imagery underwent standard preprocessing to prepare it for analysis. Geometric

correction — including geo-referencing and orthorectification — was confirmed as pre-applied by USGS, ensuring accurate spatial positioning. Radiometric correction to convert raw digital numbers (DN) to true surface reflectance was verified as auto-corrected, with no further adjustment required. Image layer stacking (combining individual spectral bands into a multiband composite), mosaicking, and subsetting to the Asaba study area boundary were performed in ERDAS Imagine 2015.

2.3.2 Land Use/Land Cover Classification

Supervised image classification was applied to multi-spectral Landsat bands (bands 1–5 and 7) for each epoch (2002, 2012, and 2022). In supervised classification, the analyst defined training sites representing known land cover types; the software then determined the spectral signature of each class and assigned all image pixels accordingly. Heads-up (on-screen) digitizing was used to trace and verify features directly from satellite imagery. A minimum of four training samples per class were created to ensure classification accuracy. Four land cover categories were adopted based on the Anderson *et al.* (1976) [1] USGS classification scheme:

Table 2.2: LULC Classification Scheme

S. No	LULC Class	Description
1	Bare Soil	Exposed rock, uncultivated lands, mines
2	Built-up Area	Residential and commercial developments
3	Water Body	Streams, rivers, and inland water
4	Vegetation	All vegetation types

2.4 Accuracy Assessment

Classification accuracy was evaluated for each of the three epochs using confusion matrices (error matrices), which compare classified image output against independently collected ground truth reference data on a class-by-class basis. Two key metrics were computed: Overall Accuracy — the proportion of correctly classified pixels — and the Kappa Coefficient, which measures agreement beyond chance. Results are summarised below:

Table 2.3: Classification Accuracy Assessment Results

Year	Overall Accuracy (%)	Kappa Coefficient
2002	98.31%	0.974
2012	100%	1.000
2022	96.55%	0.942

All three classification results exceeded the 85% overall accuracy threshold recommended by Anderson *et al.* (1976) [1] as the minimum acceptable standard for LULC mapping. The 2012 classification achieved perfect accuracy (Kappa = 1.0), reflecting excellent spectral separability and training sample quality. The marginal reduction in 2022 accuracy (96.55%) is attributed to increased urban complexity, mixed pixels, and rapid land cover transitions driven by urban expansion. These high accuracy values validate the reliability of all subsequent change detection and thermal analyses.

2.5 Land Surface Temperature (LST) Extraction

Land Surface Temperature (LST) — the radiative skin temperature of the land surface — was extracted from the thermal infrared band (Band 6 for Landsat 5/7; Band 10 for Landsat 8) for 2002, 2012, and 2022 using a standardised multi-step procedure applied consistently across all epochs.

Step 1: Digital Number (DN) to Spectral Radiance

Raw pixel digital numbers were converted to Top-of-Atmosphere (TOA) spectral radiance (L_{λ} , in $W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$) using sensor-specific linear rescaling equations. For Landsat 5 TM and 7 ETM+, the conversion used maximum and minimum radiance calibration values (L_{max} , L_{min}) and quantized pixel value ranges. For Landsat 8 OLI/TIRS, radiance multiplicative (ML) and additive (AL) scaling factors from the accompanying metadata (MTL) file were applied.

Step 2: Spectral Radiance to At-Sensor Brightness Temperature

Spectral radiance values were converted to at-sensor brightness temperature (TB, in Kelvin) using the inverse of Planck's radiation equation, incorporating sensor-specific pre-launch thermal calibration constants $K1$ and $K2$ (Landsat 5: $K1 = 607.76$, $K2 = 1260.56$; Landsat 7: $K1 = 666.09$, $K2 = 1282.71$; Landsat 8: $K1 = 774.89$, $K2 = 1321.08$).

Step 3: NDVI and Proportion of Vegetation

The Normalized Difference Vegetation Index (NDVI) was computed from near-infrared (NIR) and red bands to characterise vegetation density across the study area. NDVI values range from -1 to $+1$, with higher values indicating dense vegetation. The proportion of vegetation (P_v) was subsequently derived from NDVI using a normalized quadratic expression relating pixel NDVI to the minimum and maximum NDVI values within the study area.

Step 4: Land Surface Emissivity (ϵ)

Surface emissivity (ϵ) — a measure of a surface's efficiency in emitting thermal radiation — was estimated from the proportion of vegetation using the empirical relationship: $\epsilon = 0.004 \times P_v + 0.986$. This approach accounts for surface heterogeneity and improves LST accuracy in mixed urban-vegetated environments.

Step 5: Final LST Calculation

The final LST was computed by correcting brightness temperature for surface emissivity using the standard Planck function inversion, incorporating the wavelength of emitted radiance ($\lambda \approx 10.895 \mu m$) and the constant $\rho = h \times c / \sigma = 1.438 \times 10^{-2} m \cdot K$ (where h is Planck's constant, c is the speed of light, and σ is the Boltzmann constant). The resulting LST values in Kelvin were converted to degrees Celsius by subtracting 273.15, producing spatially distributed surface temperature maps for each study epoch.

3. Results and Discussion

This chapter presents the results and discussion of Land Use/Land Cover (LULC), Normalized Difference Vegetation Index (NDVI), and Land Surface Temperature (LST) analysis carried out for the study area for the years

2002, 2012, and 2022. Results are presented using tables and maps, while interpretations are provided based on the derived statistics generated from map analysis.

3.1 Land Use/Land Cover Classification Results

3.1.1 Land Use/Land Cover Classification (2002)

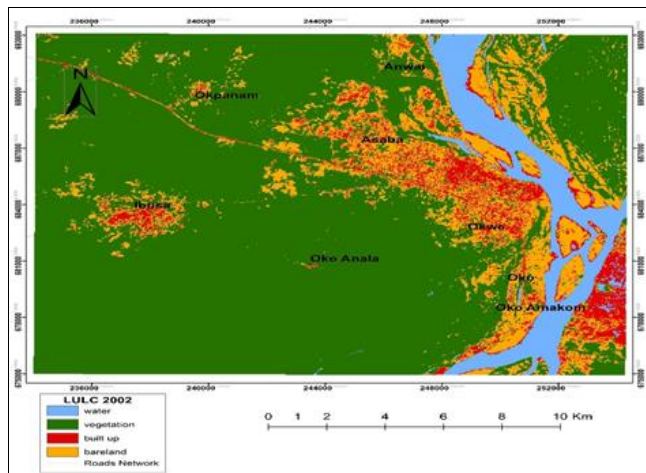


Fig 3.1: Spatial Distribution of Land Use Land Cover 2002

Table 3.1: LULC Area Coverage for Year 2002

Class	Area (km ²)	Percentage (%)
Built-up	19.37	5.21
Vegetation	271.29	72.99
Water Bodies	26.56	7.14
Bare Land	54.48	14.66

In 2002, vegetation dominated the study area, accounting for 72.99% of the total land cover. Built-up areas occupied only 5.21%, indicating limited urban development at the time. Bare land covered 14.66%, reflecting agricultural land preparation and undeveloped surfaces. Water bodies accounted for 7.14%, corresponding mainly to river channels and wetlands. This distribution reflects a largely natural and agrarian landscape with minimal anthropogenic influence.

3.1.2 Land Use/Land Cover Classification (2012)

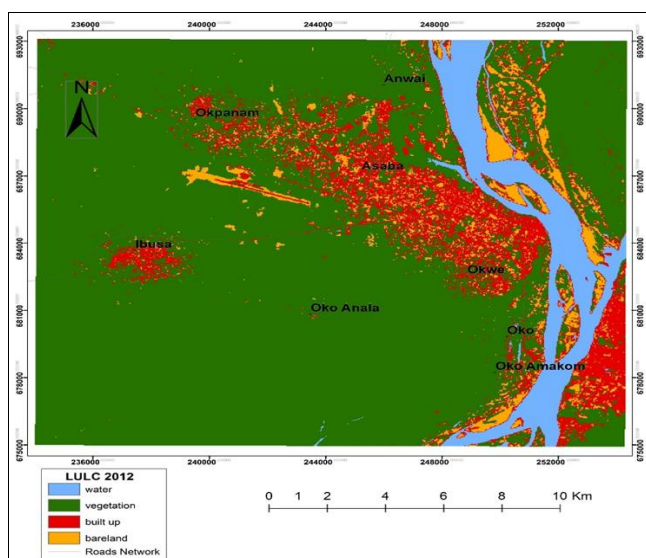


Fig 3.2: Spatial Distribution of Land Use Land Cover 2012

Table 3.2: LULC Area Coverage for Year 2012

Class	Area (km ²)	Percentage (%)
Built-up	39.84	10.72
Vegetation	286.29	77.02
Water Bodies	26.91	7.24
Bare Land	18.65	5.02

In 2012, built-up areas increased to 10.72%, representing a more than 100% increase, showing rapid urban expansion compared to 2002. Vegetation increased slightly to 77.02%, possibly due to regrowth and seasonal vegetation expansion during image acquisition. Bare land significantly decreased to 5.02%, suggesting conversion into built-up or vegetated surfaces.

3.1.3 Land Use/Land Cover Classification (2022)

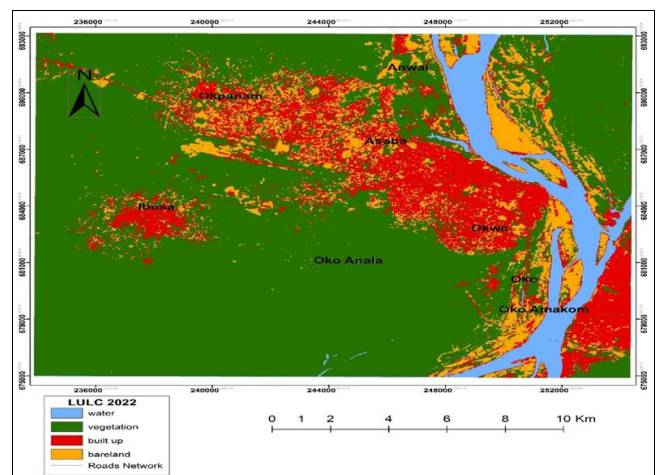


Fig 3.3: Spatial Distribution of Land Use Land Cover 2022

Table 3.3: LULC Area Coverage for Year 2022

Class	Area (km ²)	Percentage (%)
Built-up	56.90	15.11
Vegetation	255.75	67.91
Water Bodies	24.00	6.37
Bare Land	39.97	10.61

By 2022, built-up areas expanded further to 15.11%. Vegetation declined to 67.91%, indicating land conversion due to urbanization. Bare land increased to 10.61%, reflecting ongoing construction activities. These trends confirm progressive urban growth over the study period.

Table 3.4: Land Use Land Cover Change 2002–2022

LULC Class	Area 2002 (km ²)	Area 2012 (km ²)	Area 2022 (km ²)	Change 2002–2012 (km ²)	Change 2012–2022 (km ²)	Change 2002–2022 (km ²)
Built-up	19.373	39.841	56.896	+20.468	+17.055	+37.523
Vegetation	271.29	286.292	255.747	+15.002	-30.545	-15.543
Water Body	26.557	26.913	23.998	+0.356	-2.915	-2.559
Bare Land	54.476	18.652	39.974	-35.824	+21.322	-14.502

The land use/land cover change analysis reveals a substantial expansion of built-up areas in Asaba between 2002 and 2022, with a net increase of 37.52 km². This growth reflects rapid urbanization and infrastructure development within the study area. Vegetation cover showed an initial increase between 2002 and 2012, followed

by a significant decline by 2022, indicating conversion of vegetated land to urban and other land uses. Water bodies experienced a slight reduction over the study period, while bare land fluctuated, suggesting transitional land cover associated with construction and land development activities.

3.2 Land Surface Temperature (LST) Results

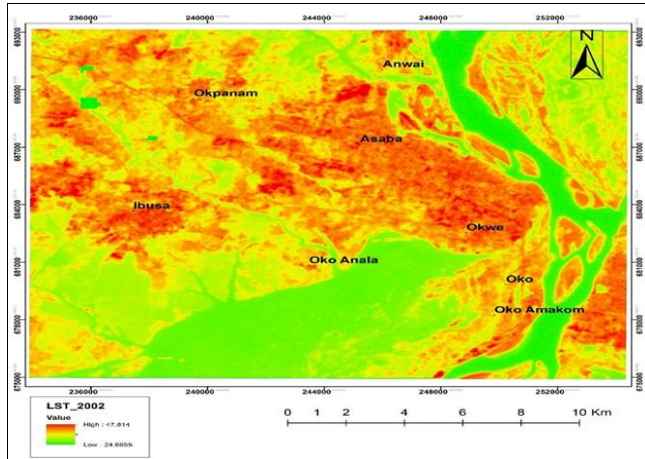


Fig 3.4: Spatial Distribution of Land Surface Temperature 2002

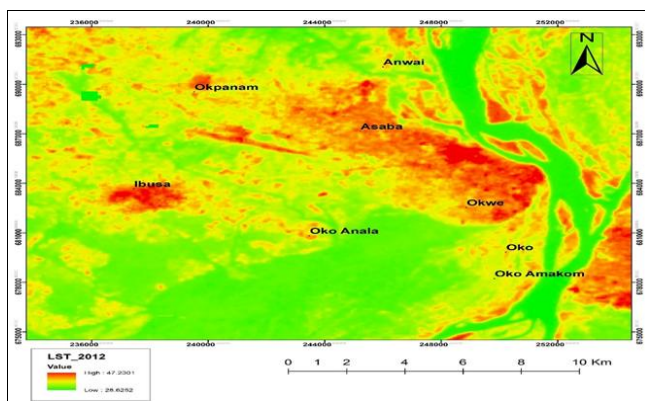


Fig 3.5: Spatial Distribution of Land Surface Temperature 2012

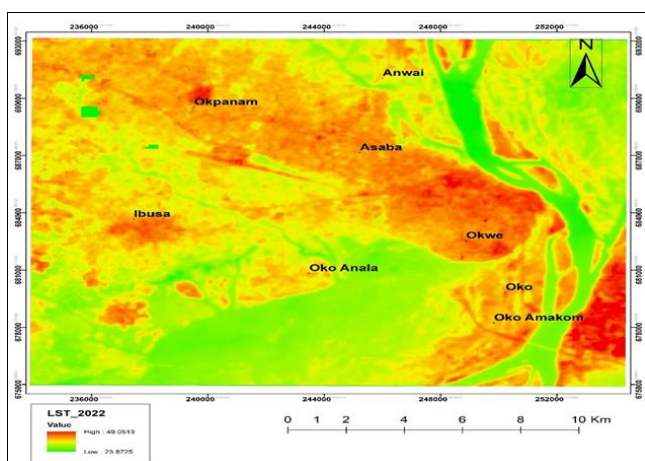


Fig 3.6: Spatial Distribution of Land Surface Temperature 2022

Table 3.5: LST Statistics for Selected Years 2002–2022

Year	Min (°C)	Max (°C)	Mean (°C)
2002	25.28	50.54	34.24
2012	28.27	47.19	34.80
2022	25.18	45.92	35.04

The mean LST increased from 34.24°C in 2002 to 35.04°C in 2022. Built-up and bare land areas recorded higher temperatures, while vegetation and water bodies showed lower temperatures. This pattern demonstrates the urban heat island effect.

3.3 Normalized Difference Vegetation Index (NDVI) Distribution

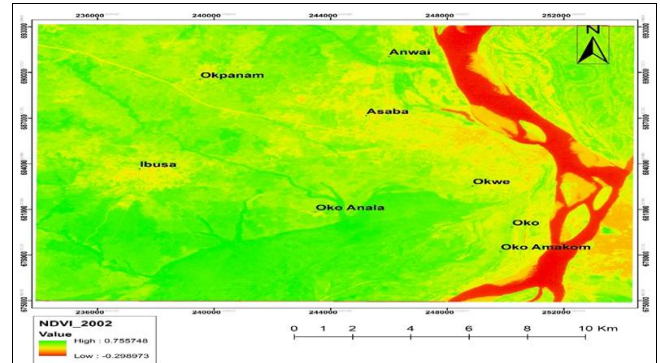


Fig 3.7: Spatial Distribution of NDVI 2002

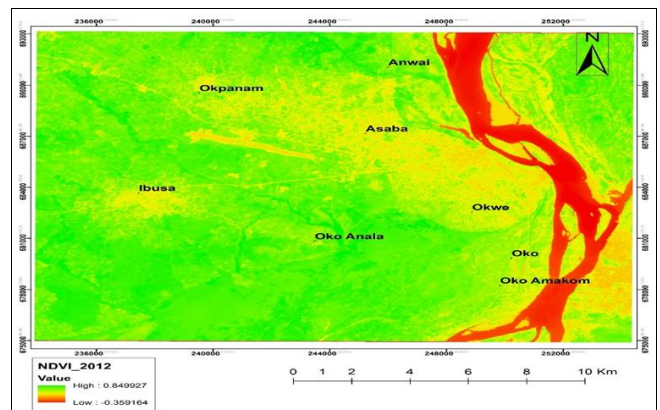


Fig 3.8: NDVI Distribution of the Study Area 2012

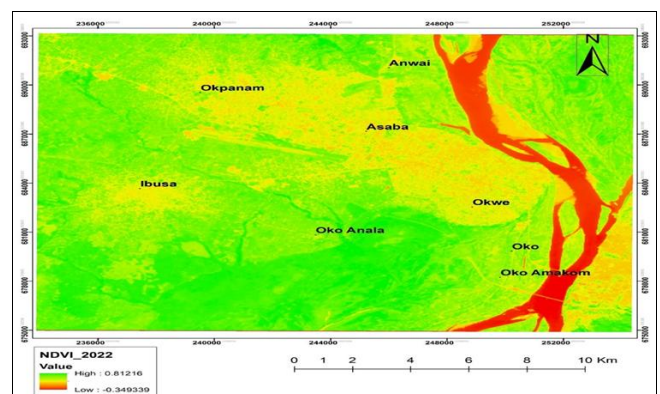


Fig 3.9: NDVI Distribution of the Study Area 2022

Table 3.6: Normalized Difference Vegetation Index (NDVI) Statistics

Year	Min	Max	Mean
2002	-0.299	0.756	0.402
2012	-0.359	0.850	0.490
2022	-0.349	0.812	0.458

NDVI values ranged from negative values over water bodies to high positive values over dense vegetation. Mean NDVI increased from 0.402 in 2002 to 0.490 in 2012, before

declining to 0.458 in 2022, indicating vegetation loss in recent years.

3.4 Relationship Between NDVI and Land Surface Temperature (LST)

To further examine the relationship between vegetation cover and surface temperature within the study area, a Pearson correlation analysis was carried out between NDVI and Land Surface Temperature (LST) for the years 2002, 2012, and 2022.

Table 3.7: NDVI–LST Correlation Results

Year	Pearson Correlation (r)	Relationship Strength	Significance
2002	-0.11	Weak negative	Significant
2012	-0.03	Very weak negative	Significant
2022	-0.21	Moderate negative	Significant

The correlation results reveal a consistently negative relationship between NDVI and Land Surface Temperature across all study years. In 2002, a weak negative correlation ($r = -0.11$) was observed, indicating that areas with higher vegetation density generally experienced lower surface temperatures. This relationship became very weak in 2012 ($r = -0.03$), suggesting a reduced cooling influence of vegetation during that period, possibly due to seasonal effects or increased urban disturbance.

By 2022, the correlation strengthened to a moderate negative relationship ($r = -0.21$), reflecting an increasingly clear contrast between vegetated and non-vegetated surfaces. This trend corresponds with intensified urban expansion and vegetation loss, which enhanced thermal differences between land cover types.

The observed negative correlations confirm that vegetation plays a significant role in regulating land surface temperature through shading and evapotranspiration. Areas with reduced vegetation cover, particularly built-up and bare land surfaces, consistently exhibited higher surface temperatures, while vegetated areas maintained relatively lower temperatures. These findings are consistent with established urban climate studies and strongly support the conclusion that declining vegetation cover contributes to rising land surface temperatures within the study area.

3.5 Summary of Findings

Built-up areas increased significantly between 2002 and 2022, vegetation declined, and land surface temperature increased. NDVI and LST exhibited a consistent inverse relationship. The combined analysis of LULC, NDVI, and LST results demonstrates a strong link between land cover changes and surface temperature dynamics within the study area. Increased urbanization led to vegetation loss, which in turn contributed to rising land surface temperatures. NDVI showed a negative correlation with LST, confirming the cooling effect of vegetation. These findings align with previous studies that highlight the environmental consequences of rapid urban growth in developing regions.

The major findings of the study are summarized as follows:

- **Rapid Urban Expansion:** Built-up areas increased significantly from 19.37 km² (5.21%) in 2002 to 56.90 km² (15.11%) in 2022, indicating accelerated urban growth driven by population increase and infrastructure development.
- **Decline in Vegetation Cover:** Vegetation cover declined from 72.99% in 2002 to 67.91% in 2022,

reflecting continuous conversion of vegetated land into built-up and transitional land uses.

- **Increase in Land Surface Temperature:** Mean land surface temperature rose from 34.24°C in 2002 to 35.04°C in 2022, with higher temperatures consistently recorded over built-up and bare land surfaces.
- **Inverse NDVI–LST Relationship:** NDVI exhibited a consistent negative correlation with LST across all study years, confirming that areas with higher vegetation density experienced lower surface temperatures.
- **Urban Heat Island Development:** Spatial LST patterns revealed the emergence and intensification of urban heat islands, particularly within densely built-up zones of Asaba.
- **Reliability of Classification Results:** Accuracy assessment results for all classified images exceeded 96%, confirming the reliability of the derived LULC maps and subsequent analyses.

These findings collectively demonstrate that urban growth and vegetation loss are primary drivers of rising surface temperatures in Asaba metropolis.

4. Conclusion

This study examined the spatio-temporal dynamics of land use/land cover changes and their influence on land surface temperature within Asaba metropolis, Delta State, Nigeria, for the years 2002, 2012, and 2022. The research integrated remotely sensed Landsat imagery, GIS techniques, NDVI analysis, and land surface temperature modelling to assess how urban growth and vegetation change affect surface thermal patterns.

Supervised image classification was applied to derive LULC maps, which were validated using accuracy assessment techniques yielding overall accuracies above internationally accepted thresholds. Land Surface Temperature was extracted using thermal infrared bands with emissivity correction derived from NDVI. Statistical analysis was further employed to examine the relationship between vegetation cover and surface temperature. The study addressed the identified research gap by integrating LULC change, urban growth, NDVI, and LST modelling into a single analytical framework, providing a holistic understanding of urbanization-induced thermal dynamics in the study area.

Based on the results obtained from this study, it can be concluded that urbanization has significantly altered the land use structure of Asaba metropolis, resulting in increased land surface temperatures and reduced vegetation cover. The spatio-temporal analysis confirms that land cover transformation—particularly the expansion of built-up areas—plays a critical role in the formation and intensification of urban heat islands.

The observed inverse relationship between NDVI and LST emphasizes the importance of vegetation in regulating urban thermal environments through shading and evapotranspiration. The integration of remote sensing and GIS techniques proved effective in detecting land cover transitions and quantifying their thermal impacts.

Overall, the study successfully achieved its objectives by demonstrating that uncontrolled urban expansion, coupled with inadequate land use planning, contributes directly to surface temperature rise and increased thermal discomfort. The findings provide scientific evidence needed to support

climate-responsive urban planning and sustainable land management strategies in Asaba and similar rapidly growing cities.

4.1 Recommendations

Based on the findings and conclusions of this study, the following recommendations are proposed:

- **Promotion of Green Infrastructure:** Urban planners should prioritize the integration of green spaces, urban forests, parks, and green belts to mitigate rising surface temperatures.
- **Climate-Sensitive Urban Planning:** Land use planning policies should incorporate thermal impact assessments to minimize heat retention from impervious surfaces.
- **Vegetation Conservation and Restoration:** Existing vegetated areas should be protected, while degraded areas should be rehabilitated through afforestation and urban greening programs.
- **Use of Heat-Reducing Construction Materials:** Adoption of cool roofing materials, reflective pavements, and permeable surfaces should be encouraged to reduce heat absorption.
- **Continuous Geospatial Monitoring:** Government agencies should institutionalize the use of GIS and remote sensing for continuous monitoring of land use change and urban heat dynamics.
- **Public Awareness and Policy Enforcement:** Awareness campaigns should be conducted to educate stakeholders on the impacts of land use change on urban climate, supported by strict enforcement of planning regulations.

5. References

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