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Contributors of Urban Heat Island and their Impact on Liveability in Selected Residential Neighbourhoods in Port Harcourt Metropolis

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Abstract
Urban Heat Island has become a prominent urban phenomenon and environmental crisis affecting urban dwellers' living conditions. The study assessed the impact of the urban heat island effect on liveability in Port Harcourt metropolis, Nigeria. The study adopted a quantitative approach and descriptive design. The study utilised cluster and simple random sampling techniques to select two neighbourhoods, namely Nkpolu-Oroworukwo and Rumuagholu, to represent each LGA in the metropolis. A total sample size of 398 was determined employing Taro Yamane's formula at 5% precision level. Thus, a total of 382 questionnaires were returned and valid for analysis. Geospatial analytical techniques using satellite imagery were used to map and quantify UHI variations across neighbourhoods, and descriptive statistics were used to analyse the collected data. The findings revealed that Nkpolu-Oroworukwo experienced higher UHI intensities than Rumuagholu in 2015, 2020, and 2025, with average UHI intensities of 27.7°-35.2°C, 27.7°-34.2°C, and 31.9°C-32.1°C, respectively. The differential records showed a decline in UHI from +7.5°C to +6.5 °C and to +0.5°C in 2015, 2020, and 2025, respectively, in the neighbourhoods. The UHI effect had a notable impact on residents' liveability, contributing to health and well-being challenges such as skin rashes and heat burn, headache and dizziness, and dehydration and fatigue, reduced comfort from hot indoor spaces and sleep disruption, increased electricity consumption, safety risks such as overheating of electrical equipment, and emotional stress, including irritation and reduced motivation. Residents also reported dissatisfaction with their neighbourhood's liveability, particularly in Nkpolu-Oroworukwo. Thus, from the findings, the study has suggested the following recommendations including government should carry out regular urban heat assessment in neighbourhoods; regulate physical development and other activities that generate heat in the neighbourhoods; preserve green and blue infrastructure within the neighbourhoods; use of environmentally friendly materials in landscaping; form environmental awareness organisations to campaign and sensitise in use of environmentally friendly cooling materials in construction; and introduce green infrastructure in the neighbourhoods.

Key words: Contributors, Urban Heat Island, Liveability, Port Harcourt Metropolis

Introduction
Urbanisation has led to significant changes in land surface characteristics, resulting in the urban heat island (UHI) effect, in which urban areas experience higher temperatures than surrounding rural areas due to human activities. Replacing natural landscapes with impervious surfaces such as asphalt, concrete, and rooftops reduces evapotranspiration, increases heat retention, and alters local climatic conditions. Anthropogenic heat emissions from transportation, industrial activities, and household energy consumption have further contributed to increased temperatures in urban environments. Globally, the temperatures of many large cities are rising faster than those of their surrounding peripheral or rural regions, a phenomenon known as the Urban Heat Island (UHI) effect [1-5].

The UHI effect has been observed since the early stages of industrialisation, but its intensity has increased with rapid urbanisation. Over time, the concern has expanded globally due to its link with climate change, air pollution, and increased energy consumption. Heat waves in major cities have been widely studied and are proven to be a direct consequence of increased artificial surfaces. In Nigeria, cities such as Lagos, Abuja, Port Harcourt, Kano, and Ibadan are experiencing rising urban temperatures, linked to rapid urban expansion and poor urban planning [6].

Port Harcourt metropolis, the capital of Rivers State, Nigeria, has undergone rapid urban expansion driven by population growth, industrialisation, and infrastructure development. Between 2000 and 2020, urbanised areas in Port Harcourt increased significantly, leading to a marked rise in land surface temperatures (LSTs) and thermal discomfort. Satellite-based studies indicate that the average LST in densely built-up areas has increased from 28°C in 2000 to over 35°C in recent years, with urban core regions experiencing the highest temperatures. The UHI effect has direct implications for liveability, affecting thermal comfort, public health, environmental quality, and urban sustainability [7,8].

However, current urban development policies in Port Harcourt have not adequately incorporated climate adaptation measures, leaving many areas highly susceptible to increasing urban temperatures. The urban geometry and general structure, such as the height and pattern of these buildings, affect the rate at which solar energy absorbed during the day is often emitted from impervious urban paved surfaces. Therefore, understanding the population dynamics, anthropogenic activities, and urban pavement materials in the Port Harcourt metropolis and environs will provide better insight into managing the UHI effect across different land-use types in the city. The UHI effect also contributes to urban flooding, as high temperatures alter rainfall patterns and stormwater drainage systems. Climate change further intensifies the UHI effect, making cities more vulnerable to extreme heat events and erratic weather conditions. Sustainable urban planning and mitigation strategies are crucial for reducing the negative impacts of UHI on residents. Potential solutions include incorporating green spaces, improving urban forestry, using reflective roofing materials, ensuring proper waste disposal, and implementing policies that promote energy-efficient buildings. Addressing the UHI impacts on residents' liveability in the Port Harcourt metropolis is crucial to improving the city's overall quality of life, reducing environmental risks, and ensuring sustainable urban development [9-11].

Statement of the Problem

The UHI effect has become a significant environmental challenge in the Port Harcourt metropolis due to rapid urbanisation, uncontrolled or unregulated land use changes, and increasing anthropogenic heat emissions. Despite these alarming trends, there is a lack of comprehensive research on the direct impact of the UHI on liveability in the Port Harcourt metropolis, particularly on thermal comfort, public health, energy demand, and environmental quality. Without a clear understanding of this phenomenon, urban planning efforts may fail to address critical issues related to climate adaptation, public health, and sustainable city growth. There is an increase in ambient temperatures that makes urban spaces uncomfortable and contributes to excessive heat buildup. The lack of green spaces and reflective surfaces further amplifies the heat retention of buildings and roads. Poor air quality results from the interaction between high temperatures and pollutants, leading to smog formation and respiratory hazards. Local weather patterns may also be disrupted, affecting rainfall distribution and water resources. Extreme heat can pose significant health risks, and vulnerable populations, such as children, the elderly, and individuals with pre-existing health conditions, face higher risks of heat-related illnesses, including heat exhaustion, dehydration, and respiratory complications. Similarly, productivity declines as workers struggle to perform efficiently under extreme heat, especially those engaged in outdoor labour. Poorly ventilated and densely populated urban areas become unbearable, particularly for low-income residents who may lack access to cooling systems. Public spaces and recreational areas lose their appeal as excessive heat discourages outdoor activities and social interactions, reducing overall community well-being. By addressing these issues, Port Harcourt metropolis can move towards a more sustainable and liveable urban environment, reducing the negative impacts of UHI on its residents.

Aim and Objectives of the Study

The study aims to assess the impacts of urban heat islands on residents' liveability in the Port Harcourt metropolis, Rivers State, Nigeria.

The specific objectives of the study are to:

- Map and analyse the differential variations of UHI across neighbourhoods of the study area in 2015, 2020 and 2025;
- Contributors to UHI in the neighbourhoods; and
- Assess the impact of the differential variations of UHI on the liveability of residents in the neighbourhoods of the study area.

The Study Area

Port Harcourt, the metropolis, is located in the southern part of Nigeria and serves as the capital of Rivers State. It lies approximately between latitude 4°45'N and longitude 7°00'E, situated within the Niger Delta region, a low-lying coastal area characterised by rivers, creeks, and wetlands (see Figure 1). The city is strategically positioned along the Bonny River, which flows into the Atlantic Ocean, making it a significant hub for trade, commerce, and the oil and gas industry. The metropolis encompasses two Local Government Areas (LGAs): Port Harcourt City LGA and Obio/Akpor LGA, which together make up the metropolitan area. Emohua LGA borders it to the north, Ikwerre LGA to the west, Oyigbo LGA to the east, and the Atlantic coastline to the south, making it a key transportation and industrial centre in the South-South geopolitical zone of Nigeria.

Port Harcourt metropolis experiences a tropical monsoon climate (Am) under the Köppen climate classification, characterised by high temperatures, high humidity, and significant rainfall throughout the year. Average temperatures typically range from 25 °C to 28 °C (77.0 to 82.4 °F), influenced by the Atlantic Ocean and the city's low-lying coastal location in the Niger Delta. Flat plains characterise the topography and vegetation of Port Harcourt Metropolis, with a network of rivers and tributaries, and vegetation dominated by mangrove swamps near the coast and lowland rainforest inland, which are typical features of the Niger Delta environment.

Port Harcourt metropolis has experienced rapid population growth and urban densification over the past few decades, driven by industrialisation, economic opportunities, and rural-urban migration. According to census records and projections, Port Harcourt had an estimated population of 703,416 in 1991. By 2006, the population had grown to 1,382,592. Recent estimates suggest that the population has now surpassed 2 million dues to ongoing urban expansion and migration trends. The city is known for hosting many petroleum industries, including two oil refineries, as well as other trading and transportation industries for import and export. The city has undergone significant infrastructural development with several transportation systems and networks, educational and healthcare facilities built across the cityscape to meet the growing population and spatial expansion [12-25].

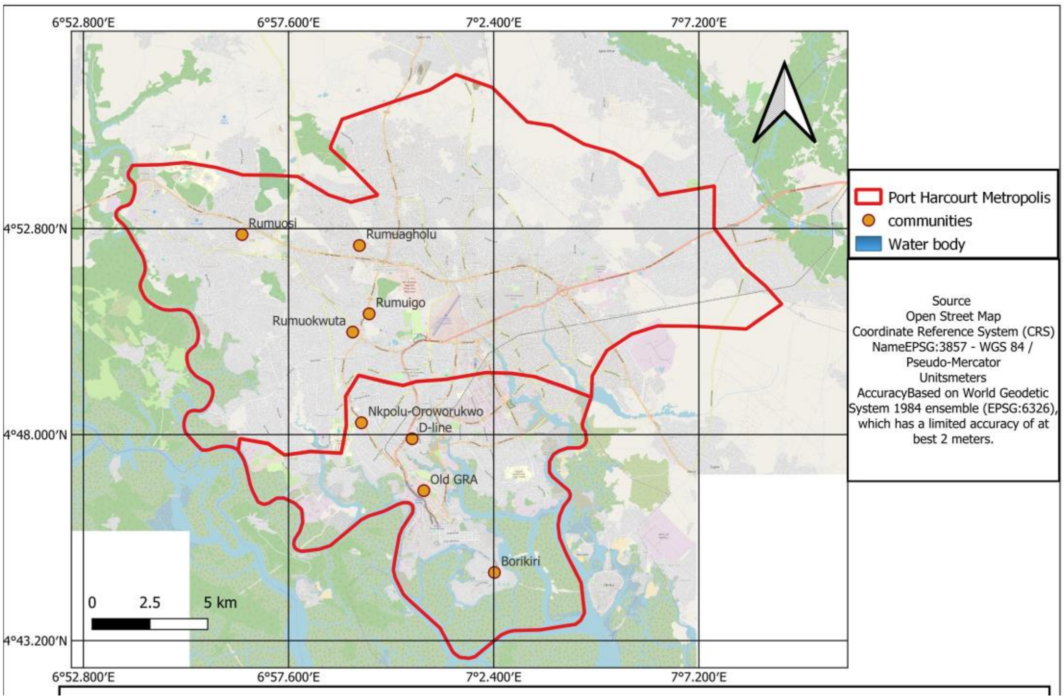

Figure 1: Map of Port Harcourt Metropolis

Source: GIS Lab, Department of Urban and Regional Planning, Rivers State University, 2025

Literature Review

Concept of Urban Heat Island

The concept of UHI refers to the phenomenon in which urban areas experience significantly higher temperatures than their surrounding rural areas due to human activities and land-use changes. This temperature difference is primarily caused by replacing natural vegetation with heat-absorbing materials such as asphalt, concrete, and rooftops, which store solar energy during the day and release it slowly at night. Additionally, the dense concentration of buildings and reduced airflow in cities traps heat, while limited vegetation decreases cooling through evapotranspiration, further intensifying the UHI effect. Factors such as building geometry, surface albedo, anthropogenic heat release from vehicles and industries, and the lack of green infrastructure contribute to the spatial and temporal variability of UHI within a city. The intensity of UHI can vary depending on urban form, population density, and climate conditions.

Studies emphasise the role of climate change in exacerbating UHI effects, as rising global temperatures compound local heat stresses in cities. Strategies to mitigate UHI include implementing green roofs, planting urban trees, using reflective or cool roofing materials, and promoting sustainable urban planning that prioritises green and blue infrastructure. These measures help to increase surface reflectivity, enhance shade, and improve air circulation, all of which contribute to lowering urban temperatures [26,27].

Concept of Liveability

The concept of liveability refers to the extent to which an environment supports the health, comfort, safety, and overall well-being of its inhabitants. In urban planning, liveability is used as a benchmark for assessing how well a city meets the needs of its residents across housing, transportation, employment, education, healthcare, and recreational opportunities. A liveable city is not just functional, but also offers a high quality of life, where residents feel secure, connected, and supported by both physical infrastructure and social systems. It reflects how conducive a place is for daily life, growth, and long-term settlement. One of the key components of liveability is access to basic urban services and infrastructure. This assumption includes reliable public transportation, clean water, affordable housing, healthcare facilities, and education systems. Efficient urban services ensure that people can carry out their daily activities without undue stress or barriers, contributing to individual and community well-being. The spatial distribution of these services also affects liveability; cities that promote equity and inclusivity by providing access to underserved populations tend to be more liveable for a broader segment of society [28,29].

Environmental quality is another vital factor influencing liveability. Clean air, green spaces, low noise pollution, and climate resilience all play crucial roles in shaping a healthy and comfortable urban experience. With increasing urbanisation and the intensifying effects of climate change, integrating environmental sustainability into urban planning has become a priority. Cities that adopt nature-based solutions such as urban parks, green roofs, and tree planting are more likely to support physical and mental health, mitigate urban heat, and reduce exposure to environmental hazards. Social and cultural dimensions significantly affect liveability. Community cohesion, cultural vibrancy, public participation, and a sense of belonging are essential to fostering liveable spaces. Urban areas that encourage civic engagement and provide spaces for social interaction enhance residents' satisfaction and attachment to their communities. Therefore, liveability is not just a technical concept but a holistic one, encompassing physical, environmental, and socio-cultural aspects that collectively determine the quality of urban life [30].

Mapping of Urban Heat Island

Mapping UHI involves using spatial data and remote sensing techniques to detect and visualise temperature variations across different parts of an urban area. This process identifies locations, commonly referred to as hotspots, that experience significantly higher temperatures than their surrounding rural areas due to human activities and land surface modifications. UHI mapping provides valuable insights into the intensity, distribution, and causes of heat accumulation in cities, which is crucial for urban planning and environmental management. A common method for mapping UHI is through satellite-based thermal remote sensing, which captures LST data. Sensors aboard satellites such as Landsat 8 or the Moderate Resolution Imaging Spectroradiometer (MODIS) detect infrared radiation emitted from the Earth's surface, which can be analysed to estimate temperature variations across an urban landscape. These thermal images are then processed using Geographic Information System (GIS) to produce detailed spatial maps that display temperature gradients, often in relation to land use, vegetation cover, or building density [31-33].

GIS tools allow overlaying LST data with other spatial datasets, such as population density, vegetation indices (e.g., Normalised Difference Vegetation Index, NDVI), and land use classifications, to examine the relationship between urban form and temperature distribution. This integrated analysis helps identify which features of the built environment contribute most to heat buildup. Additionally, temporal comparisons using multi-year satellite data enable monitoring of changes in UHI intensity, which is important for assessing the impacts of urban growth and climate change [34].

Analysis of Urban Heat Island

Analysis of UHI involves a detailed investigation of the spatial and temporal variations in urban temperatures, as well as the underlying factors that contribute to this phenomenon. The primary aim is to understand how urbanisation modifies local climates, leading to elevated surface and air temperatures. UHI analysis typically begins with the collection of temperature data using satellite remote sensing, ground-based weather stations, and mobile sensors. These datasets are analysed using GIS to generate maps that highlight hotspots, temperature gradients, and correlations with land cover characteristic.

A central component of UHI analysis is the assessment of LST, often derived from thermal infrared satellite data such as Landsat, MODIS, or Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). These measurements help in identifying how surface materials like asphalt, concrete, and rooftops absorb and retain heat differently than vegetated or water-covered areas. This data is often combined with indices such as the NDVI to evaluate the relationship between vegetation cover and urban temperatures. Areas with lower NDVI values, indicating less vegetation, often align with zones of higher temperature, confirming vegetation's role in moderating urban heat [35].

Another critical part of UHI analysis is temporal comparison, which evaluates how UHI patterns evolve in response to urban growth, land-use changes, and climate variation. By comparing temperature datasets across different seasons or years, it can be assessed whether UHI intensity is increasing and whether areas where mitigation strategies have been effective can be identified. In addition, statistical methods such as regression analysis and spatial correlation are used to quantify the relationship between temperature and various urban features, including building density, land-use types, road networks, and population distribution. These analyses provide a comprehensive understanding of how different urban elements influence heat accumulation [36].

Impact of Urban Heat Island on Liveability in Neighbourhoods

The UHI effect significantly impacts the liveability of neighbourhoods, particularly in densely populated urban areas. UHI occurs when urban surfaces such as roads, rooftops, and buildings absorb and retain heat, causing temperatures in cities to be significantly higher than in nearby rural areas. This elevated temperature can reduce thermal comfort, especially during the hot season, making day-to-day living conditions more difficult for residents. In extreme cases, it can contribute to heat stress, dehydration, and increased risk of heat-related illnesses, especially among vulnerable groups such as children, the elderly, and people with pre-existing health conditions. The absence of permeable surfaces prevents rainwater from infiltrating the ground, leading to increased surface runoff. This situation not only overwhelms drainage systems but also causes flash floods, especially in low-lying or poorly planned areas. Flooding can damage homes and infrastructure, displace residents, and contaminate water supplies, all of which severely impact the quality of life and liveability in affected neighbourhoods. When combined with UHI-induced intense heat, these events can strain community resilience and worsen environmental stress [37,38].

The compounded effects of UHI and flooding also degrade air and water quality, further reducing environmental livability. UHI intensifies the formation of ground-level ozone and smog, leading to respiratory problems, while floodwaters can carry pollutants and waste into living areas. These environmental stressors make outdoor spaces unsafe or uncomfortable, discourage active lifestyles, and limit social interaction, which are key elements of a healthy, liveable neighbourhood. UHI worsens air quality by intensifying the formation of ground-level ozone and increasing pollutant concentrations. These changes not only degrade neighbourhood environmental quality but also exacerbate respiratory conditions such as asthma and bronchitis, thereby negatively impacting public health. The combination of heat and poor air quality can make outdoor spaces less usable and discourage active lifestyles, reducing opportunities for recreation and social interaction, which are essential components of a liveable community [6,39].

Moreover, UHI contributes to higher energy consumption as residents and businesses rely more heavily on-air conditioning to maintain comfortable indoor temperatures. This increased energy demand can lead to higher utility bills and strain urban power grids, which may not be equally accessible or affordable in low-income neighbourhoods. The resulting energy burden disproportionately affects economically disadvantaged populations, exacerbating inequality and reducing their capacity to adapt to climate stressors, thus diminishing the equity and sustainability of urban liveability [6].

Empirical Reviews

A study by Oke (1982), titled "The Energetic Basis of the Urban Heat Island," is foundational in the field of urban climatology. In this research, he sought to quantify the temperature differences between urban centres and their rural surroundings across multiple cities in temperate regions. He focused on understanding the underlying causes of these thermal differences, which he collectively termed the UHI effect. His goal was to identify consistent patterns and contributing variables across diverse urban environments. This work laid the groundwork for many of the modern methods used to study urban climate dynamics. He employed a comparative analysis using long-term observational data from meteorological stations situated in both urban cores and their rural fringes. These stations provided hourly and daily temperature data, which he analysed to determine the maximum UHI intensity under different weather conditions. He also incorporated data on urban form, such as building density, street width-to-height ratios (urban canyon effect), and surface albedo, to establish correlations between urban morphology and thermal accumulation. His approach was both empirical and conceptual, as he developed theoretical models to explain observed patterns using surface energy budgets.

The study found that urban areas consistently exhibited elevated temperatures, typically 2°C to 6°C higher than those in nearby rural areas, especially at night. Oke (1982) identified key contributors to this effect: lower wind speeds due to dense building structures, greater absorption of solar radiation by impervious surfaces such as asphalt and concrete, and reduced evapotranspiration resulting from limited vegetation. He also noted the role of anthropogenic heat sources, such as vehicles and industrial activities, in amplifying UHI. His findings significantly influenced urban planning and climate adaptation strategies, highlighting the need for vegetation cover, reflective materials, and ventilation corridors in city design.

Adelekan (2010) conducted a study in Ibadan, Nigeria, to assess the human health impacts of urban warming, specifically the effects associated with the UHI phenomenon. As urban areas in tropical regions like Ibadan continue to grow rapidly, concerns about rising ambient temperatures and their effects on human well-being have become increasingly relevant. The study was motivated by the need to understand how residents in low- and middle-income urban neighbourhoods experience and respond to urban heat, particularly given limited access to cooling infrastructure such as air conditioning. The study involved a structured household survey across several neighbourhoods in Ibadan, with respondents selected based on urban density and heat exposure. The questionnaire collected data on residents' perceptions of temperature changes, frequency of heat-related symptoms (such as headaches, dehydration, fatigue, and sleep disturbances), coping strategies, and access to healthcare. The study also incorporated meteorological data to correlate reported health experiences with recorded temperature variations, allowing the researcher to link perceived heat stress to objective temperature measurements in the selected areas.

Findings from the survey indicated that residents in areas with higher urban density and less vegetation cover, typically UHI hotspots, reported a significantly higher incidence of heat-related illnesses and discomfort. Many participants reported poor sleep quality, excessive night sweating, and increased daytime fatigue, especially during the dry seasons. The study concluded that the health impacts of UHI are not merely theoretical but are already being felt by vulnerable urban populations. Adelekan emphasised the need for urban planning policies that prioritise shading, ventilation, and green infrastructure to protect public health in warming cities like Ibadan.

Owusu, Waylen, and Qiu (2017) conducted research to examine the spatial and temporal dynamics of LST in Accra, Ghana, over 25 years. The aim was to investigate how rapid urbanisation and land-use/land-cover (LULC) changes have influenced the formation and intensity of the UHI effect in the city. Accra, like many West African cities, has experienced significant population growth and urban sprawl in recent decades, leading to the conversion of natural landscapes into built-up areas. The researchers sought to determine the extent to which these changes have affected urban temperatures and contributed to heat-related stress in the region.

The study utilised Landsat satellite imagery from 1990, 2000, 2010, and 2015, analysing thermal infrared bands to derive LST values. Supervised classification was applied to identify and categorise land-use types, including built-up areas, vegetation, bare land, and water bodies. The results revealed a consistent increase in LST over time, especially in areas that transitioned from vegetated to impervious surfaces. For example, densely built-up areas recorded LST exceeding 35°C, while vegetated zones remained significantly cooler. The study concluded that vegetation loss was the most critical driver of UHI formation in Accra. It recommended urban greening and sustainable planning policies to mitigate heat exposure and improve liveability.

Nduka, Nwachukwu and Enyinna (2021) undertook a comprehensive remote sensing study to analyse the spatiotemporal dynamics of the UHI effect in Port Harcourt Metropolis over 20 years (2000–2020). Recognising the rapid urban expansion and loss of green spaces in the city, the researchers aimed to understand how these land use changes influenced LST patterns and contributed to rising urban heat levels. Port Harcourt, as one of Nigeria's fastest-growing cities, has undergone extensive transformation, with formerly vegetated areas now converted into commercial, industrial, and residential developments. The study employed satellite imagery obtained from the MODIS and Landsat missions. Using thermal bands from both datasets, the researchers calculated LST values for selected years across the two decades. They also conducted supervised land-use/land-cover classification to identify surface types, including built-up areas, vegetation, wetlands, and open land. They used GIS tools to overlay these classifications with LST data. Change detection analysis was then used to track shifts in land cover and their direct relationship with temperature variation across different neighbourhoods. Findings revealed a consistent increase in land surface temperature, particularly in areas with high urban density and significant vegetation loss. Neighbourhoods such as Diobu (Mile 3), Trans-Amadi, and Rumuola were identified as UHI hotspots, with average LST increases of over 3°C between 2000 and 2020. These areas also corresponded with zones of high population density and economic activity. The study concluded that urbanisation without adequate green infrastructure has intensified thermal discomfort and reduced residents' liveability.

Methodology

The study adopted a quantitative, descriptive research design to assess the impacts of the urban heat island on residents' livability in the Port Harcourt metropolis. The study employed cluster and simple random sampling techniques to collect data. Two clusters were identified: Port Harcourt City and Obio/Akpor LGAs, which together made up the metropolis. The neighbourhoods of Nkpolu-Oroworukwo and Rumuagholu were randomly selected to represent each cluster, respectively. The Taro Yamane formula at 5% precision level was employed to determine the sample size of 398 respondents for the study (see Table 1). However, to achieve the sample size, the population of these selected neighbourhoods was projected from the 1991 National Population Commission (NPC) Census report to 2025, using a 6.5% growth rate. Furthermore, an average of 5 persons per household was used to determine the number of households in each selected neighbourhood. Thus, the Taro Yamane (1967) formula was applied to the total number of households in the selected neighbourhoods to determine the sample size, which was then distributed proportionately across the study neighbourhoods. Consequently, a simple random technique was employed to select respondents (residents) who were interviewed. A total of 382 questionnaires were returned and considered valid for analysis. Geospatial analytical techniques were also utilised with Landsat 8 imagery, and descriptive statistics were used to analyse the data collected for the study [40-45].

S/N	Cluster (LGAs)	Studied Neighbourhoods	Population (1991)	Population (2025)	No. of Household (5 persons per Household)	No. of Households Sampled
1	Port Harcourt City	Nkpolu-Oroworukwo	52,613	447,684	89,536	375
2	Obio/Akpor	Rumuagholu	3,093	26,318	5,263	23
	Total		**55,706**	**474,002**	**94,799**	**398**
Source: NPC 1991, NPC, 2018, NBS, 2026; Researchers' Computation, 2025						

Table 1: Determination of Sample Size

Results and Findings

Mapped and Analysed the Differential Variations of UHI Across the Neighbourhoods in 2015, 2020 and 2025

The mapping of UHI patterns across Rumuagholu and Nkpolu-Oroworukwo for 2015, 2020, and 2025 provides insights into the spatial and temporal dynamics of temperature variation within the Port Harcourt metropolis. The data in Figures 2 and 3 show the 2015 UHI map highlighting the spatial distribution of surface heat across the study area. From the data analysed, Rumuagholu recorded comparatively lower UHI levels, with temperatures ranging from 15.8°C (low) to 39.5°C (high). In Nkpolu-Oroworukwo, the UHI intensity was much higher, with temperatures ranging from 25.6°C (low) to 44.7°C (high). This trend continued in the analysed data, as indicated in Figures 4 and 5, which shows in the 2020 UHI map of the study area. The data analysed in 2020 illustrate a more intensified pattern of surface heat distribution, as in Rumuagholu, which recorded a low temperature of 15.8°C and a high temperature of 39.5°C. Nkpolu-Oroworukwo recorded higher intensity values ranging from 26.1°C (low) to 42.3°C (high). However, a further analysis, as shown in Figures 6 and 7 of the 2025 UHI map of the study area, revealed that Rumuagholu recorded a low temperature of 23.7°C and a high temperature of 40.0°C, while Nkpolu-Oroworukwo recorded a low temperature of 23.4°C and a high temperature of 40.8°C.

These findings suggest that Nkpolu-Oroworukwo has been more susceptible to intense UHI effects due to its dense urban fabric, high concentration of impervious surfaces, and limited vegetation cover. At the same time, Rumuagholu initially benefited from more open spaces and vegetation that allowed nighttime cooling. However, the convergence of temperature ranges in 2025 points to increasing urbanisation and densification in Rumuagholu, which is gradually reducing its cooling advantage. This finding aligns with Oke (1982), who argued that the proportion of built-up areas and anthropogenic activities strongly influences UHI intensity. These findings are consistent with Oke (1982), who established that the urban heat island effect arises from the replacement of natural surfaces with heat-retentive materials such as asphalt and concrete, combined with dense urban morphology. Nkpolu-Oroworukwo's higher values clearly reflect this mechanism, as the dominance of concrete housing and asphalt roads amplifies heat absorption and storage.

Furthermore, the gradual increase in heat intensity between 2015 and 2025 aligns with the findings of Owusu, Waylen, and Qiu (2017), who argued that rapid urbanisation and vegetation loss across African cities intensify urban heat risks and reduce resilience. The findings also resonate with Adelekan (2010), who highlighted that African cities such as Ibadan face heightened vulnerability to climate hazards due to poor urban planning and weak infrastructure. Similar to Ibadan, Port Harcourt's neighbourhoods show little integration of green infrastructure, leaving residents exposed to extreme heat. The absence of significant vegetation and water bodies in both Nkpolu-Oroworukwo and Rumuagholu reduces natural cooling, thereby worsening the UHI effect.

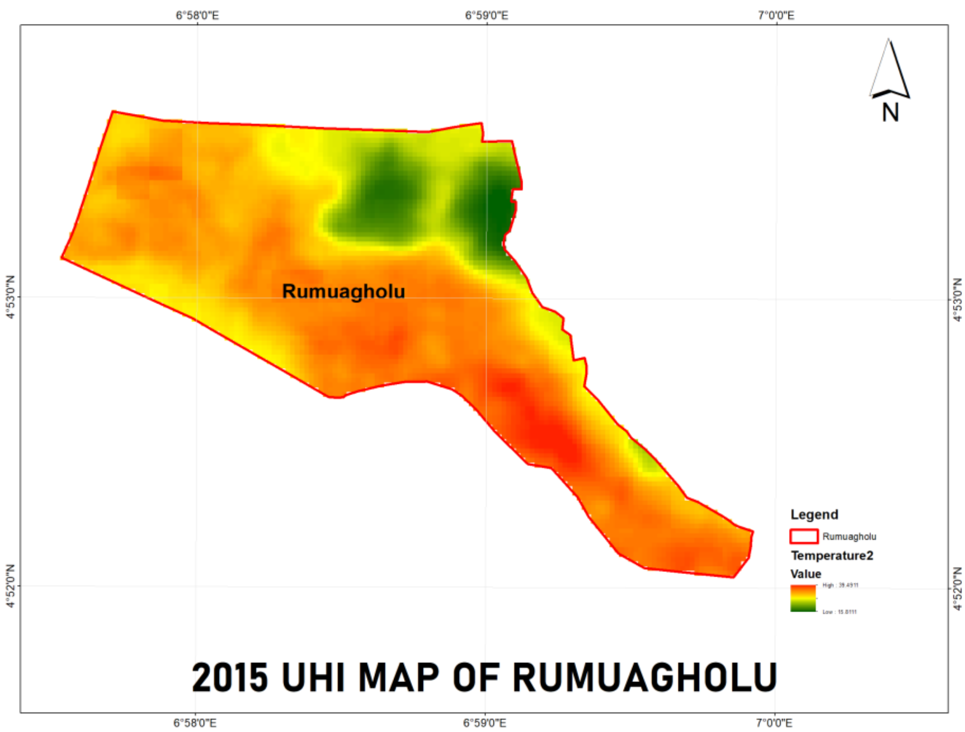

Figure 2: 2015 UHI Map of Rumuagholu

Source: GIS Lab, Department of Urban and Regional Planning, Rivers State University, 2025

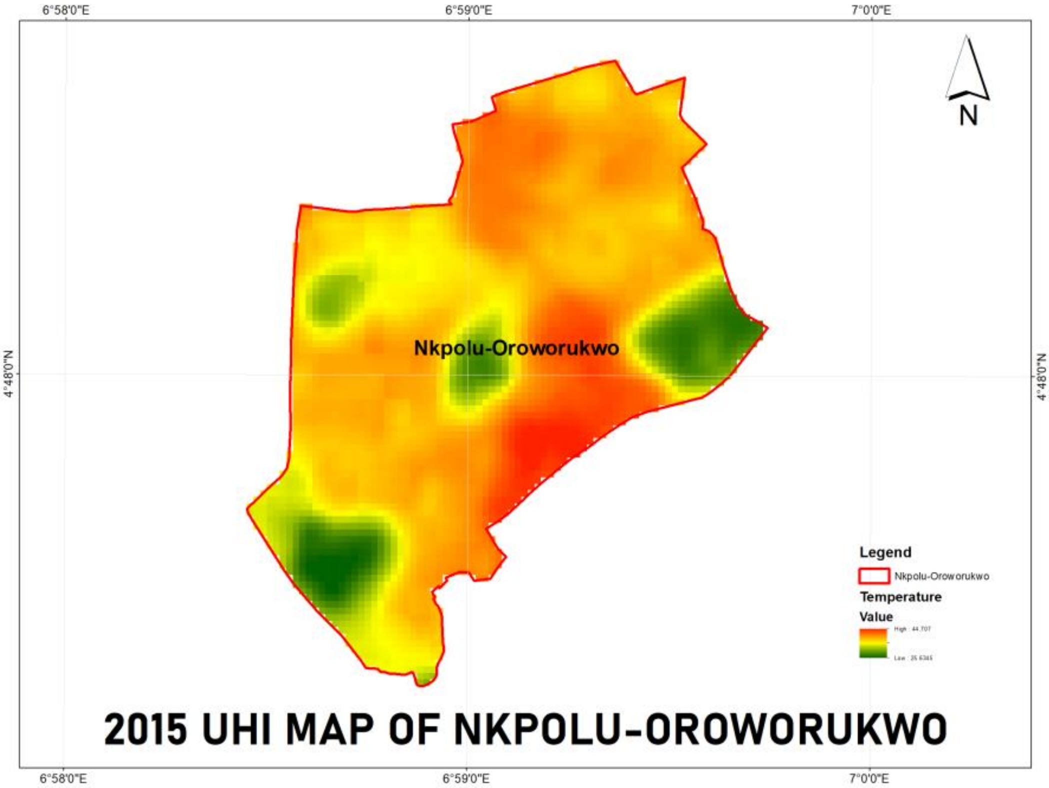

Figure 3: 2015 UHI Map of Nkpolu-Oroworukwo

Source: GIS Lab, Department of Urban and Regional Planning, Rivers State University, 2025

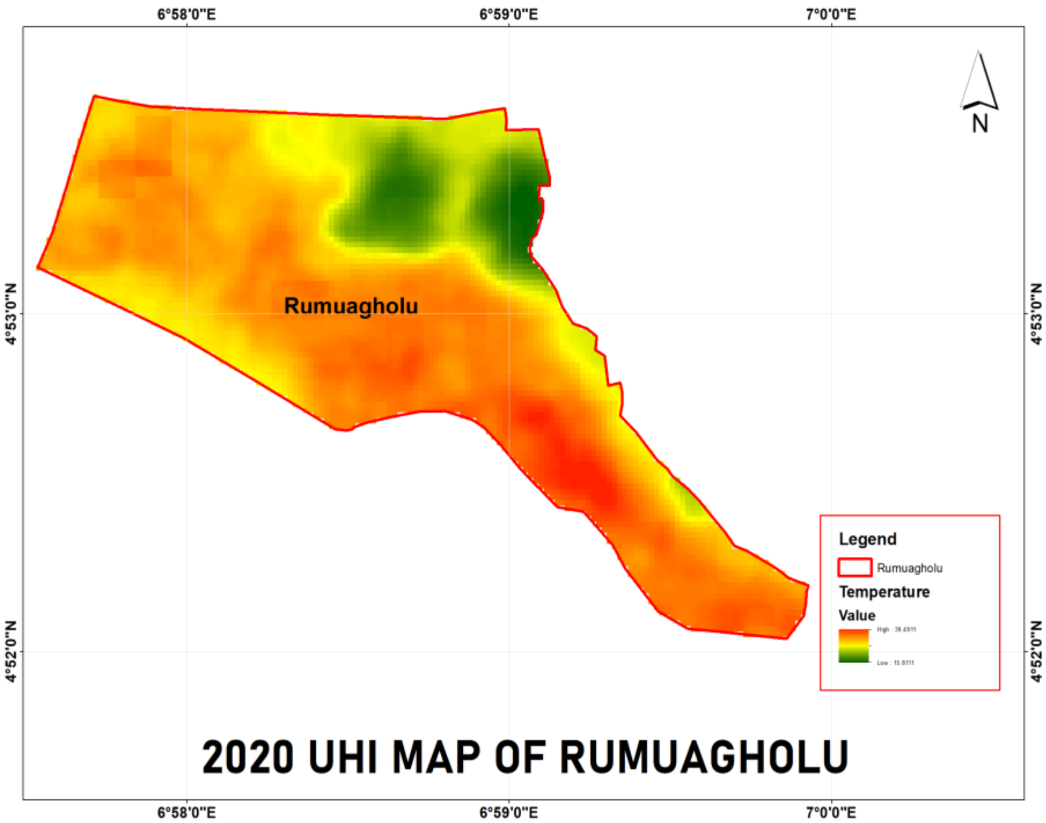

Figure 4: 2020 UHI map of Rumuagholu

Source: GIS Lab, Department of Urban and Regional Planning, Rivers State University, 2025

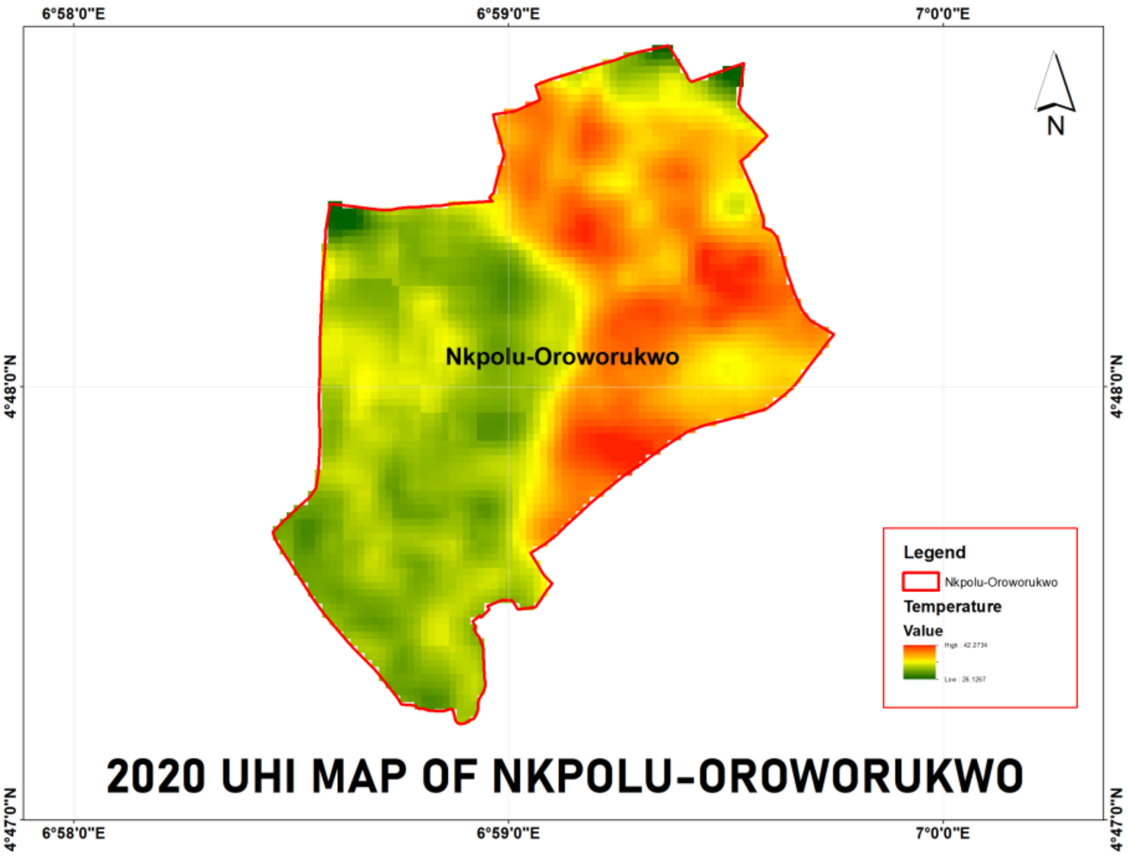

Figure 5: 2020 UHI Map of Nkpolu-Oroworukwo

Source: GIS Lab, Department of Urban and Regional Planning, Rivers State University, 2025

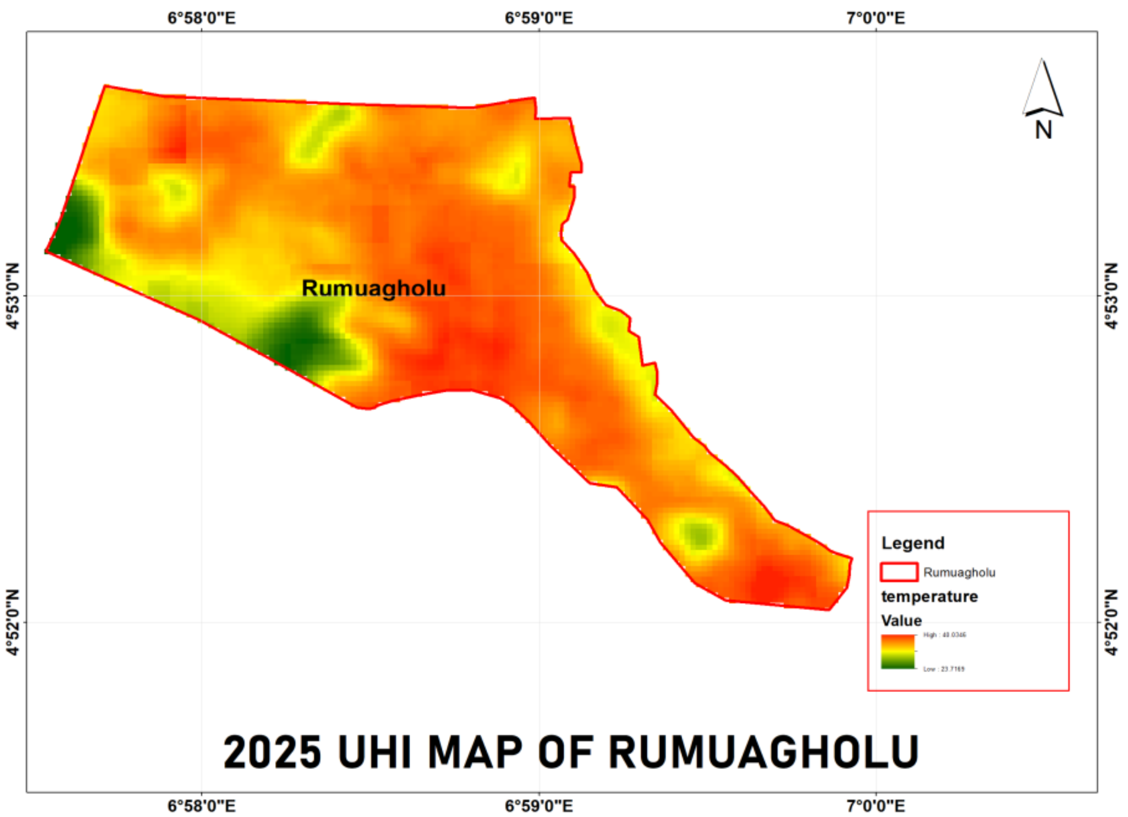

Figure 6: 2025 UHI map of Rumuagholu

Source: GIS Lab, Department of Urban and Regional Planning, Rivers State University, 2025

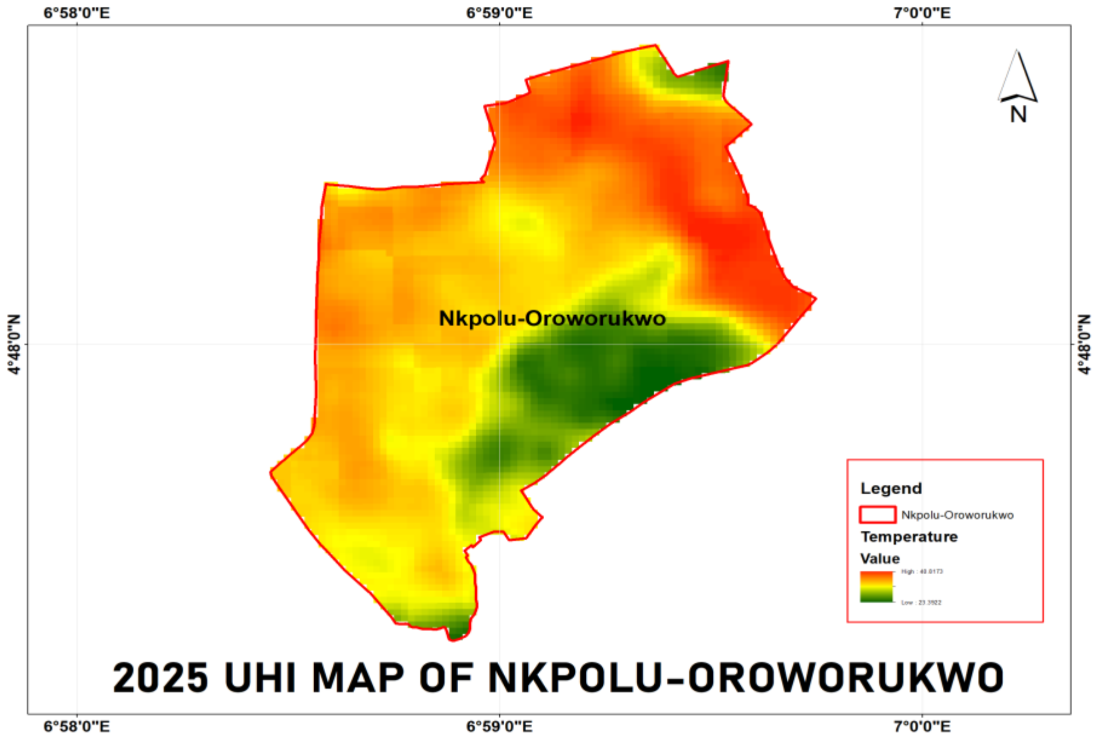

Figure 7: 2025 UHI Map of Nkpolu-Oroworukwo

Source: GIS Lab, Department of Urban and Regional Planning, Rivers State University, 2025

The analysed data in Table 2 clearly highlight differential variations of UHI intensity between Rumuagholu and Nkpolu-Oroworukwo across the three reference years. In 2015, both neighbourhoods exhibited a stronger UHI effect, with nighttime (low) temperatures 9.8 °C warmer and daytime (high) temperatures 5.2 °C warmer, resulting in an average UHI differential of 7.5 °C. However, Nkpolu-Oroworukwo experienced more intense heat than Rumuagholu. This trend continued in 2020 and 2025 as both neighbourhoods indicated differential variations of +10.3°C hotter at night (low) and 2.8°C hotter during the day (high), and -0.3°C hotter at night (low) and 0.8°C hotter during the day (high), showing an average differential UHI of +0.5. Sequentially, Nkpolu-Oroworukwo experienced more intense heat than Rumuagholu, according to the individual neighbourhood records.

This significant variation reflects the influence of land-use and land-cover patterns and changes. Nkpolu-Oroworukwo is a densely built-up and highly commercialised neighbourhood with minimal vegetation cover, heavy reliance on asphalt roads, and extensive use of concrete materials, all of which intensify surface heat storage and reradiation. Hence, Rumuagholu neighbourhood is transforming as it becomes urbanised, with many concrete surfaces and vegetation being cleared for this purpose. This finding is consistent with Oke's (1982) classical UHI studies, which established that compact urban cores record higher heat intensities due to impervious surfaces and reduced evapotranspiration. By 2020, the differential variation revealed an even wider gap at night (+10.3°C) but a narrower gap during the day (+2.8°C). This pattern suggests that heat retention capacity remained higher due to the thermal mass of its built environment, while daytime solar exposure affected both neighbourhoods more evenly. The dominance of anthropogenic heat sources, such as traffic congestion, commercial activity, and air-conditioning in the neighbourhoods, further reinforces this outcome.

By 2025, however, the differential variations converged significantly. Rumuagholu recorded a slightly cooler nighttime temperature (–0.3°C), but Nkpolu-Oroworukwo remained marginally hotter during the day (+0.8°C). This change indicates that Rumuagholu, which was historically less urbanised, has undergone substantial land conversion and urban growth. The reduction in vegetation cover, expansion of residential housing, and increased use of impervious surfaces have diminished its cooling advantage. This finding also aligns with the findings of Rizwan, Dennis and Liu (2008), who noted that peri-urban areas gradually develop UHI characteristics as urbanisation intensifies. The reduction of vegetation, the expansion of impervious surfaces, and increased human activity have contributed to this convergence in temperature ranges. As a result, the spatial contrasts in UHI intensity observed in earlier years are progressively flattening out, highlighting a homogenisation of thermal stress across the metropolis. These patterns align with Oke's (1987) arguments, who noted that variations in building density, land-use intensity, and surface cover largely explain differential UHI effects across urban neighbourhoods. Nkpolu-Oroworukwo's higher values can be explained by its dominance of concrete surfaces, narrow road networks, and minimal shading vegetation.

Similarly, the observed differences align with Adelekan (2010), who noted that African cities with weak planning controls are highly vulnerable to climate hazards. Nkpolu-Oroworukwo's urban form reflects this vulnerability, as it accommodates high levels of trading and human activities that generate additional heat. The contrast with Rumuagholu underscores how variations in land use, population density, and urban planning can produce differential exposure to heat stress within the same metropolis. The trend of sustained high UHI levels in both areas, despite differences, echoes the findings of Owusu, Waylen, and Qiu (2017), who argued that rapid population growth and loss of vegetation in African cities exacerbate localised warming. The gradual rise in UHI in Rumuagholu, although less severe than in Nkpolu-Oroworukwo, demonstrates that even semi-urban or less-dense neighbourhoods are not immune to the effects of urbanisation and climate change. Overall, the data show a temporal narrowing of UHI differences between the two neighbourhoods, reflecting the effects of rapid urbanisation in Rumuagholu and persistent heat-retention features in Nkpolu-Oroworukwo.

Year	Rumuagholu (°C)			Nkpolu-Orowurukwo (°C)			Low Difference (°C)	High Difference (°C)	Average Difference (°C)
	Low	High	Average	Low	High	Average			
2015	15.8	39.5	27.7	25.6	44.7	35.2	+9.8	+5.2	+7.5
2020	15.8	39.5	27.7	26.1	42.3	34.2	+10.3	+2.8	+6.5
2025	23.7	40.0	31.9	23.4	40.8	32.1	-0.3	+0.8	+0.5
Source: Researchers' Field Survey, 2025									

Table 2: Differential UHI Estimate Between Neighbourhoods Studied

Contributors to UHI in the Neighbourhoods

The findings revealed several key factors contributing to the UHI effect in the studied neighbourhoods of Nkpolu-Oroworukwo and Rumuagholu. These factors reflect the influence of land-use patterns, building and road construction materials, landscape materials, human activities, and other environmental factors on heat accumulation in the urban environment. Human activities have significantly contributed to UHI in the neighbourhoods. In Nkpolu-Oroworukwo, trading, transportation, and the widespread use of generators intensified heat emissions, while in Rumuagholu, reliance on generators and transportation activities played a similar /role as shown in Tables 2 and 3. From the data, other contributing activities included motorised devices, car exhaust, and the use of air conditioners releasing hot air into the environment, as recorded mostly in the Nkpolu-Oroworukwo neighbourhood. This finding aligns with Adelekan (2010), who highlighted that rapid urbanisation and economic activities in African cities exacerbate heat risks due to increased energy demand and emission sources.

Data in Tables 4 and 5 showed that 91.1% of buildings in both neighbourhoods were constructed primarily with concrete. At the same time, roads were almost entirely paved with asphalt in Nkpolu-Oroworukwo and partly with earth surfaces in Rumuagholu. Hence, the roads in the studied neighbourhoods are paved with asphalt, accounting for 93% of the responses. These materials trap and radiate heat, leading to elevated surface temperatures. This finding aligns with Oke (1982), who explained that the thermal properties of urban materials play a central role in amplifying UHI effects. Another contributor is the loss of vegetation and the absence of waterbodies, as shown in Table 7, where both neighbourhood respondents indicated that trees and green cover were either very sparse or absent, with Nkpolu-Oroworukwo showing slightly more vegetation than Rumuagholu, due to steady increases in physical development. The complete absence of waterbodies further deprived the neighbourhoods of natural cooling systems, as shown in Table 7. This finding supports the observations of Owusu, Waylen, and Qiu (2017), who linked vegetation loss and ecological imbalance in African cities to increased vulnerability to UHI.

Thus, one of the most significant contributors is the dominance of impervious surfaces, such as concrete and asphalt, across the studied neighbourhoods, as observed in respondents' survey responses in Table 6. Furthermore, population growth and overcrowding were identified in Table 7 as indirect but critical contributors. Nkpolu-Oroworukwo, with its higher population density and congested mixed-use development, exhibited greater heat concentration than Rumuagholu. This finding resonates with Nduka, Nwachukwu, and Eyinna (2021), who observed that population pressure and unplanned urban growth in Nigerian cities intensify UHI and reduce overall liveability.

S/N	Type of Activity	Nkpolu-Oroworukwo		Rumuagholu		Aggregate	
		N	%	N	%	N	%
1	Trading	359	100	8	33.3	367	96
2	Transportation	0	0	15	66.7	15	4
3	Industrial	0	0	0	0	0	0
4	Others (specify)	0	0	0	0	0	0
	Total	**359**	**100**	**23**	**100**	**382**	**100**
Source: Researchers' Field Survey, 2025							

Table 2: Type of Activities

S/N	Human Activities	Nkpolu- Oroworukwo		Rumuagholu		Aggregate	
		N	**%**	**N**	**%**	**N**	**%**
1	Use of generators and machinery	161	44.7	23	100	184	48
2	Overpopulation and overcrowding	180	50	0	0	180	47
3	Car exhaust	9	2.6	0	0	9	2.1
4	Use of air conditioners releasing hot air	9	2.6	0	0	9	2.1
5	Others (specify)	0	0	0	0	0	0
	Total	**359**	**100**	**23**	**100**	**382**	**100**
Source: Researchers' Field Survey, 2025							

Table 3: Human Activities that Increase Temperature in the Neighbourhoods

S/N	Building Material Type	Nkpolu- Oroworukwo		Rumuagholu		Aggregate	
		N	**%**	**N**	**%**	**N**	**%**
1	Concrete block	325	90.4	23	100	348	91.1
2	Wood	7	2.1	0	0	7	1.8
3	Glass	0	0	0	0	0	0
4	Brick	27	7.4	0	0	27	7.1
5	Metal	0	0	0	0	0	0
6	Others (specify)	0	0	0	0	0	0
	Total	**359**	**100**	**23**	**100**	**382**	**100**
Source: Researchers' Field Survey, 2025							

Table 4: Building Materials Primarily Used for Construction

S/N	Landscape Type	Nkpolu- Oroworukwo		Rumuagholu		Aggregate	
		N	**%**	**N**	**%**	**N**	**%**
1	Paved surfaces	293	81.9	16	66.7	309	81
2	Vegetation	0	0	0	0	0	0
3	Trees	0	0	0	0	0	0
4	Bare ground	47	12.8	7	31.3	54	14
5	Mixed with concrete and vegetation	19	5.3	0	0	19	5
	Total	**359**	**100**	**23**	**100**	**382**	**100**
Source: Researchers' Field Survey, 2025							

Table 5: Landscape Type that Surrounds Building

S/N	Road Construction Material	Nkpolu-Oroworukwo		Rumuagholu		Aggregate	
		N	**%**	**N**	**%**	**N**	**%**
1	Asphalt	348	96.8	23	33.3	355	93
2	Concrete	8	2.1	0	0	8	2
3	Gravel	0	0	0	0	0	0
4	Interlocking stones	4	1.1	0	0	4	1
5	Earthed road	0	0	4	66.7	15	4
	Total	**359**	**100**	**23**	**100**	**382**	**100**
Source: Researchers' Field Survey, 2025							

Table 6: Materials Used for Road Construction

S/N	Factors that Contributes to UHI	Nkpolu- Oroworukwo		Rumuagholu		Aggregate	
		N	%	N	%	N	%
1	Absence of waterbodies	34	9.6	8	33.3	42	11
2	Population growth	164	45.7	0	0	164	43
3	Loss of vegetation	100	27.7	15	66.7	115	30
4	Industrialisation	3	1.1	0	0	3	1
5	Increase in building concrete space	57	17	0	0	57	15
	Total	**359**	**100**	**23**	**100**	**382**	**100**
Source: Researchers' Field Survey, 2025							

Table 7: Factors that Contributes to UHI in the Neighbourhoods

Impact of UHI on Liveability

The differential variations in UHI observed between Nkpolu-Oroworukwo and Rumuagholu have had significant impacts on the liveability of residents in both neighbourhoods, as indicated by the survey data analysed. The data indicated that Nkpolu-Oroworukwo consistently recorded higher surface temperatures, reflecting more intense UHI effects than Rumuagholu. This scenario has manifested across multiple dimensions of urban liveability, including health, comfort, emotional and mental well-being, and the safety of residents. Consequently, the health impacts of differential UHI were evident as in Nkpolu-Oroworukwo, where the UHI was strongest, a majority of respondents reported skin rashes and heat burns, headache and dizziness, and dehydration and fatigue. At the same time, Rumuagholu recorded lower but significant health issues of skin rashes and heat burns, as revealed in Table 8. Aggregately, the skin rashes and heat burn recorded a modal response of 92% as the most prevalent health concern, though headache and dizziness, as well as dehydration and fatigue, are also suffered by residents in the neighbourhoods. The higher concentration of concrete structures and limited vegetation in Nkpolu-Oroworukwo created heat-trapping conditions that intensified physical stress, in line with Nduka, Nwachukwu, and Eyinna (2021), who found that UHI worsens public health outcomes in Nigerian cities.

Thus, residents' comfort levels were more negatively affected in Nkpolu-Oroworukwo than in Rumuagholu. Findings showed that a majority of residents in Nkpolu-Oroworukwo experienced difficulty sleeping, increased electricity use for cooling, and hot indoor environments, while Rumuagholu respondents reported fewer comfort-related challenges, as shown in Table 9. Cumulatively, discomfort reported by residents in the neighbourhoods included difficulty sleeping, making indoor spaces hot and stuffy, and increasing electricity use (fans, air conditioners), accounting for 62%, 25%, and 13% of the responses, respectively. This difference reflects the role of urban form, as highlighted by Oke (1982), who linked denser built-up areas with reduced nighttime cooling and higher thermal discomfort. Consequently, the impact of UHI on emotional and mental well-being was also more pronounced in the Nkpolu-Oroworukwo neighbourhood. Most respondents associated extreme heat with difficulty sleeping, stress, and irritation. Other impacts recorded were reduced motivation and energy, which affect social interaction amongst residents in the neighbourhood. In Rumuagholu, where the UHI effect was less severe, all respondents reported that it made it harder for them to sleep (see Table 10). This suggests that the cumulative effect of persistent high temperatures in dense urban neighbourhoods not only affects physical health but also undermines mental resilience, reducing overall quality of life and well-being.

Furthermore, safety risks were unequally distributed across the neighbourhoods studied. In Nkpolu-Oroworukwo, the data analysis highlighted overheating of electrical equipment and the risk of fire outbreaks as the most significant dangers. At the same time, Rumuagholu respondents largely reported no noticeable safety issues. Thus, the aggregate data reported by the respondents indicated that overheating of electrical equipment was the most common response, accounting for 33% of responses. In comparison, the risks of fire outbreaks and traffic accidents due to heat fatigue accounted for 3% and 1%, respectively, as shown in Table 11. Though the majority of the residents surveyed reported having no noticeable safety issues. This aligns with Adelekan's (2010) findings, which argued that vulnerabilities to climate hazards in African cities are unevenly distributed, with densely populated, infrastructurally stressed communities bearing the highest risks. The literature by Owusu, Waylen, and Qiu (2017) supports this, showing that urban livelihoods in African cities often expose residents to health risks, thereby reducing liveability. The combined effects of health, comfort, emotional and mental well-being, and safety risk challenges translated into low satisfaction with urban liveability in both neighbourhoods, as perceived by residents. In Nkpolu-Oroworukwo, the stronger UHI effect corresponded with high levels of dissatisfaction, while in Rumuagholu, although the intensity was lower, a majority of residents still expressed dissatisfaction. In both neighbourhoods, respondents' perceptions also indicated a neutral-to-satisfactory level of liveability regarding UHI. The aggregate data indicate that residents are mostly dissatisfied and neutral, accounting for 63% and 32% of responses, respectively. These satisfactory feelings are triggered by the contributors of UHI observed by the respondents in the neighbourhoods from the study findings, including the use of generators and machinery, overpopulation and overcrowding, use of concrete block for building, paved surfaces, use of asphalt for road construction, rapid population growth and loss of green infrastructure in the neighbourhoods.

S/N	Health Problems	Nkpolu-Oroworukwo		Rumuagholu		Aggregate	
		N	%	N	%	N	%
1	Headaches and dizziness	15	4.3	0	0	15	4
2	Skin rashes and heat burn	329	91.5	23	100	352	92
3	Breathing difficulties	0	0	0	0	0	0
4	Dehydration and fatigue	4	1.1	0	0	4	1
5	No noticeable health effects	11	3.2	0	0	11	3
	Total	**359**	**100**	**23**	**100**	**382**	**100**
Source: Researchers' Field Survey, 2025							

Table 8: Health Problems Experienced During Hot Weather

S/N	Effect of High Temperature on Comfort	Nkpolu- Oroworukwo		Rumuagholu		Aggregate	
		N	%	N	%	N	%
1	Difficult to sleep	229	63.8	4	16.7	237	62
2	Increases electricity use (fans, air conditioners)	46	12.8	4	16.7	50	13
3	Makes indoor space hot and stuffy	84	23.4	15	66.7	95	25
4	No effect on comfort	0	0	0	0	0	0
	Total	**359**	**100**	**23**	**100**	**382**	**100**
Source: Researchers' Field Survey, 2025							

Table 9: Effect of High Temperature on Comfort

S/N	Effect on Emotional and Mental Wellbeing	Nkpolu- Oroworukwo		Rumuagholu		Aggregate	
		N	%	N	%	N	%
1	Cause stress and irritation	31	8.5	0	0	31	8
2	Makes it harder to sleep	302	84	23	100	325	85
3	Affects social interaction	4	1.1	0	0	4	1
4	Reduces motivation and energy	11	3.2	0	0	11	3
5	No effect	11	3.2	0	0	11	3
	Total	**359**	**100**	**23**	**100**	**382**	**100**
Source: Researchers' Field Survey, 2025							

Table 10: Effect of Heat on Emotional and Mental Wellbeing

S/N	Safety Risks of Increased Heat	Nkpolu-Oroworukwo		Rumuagholu		Aggregate	
		N	%	N	%	N	%
1	Risk of fire outbreaks	11	3.2	0	0	11	3
2	Traffic accidents due to heat fatigue	4	1.1	0	0	4	1
3	Increased risk of illness or death	0	0	0	0	0	0
4	Overheating of electrical equipment	126	35.1	0	0	126	33
5	No noticeable safety issues	217	60.6	23	100	240	63
	Total	**359**	**100**	**23**	**100**	**382**	**100**
Source: Researchers' Field Survey, 2025							

Table 11: Safety Risks Associated with Increased Heat

S/N	Satisfactory Level	Nkpolu- Oroworukwo		Rumuagholu		Aggregate	
		N	%	N	%	N	%
1	Very satisfied	0	0	0	0	0	0
2	Satisfied	15	4.3	0	0	15	4
3	Neutral	115	31.9	8	33.3	122	32
4	Dissatisfied	225	62.8	15	66.7	241	63
5	Very dissatisfied	4	1.1	0	0	4	1
	Total	**359**	**100**	**23**	**100**	**382**	**100**
Source: Researchers' Field Survey, 2025							

Table 12: Satisfactory Level in Regards to Urban Heat and Liveability

Conclusion

This research investigated the UHI effect and its impact on liveability in Port Harcourt Metropolis, focusing on two neighbourhoods. The findings revealed that Nkpolu-Oroworukwo experienced higher UHI than Rumuagholu in 2015, 2020, and 2025, with average UHI of 27.7°-35.2°C, 27.7°-34.2°C, and 31.9°C-32.1°C, respectively. However, the differential records showed a decline in UHI in 2015, 2020, and 2025 in the neighbourhoods, from +7.5°C to +6.5°C and to +0.5°C, respectively. The persistent differential reflected variations in urban morphology, land use, and vegetation cover. Nkpolu-Oroworukwo, with its mixed-use density, asphalt roads, concrete buildings, and overcrowding, exhibited more severe UHI than Rumuagholu, which is relatively less congested but still affected by reduced vegetation and reliance on generators. This convergence suggests that Rumuagholu is experiencing accelerated urbanisation, resulting in the loss of vegetation and an increase in impervious surfaces.

The study found that the major contributors to the increasing temperatures in the neighbourhoods were the constant use of generators and machinery, overpopulation and overcrowding, more concrete-block buildings, paved landscape surfaces, road construction with asphalt, rapid population growth, and the loss of vegetation, which have generated impacts. The impacts of UHI on residents were multidimensional, encompassing health, comfort, emotional and mental well-being, and safety risks. From the findings, the prevailing impacts were skin rashes and heat burn; headaches and dizziness; and dehydration and fatigue, as indicated by the health indicator. For the comfort indicator, difficulty to sleep, indoor space hot and stuffy, increased electricity use for cooling, and hot indoor environments, while for the emotional and mental well-being indicator, issues such as making it harder for residents to sleep, causing stress and irritation, reducing motivation and energy, and affecting social interaction. The findings further revealed the safety risks indicator as overheating of electrical equipment and risk of fire, and traffic accidents due to heat fatigue. These conditions affect residents of the studied neighbourhoods, who express dissatisfaction with their quality of life regarding UHI and liveability. The implications of these findings are significant. UHI not only worsens thermal discomfort and health challenges but also reduces social well-being and safety, thereby undermining the sustainability of urban life. Without intervention, Port Harcourt metropolis is likely to face worsening heat risks, reduced resilience, and declining quality of life. Therefore, sustainable urban planning and management strategies are needed to address the UHI effect, safeguard residents and the environment, and enhance liveability.

Recommendations

Based on the findings and discussions, the following recommendations are suggested:

- The government should regularly conduct urban heat assessments in neighbourhoods to monitor temperatures.
- The government should regulate physical development and other activities that generate heat in the neighbourhoods to reduce the increasing UHIs.
- Government and neighbourhood residents should collaborate to preserve green and blue infrastructure within neighbourhoods to reduce rising temperatures.
- The government should encourage developers to use environmentally friendly materials for neighbourhood surfaces that will absorb heat, especially during hot seasons.
- Government and the neighbourhood stakeholders (landlords and tenants) should collaborate to form environmental awareness organisations to campaign and sensitise the developers and dwellers to use environmentally friendly cooling materials in the construction of buildings in the neighbourhoods to enhance health, comfort, well-being and safety of residents; and
- Government and neighbourhood stakeholders should campaign to introduce green infrastructure (planting trees along streets, and developing neighbourhood parks and gardens as open spaces) in the neighbourhoods.

References

1. Oke, T. R., Mills, G., Christen, A., & Voogt, J. A. (2017). Urban climates. Cambridge university press.
2. Santamouris, M. (2020). Innovative Urban Cooling Strategies to Mitigate the Urban Heat Island Effect. *Renewable and Sustainable Energy Reviews, 130*, 109946.
3. Rizwan, A.M., Dennis, L.Y. & Liu, C. (2022). A Review on the Generation, Determination, and Mitigation of Urban Heat Islands. *Journal of Environmental Sciences, 114*, 90–105.

4. Adinna, E. N., Christian, E. I., & Okolie, A. T. (2009). Assessment of urban heat island and possible adaptations in Enugu urban using landsat-ETM. *Journal of Geography and Regional Planning, 2*(2), 30.
5. Synnefa, A., Dandou, A., Santamouris, M., Tombrou, M., & Soulakellis, N. (2008). On the use of cool materials as a heat island mitigation strategy. *Journal of Applied Meteorology and Climatology, 47*(11), 2846-2856.
6. Santamouris, M. (2015). Analyzing the heat island magnitude and characteristics in one hundred Asian and Australian cities and regions. *Science of the Total Environment, 512*, 582-598.
7. Nnah, B. C., Okenwa, A. I., Oloyede, O. A., Nwaibe, O., & Agbu, A. U. (2021). Geospatial assessment of urban heat island in Port Harcourt LGA, Rivers State, Nigeria. *International Journal of Sciences: Basic and Applied Research* (*IJSBAR*), 33-55.
8. Weli, V.E. & Okoli, A.C. (2021). Urban Expansion and Land Surface Temperature Variability in Port Harcourt Metropolis: A Remote Sensing Approach. *Urban Climate*, 38, 100900.
9. Efe, S.I. (2011). Quality of Water from Hand Dug Wells in Onitsha Metropolitan Area, Nigeria. *African Journal of Environmental Science and Technology*, 5(3), 189–195.
10. Nwokoro, I. & Okusipe, M.T. (2017). Assessment of Urban Infrastructure Management in Nigerian Cities: A Case Study of Lagos. *Journal of Sustainable Development in Africa, 19*(3), 115–127.
11. Ajibola, M.O., Adeyemi, A.O., & Ibraheem, T.O. (2012). Urbanization and the Challenges of Sustainable Housing Development in Nigeria. *Journal of Sustainable Development, 5*(8), 114–124.
12. Nwankwoala, H.O., & Udom, G.J. (2011). Impact of Urbanisation on Wetland Degradation: A Case Study of the Upper Bonny Estuary, Port Harcourt, Nigeria. *Journal of Sustainable Development in Africa, 13*(4), 49–61.
13. Akarolo, D.O. (2012). An Overview of the Port Harcourt Metropolis. *Journal of the Nigerian Institute of Town Planners, 21*(2), 45–53.
14. Ogbonna, D.N., Amangabara, G.T. & Ekere, N.R. (2020). Assessment of Municipal Waste Management Practices in Port Harcourt Metropolis. *Environmental Research Journal, 14*(3), 55–67.
15. Niger Delta Environmental Survey (NDES). (1997). *Environmental and Socio-economic Characteristics. Phase I Report, Volume* 1.
16. Ayoade, J.O. (2004). *Introduction to Climatology for the Tropics*. Spectrum Books.
17. Ogungbenro, S.B. & Morakinyo, T.E. (2014). Rainfall Distribution and Trends in Nigeria. *Theoretical and Applied Climatology, 115*(3–4), 501–509.
18. Fakayode, S.O. (2003). Geography of the Niger Delta: An Overview. Journal of Geographical Research, 12(2), 45–58.
19. Nkem, J.N. et al. (2011). Vegetation and Land Use Patterns of the Niger Delta Region of Nigeria. *Environmental Research Letters, 6*(3), 56–67.
20. Owei, O. B., Obinna, V. C., & Ede, P. N. (2010, September). The challenges of sustainable land use planning in Nigerian cities: The case of Port Harcourt. In *46th ISOCARP congress* (pp. 1-10).
21. National Population Commission. (2006). Population census report of Nigeria. *Abuja: NPC*.
22. Mabogunje, A.L. (2002). *Urbanization in Nigeria: Challenges and Opportunities.* Lagos, Nigeria: University of Lagos Press.
23. Omole, F. & Olaleye, A. (2009). Port Harcourt: The Industrial and Commercial Hub of Nigeria. *Nigerian Journal of Business and Economic Studies*, 7(2), 45–60.
24. Ayeni, O. & Adeyemi, K. (2015). Urban Infrastructure and Challenges of Urbanization in Nigerian Cities: A Case Study of Port Harcourt. *Journal of Urban Planning and Development*, 12(1), 65–78.
25. Olatunji, A. (2013). Transportation and Urbanization in Nigerian Cities. *Transportation Research Journal*, 8(4), 115–130.
26. United States Environmental Protection Agency (USEPA) (2023a). *Urban Heat Island Basics*. United States Environmental Protection Agency.
27. World Meteorological Organisation (WMO). (2023). *State of the Global Climate 2023*. World Meteorological Organization.
28. Gleeson, B. J., & Low, N. (2000). *Australian urban planning: New challenges, new agendas*. Allen & Unwin.
29. Habitat, U. N. (2020). The value of sustainable urbanization. *World Cities Report*.
30. World Health Organization (WHO). (2022). *Climate Change and Health: Key Facts*.
31. Voogt, J. A., & Oke, T. R. (2003). Thermal remote sensing of urban climates. *Remote sensing of environment, 86*(3), 370-384.
32. Douglas, I., Alam, K., Maghenda, M., Mcdonnell, Y., McLean, L., & Campbell, J. (2008). Unjust waters: climate change, flooding and the urban poor in Africa. *Environment and urbanization, 20*(1), 187-205.
33. United States Environmental Protection Agency (USEPA) (2023b). *Heat Island Effect*. United States Environmental Protection Agency.
34. National Population Commission (NPC). (1991). *1991 Population Census Report of Nigeria*. Lagos, Nigeria: Federal Government Press.
35. National Population Commission (NPC) (2018). *NPC Puts Nigeria's Population at 198 Million*. Retrieved 27th May, 2021 from
36. National Bureau of Statistics (NBS) (2016). *General Household Survey – Panel Wave 3 (Post Planting)* 2015-2016. Abuja, Nigeria: National Bureau of Statistics.
37. Adelekan, I. O. (2010). Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria. Environment and urbanization, 22(2), 433-450.
38. Newton, P. W. (2012). Liveable and sustainable? Socio-technical challenges for twenty-first-century cities. Journal of

Urban Technology, 19(1), 81-102.
39. Nichol, J., & Wong, M. S. (2005). Modeling urban environmental quality in a tropical city. Landscape and urban planning, 73(1), 49-58.
40. Nigerian Meteorological Agency (NIMET). (2020). *Climate Data for Nigerian Cities*. Nigerian Meteorological Agency.
41. Oke, T. R. (1982). The energetic basis of the urban heat island. Quarterly journal of the royal meteorological society, 108(455), 1-24.
42. Owusu, K., Waylen, P.R. & Qiu, Y. (2017). Changing Urban Landscape and the Urban Heat Island Phenomenon in Accra, Ghana. *Theoretical and Applied Climatology*, 129, 125–137.
43. Weng, Q. (2009). Thermal Infrared Remote Sensing for Urban Climate and Environmental Studies: Methods, Applications, and Trends. *ISPRS Journal of Photogrammetry and Remote Sensing*, 64(4), 335–344.
44. Yamane, T. (1967). *Statistics: An Introductory Analysis* (2nd ed.). Harper and Row.
45. Yow, D. M. (2007). Urban heat islands: Observations, impacts, and adaptation. Geography Compass, 1(6), 1227-1251.