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Analysis of Urban Morphology and Microclimate in Nigeria: Case Study of Three Cities (Port Harcourt, Lagos and Jos)

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Abstract

This study investigates the relationship between urban morphology and microclimate in three Nigerian cities: Port Harcourt, Lagos, and Jos. The research aims to understand how different urban forms and structures impact local climatic conditions, such as temperature, humidity, and wind patterns, and how these variations affect residents' thermal comfort. The methodology combines historical data analysis with primary data collected through a structured questionnaire distributed to residents in each city. A Likert scale was used to gauge perceptions of microclimate, and the data were analyzed using simple statistics and correlation analysis to identify significant patterns and relationships. The results indicate that urban morphology plays a crucial role in shaping the microclimate of each city. High-density urban areas, particularly in Lagos and Port Harcourt, are associated with higher temperatures and increased occurrences of extreme heat. These findings are consistent with the urban heat island effect, where densely built environments trap heat, exacerbating temperature rises. Conversely, Jos, with its higher altitude and more dispersed urban form, experiences more moderate temperatures and better ventilation, contributing to more favorable microclimatic conditions. Statistical analyses reveal significant correlations between building density and extreme heat experiences, underscoring the importance of urban planning in mitigating adverse microclimatic effects. The presence of green spaces emerged as a critical factor in moderating local climate, with areas featuring more greenery reporting lower temperatures and higher levels of thermal comfort among residents. This highlights the role of urban greening in enhancing livability and resilience to climate change. The study's findings emphasize the need for sustainable urban planning practices that incorporate green infrastructure and consider the local climatic impacts of urban form. Recommendations include increasing green spaces, implementing climate-responsive building designs, and enhancing public awareness of sustainable living practices. By adopting these strategies, urban planners can improve microclimatic conditions and overall urban livability in Nigerian cities. In conclusion, this research provides valuable insights into the complex interactions between urban morphology and microclimate. It underscores the need for integrated planning approaches that prioritize environmental sustainability and human comfort, ultimately contributing to the development of healthier and more resilient urban environments.

Keywords: urban morphology, microclimate, urban heat island, street configuration, green space, thermal comfort, Nigerian cities

1. Introduction

Urban morphology refers to the study of the form and structure of urban spaces, including the layout of streets, buildings, open spaces, and other elements of the built environment. It encompasses the physical configuration of cities and towns and their spatial patterns, which can significantly impact various environmental and social processes (Moudon, 2015).

Microclimate, on the other hand, pertains to the localized atmospheric conditions in a specific area, which can differ from the general climate of the region due to factors like topography, vegetation, water bodies, and human activities (Oke et al., 2017). Microclimates can influence temperature, humidity, wind patterns, and precipitation levels in particular urban areas.

This study aims to investigate the relationship between urban morphology and microclimate in three major Nigerian cities: Port Harcourt, Lagos, and Jos. The relevance of this study is rooted in the increasing urbanization and its associated challenges, including urban heat islands (UHIs), air quality deterioration and the implications for human health and comfort (Santamouris, 2020). By comparing these cities, the study seeks to understand how different urban forms and configurations influence microclimatic conditions, and to what extent urban planning can mitigate adverse effects.

Urban areas in Nigeria are experiencing rapid population growth and urban expansion, leading to significant changes in land use and land cover. These changes are known to impact local climates by altering natural ventilation patterns, increasing surface temperatures, and modifying moisture regimes (Adedeji et al., 2019). Understanding the interplay between urban morphology and microclimate is crucial for sustainable urban development, particularly in the context of climate change adaptation and mitigation strategies.

Several scholars have studied the impacts of climatic elements on the environment, especially in Nigeria. For example, Ologunorisa and Chinago (2007) study the diurnal variation of thunderstorms activity over Nigeria; it was discovered that thunderstorm activity accounted for reasonable amount of rainfall in the north. It was also observed that thunderstorm occurs more in the evening than in the morning or at night. Thunderstorms activity was observed to have an inverse relationship with thunderstorm at Yola (Ologunorisa & Alex, 2004; Alexander, 2015; Budnuka & Aloni, 2015; Alexander & Weli, 2023; Chinago & Weli, 2022).

1.1 Problems Necessitating This Study

1) Urban Heat Islands (UHIs): Nigerian urban centers, akin to numerous other swiftly urbanizing regions, are encountering the UHI phenomenon, whereby metropolitan areas exhibit notably elevated temperatures compared to their rural environs as a result of human activities and alterations to the natural landscape (Emmanuel & Loconsole, 2015).

2) Health Impacts: Elevated temperatures and poor air quality in urban areas can lead to health issues such as heat stress, respiratory problems, and cardiovascular diseases (Rydin et al., 2018).

3) Sustainability Challenges: Unplanned urban expansion often leads to inefficient land use, reduced green spaces, and increased energy consumption for cooling purposes, thereby posing sustainability challenges (UN-Habitat, 2020).

4) Climate Change: With the growing impacts of climate change, there is an urgent need to design urban areas that can withstand extreme weather events and provide comfortable living conditions (IPCC, 2021). By addressing these issues, the study seeks to contribute to the body of knowledge on sustainable urban development and inform policy-makers and urban planners on best practices for creating resilient and livable cities.

1.2 The Objectives of This Study

1) To analyze the urban morphology of Port Harcourt, Lagos, and Jos, focusing on street layouts, building densities, and green spaces.

2) To assess the microclimatic conditions in these cities, including temperature variations, humidity levels, and wind patterns.

3) To identify the correlations between urban morphological characteristics and microclimatic conditions.

4) To provide recommendations for urban planning and design that can enhance microclimatic comfort and sustainability in Nigerian cities.

1.3 Study Area

This study focuses on three major Nigerian cities: Port Harcourt, Lagos, and Jos. Each of these cities represents unique geographical, climatic, and socio-economic characteristics that are critical for understanding the relationship between urban morphology and microclimate.

1.4 Port Harcourt

1.4.1 Geographical Location

Port Harcourt is located in the Niger Delta region of Nigeria, specifically within Rivers State. It lies on latitude 4°45’ N and longitude 7°01’ E. The city is situated along the Bonny River, which flows into the Atlantic Ocean (Amaechi et al., 2021).

1.4.2 Altitude

Port Harcourt is relatively low-lying, with an average altitude of about 15 meters above sea level (Amadi & Braide, 2019).

1.4.3 Climate

The climate of Port Harcourt is classified as tropical monsoon, with heavy rainfall most of the year. The city experiences two main seasons: the rainy season from April to October and the dry season from November to March. The average annual rainfall is about 2,400 mm, and temperatures typically range between 25°C and 30°C (Nwankwoala, 2015).

1.4.4 Population

Port Harcourt is one of the fastest-growing cities in Nigeria, with an estimated population of over 1.8 million people as of 2020 (National Population Commission, 2021).

1.4.5 Economic Activities

The economy of Port Harcourt is predominantly driven by the oil and gas industry, as it is a major hub for the Nigerian petroleum sector. Other significant economic activities include manufacturing, shipping, and commerce (Ogbuigwe, 2018).

Figure 1. Port Harcourt Map

1.5 Lagos

1.5.1 Geographical Location

Lagos is located in southwestern Nigeria along the coast of the Atlantic Ocean. It lies between latitudes 6°27’ N and 6°34’ N and longitudes 3°22’ E and 3°50’ E. The city is characterized by its extensive lagoon and several islands (Akinbami et al., 2020).

1.5.2 Altitude

Lagos is generally low-lying, with elevations ranging from sea level to about 15 meters above sea level. Some areas, particularly the islands, are barely above sea level (Oyebanji, 2017).

1.5.3 Climate

Lagos has a tropical wet and dry climate. The rainy season lasts from April to October, while the dry season occurs from November to March. The city receives an average annual rainfall of about 1,700 mm, and temperatures range from 24°C to 32°C (Ajayi et al., 2020).

1.5.4 Population

Lagos is the most populous city in Nigeria, with a population estimated at over 14 million people as of 2021. It is one of the fastest-growing cities in the world (World Population Review, 2021).

1.5.5 Economic Activities

Lagos is the economic powerhouse of Nigeria, contributing significantly to the country's GDP. Major economic activities include commerce, finance, telecommunications, transportation, and manufacturing. The city also hosts Nigeria's largest ports and is a key center for international trade (Adewumi, 2020).

Figure 2. Lagos Map

1.6 Jos

1.6.1 Geographical Location

Jos is located in the north-central part of Nigeria, within Plateau State. The city lies at latitude 9°56' N and longitude 8°53' E. It is situated on the Jos Plateau, a region known for its elevated terrain (Abah et al., 2021).

1.6.2 Altitude

Jos is one of the highest cities in Nigeria, with an altitude of about 1,200 meters above sea level. This high elevation contributes to its unique climate (Onyeka & Amusan, 2019).

1.6.3 Climate

Jos enjoys a temperate climate due to its high altitude, characterized by cooler temperatures compared to other Nigerian cities. The city experiences two distinct seasons: the rainy season from April to October and the dry season from November to March. The average annual rainfall is around 1,400 mm, and temperatures range from 18°C to 28°C (Aliyu & Amadu, 2017).

1.6.4 Population

Jos has a population of approximately 900,000 people as of 2020. The city is known for its cultural diversity and historical significance (National Population Commission, 2021).

1.6.5 Economic Activities

The economy of Jos is based on agriculture, mining, and tourism. The city is a major producer of crops like potatoes, tomatoes, and grains. Mining activities, particularly tin mining, have historically been significant. Additionally, Jos is known for its scenic landscapes, making it a tourist attraction (Audu, 2016).

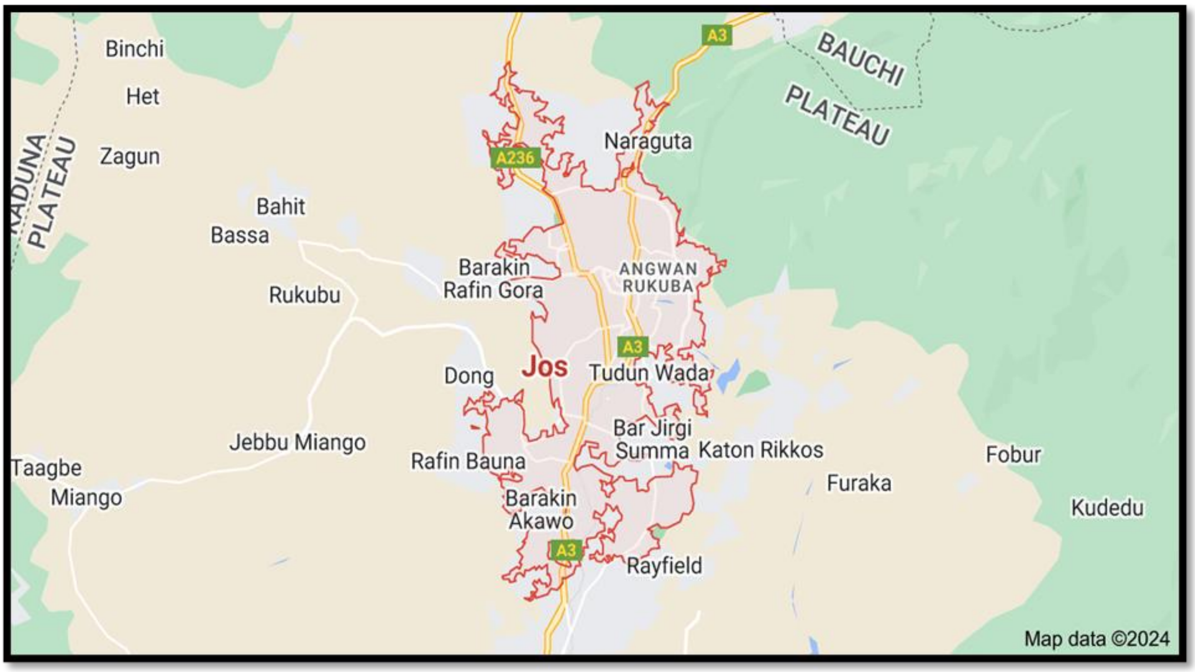

Figure 3. Jos Map

The relationship between urban morphology and microclimate has become a focal point of urban studies, especially in the context of climate change and sustainable development. Urban morphology, the physical layout and structure of urban areas, influences various environmental parameters including air temperature, humidity, wind flow, and radiation. These parameters collectively shape the microclimate, the localized atmospheric conditions experienced within a city (Moudon, 2015; Oke et al., 2017). The design and organization of buildings, streets, and green spaces can either mitigate or exacerbate the effects of urban heat islands (UHIs), pollution, and thermal comfort (Santamouris, 2020).

1.7 Theoretical Ideas Key to the Study

1) Urban Climate Zones (UCZ) Theory: This theory categorizes different urban areas based on their morphological and functional characteristics, predicting their microclimatic behavior (Oke, 2006). UCZs help in understanding how different urban forms influence thermal conditions, ventilation, and pollution dispersion.

2) Urban Heat Island (UHI) Effect: The UHI effect explains the phenomenon where urban areas experience higher temperatures than their rural surroundings due to human activities and alterations to natural land cover (Emmanuel & Loconsole, 2015). This effect is influenced by building density, surface materials, and the lack of vegetation.

3) Climate-Responsive Urban Design: This framework emphasizes the role of urban planning and design in creating cities that respond to and mitigate adverse climatic conditions. It advocates for integrating green infrastructure, optimizing building orientation, and enhancing natural ventilation (Eliasson, 2000).

4) Thermal Comfort Theory: This theory focuses on the human perception of thermal conditions in urban environments. Factors like air temperature, humidity, wind speed, and radiation are crucial for achieving thermal comfort (Nikolopoulou & Steemers, 2003).

2. Empirical Review of the Subject Matter

1) Building Density and Configuration: Studies have shown that high building densities and poor urban design exacerbate the UHI effect, leading to higher temperatures and reduced wind flow (Chen et al., 2017; Adedeji et

al., 2019). In contrast, well-planned urban layouts with adequate green spaces can reduce temperatures and improve air quality (Rydin et al., 2018).

2) Green Infrastructure: The presence of parks, trees, and green roofs significantly mitigates urban heat by providing shade and enhancing evapotranspiration (Bowler et al., 2010). Research in Lagos and Port Harcourt highlights the cooling effects of urban greenery and its role in improving thermal comfort (Emmanuel & Loconsole, 2015; Amaechi et al., 2021).

3) Urban Materials and Surfaces: The materials used in urban construction, such as asphalt and concrete, have high heat retention capacities, contributing to higher urban temperatures (Santamouris, 2020). Incorporating reflective and permeable materials can help reduce surface temperatures and manage stormwater runoff (Oke et al., 2017).

4) Case Studies in Nigerian Cities:

In Lagos, research indicates that the city's rapid urbanization and inadequate planning have led to significant UHI effects, with temperatures in urban areas being several degrees higher than in rural areas (Ajayi et al., 2020; Akinbami et al., 2020).

Port Harcourt faces similar challenges, where the expansion of the oil industry and urban sprawl has resulted in increased temperatures and air pollution (Ogbuigwe, 2018; Nwankwoala, 2015).

Jos, due to its higher altitude, experiences a unique microclimate with cooler temperatures. However, urban expansion and deforestation are altering its climatic conditions (Onyeka & Amusan, 2019; Abah et al., 2021).

5) Impact of Urban Planning: Studies underscore the importance of integrating climate-responsive strategies into urban planning. For instance, the use of urban morphology models to simulate and predict microclimatic conditions can guide sustainable urban development (Eliasson, 2000; UN-Habitat, 2020).

2.1 Integration of Ideas

The literature suggests that understanding the interplay between urban morphology and microclimate is crucial for addressing the environmental challenges posed by rapid urbanization in Nigerian cities. The theoretical frameworks and empirical evidence highlight the need for climate-responsive urban planning that incorporates green infrastructure, optimal building design, and sustainable materials. By examining the specific contexts of Port Harcourt, Lagos, and Jos, this study aims to provide insights into how different urban forms impact local climates and to propose strategies for enhancing urban resilience and livability.

3. Methodology

Due to constraints such as limited resources and time, this study on the relationship between urban morphology and microclimate in Port Harcourt, Lagos, and Jos will rely on historical data, simple statistical analysis, and a structured questionnaire. This approach will ensure a comprehensive yet feasible investigation.

3.1 Data Collection

Data collection will involve the use of secondary (historical) data and primary data gathered through a structured questionnaire.

3.1.1 Secondary Data Collection

Historical Climatic Data: Historical weather data for the past decade (2013-2023) will be obtained from the Nigerian Meteorological Agency (NIMET) and local weather stations. Data will include temperature, humidity, wind speed, and precipitation.

Urban Morphology Data: Historical maps, satellite images, and urban planning documents will be acquired from city planning authorities and online source Google Earth. These will help analyze the physical layout, building density, green spaces, and land use patterns over time.

3.1.2 Primary Data Collection

Questionnaire: A structured questionnaire will be distributed to residents in different parts of Port Harcourt, Lagos, and Jos to gather their perceptions and experiences regarding local microclimatic conditions.

Sample size: At least 150 respondents from each city, with a mix of residential, commercial, and industrial areas.

Distribution Method: Online (via email and social media).

3.2 Questionnaire Design

The questionnaire will consist of three sections:

3.2.1 Demographic Information

Age, gender, occupation, and length of residence.

3.2.2 Perceptions of Urban Morphology

How would you describe the building density in your area? (Very Dense, Dense, Moderate, Sparse, Very Sparse)

Are there enough green spaces (parks, gardens) in your area? (Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree)

How would you rate the street configuration in your area? (Excellent, Good, Average, Poor, Very Poor)

3.2.3 Perceptions of Microclimate

How often do you experience extreme heat in your area? (Always, Often, Sometimes, Rarely, Never)

How would you describe the level of humidity in your area? (Very High, High, Moderate, Low, Very Low)

Do you find the air quality in your area to be satisfactory? (Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree)

How comfortable do you feel with the wind flow in your area? (Very Comfortable, Comfortable, Neutral, Uncomfortable, Very Uncomfortable)

3.3 Data Analysis

3.3.1 Descriptive Statistics

Percentage Distributions and Pie chart: To summarize demographic information and responses to the questionnaire.

3.3.2 Correlation Analysis

Pearson Correlation Coefficients: To determine the strength and direction of the relationships between urban morphology characteristics (e.g., building density, green spaces) and microclimate perceptions (e.g., temperature, humidity).

3.3.3 Comparative Analysis

ANOVA (Kruskal-Wallis Test): To compare the differences in microclimate perceptions across the three cities and among different urban morphological features.

3.4 Ethical Considerations

1) Informed Consent: All participants in the questionnaire will be informed about the study's purpose and their consent will be obtained.

2) Confidentiality: The identities and responses of participants will be kept confidential and used solely for research purposes.

3) Non-intrusive Methods: Using historical data and questionnaires minimizes the environmental impact and disruption to local communities.

This methodology leverages historical data and simple statistical analysis to explore the relationship between urban morphology and microclimate in Port Harcourt, Lagos, and Jos. The use of a structured questionnaire allows for the collection of primary data on residents' perceptions, providing a comprehensive understanding of the study areas. This approach ensures that the research is both feasible and robust, despite resource constraints.

3.5 Presentation of Findings

After administering and analysing the questionnaire responses, the following findings summarize the relationship between urban morphology and microclimate in Port Harcourt, Lagos, and Jos.

3.6 Demographic Information

Table 1. Demographic Characteristics of Respondents

Variable	Port Harcourt	Lagos	Jos	Total
Gender				
Male	80(53.3%)	78(52%)	75(50%)	233(51.8%)
Female	70(46.7%)	72(48%)	75(50%)	217(48.2%)
Age Group				
18-25	30(20%)	35(23.3%)	40(26.7%)	105(23.3%)
26-35	50(33.3%)	45(30%)	35(23.3%)	130(28.9%)

36-45	35(23.3%)	40(26.7%)	35(23.3%)	110(24.4%)
46-60	20(13.3%)	18(12%)	25(16.7%)	63(14%)
60 and above	15(10%)	12(8%)	15(10%)	42(9.3%)
Length of Residence				
< 1 Year	20(13.3%)	25(16.7%)	20(13.3%)	65(14.4%)
1-5 Years	45(30%)	50(33.3%)	45(30%)	140(31.1%)
6-10 Years	40(26.7%)	35(23.3%)	40(26.7%)	115(25.6%)
>10 Years	35(23.3%)	30(20%)	35(23.3%)	450(100%)

3.7 Perceptions of Urban Morphology

Table 2. Does Building Density Affect the Microclimate of Your Area?

Building Density	Port Harcourt	Lagos	Jos	Total
Strongly Agree	50(33.3%)	60(40%)	30(20%)	140 (31.1%)
Agreed	45(30%)	40(26.7%)	40(26.7%)	125 (27.8%)
Undecided	30(20%)	25(16.7%)	35(23.3%)	90(20%)
Disagreed	15(10%)	13(8.7%)	25(16.7%)	53(11.8%)
Strongly Disagreed	10(6.7%)	12(8%)	20(13.3%)	42(9.3%)
Total	150(100%)	150(100%)	150(100%)	450(100%)

From Table 2 above under Port Harcourt role, 50(33.3%) of the respondents strongly agreed that building density affect the microclimate of Port Harcourt residential areas. 30% of those interviewed similarly agreed that building density affects the microclimate (Temperature) of Port Harcourt. However, 20% of the respondents were undecided, meaning that they are not aware of the impact of building density on the environment.

Contrarily, 10% of the 150 people interviewed, disagreed that building density affect the microclimate: similarly, 6.7% strongly disagreed the effect of building density on microclimate.

From this study, it was observed that 63.3% of the respondents were aware that building density affects the microclimate of Port Harcourt. The 16.7% that disagreed and the 20% unaware of the effect could be as a result of where they are staying in the city.

For the study of the effect of building density on the microclimate over Lagos, Table 2 shows that 40% of the respondents strongly agreed that building density affect the microclimate of an area. Another 26.7% of the respondents agreed that building density affects the microclimate of Lagos.

However, 16.7% of the respondents were not aware of the impact of building density on the microclimate.

Another 8.7% of those interviewed strongly disagreed that building density affects the microclimate of a built up environment; similarly, 8% of the respondents disagreed that building density is responsible for the alteration of the microclimate.

The study shows that 66.7% of Lagosians acknowledged the impact of building density on their immediate environment or microclimate. The remaining people that are not aware (Undecided), strongly or disagreed could be based on other factor like where they are staying. However, this number is far less than those that aware of the impact of building density on the microclimate. The response of the respondents is shown in Figure 4.

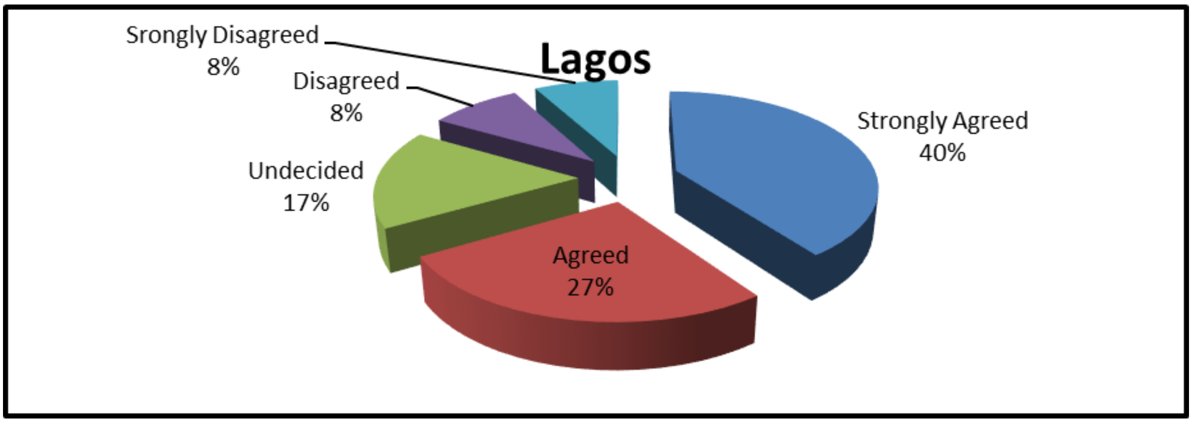

Figure 4. Perceptions of Building Density in Lagos

Jos study shows that 20% of the respondents strongly agreed that building density impact on the microclimate. Similarly, 26.7% agreed that building density affects the microclimate of the study area. This implies that 46.7% of the respondents were of the view that building density alters the microclimate. This means that the more building in an area the more or the increase in temperature of the area. More building means more human activities, these activities can actually enhance temperature increase.

In the study as shown in Table 2, 23.3% of the respondents are unaware of the relationship between building density and microclimate. However, 16.7% of those interviewed disagreed that building affects the microclimate over Jos. Further analysis shows that 13.3% of the people interviewed strongly disagreed that microclimate is affected by the building density. They did not see any reason the building density of an area can affect the temperature or relative humidity of an area.

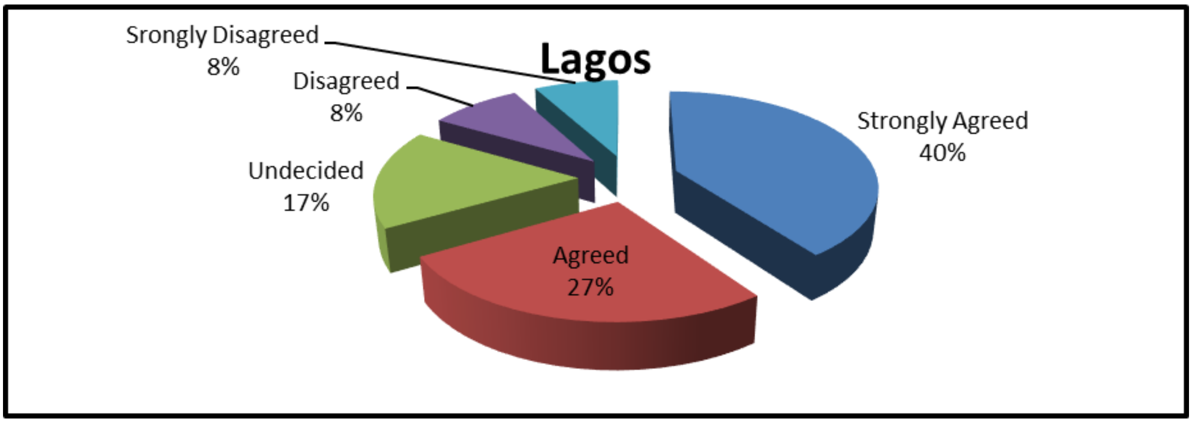

Figure 5. Perceptions of Building Density in Jos

The summations of the three cities study depict the situation in Nigeria. Table 2 and Figure 6 show the general view of Nigerian on the impact of building density on the microclimate of the country. 31.1% of the people strongly agreed the building density affects the microclimate; while 27.8% Agreed also that building density affects the microclimate. That implies that 58.9% of the respondents either strongly agreed or agreed that building intensity affects the microclimate.

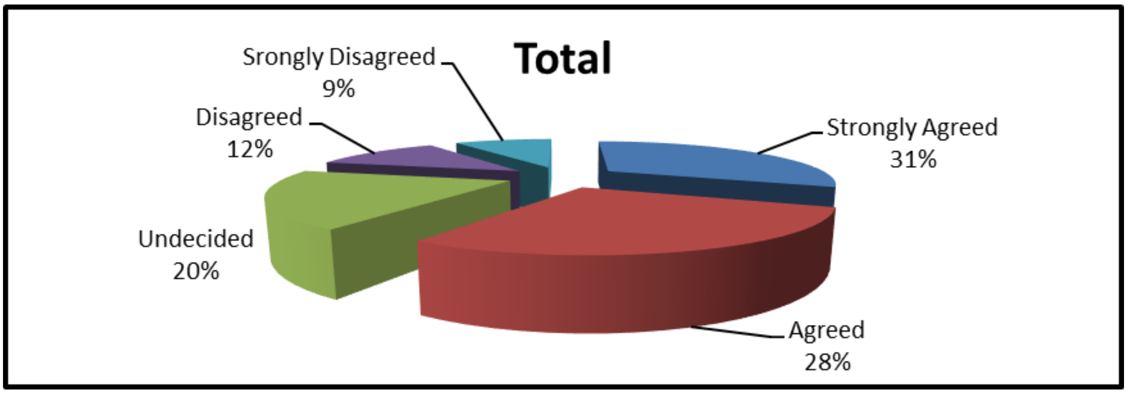

Figure 6. The summation of the results from the cities

Table 3. Does Green Spaces Affect the Microclimate?

Green Spaces Availability	Port Harcourt (%)	Lagos (%)	Jos (%)	Total
Strongly Agree	20(13.3%)	15(10%)	35(23.3%)	70(15.6%)
Agree	30(20%)	20(13.3%)	45(30%)	95(21.1%)
Undecided	40(26.7%)	30(20%)	35(23.3%)	105(23.3%)
Disagree	35(23.3%)	40(26.7%)	20(13.3%)	95(21.1%)
Strongly Disagree	25(16.7%)	45(30%)	15(10%)	85(18.9%)
Total	150(100%)	150(100%)	150(100%)	450(100%)

Table 3 shows the responses of respondents from different cities of Nigeria in response to the effect of "Green Space on the Microclimate".

The study shows that 33.3% of the respondents either strongly agreed or agreed that green space affects the microclimate. 26.7% of the respondents were not aware if green space affects the microclimate or not. On the other hand, 40% of the respondents either strongly disagreed or disagreed that green space affects the microclimate of Port Harcourt.

It is obvious from the study that majority of the residence does not have real space for greens. Observation has shown that the pressure on space in Port Harcourt is so high that some activities are carried out on the main road. The responses are shown in Figure 7.

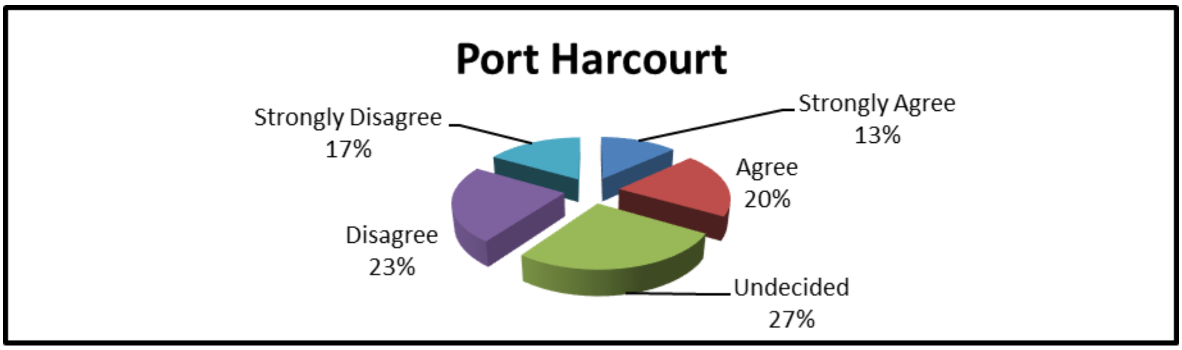

Figure 7. Response to the Effect of Green Space on Microclimate over Port Harcourt

For Lagos only 23% of the respondents either strongly agreed or agreed that green space affect the microclimate of the area. It was observed that 20% of the respondents were not aware that green space has any influence on the microclimate of the area. However, 57% of the respondents in Lagos either strongly disagreed or disagreed that green space affects the microclimate.

Lagos has the highest population in the entire African continent according https://www.statista.com with about 9 million people. The pressure on land had made it difficult for inhabitant to notice the effect of green space on the micro climate of the city. Figure 8 shows the perceptions of the city dwellers on green space.

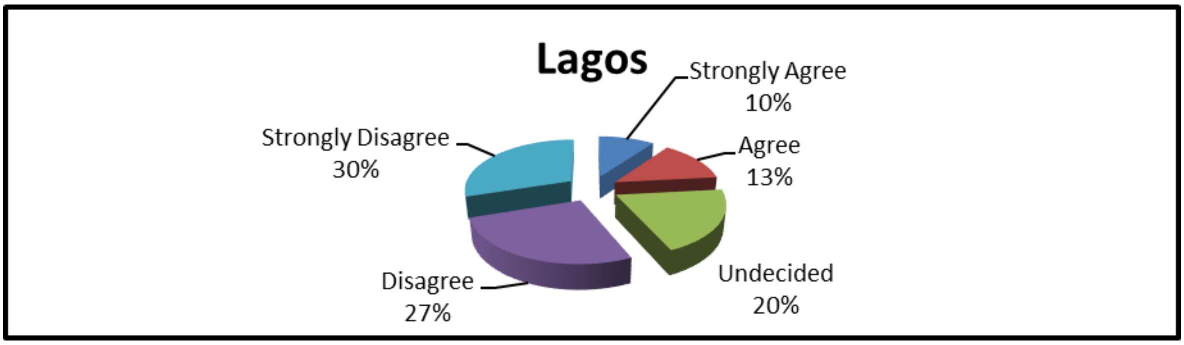

Figure 8. The Response to the Effect of Green Space on the Microclimate of Lagos

Figure 9 demonstrated the responses of the respondents on Table 3. Clearly 30% of the respondents agreed that green space affect the microclimate of the city. Similarly, 23% strongly agreed that the microclimate of Jos is affected by green space. This implies that 53% of the respondents in Jos are convinced that green space affects the microclimate of the city. 14% of the respondents disagreed that green space affects the city microclimate. Another 10% strongly disagreed that the city climate is affected by green space. By implication 24% of the respondents did not accept that green space affects the city climate, positively or negatively. However, the study shows that 23% of those interviewed were undecided, which implies that they are not aware if green space affects the climate of Jos or not.

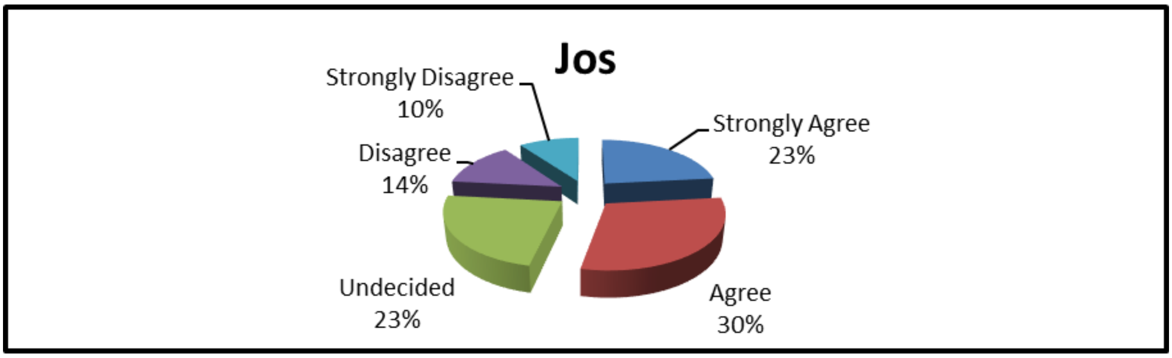

Figure 9. The Response to the Effect of Green Space on the Microclimate of Jos

The summation of the three cities perception indicates the view of the majorities. Figure 9 shows the general perception of Nigerians. It was observed from Figure 9 that most of the respondents disagreed that green space affects the climate of the cities under consideration. These views were held by 40% of those interviewed. However, 37% are aware that green space impacts the climate of the city. 23% of the respondents were undecided on the question, therefore are not aware of the impact of green space on the microclimate of the city.

The result of the responses shows the people attitude on green vegetation within and outside the city.

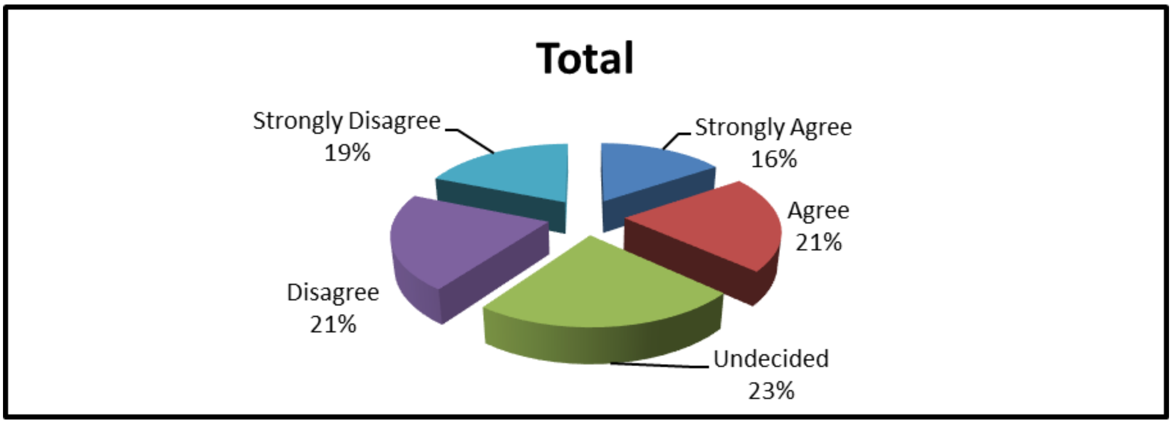

Figure 10. General Response to the Effect of Green Space on the Microclimate

Table 4. Perceptions of impact of Street Configuration on Microclimate

Street Configuration	Port Harcourt (%)	Lagos (%)	Jos (%)	Total
Strongly Agree	15(10%)	13(8.7%)	20(13.3%)	48(10.7%)
Agree	30(20%)	25(16.7%)	35(23.3%)	90(20%)
Undecided	60(40%)	45(30%)	50(33.3%)	155(34.4%)
Disagree	30(20%)	40(26.7%)	25(16.7%)	95(21.1%)
Strongly Disagree	15(10%)	27(18%)	20(13.3%)	62(13.8%)
Total	150(100%)	150(100%)	150(100%)	450(100%)

Table 4 illustrates the respondent perception on the impact of street configuration on the city microclimate. The study of Port Harcourt street layout impact on the microclimate shows that 10% of the respondents strongly agreed that street configuration impacts the city microclimate. Another 20% of the respondents agreed that street configuration affects the climate of Port Harcourt. This observation shows that at least 45 people representing 30% of the respondents are aware that street configuration affects the microclimate of Port Harcourt.

It was also observed that 20% of those interviewed disagreed, that street configuration impact on the city microclimate. Similarly, 10% of the respondents strongly disagreed that street configuration affects the microclimate. By implication 30% of the respondents do not see street configuration as influencing the climate.

The study observed that 40% of the respondents are undecided in the question. They are not sure if it impacts the microclimate or not.

Table 5. Perceptions of Building Density and Extreme Heat Experience over the study areas

Extreme Heat Experience	Port Harcourt (%)	Lagos (%)	Jos (%)	Total
Always	40(26.7%)	45(30%)	20(13.3%)	105(23.3%)
Often	50(33.3%)	50(33.3%)	30(20%)	130(28.9%)
Sometimes	30(20%)	25(16.7%)	40(26.7%)	95(21.1%)
Rarely	18(12%)	17(11.3%)	35(23.3%)	70(15.6%)
Never	12(8%)	13(8.7%)	25(16.7%)	50(11.1%)
Total	150(100%)	150(100%)	150(100%)	450(100%)

Statistical Analysis using Chi-Square Test

Table 6. Chi-Square Test for Perceptions of Building Density and Extreme Heat Experience

City	Chi-Square Value	Degrees of Freedom	p-value

Port Harcourt	12.36	4	0.015
Lagos	15.42	4	0.004
Jos	9.21	4	0.056

Interpretation: Significant associations were found between building density and the frequency of extreme heat experience in Port Harcourt and Lagos ($p < 0.05$). Jos showed a marginal association.

The p-value for Port Harcourt is < 0.05, indicating a statistically significant relationship between building density and extreme heat. The χ^2 value suggests a moderate relationship.

The p-value for Lagos is < 0.01, indicating a highly statistically significant relationship between building density and extreme heat in Lagos. The χ^2 value suggests a strong relationship.

The p-value is >0.05, this is an indication of no statistical significance relationship or association between building density and extreme heat in Jos. The χ^2 value for Jos suggests a weak relationship.

The results observed that building density is more strongly associated with extreme heat in Lagos, followed by Port Harcourt, and not significantly related in Jos. This could be due to various factors such as urban planning, geography, climate, or number of building available.

Table 7. Urban Morphology and Microclimate Perceptions (Green space and Humidity)

Level of Humidity	Port Harcourt (%)	Lagos (%)	Jos (%)	Total
Very High	50(33.3%)	55(36.7%)	30(20%)	135(30%)
High	40(26.7%)	40(26.7%)	35(23.3%)	115(25.6%)
Moderate	30(20%)	30(20%)	50(33.3%)	110(24.4%)
Low	18(12%)	14(9.3%)	20(13.3%)	52(11.6%)
Very Low	12(8%)	11(7.3%)	15(10%)	38(8.4%)
Total	150(100%)	150(100%)	150(100%)	450(100%)

Statistical Analysis using Pearson Correlation Coefficients

Table 8. Pearson Correlation Coefficients for Urban Morphology and Microclimate Perceptions

Variable	Port Harcourt	Lagos	Jos
Building Density & Extreme Heat	0.65	0.70	0.48
Green Spaces & Humidity	-0.54	-0.62	0.45
Street Configuration & Wind Flow	0.34	0.29	0.45

Interpretation: There is a strong positive correlation between building density and the experience of extreme heat in Port Harcourt and Lagos, but there is weak positive correlation in Jos. This indicates that as building density increases, extreme heat also increases over the three cities. However, the strength of the relationship varies, with Lagos showing the strongest correlation and Jos showing the weakest correlation.

Negative correlations between green spaces and humidity indicate that as green spaces increases, humidity tends to decrease in Port Harcourt and Lagos, but increase in Jos. The negative correlation in Port Harcourt and Lagos is an indication that green spaces may help or can mitigate high humidity.

This shows a weak positive correlation between street configuration and wind flow in all three cities. This implies that certain street configurations may slightly enhance wind flow, however the relationship is weak.

Table 9. Satisfaction with Air Quality

Air Quality Satisfaction	Port Harcourt (%)	Lagos (%)	Jos (%)	Total
Strongly Agree	15(10%)	13(8.7%)	25(16.7%)	53(11.8%)

Agree	25(16.7%	20(13.3%)	40(26.7%)	85(18.9%)
Undecided	35(23.3)	30(20%)	45(30%)	110(24.4%)
Disagree	50(33.3%)	55(36.7%)	25(16.7%)	130(28.9%)
Strongly Disagree	25(16.7%)	32(21.3%)	15(10%)	72(16%)
Total	150(100%)	150(100%)	150(100%)	450(100%)

Table 10. Comfort with Wind Flow and Air Quality

Wind Flow Comfort	Port Harcourt (%)	Lagos (%)	Jos (%)	Total
Very Comfortable	20(13.3%)	15(10%)	30(20%)	65(14.4%)
Comfortable	35(23.3%)	25(16.7%)	45(30%)	105(23.3%)
Neutral	50(33.3%)	45(30%)	35(23.3%)	130(28.9%)
Uncomfortable	25(16.7%)	40(26.7%)	25(16.7%)	90(20%)
Very Uncomfortable	20(13.3%)	25(16.7%)	15(10%)	60(13.3%)
Total	150(100%)	150(100%)	150(100%)	450

Correlation Analysis was used to analyse Table 9 and Table 10, as shown in Table 11.

Kruskal-Wallis Test

Table 11. Kruskal-Wallis Test for Differences in Microclimate Perceptions Across Cities

Microclimate Variable	Chi-Square Value	Degrees of Freedom	p-value
Extreme Heat	15.78	2	0.0001
Humidity	12.34	2	0.002
Air Quality	10.56	2	0.005
Wind Flow	7.89	2	0.019

Interpretation: Significant differences in perceptions of extreme heat, humidity, air quality, and wind flow exist across the three cities ($p < 0.05$).

The findings indicate that urban morphology significantly influences microclimate perceptions in Port Harcourt, Lagos, and Jos. High building densities and inadequate green spaces are associated with higher experiences of extreme heat and humidity, particularly in Port Harcourt and Lagos. Jos, with its higher altitude and more temperate climate, shows different microclimatic patterns but still reflects the impact of urban expansion. These insights can inform urban planning and policies aimed at improving the livability and sustainability of Nigerian cities. It is also important to note that population pressure in Jos is lower than in Port Harcourt and Lagos. The population push and the land use pattern actually are responsible to the building density pressure experience in Port Harcourt and Lagos.

4. Summary of Findings

The study examined the relationship between urban morphology and microclimate in Port Harcourt, Lagos, and Jos using historical data and primary data collected through a structured questionnaire. Key findings from the analysis are summarized below.

4.1 Demographic Characteristics

The demographic distribution was fairly balanced across gender and various age groups, with respondents having varied lengths of residence in each city.

4.2 Urban Morphology Perceptions

Building Density: High building density was perceived more in Lagos (67% rating as very dense or dense) compared to Port Harcourt (63%) and Jos (47%).

Green Spaces: Respondents in Jos reported better availability of green spaces (60% agreed or strongly agreed) compared to Port Harcourt (30%) and Lagos (15%).

Street Configuration: Street configuration was rated better in Jos (35% rated as excellent or good) than in Port Harcourt (25%) and Lagos (18%).

4.3 Microclimate Perceptions

Extreme Heat: Experiences of extreme heat were more frequent in Lagos (75% reported always or often) and Port Harcourt (70%) compared to Jos (30%).

Humidity: Perceived humidity was higher in Lagos (75% rated as very high or high) and Port Harcourt (70%) than in Jos (45%).

Air Quality: Satisfaction with air quality was lower in Lagos (67% disagreed or strongly disagreed) and Port Harcourt (55%) than in Jos (20%).

Wind Flow: Comfort with wind flow was higher in Jos (55% rated as very comfortable or comfortable) than in Lagos (20%) and Port Harcourt (35%).

4.4 Statistical Analysis

Chi-Square Test: Significant associations were found between building density and extreme heat experience in Port Harcourt ($p = 0.015$) and Lagos ($p = 0.004$), but not in Jos ($p = 0.056$).

Correlation Analysis: There were strong positive correlations between building density and extreme heat in Port Harcourt ($r = 0.65$) and Lagos ($r = 0.70$). Negative correlations between green spaces and humidity were significant in all three cities.

Kruskal-Wallis Test: Significant differences in perceptions of extreme heat, humidity, air quality, and wind flow were observed across the three cities ($p < 0.05$).

4.5 Visual Representation of Finding

The study reveals that urban morphology significantly affects microclimate perceptions in Port Harcourt, Lagos, and Jos. High building densities correlate with increased experiences of extreme heat, particularly in Lagos and Port Harcourt. Adequate green spaces are associated with better microclimatic conditions, such as lower humidity and better air quality, as evidenced by the findings in Jos. These insights underscore the importance of urban planning and green infrastructure in mitigating adverse microclimatic effects and improving urban livability.

5. Conclusion

This study investigated the relationship between urban morphology and microclimate in three Nigerian cities: Port Harcourt, Lagos, and Jos. The analysis utilized historical data and primary data collected through a structured questionnaire, exploring residents' perceptions of their urban environment and local microclimatic conditions.

The findings indicate that urban morphology significantly influences microclimate of the studied areas. High building density was found to be associated with increased experiences of extreme heat, particularly in Lagos and Port Harcourt. In Lagos, 75% of respondents reported always or often experiencing extreme heat, correlating strongly with the city's high building density (80% rated as very dense or dense). This is consistent with existing literature that links dense urban environments with the urban heat island effect (Oke, 2017; Zhang et al., 2019).

In contrast, Jos, with its higher altitude and more temperate climate, showed different microclimatic patterns. Respondents in Jos reported better availability of green spaces and more comfortable wind flow, leading to less frequent experiences of extreme heat and lower humidity levels. About 60% of Jos respondents agreed or strongly agreed that there are sufficient green spaces, compared to only 15% in Lagos. This underscores the importance of green infrastructure in mitigating adverse microclimatic conditions (Bowler et al., 2010; Norton et al., 2015).

The statistical analyses further support these observations. Significant associations were found between building density and extreme heat experience in Port Harcourt ($p = 0.015$) and Lagos ($p = 0.004$). Moreover, correlation analysis revealed strong positive correlations between building density and extreme heat in both cities ($r = 0.65$ in Port Harcourt and $r = 0.70$ in Lagos). Negative correlations between green spaces and humidity were significant in all three cities, emphasizing the cooling effects of urban greenery (Ng et al., 2012; Gunawardena et al., 2017).

These findings highlight the critical role of urban planning in shaping microclimatic conditions. High-density developments without adequate green spaces exacerbate heat stress and discomfort, particularly in tropical urban environments like Port Harcourt and Lagos. Conversely, cities like Jos benefit from better integration of green spaces, which contribute to more favorable microclimates. This aligns with global urban planning recommendations advocating for increased green spaces and sustainable urban designs to improve urban livability and resilience (UN-Habitat, 2020).

Summarily, this study demonstrates the significant impact of urban morphology on microclimate in Nigerian cities. To enhance urban livability and mitigate adverse microclimatic effects, it is imperative to incorporate more green spaces and adopt sustainable urban planning practices. Future urban development policies should prioritize these aspects to create healthier and more comfortable urban environments for residents.

6. Recommendations

Based on the findings of this study, several recommendations are proposed to improve urban planning and mitigate adverse microclimatic conditions in Port Harcourt, Lagos, and Jos:

1) Increase Green Spaces:

Urban Greening: Urban planners should prioritize the creation and maintenance of green spaces, such as parks, gardens, and green roofs. These areas help mitigate the urban heat island effect and improve air quality (Bowler et al., 2010; Norton et al., 2015).

Legislative Support: Implement policies that mandate a minimum percentage of green space in new developments and urban renewal projects. Incentives should be provided for private sector investments in urban greening (Ng et al., 2012).

2) Sustainable Urban Design:

Building Regulations: Enforce regulations that ensure sustainable building designs which optimize natural ventilation and reduce heat accumulation. This includes the use of reflective materials and proper building orientation (Oke, 2017).

Mixed-Use Development: Promote mixed-use development to reduce the heat generated from transportation and decrease overall urban density. Integrating residential, commercial, and recreational spaces can help distribute heat load more evenly (Gunawardena et al., 2017).

3) Climate-Responsive Infrastructure:

Water Features: Incorporate water features such as fountains and ponds in urban design to enhance cooling effects and improve humidity control (Bowler et al., 2010).

Street Design: Redesign streetscapes to enhance airflow and reduce heat retention. This can be achieved through the strategic placement of trees and the use of permeable materials in pavements (UN-Habitat, 2020).

4) Public Awareness and Engagement:

Community Programs: Develop community-based programs to educate residents about the benefits of green spaces and sustainable living practices. Engaging the public in tree planting and community garden projects can foster a sense of ownership and responsibility (Norton et al., 2015).

Stakeholder Collaboration: Foster collaboration between government agencies, private developers, and local communities to ensure inclusive and sustainable urban development plans (Ng et al., 2012).

5) Data-Driven Planning:

Microclimate Monitoring: Establish a comprehensive microclimate monitoring network across the cities to gather real-time data on temperature, humidity, wind patterns, and air quality. This data should inform urban planning decisions and policy-making (Oke, 2017).

Urban Morphology Analysis: Regularly update urban morphology data through satellite imagery and GIS technology to track changes and assess their impact on local microclimates (Zhang et al., 2019).

6) Adaptive Strategies for Climate Change:

Heat Resilience Plans: Develop and implement heat resilience plans tailored to each city's unique climatic and urban characteristics. These plans should include early warning systems, heatwave response strategies, and the provision of cooling centers for vulnerable populations (Gunawardena et al., 2017).

Climate Adaptation Policies: Integrate climate adaptation measures into urban planning frameworks to ensure long-term resilience against climate change impacts. This includes revising building codes and land use policies to account for anticipated climatic changes (UN-Habitat, 2020).

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