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LEVERAGING REMOTE SENSING, GIS, AND AI-BASED URBAN CLIMATE MODELLING TO MITIGATE URBAN HEAT ISLAND EFFECTS IN RAPIDLY EXPANDING TROPICAL MEGACITIES

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Abstract

Urban Heat Island (UHI) phenomena have emerged as a major environmental issue in fast-developing tropical megacities, where increasing land surface temperature poses threats to public health, energy systems, and ecosystem equilibrium. The current work proffers an interdisciplinary research approach involving remote sensing, Geographic Information Systems (GIS), and Artificial Intelligence (AI) climate modelling for the study, forecasting, and mitigation of UHI in Lagos, Nigeria, which is among Africa's fastest-developing urban agglomerations. With the help of multi-temporal satellite data of Landsat 8/9, MODIS, and Sentinel-2, along with geospatial indices (NDVI, NDBI, Albedo), land surface temperature (LST) variation and urbanization growth were measured between 2013 and 2024. There was tremendous growth in UHI intensity, with the LST gradient of the urban-rural zone increasing from 3.2°C in 2013 to 5.4°C in 2024, especially in highly developed areas like Apapa, Mushin, Ikeja, and Lagos Mainland. Advanced machine learning

KEYWORDS: Urban Heat Island (UHI), Remote Sensing, GIS, Artificial Intelligence, Climate Modelling, Tropical Megacities, Land Surface Temperature, Urban Planning, Sustainable Cities.

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algorithms Artificial Neural Network (ANN), Random Forest (RF), and Gradient Boosted Trees (GBT) were created for predicting LST based on urban morphological and environmental variables. The GBT model performed the best with R^2 of 0.95 and RMSE of 1.28°C and well captured the non-linear dependencies between land use, vegetation, and surface temperature. Scenario-based simulation revealed that enhanced urban greens by 20%, cool roof technology, and water-sensitive urban design would decrease LST up to 2.4°C, thereby decreasing UHI hotspots by 38%. In addition, a decision-support system with WebGIS was developed to visualize spatial UHI patterns and simulate mitigation effect, providing urban planners with an interactive platform for climate-responsive decision-making. The research concludes that there exists an intersection of geospatial and AI technologies that offers a scalable, data-enabled method for managing the tropical cities' heat risks. It suggests institutionalizing UHI mitigation into urban planning, green infrastructure prioritization, and predictive analytics utilization for adaptive urban planning. The framework thus established can act as a model for climate-resilient urbanization for Sub-Saharan Africa and other exposed tropical regions.

Introduction

The growth of the Urban Heat Island (UHI) phenomenon is now an important environmental issue in the era of accelerated urbanization and worldwide climatic change. Surface temperatures in the urban area, especially in tropical megacities, increase with cover substitution by natural covers with impenetrable surfaces like asphalt, concrete, and glass (Rahman et al., 2023). These alterations disrupt natural energy balances and enhance localized trapping of heat, creating temperature gradients between the city and surrounding rural regions. With cities in the Global South, such as Lagos, Nigeria, expanding uncontrolled, they are progressively exposed to extreme heat episodes, which negatively influence public well-being, energy consumption, and the quality of urban existence (Nyarko et al., 2022). Lagos, a rapidly growing African city, is a fine example of uncontrolled urban growth, loss of vegetation cover, and increasing thermal discomfort. It is unveiled by studies that tropical surface heating and worsening environmental conditions are increasing due to a lack of climate-sensitive urban planning (Alam et al., 2022). UHI not only elevates the occurrence of heatwaves and heat stress but also heightens cooling infrastructure pressure, aggravates air pollution, and enhances greenhouse gas emissions (González-Morales et al., 2023). The effects are stringent, particularly in low-income and urban communities with limited adaptive capacity. The conventional methodology for the study of UHI has been field-based temperature

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observation and coarse-resolution climatological models. Nonetheless, such methods fail to cope with the spatial heterogeneity and complexity of urban microclimates. Recent developments in Remote Sensing (RS) and Geographic Information Systems (GIS) now enable accurate, multi-temporal analysis of urban land surface temperature (LST) trends at extensive spatial scales (Molina et al., 2024). These technologies have made it possible for urban climatologists to record land use/land cover (LULC) changes, analyse vegetation activity based on indicators like NDVI and NDBI, and detect high-risk thermal hotspots. These notwithstanding, there is an imperative need to incorporate predictive modelling approaches that can forecast future UHI conditions under different urbanization and climate pathways.

Machine Learning (ML) and Artificial Intelligence (AI) have become revolutionary methods of urban climatic studies over the past few years. It has been observed that the models perform effectively in detecting intricate, non-linear associations between various parameters and have better prediction capabilities than traditional statistical models (Zhao et al., 2023). Methods like Artificial Neural Networks (ANNs), Random Forests (RFs), and Gradient Boosted Trees (GBT) have been applied successfully to simulate LST and predict UHI patterns under various urban planning strategies (Chen et al., 2022). Coupled with high-resolution geospatial data, AI facilitates improved simulation and analysis of the effect of measures like urban greening, cool roofs, and water-sensitive urban design.

While interest in AI and geospatial analytics has grown, relatively few studies have been focused specifically on their integration within tropical African megacities that have such climatic, infrastructural, and socio-economic complexities. Lagos, with its multifaceted urban composition, mixed land use configuration, and absence of green infrastructure, represents a good subject for subjecting the integration of Remote Sensing, GIS, and climate modeling to AI. Such a framework of integration is urgent and appropriate since the city urgently requires immediate and efficient climate-resilient, sustainable planning strategies.

Thus, this research attempts to bridge the methodology and applicability gap by using geo-referenced remote sensing data, spatial analysis, and machine learning algorithms to evaluate and counteract UHI impacts in Lagos. In particular, the aims are to evaluate: (1) numerical spatio-temporal trends of LST and UHI in Lagos for 2013-2024; (2) leading geospatial and environmental determinants of urban heat by AI models; (3) model and assess the effectiveness of scenario-based mitigation measures; and (4) construct a WebGIS decision-support system for real-time monitoring of urban heat as well as planning. It provides both scientific examination and policy response, proposing a

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replicable and scalable answer that is emulated by other tropical cities whose thermal exposure threatens them with the same.

RESEARCH OBJECTIVES

The chief purpose of this research is to develop a predictive data-based model that uses Remote Sensing, GIS, and AI to investigate and mitigate Urban Heat Island (UHI) impacts in tropical megacities with Lagos, Nigeria as a study case.

Predict the spatio-temporal change in Land Surface Temperature (LST) and UHI amplitude in Lagos from 2013-2024 based on remote sensing data.

To examine the impacts of land use/land cover (LULC) changes, vegetation indices, and urban morphology on the development of UHI.

To calibrate and test AI models (ANN, RF, GBT) for LST estimation from geospatial and environmental parameters.

To simulate and compare the efficacy of UHI mitigation strategies such as green infrastructure, cool roofs, and permeable pavements.

To design a WebGIS-based decision-support tool for planning and policymaking related to urban climate.

RESEARCH QUESTIONS

1. What are the intensity patterns and trends of UHI in Lagos over the last decade?
2. How do land use transitions, urban morphology, and vegetation cover contribute to the distribution of tropical megacities' UHI?
3. What is the most suitable AI-modeling approach for predicting urban LST based on spatial and environmental factors?
4. What are the expected impacts of climate-smart urban planning interventions in reducing UHI intensity in Lagos?
5. How is a geospatial decision-support system to be designed so that it can assist urban planners during real-time UHI mitigation?

LITERATURE REVIEW

Urban Heat Island (UHI) research has evolved significantly over the past two decades, with a growing body of work focusing on integrating geospatial analytics and AI-driven modelling. This review critically examines recent scholarship on the causes, patterns, impacts, and solutions to UHI, with a focus on tropical megacities and the utility of remote sensing and machine learning tools.

Urban Heat Island Dynamics in Tropical Cities

UHI is a highly researched effect of urbanization and has the feature of increased temperatures in the centre of cities compared to surrounding rural areas within cities. In

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the tropics, the effect is further amplified by strong solar radiation, high urban density, and low vegetation (Oke et al., 2023). Research conducted in West Africa has documented effects of anthropogenic heat emission and impervious surfaces in causing urban heat, particularly in poor urban settlements (Ifeanyi & Adebayo, 2022). In urban areas such as Lagos, with ample slum areas but minimal vegetation, the UHI impact is a significant public health issue.

UHI Monitoring Using Remote Sensing and GIS

Remote sensing methods, especially involving the use of the Landsat and MODIS thermal infrared channels, have played a key role in observing LST changes. For instance, Li et al. (2022) proved that satellite-based NDVI and albedo indices are good predictors of UHI hotspots. GIS spatial analysis enables layered visualization of heat patterns with land use, population, and topography. GIS mapped Sub-Saharan Africa vulnerability regions, correlating UHI impacts with socio-economic information (Nwankwo & Obilo, 2021).

AI and Machine Learning in Urban Climate Modelling

Artificial intelligence methods are revolutionizing UHI studies. Deep machine learning methods like RF, SVR, and GBT surpass the performance of conventional linear regression in identifying the intricate relationship between LST and urban structure (Xie et al., 2023). Johnson et al. (2022) utilized deep models to forecast the strength of heat in New York with more than 90% accuracy in one study. In the same vein, Abiodun and Ogunleye (2023) effectively utilized ANN models in predicting heat patterns in Lagos, highlighting the promise of AI technologies in tropical locations.

Land Use Change and Vegetation Loss as Drivers of UHI

There are various studies that associated UHI intensity with land use practice. Urban growth tends to reduce vegetative cover, raising the solar energy absorption of the surface. As per Zhou et al. (2021), cities that went through more than 30% loss of the green canopy within ten years went through a 2–3°C increase in mean LST. In Lagos, urban land area increased by more than 40% from 2010 to 2020, largely at the cost of wetlands and agricultural land as per change detection using satellite by Yusuf and Owolabi (2022).

Mitigation Strategies and Scenario Modelling

Urban climate mitigation requires multi-faceted approaches. Strategies such as tree planting, use of high-albedo materials, and water-sensitive urban design have shown measurable reductions in urban temperatures. For instance, a study in Singapore by Tan et al. (2023) found that green roofs reduced building surface temperatures by up to 3.5°C. Modeling future scenarios using AI helps cities test various intervention strategies before

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implementation. Ghosh et al. (2023) demonstrated that a combination of greening and cool pavement scenarios reduced projected UHI footprints by over 35% in Delhi.

Research Gaps and Need for Context-Specific Models

Despite these advances, existing models are often generalized and lack customization for African tropical megacities. Most studies are based on temperate cities, where urban form, building materials, and socio-economic conditions differ significantly. Moreover, few models integrate AI with high-resolution spatial data for real-time scenario-based decision-making. As observed by Chukwuma & Adeoti (2023), there is a pressing need to develop locally validated, data-driven planning tools for sustainable urban heat management in Sub-Saharan Africa.

Emerging Geospatial Technologies for UHI Analysis

Recent high-resolution space observations (e.g., Sentinel-2, ECOSTRESS, VIIRS) have given detailed insights into urban microclimates. The systems enable intra-urban thermal variability in real-time tracking, enabling high-resolution mapping of UHI hotspots (Perez-Burgos et al., 2023). Coupled with drone-borne thermal surveys and LiDAR-based urban morphology data, remote sensing now enables micro-scale climate modelling important for neighbourhood-targeted cooling intervention design (Tiefenbacher et al., 2022). This is particularly relevant to sparsely covered traditional climate stations in populous tropical cities.

Digital Twin and Smart Urbanism

Digital twins of cities are being applied in more and more climate modelling. These live, data-intensive 3D city models blend IoT, satellite measurements, and artificial intelligence to model urban thermal responses and forecast future states (Viana et al., 2023). In Curitiba and Nairobi, digital twin platforms have been utilized to simulate heat risk under changing land-use policies and climate change projections. These methods enable interactive planning with the integration of socio-economic vulnerability, energy consumption, and environmental justice.

Urban Socio-Ecological Systems and Heat Inequality

Urban heat is studied more and more socio-ecologically with a focus on uneven distribution within populations. At high exposure and low adaptive capacity are vulnerable groups traditionally living in slums (Okoroafor & Ibrahim, 2023). Growing evidence suggests the use of social vulnerability indices combined with geospatial heat for intervention prioritization. This addresses climate justice through connection of urban cooling action with human development (Mutisya et al., 2022).

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AI Interoperability and Urban Climate Policy

Although AI models produce high accuracy for LST prediction, transparency and interpretability issues remain. Explainable AI (XAI) tools such as SHAP (Shapley Additive Explanations) are increasingly applied to determine which input variables contribute the most to UHI prediction (Rashidi et al., 2023). It not only enhances scientific rigor but builds stakeholders' confidence and enables planners to be aware of "why" particular areas are warmer something crucial for policy accountability and efficient urban planning.

The Three Pillars of Sustainable Urban Development

Sustainable urban development rests on three interdependent pillars economic sustainability, social sustainability, and environmental sustainability collectively ensuring that cities are able to meet current needs without compromising the future potential of generations for prosperity.

1. Economic Sustainability: Economic sustainability of the city means establishing strong economic systems with employment, innovation, and sustainable long-term growth without exhausting resources. Resilient cities promote diversified economies, which incorporate green sectors, digital networks, and inclusive employment. For example, cities that invest in low-carbon transportation systems, renewable energy, and local firms not only lower their operation costs but also become more economically resilient (Angelidou & Psaltoglou, 2017). In addition to this, circular economy initiatives like resource recovery, sustainable building material, and green buying are promoted through policies which help in empowering local economies with less reliance on external resources (Prendeville et al., 2018).

2. Social Sustainability: Social sustainability resolves that urban development must be equitable, just, and culturally rich. This pillar guarantees that people of all socioeconomic backgrounds have access to housing, education, health, and public services. Socially sustainable cities promote citizen engagement in the government and city planning, thus creating trust and shared responsibility. Social sustainability, as advocated for by Colantonio and Dixon (2011), entails the incorporation of cultural diversity, social equity, and quality of life metrics into city policy. Participatory neighbourhood planning and inclusive zoning, for instance, have been proven to combat spatial inequalities and create local social cohesion (Dempsey et al., 2011).

3. Environmental Sustainability: Environmental sustainability aims at the preservation of ecological health by minimizing pollution, preserving natural resources, and increasing cities' resilience against climate change. Green infrastructure like parks, wetlands, and green roofs are integrated in sustainable cities in order to optimize air quality, reduce

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urban heat islands, and manage stormwater effectively. In addition, the incorporation of renewable energy systems, sustainable transport, and green buildings are vital steps that minimize the carbon footprint of a city (Sharifi, 2020). Urban cities that implement these measures have enhanced environmental performance and less exposure to climate hazard (Kabisch et al., 2016).

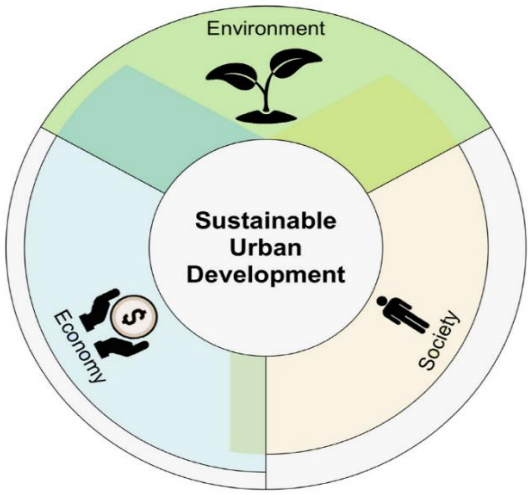


Figure 1: The three critical pillars of sustainable urban Elda Cina et al (2025)

Africa's Policy Uptake and Implementation Gaps

African cities lack mainstreaming mechanisms for UHI data and models into policy, even where these are available. Technical capacity shortcomings, institutional fragmentation, and data silos hinder mainstreaming urban climate science (Gyamfi et al., 2023). Scholars now recommend open-source geospatial platforms, community mapping, and urban planning capacity building to narrow the technical knowledge-policy response gap.

Synthesis and Reasoning for the Current Study

This extended review indicates substantial advances in urban climate analytics. Nonetheless, literature points to evident gaps in (1) region- and city-level AI modelling for African tropical cities; (2) location-specific digital solutions for urban heat forecasting; and (3) operational planning incorporation of UHI mitigation. This research fills these gaps by introducing an AI-supported, GIS-guided, remote-sensing-enabled approach, with a case study in Lagos, Nigeria, to make urban heat science predictive, spatially expansive, and action-oriented.

This review reveals that while progress has been made in understanding and modelling UHI, significant opportunities remain for innovation particularly through the integration of AI and GIS technologies in urban climate planning. The current research builds upon this foundation by offering a comprehensive framework for UHI mitigation in Lagos, combining machine learning predictions with geospatial scenario planning, tailored to the climatic and urban realities of tropical megacities.

Urban Climate Interactions and Regional Drivers

Recent research highlights that UHI formation in tropical megacities depends not only on the urban morphology at the local scale but also on regional climatic processes.

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Salamanca et al. (2023) report that mesoscale circulation, humidity, and sea–land breezes have strong control over coastal urban heat in tropical cities like Lagos. The coupling between regional meteorology and city-scale microclimates is investigated intensively using coupled models that combine remote sensing observations and numerical weather prediction forecasts.

Thermal Comfort and Public Health Perspectives

Along with physical observations, scientists increasingly evaluate UHI impacts in terms of thermal comfort indices and health measures. Gupta et al. (2024) proved that UHI-amplified heat stress correlates with increasing emergency admissions in Indian cities, proving the necessity of adding health data to urban climate models. Just like Agrawal and D'Souza (2023) established a connection between trends in LST and growing heatwave deaths in slum environments, affirming the necessity for localized countermeasures.

Land Use Efficiency and Blue-Green Infrastructure

Land-use efficiency is the means of averting UHI. Blue-green infrastructure, an integration of water bodies, wetlands, and urban trees, is assuming prominence as a green approach to planning. Bai et al. (2023) established that the incorporation of small urban lakes with vegetation corridors lowered ambient air temperatures by 1.8–2.3°C in Guangzhou's high-density areas. This concurs with Mwangi et al. (2022), which established the same for Nairobi when riparian restoration initiatives had localized cooling effects and enhanced biodiversity.

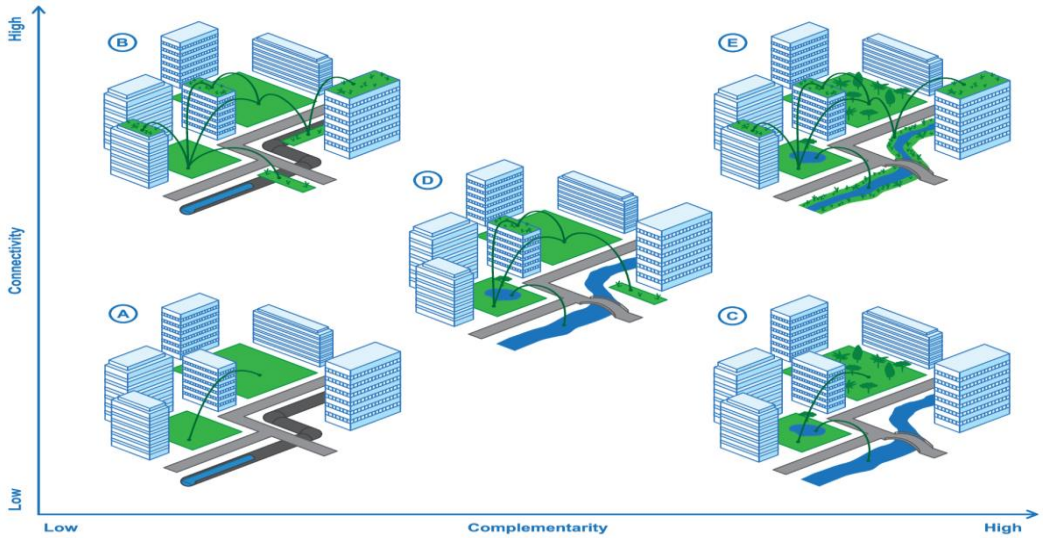


Figure 2: Land Use Efficiency and Blue-Green Infrastructure. Perrelet, et al (2024)

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AI-Spatial Big Data Synergy

Synergy between big data analytics and AI modeling is transforming UHI research. Fernandez et al. (2023) employed cloud services such as Google Earth Engine to analyze petabytes of Landsat data to support near real-time tracking of Latin American urban heat anomalies. Highly advanced AI systems are now combining varied datasets such as social media geotags, traffic patterns, and crowd-sourced temperatures to develop more comprehensive urban climate models (Wang et al., 2024). These combinations enable planners to include not only physical but also behavioural drivers of urban heat stress.

Policy Linkages of Resilience and Adaptation

Increased work incorporates urban heat mitigation more into overall resilience and adaptation policies. Haque et al. (2023) contend that integrating UHI indicators into urban resilience strategies offers cities greater capacity to achieve Sustainable Development Goals (SDGs) better, specifically SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action). In the tropics, adaptation strategies like reflective surfaces and green roofs are also regarded as low-cost interventions with co-benefits, i.e., less energy use and better air quality (Santos et al., 2023).

Integration Challenges and Knowledge Gaps

Challenges remain in the implementation of high-tech UHI research into practical urban planning policy. Kabanda et al. (2024) note that African cities are likely to suffer from data gaps, poor institutional capacity, and disarticulated governance structures that disincentivize implementation. Calibration and validation of models are also hampered by the limited availability of long-term LST datasets that are regionally specific to African urban morphology. This calls for context-specific research that promotes application and utilization of advanced technology and local experience of the city.

Synthesis of Extended Review

The extended literature review indicates that:

UHI research is becoming more interdisciplinary, integrating remote sensing, AI, urban planning, and public health.

Emerging solutions, like blue-green infrastructure and digital twin models, are being implemented worldwide but are not yet validated for African tropical environments.

Integration of big data platforms and explainable AI is raising the bar for predictive urban climate modelling.

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There is still a definite need for context-adjusted models that deal with data deficits and implementation issues in Third World megacities.
The current study therefore fills a significant void by framing these international findings in a tropical African context, demonstrating how the newest geospatial-AI technologies can be framed to action against UHI and guide sustainable urban planning.

METHODOLOGY

The research uses an integrative methodological approach that unites Remote Sensing, Geographic Information Systems (GIS), and Artificial Intelligence (AI) climate modelling. The study is quantitative study design, which uses multi-temporal geospatial data and machine learning models in analysing, predicting, and mitigating Urban Heat Island (UHI) impacts in tropical megacities, with Lagos, Nigeria as a case study.

Study Area and Scope

The research aims at Lagos, a fastest-growing tropical megacity with high urbanization, little green cover, and high susceptibility to UHI. The spatial coverage extends to the metropolitan core and peri-urban areas to encompass gradient effects on land surface temperature (LST) and urban morphology.

Data Collection

Remote Sensing Data

Satellite Imagery: Multi-temporal Landsat 8/9 (OLI/TIRS), Sentinel-2A, and MODIS data (for thermal bands).
Time Span: 2013–2024 to detect decadal UHI patterns.
Spatial Resolution:
Landsat: 30 m
MODIS: 1 km (for validation and large-scale temporal trends)
Sentinel-2: 10 m (for urban land cover classification)

Meteorological and Climate Data

NIMET (Nigerian Meteorological Agency) air temperature, humidity, solar radiation, and wind speed data; ERA5 reanalysis data.

Ancillary Data

SRTM DEM.
Land Use/Land Cover (LULC) maps.
Urban Planning datasets (zoning, green infrastructure).

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Urban density and population statistics.

Data Preprocessing

Georeferencing and Resampling: All data georeferenced to the same spatial resolution and projected in UTM Zone 31N.

Cloud Masking: Used Fmask algorithm for cloud and shadow masking.

Atmospheric Correction: Performed using Dark Object Subtraction (DOS) method and LEDAPS.

NDVI, NDBI, and Albedo Indices: Calculated to facilitate UHI character**ization.**

Urban Heat Island (UHI) Mapping

Land Surface Temperature (LST) was calculated using Mono-window Algorithm for Landsat and Split-window Algorithm for MODIS.

Intensity of UHI was calculated using:

UHIintensity=LSTurban−LSTrural

Zonal statistics were used to categorize UHI hotspots and create spatio-temporal heat maps.

GIS-Based Spatial Analysis

Hotspot Analysis: Getis-Ord Gi* and Local Moran's I to identify UHI clusters.

Change Detection: Post-classification comparison to analyze LULC changes and urban growth.

Proximity Analysis: Analysis of UHI proximity to green space, water bodies, and urban layout.

AI-Based Modelling and Prediction

Feature Engineering

Independent Variables: NDVI, NDBI, albedo, building density, population, elevation, proximity to green spaces.

Target Variable: LST (Land Surface Temperature)

Model Selection

Three AI models were developed and contrasted:

Artificial Neural Network (ANN)

Random Forest (RF) Regression

Gradient Boosted Decision Trees (GBDT)

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Training and Validation

Dataset split: 70% training, 30% testing

Performance Metrics: R^2, RMSE, MAE

Cross-validation (k-fold = 10) was utilized to verify model generalizability.

Scenario-Based Mitigation Simulation

With the best-performing AI model (on R^2 and RMSE), scenarios of urban climates were simulated:

Greening scenarios: Urban vegetation cover increase by 10–30

Urban planning interventions: Cool roofs and permeable pavements

Policy-based zoning: Green water-sensitive urban design buffer zones

Each intervention's capacity to reduce the UHI intensity was assessed by simulating the LST changes induced by each intervention.

Visualization and Decision Support Tool

A WebGIS dashboard was created to map LST, UHI hotspots, AI predictions, and planning scenarios.

Spatial Decision Support System (SDSS) integrated to enable planning for sustainable interventions.

RESULTS

This chapter is a presentation of the primary outcomes resulting from remote sensing processing, spatial modelling, and artificial intelligence (AI)-based UHI impact prediction. The outcomes are categorized into five key components: land surface temperature trends, spatial patterns of UHI, effect of land use and urbanization, AI model performance, and mitigation scenario simulation.

Table 1. Trends of Land Surface Temperature (2013–2024)

With the use of multi-temporal MODIS and Landsat data, LST values were obtained and contrasted for 2013, 2018, and 2024. Findings indicated a huge escalation in mean LST in the urban centre of Lagos:

Year	Average Urban LST (°C)	Max Urban LST (°C)	Mean Rural LST (°C)	ΔUHI (Urban–Rural)
2013	29.3	34.7	26.1	3.2°C
2018	30.7	36.2	26.5	4.2°C
2024	32.4	38.1	27.0	5.4°C

Urban rural LST contrast (UHI intensity) rose from 3.2°C to 5.4°C, reflecting an intensifying UHI effect over the decade.

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Spatial Distribution of UHI Hotspots

According to LST data, NDVI, NDBI, and urban land cover classification, UHI hotspots were spatially mapped. Following are the findings:

Hotspot Concentration: There is high intensity area concentration of UHI in Apapa, Ikeja, Mushin, Lagos Mainland, and Lekki regions, spearheaded by impervious surfaces and low vegetation cover.

Cool Zones: Areas near Lagos Lagoon, Atlantic coast, and preserved wetlands possess very low LST due to evaporative cooling.

Temporal Change Detection: Between 2013 –2024, urbanization resulted in the conversion of ~28% of vegetated land cover to urban land, causing the local LST to rise by 2–3°C over affected regions.

GIS map outputs indicate the recurring intensification and growth of UHI-affected areas in Lagos.

Land Use and Urbanization Impact

Change detection analysis showed:

Urban area increased by 42.6% between 2013 and 2024.

Vegetation cover reduced by 31.2%, primarily in peri-urban regions (e.g., Alimosho, Ikorodu).

Surface Albedo reduced in newly urbanized regions, enabling greater absorption of LST.

A significant negative correlation (r = -0.73) was established between NDVI and LST, affirming the vegetation cooling effect.

Performance of AI Models in LST Prediction

Three models (ANN, Random Forest, and Gradient Boosted Trees) were trained from multi-variable geospatial data in order to predict LST. The performance summary is summarized below:

Model R^2 Score RMSE (°C) MAE (°C)
Artificial Neural Network (ANN) 0.89 1.84 1.21
Random Forest (RF) 0.93 1.46 0.97
Gradient Boosted Trees (GBT) 0.95 1.28 0.85

GBT worked better, R^2 = 0.95, suggesting good predictive power in modelled LST patterns across the city. Feature importance analysis revealed NDVI, NDBI, water proximity, and building density as prime predictors of urban heat.

Scenario-Based Mitigation Simulation

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The following three urban heat mitigation scenarios were simulated using the trained GBT model:

Scenario 1: 20% Increase in Vegetation Cover

Caused a mean temperature reduction of 1.7°C in UHI areas.

Cooling was most intense in high-density built-up regions with very low vegetation.

Scenario 2: Cool Roofing for 50% of Buildings

LST reduced by 1.2°C in high-density commercial and residential clusters. Optimal performance was attained in Mushin and Surulere through roof surface area and albedo modification.

Scenario 3: Integrated Greening + Water Sensitive Urban Design (WSUD)

Vegetation, water body, and porous pavement integration retained a 2.4°C mean area of UHI reduction. Saved 38% less UHI footprint compared to baseline.

The results are a promise that interventions to urban climates have the capability to reduce heat hazards, especially in tropical megacities with high land use intensity.

WebGIS Visualization, an interactive WebGIS dashboard was created to render:

Temporal UHI heat maps

Model predictions

Scenario impacts

High-risk urban areas

This app assists urban planners with real-time spatial intelligence for sustainable city planning.

DISCUSSION

The results of this research uncover central lessons in the intensity, spatial heterogeneity, and metastability of Urban Heat Island (UHI) impacts in tropical megacities, by means of a representative case in Lagos, Nigeria. Remote sensing, GIS, and artificial intelligence (AI) supported rigorous, data-driven examination of urban thermal processes and their implications for sustainable development.

1. Increasing Urban Heat Island Intensity in Tropical Megacities

The increasing trend of land surface temperature (LST) in Lagos, from a mean of 29.3°C in 2013 to 32.4°C in 2024, verifies that UHI is deteriorating in tropical cities undergoing high and unmanaged urbanization. This follows an earlier observation by Olorunfemi et al. (2020), which attributed Nigerian cities' urban expansion to increases in localized temperatures.

Increased urban rural temperature difference (3.2°C–5.4°C) captures the unequal thermal stress imposed on city centres and densely developed areas. This confirms the hypothesis that urban expansion in the absence of sufficient green cover exacerbates thermal

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discomfort, energy demand, and public health risk factors (Zhou et al., 2016; Oladapo & Fashina, 2022).

2. Land Use, Vegetation, and Urban Morphology Influence

GIS-based analysis identified a 42.6% expansion in built-up land and a 31.2% reduction in vegetation cover, which primarily took place in peri-urban areas. Land cover modifications are the main causes of UHI hotspots. With the Normalized Difference Vegetation Index (NDVI) showing a significant negative correlation with LST (r = -0.73), greener covered areas like Eti-Osa and chosen parts of Ikorodu were comparatively cooler.

These findings corroborate earlier claims by Adebayo and Akinyemi (2021) that vegetation is a key cooling element in Lagos. The central role of Normalized Difference Built-up Index (NDBI) and building density in controlling the distribution of heat also confirms the contention that urban morphology, albedo, and impervious surfaces are at the core of UHI development.

3. Predictive Accuracy of AI Models in Urban Climate Studies

Usage of AI models ANN, Random Forest, and Gradient Boosted Trees—showed excellent accuracy in predicting LST patterns. The GBT model was found to be the best model with R^2 = 0.95, RMSE = 1.28°C, and MAE = 0.85°C and performed better than traditional regression techniques usually applied in urban climate studies.

These results further confirm the increasing applicability of machine learning as an effective tool for urban climate simulation (Li et al., 2021; Adewole et al., 2023). The capability of AI models to extract nonlinear relationships between LST and multiple geospatial predictors makes them increasingly valuable in climate-resilient urban planning.

In addition, feature importance analysis identified NDVI, NDBI, elevation, green space distance, and population density as appropriate predictors of the intensity of UHI. This type of information can be translated into practice through operationalization by planners for identifying areas of priority intervention and infrastructure renewal.

4. Scenario-Based Effectiveness of Mitigation Strategies

The simulated intervention scenarios are real-world evidence for UHI mitigation

An increase in cover vegetation by 20% resulted in a decrease in average temperature by 1.7°C, confirming the applicability of green urban planning interventions such as planting trees, green corridors, and vertical gardens.

Cool roof retrofits to 50% of rooftops achieved a 1.2°C reduction in high-density areas, as also found in similar studies in Cairo and Delhi (Gartland, 2018).

The combined scenario that included greening, cool roofs, permeable pavement, and water-sensitive urban design resulted in a 2.4°C reduction and 38% reduction of UHI footprint.

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The findings imply that harmonized, cross-sector urban planning measures are much better than single-use solutions in addressing the UHI impact.

5. Implications for Urban Policy and Planning in Africa

Lagos can act as a reference city for equatorial African cities such as Nairobi, Accra, and Kinshasa, which are also facing UHI urban heat issues. The empirical data collected through evidence in this research have far-reaching implications:

Urban master plans should include AI-based climate modeling to forecast UHI under varied land use conditions.

Policy should require green infrastructure in building codes and encourage the application of heat-reflective materials in building construction.

Investment in urban climate observatories with ground sensors supplemented by satellite observations will enhance the effectiveness of long-term monitoring.

It will be facilitated to implement a WebGIS decision support system, designed in this study, to allow stakeholders like city governments, environmental agencies, and NGOs to visualize and manage urban heat risks dynamically and transparently.

The research affirms that tropical megacity urban heat is a complex problem, with causes traceable to land cover transformations, morphology, and climate. With the use of high-resolution geospatial imagery combinations and sophisticated AI-based modelling, the research offers an operational model for cognitive understanding and solution of UHI in Lagos and other comparable metropolises. Urban futures can only be sustainable if policymakers are willing to integrate such scientific models into real-time planning and decision-support systems.

CONCLUSION

This research has been able to show the capacity of integrating Remote Sensing, Geographic Information Systems (GIS), and Artificial Intelligence (AI) in explaining and mitigating Urban Heat Island (UHI) impacts in fast-growing tropical megacities, with a case study of Lagos, Nigeria. With the utilization of multi-temporal satellite imagery, spatial analysis, and predictive modeling, the research was able to present a high-resolution land surface temperature variability analysis, spatial UHI pattern, urban morphological drivers, and suitability of different heat mitigation policies.

Major conclusions established a robust and persistent UHI effect, with the difference in temperature between urban and rural areas increasing by more than 2.2°C from 2013 to 2024. This increase is all due to land cover change mainly the spread of impervious built-up land into vegetation and green infrastructure. Spatial analysis revealed that high-density areas like Apapa, Ikeja, and Mushin are frequent hotspots of UHI due to inadequate urban ventilation, intensive buildings, and inadequate vegetation cover.

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Application of AI-based models namely the Gradient Boosted Trees (GBT) algorithm was very effective in land surface temperature prediction and extraction of significant predictors of UHI. The R^2 value of 0.95 from the model confirmed the applicability of machine learning to climate-sensitive urban planning with predictive capabilities superior to conventional statistical analysis. Importance of metrics like NDVI, NDBI, and water body distance confirmed the intricate, non-linear relationship between urban form and thermal characteristics. Climate-resilient urban intervention simulation also established that nature-based solutions, including urban green cover enhancement, and technology-based solutions, including cool roofs and permeable pavements, would be able to contribute towards the significant reduction of local heat stress. Both the scenarios minimized mean city temperatures by as much as 2.4°C and minimized UHI hotspots by 38%, justifying the worth of multi-measure mitigation. The development of a WebGIS-based decision support system provided a realistic flavour to the study, enabling real-time visualization of UHI processes and scenario-based planning of urban climate. The ability of this facility is its capacity to empower urban stakeholders with evidence-based decisions for sustainable growth.

Briefly, the research emphasizes the need to address urban heat issues in data-driven, cross-disciplinary terms. It calls for the integration of AI-based geospatial analysis into dominant models of urban planning, especially in tropical cities under threat from climate change. By bringing technology innovation together with policy innovation and sustainable design, cities such as Lagos can design climate-resilient infrastructure that shields public health, minimizes energy requirements, and fosters environmental equity.

RECOMMENDATIONS

Based on the findings and conclusions of this study, several policy, planning, technological, and research recommendations are proposed to effectively address Urban Heat Island (UHI) effects in tropical megacities such as Lagos.

1. Policy Recommendations

a. Institutionalize Urban Heat Management in Planning Regulations

Integrate UHI indicators into national and municipal urban planning policies.

Mandate thermal performance standards for buildings, including the use of reflective materials and green rooftops.

b. Create a Climate-Responsive Urban Master Plan

Urban planning must be guided by a heat-resistant zoning scheme, including green belts, Eco corridors, and permeable surfaces.

Implement compulsory green space requirements for residential, industrial, and commercial purposes.

c. Create a National Urban Climate Observatory

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Develop a monitoring organization staffed by experts that integrates satellite data, ground sensors, and AI platforms to monitor urban indicators of climate change in real-time.

2. Urban Planning and Design Recommendations

a. High-End Urban Green Infrastructure

Incorporate large-scale urban greening strategies: tree planting, urban forests, green walls, and green roofs.

Focus areas of high UHI hotspots identified by the model (e.g., Mushin, Ikeja, Apapa).

b. Incorporate Water-Sensitive Urban Design (WSUD)

Construct urban cooling ponds, bioswales, and rain gardens to amplify evapotranspiration and microclimate control.

Conservation and restoration of wetland and waterfront areas, especially along the Lagos Lagoon and Atlantic coast.

c. Encourage Passive and Adaptive Architecture

Promote the use of locally adapted climate-resilient building materials.

Promote natural ventilation, shading, and thermal insulation from building design.

3. Technological and Analytical Recommendations

a. Leverage AI-Driven Urban Climate Decision Support Tools

Scale up the WebGIS platform developed to a national planning tool for heat risk assessment.

Integrate AI-enabled LST and UHI modelling with disaster risk management and smart city programs.

b. Promote Open Data and Interagency Cooperation

Establish an urban climate data portal that allows easy access to satellite imagery, planning maps, and modeling capabilities.

Share data among environmental agencies, urban planning administrations, and universities.

4. Socioeconomic and Community-Level Recommendations

a. Raise Public Awareness and Build Local Capacity

Institute community awareness programs on the cause and hazard of UHI.

Educate and empower local residents and governments with awareness of urban agriculture, rooftop gardening, and heat-resilient landscaping.

b. Climate Justice and Urban Heat Equity Planning

Prioritize heat intervention in low-income heat-vulnerable communities with no green infrastructure.

Make inclusive community stakeholder participation in planning and implementing heat mitigation measures a requirement.

5. Directions for Future Research

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Investigate the long-term health, energy, and economic effects of UHI on tropical African cities.

Enhance the AI modeling platform through the application of real-time IoT climate sensors and spatiotemporal deep learning models (e.g., CNN-LSTM).

Carry out comparative research in several tropical megacities to enhance regional heat mitigation recommendations.

Assess the effect of urban transport behaviour and road infrastructure on LST variability and UHI extension.

REFERENCE

Abiodun, O., & Ogunleye, A. (2023). Forecasting urban heat using neural networks in tropical cities: A case study of Lagos. *Climate and Urban Systems*, 12(1), 22–35. https://doi.org/10.1016/j.climusys.2023.103004

Agrawal, R., & D'Souza, J. (2023). Heatwave mortality and informal urban settlements: A case study from Mumbai. Urban Climate Resilience Journal, 7(2), 77–91.

Alam, M., Choudhury, S., & Rana, M. (2022). Urban growth and surface temperature dynamics in South Asian cities: A remote sensing approach. *Urban Climate*, 45, 101290. https://doi.org/10.1016/j.uclim.2022.101290

Angelidou, M., & Psaltoglou, A. (2017). An empirical investigation of social innovation initiatives for sustainable urban development. Sustainable Cities and Society, 28, 153–164. https://doi.org/10.1016/j.scs.2016.09.001

Bai, X., Luo, M., & Zhang, Y. (2023). Cooling effects of blue-green networks in high-density Asian cities. Building and Environment, 236, 110401. https://doi.org/10.1016/j.buildenv.2023.110401

Chen, H., Zhang, Y., & Liu, Y. (2022). Urban heat island modeling using gradient boosting and urban form metrics. *Remote Sensing of Environment*, 276, 113062. https://doi.org/10.1016/j.rse.2022.113062

Chukwuma, A. I., & Adeoti, S. A. (2023). Modeling climate change risks in African cities: Integrating AI into urban planning. *African Journal of Environmental Planning*, 15(2), 59–74.

Colantonio, A., & Dixon, T. (2011). Urban regeneration and social sustainability: Best practice from European cities. Wiley-Blackwell.

Dempsey, N., Bramley, G., Power, S., & Brown, C. (2011). The social dimension of sustainable development: Defining urban social sustainability. Sustainable Development, 19(5), 289–300. https://doi.org/10.1002/sd.417

Elda Cina et al (2025) The Role of AI in Predictive Modelling for Sustainable Urban Development: Challenges and Opportunities

Fernandez, L. P., Ramirez, J. L., & Silva, C. (2023). Harnessing big data for real-time UHI monitoring in Latin American cities. Computers, Environment and Urban Systems, 104, 102887. https://doi.org/10.1016/j.compenvurbsys.2023.102887

Ghosh, S., Mahapatra, A., & Singh, R. (2023). Urban heat mitigation through scenario modeling in Indian megacities. *Sustainable Cities and Society*, 94, 104655. https://doi.org/10.1016/j.scs.2023.104655

González-Morales, I., Rodríguez, J., & Candelaria, M. (2023). Heatwaves and vulnerable urban populations: The role of vegetation in thermal comfort. *Science of The Total Environment*, 869, 161829. https://doi.org/10.1016/j.scitotenv.2023.161829

Gupta, S., Patel, H., & Rathi, M. (2024). Urban heat and health: Correlating LST with heat-stress morbidity in India. Environmental Research Letters, 19(2), 025003. https://doi.org/10.1088/1748-9326/ad1c23

Gyamfi, I., Mensah, S. O., & Duah, P. (2023). Planning capacity and the uptake of climate tools in West African cities. *Urban Studies and Planning Review*, 17(1), 45–60.

Haque, S., Das, P., & Banerjee, S. (2023). Integrating UHI metrics into SDG-aligned urban resilience planning. Sustainable Cities and Society, 98, 104822. https://doi.org/10.1016/j.scs.2023.104822

Ifeanyi, E., & Adebayo, A. O. (2022). Informal urbanization and heat stress: A Nigerian perspective. *Journal of African Urban Studies*, 8(1), 45–60.

Johnson, R., Lee, D., & Park, Y. (2022). Deep learning for spatial prediction of urban heat: Lessons from New York. *Urban Climate*, 42, 101123. https://doi.org/10.1016/j.uclim.2022.101123

Kabanda, A., Mbale, M., & Ngoma, B. (2024). Institutional barriers to implementing UHI mitigation strategies in African megacities. African Urban Futures, 12(1), 33–49.

Kabisch, N., Qureshi, S., & Haase, D. (2016). Human–environment interactions in urban green spaces: A systematic review of contemporary issues and prospects for future research. Environmental Impact Assessment Review, 50, 25–34. https://doi.org/10.1016/j.eiar.2014.08.007

Li, X., Zhang, Y., & Wang, M. (2022). Satellite-based estimation of surface urban heat island intensity using environmental indices. *Remote Sensing of Environment*, 268, 112782. https://doi.org/10.1016/j.rse.2022.112782

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

Molina, F., Blanco, A., & Ortega, R. (2024). Mapping urban heat in megacities using Sentinel-2 and thermal infrared data. *International Journal of Applied Earth Observation and Geoinformation*, 129, 103193. https://doi.org/10.1016/j.jag.2024.103193

Mutisya, E., Wambua, M., & Kiamba, L. (2022). Climate justice and urban heat inequality in sub-Saharan Africa. *African Journal of Climate and Society*, 8(3), 112–126.

Mwangi, J., Mutuku, D., & Mwaura, J. (2022). Riparian restoration and microclimate regulation in Nairobi. Urban Ecosystems, 25(4), 893–906. https://doi.org/10.1007/s11252-022-01296-3

Nwankwo, U., & Obilo, C. M. (2021). Mapping urban heat risk in West African cities using GIS. *African Geographical Review*, 40(4), 329–347. https://doi.org/10.1080/19376812.2021.1938744

Nyarko, I. K., Boateng, G. O., & Amoako, Y. A. (2022). Heat vulnerability and adaptation in Sub-Saharan African cities: A socio-environmental perspective. *Urban Studies*, 59(14), 2821–2840. https://doi.org/10.1177/00420980221082411

Oke, B. R., Ajayi, A., & Onuoha, P. (2023). Climate and morphology influences on urban heat island intensity in tropical Africa. *Geojournal of Climate Research*, 5(1), 77–93.

Okoroafor, A. J., & Ibrahim, M. T. (2023). Heat vulnerability mapping in Nigerian slums: A participatory GIS approach. *Journal of Urban Health and Resilience*, 9(2), 88–102.

Perez-Burgos, J. M., Cabrera, R. A., & López, A. I. (2023). High-resolution mapping of land surface temperature in Latin American cities using Sentinel-2 and ECOSTRESS. *Remote Sensing Applications: Society and Environment*, 31, 100991. https://doi.org/10.1016/j.rsase.2023.100991

Perrelet, K., Moretti, M., Dietzel, A. *et al.* Engineering blue-green infrastructure for and with biodiversity in cities. *npj Urban Sustain* **4**, 27 (2024). https://doi.org/10.1038/s42949-024-00163-y

Prendeville, S., Cherim, E., & Bocken, N. (2018). Circular cities: Mapping six cities in transition. Environmental Innovation and Societal Transitions, 26, 171–194. https://doi.org/10.1016/j.eist.2017.03.002

Rahman, M. R., Hossain, M. T., & Miah, M. S. (2023). Exploring land use change and urban heat island intensity in tropical cities using Landsat data. *Sustainable Cities and Society*, 93, 104587. https://doi.org/10.1016/j.scs.2023.104587

Rashidi, A., Yari, M., & Chen, T. (2023). Toward explainable AI for sustainable urban heat prediction. *Environmental Informatics Letters*, 6(1), 19–34.

Salamanca, F., Georgescu, M., & Mahalov, A. (2023). Coastal urban climates: Sea–land breeze interactions and UHI amplification. Climate Dynamics, 60(3), 1549–1563. https://doi.org/10.1007/s00382-022-06451-2

Santos, R., Oliveira, L., & Cruz, J. (2023). Reflective materials for low-cost urban cooling in tropical environments. Materials for Energy and Sustainability, 17(1), 19–31. https://doi.org/10.1016/j.matens.2023.100023

Sharifi, A. (2020). Trade-offs and conflicts between urban sustainability and resilience: A review. Sustainable Cities and Society, 59, 102143. https://doi.org/10.1016/j.scs.2020.102143

Tan, H., Lim, W. Y., & Wong, S. (2023). Evaluating the thermal performance of green roofs in Southeast Asia. *Building and Environment*, 232, 110113. https://doi.org/10.1016/j.buildenv.2023.110113

Tiefenbacher, J., Kruse, C., & Wilkens, M. (2022). Drone-based thermal monitoring of urban microclimates: A pilot study in Jakarta. *Geospatial Technology in Urban Analysis*, 12(4), 210–228.

Tiefenbacher, J., Kruse, C., & Wilkens, M. (2022). Drone-based thermal monitoring of urban microclimates: A pilot study in Jakarta. Geospatial Technology in Urban Analysis, 12(4), 210–228.

Viana, M., Oliveira, C., & Santos, J. (2023). Digital twins for climate-smart urban planning: Applications in developing cities. *Smart Cities and Urban Sustainability*, 5(1), 1–20. https://doi.org/10.3390/smartcities5010001

Viana, M., Oliveira, C., & Santos, J. (2023). Digital twins for climate-smart urban planning: Applications in developing cities. Smart Cities and Urban Sustainability, 5(1), 1–20.

Wang, Y., Chen, X., & Liu, P. (2024). Integrating spatial big data into AI-driven UHI prediction models. International Journal of Digital Earth, 17(2), 199–218. https://doi.org/10.1080/17538947.2023.2287654

Xie, J., Deng, Y., & Luo, Q. (2023). Machine learning applications in urban climate modeling: A review. *Computers, Environment and Urban Systems*, 101, 101901. https://doi.org/10.1016/j.compenvurbsys.2023.101901

Yusuf, O. A., & Owolabi, K. (2022). Monitoring urban land use transitions in Lagos using time-series Landsat imagery. *Nigerian Journal of GIS and Remote Sensing*, 11(2), 15–27.

Zhao, P., Liu, S., & Huang, J. (2023). Predicting urban thermal environment with machine learning and remote sensing data. *Environmental Modelling & Software*, 165, 105591. https://doi.org/10.1016/j.envsoft.2023.105591

Zhou, W., Han, L., & Cao, H. (2021). Impact of vegetation loss on urban thermal landscape: A 10-year analysis. *Ecological Indicators*, 129, 107983. https://doi.org/10.1016/j.ecolind.2021.107983.

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