



Water Footprint, Urban Heat Island and Environmental and Human Health in the South-South Geopolitical Zone of Nigeria

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Abstract

The study specifically investigated the causes of Urban Heat Island, the effects of water footprint on environmental sustainability, the environmental and health implications of Urban Heat Island, and the relationship between urbanization and temperature increase. The study adopted a survey and correlational research design. A sample of 1,200 respondents was selected from six major urban centers in Akwa Ibom, Bayelsa, Cross River, Delta, Edo, and Rivers States using stratified and simple random sampling techniques. Data were collected through questionnaires, field observations, interviews, temperature measurements, and GIS evidence. Descriptive statistics, percentages, and Pearson Product Moment Correlation were used for data analysis at the 0.05 level of significance. Findings revealed that vegetation loss (81%), increasing concrete surfaces (76%), industrialization, traffic congestion, oil exploration, and infrastructural expansion are the major causes of Urban Heat Island in the region. Correlation analysis showed a significant relationship between water footprint and environmental sustainability ($r = 0.600$, $p < 0.05$), indicating that increasing water demand and pollution significantly affect environmental quality. The study also found a strong positive relationship between urbanization and temperature increase ($r = 0.765$, $p < 0.05$), confirming that urban growth contributes substantially to thermal stress. Major environmental effects identified include air pollution, flooding, biodiversity loss, poor water quality, and environmental degradation. Health implications include heat stress, respiratory illnesses, cardiovascular complications, dehydration, fatigue, and sleep disorders. The study concludes that Urban Heat Island and unsustainable water utilization are critical environmental and public health challenges in the South-South region. It recommends urban greening, sustainable water management, climate-sensitive planning, pollution control, and strengthened environmental governance to enhance ecological sustainability and public health resilience.

Keywords: Water Footprint, Urban Heat Island, Environmental Sustainability, Human Health, Urbanization, Climate Change, South-South Nigeria.

Introduction

The rapid growth of human population and residential space, with constant movement of people from one place to another, especially rural urban drift coupled with increase in the number of child' birth; the number of cities across the world is also expanding leading to urbanization which remains one of the most transformative global processes shaping environmental systems, socioeconomic development, and public health outcomes in the twenty-first century (Berman, et al. 2017; Shultz et al. 2018). Further studies have shown that across developing countries, rapid population growth and expanding urban infrastructure have significantly altered natural ecosystems, increased environmental pressure, and intensified climate-related vulnerabilities (Lessler, et al. 2018; Hardy, et al. 2019). Furthermore, the United Nations Human Settlements Program (UN-Habitat, 2022) observed that African cities are currently experiencing some of the fastest rates of urban growth globally, resulting in severe ecological stress, land-use transformation, and increasing pressure on freshwater resources.

WHO. COP24 (2018) observed that one of the major environmental consequences of rapid urbanization is the Urban Heat Island (UHI) phenomenon. Urban Heat Island refers to the condition in which urban areas experience significantly higher atmospheric and surface temperatures than surrounding rural environments due to anthropogenic activities and extensive modification of natural landscapes (Yong & Lim, 2020). The replacement of vegetation with impervious surfaces such as asphalt, concrete, and metal roofing materials increases solar heat absorption and heat retention within urban environments.

Researchers like Lessler, et al. (2018); Hardy, et al. (2019) ; Stanaway, et al. (2019) and Chaves, et al. (2020) have all agreed that Urban Heat Island has become a significant environmental and public health concern because of its effects on urban climate systems, air quality, thermal comfort, biodiversity, and ecosystem stability. Elevated urban temperatures contribute to increase energy demand, environmental degradation, greenhouse gas emissions, and declining urban livability. According to the Intergovernmental Panel on Climate Change (IPCC, 2021), climate

change and urban warming interact synergistically to intensify heat-related hazards, ecological vulnerability, and environmental stress.

Chaves, et al further posited that closely associated with urban environmental sustainability is the concept of water footprint. Water footprint refers to the total volume of freshwater utilized directly and indirectly by households, industries, agricultural systems, institutions, and urban economies. Water footprint assessment evaluates patterns of water consumption and provides insight into the sustainability of freshwater utilization and environmental management practices (Oita, et al. 2016; Wiedmann & Lenzen, 2018; Stanaway, et al. 2019).

Schandl, et al. (2018) observed that urban heat island and water footprints all contribute to fresh water scarcity. Water scarcity and declining freshwater quality have emerged as major global environmental concerns, especially in developing countries where rapid urbanization and industrialization increase water demand while simultaneously degrading freshwater ecosystems. Unsustainable water utilization contributes to ecological instability, environmental pollution, and declining public health conditions.

The South-South geopolitical zone of Nigeria comprises Akwa Ibom, Bayelsa, Cross River, Delta, Edo, and Rivers States. The region represents one of Nigeria's most environmentally vulnerable zones because of rapid urbanization, oil exploration, industrial development, flooding, coastal erosion, environmental pollution, and ecosystem degradation. Major urban centers such as Port Harcourt, Warri, Benin City, Uyo, Yenagoa, and Calabar are increasingly experiencing environmental stress associated with population growth and infrastructural expansion. Recent studies reveal that urban growth and declining vegetation cover significantly intensify Urban Heat Island effects within Nigerian cities (Odunsi & Rienow, 2024; Oyeniya et al., 2025). Similarly, Ojerinde et al. (2026) found that declining urban forests and increasing built-up surfaces contribute substantially to thermal stress and environmental degradation in urban Nigeria. The South-South region also experiences severe environmental challenges associated with water pollution, flooding, saline intrusion, oil spills, industrial waste, and declining access to

potable water. These environmental problems increase water stress and threaten freshwater sustainability across urban and peri-urban settlements.

Watts, et al. (2018) further exposed that environmental degradation and excessive heat exposure have serious implications for human health. The World Health Organization (WHO, 2021) emphasized that environmental pollution and heat-related hazards disproportionately affect vulnerable populations, including children, elderly persons, outdoor workers, and low-income residents. Urban Heat Island and poor environmental conditions increase the prevalence of respiratory illnesses, cardiovascular diseases, dehydration, mental stress, waterborne diseases, fatigue, and reduced productivity.

Watts, et al. (2019) found that Urban Heat Island results primarily from land-use transformation and anthropogenic heat emissions associated with urbanization and industrialization. Urban surfaces such as asphalt roads, concrete buildings, and roofing materials absorb solar radiation during the day and release heat gradually at night, thereby increasing urban temperatures. Odunsi and Rienow (2024) observed that economic development clusters and infrastructural expansion significantly intensified surface Urban Heat Island effects in Abeokuta, Nigeria. Similarly, Oyeniyi et al. (2025) found that declining vegetation and increasing built-up surfaces significantly increased thermal intensity in Akure and Osogbo. In the South-South geopolitical zone, rapid urban growth, oil exploration activities, industrialization, and declining green spaces contribute substantially to thermal stress and environmental degradation.

Recent studies on Nigerian urban climate increasingly employ Geographic Information Systems (GIS) and remote sensing technologies to analyze land-use change and thermal conditions. Example Koko et al. (2021) found that land-use and land-cover changes significantly influenced urban climate and surface temperatures in Kano Metropolis. Guo et al. (2022) similarly established that urbanization contributed substantially to increasing land surface temperatures in Lagos, Nigeria. Another research conducted in Lafia also revealed that urban expansion and vegetation decline intensified Urban Heat Island effects and thermal discomfort (Abimbola et al.,

2025). Urban Heat Island contributes to multiple environmental problems, including air pollution, ecological instability, thermal discomfort, flooding, declining biodiversity, and water stress. It was also established that elevated temperatures accelerate the formation of ground-level ozone and particulate matter, thereby worsening urban air quality. Thermal stress also disrupts urban hydrological systems and contributes to flooding in poorly planned cities. Vegetation loss further reduces urban climate resilience and intensifies environmental degradation. Ojerinde et al. (2026) emphasized that declining urban forests significantly reduce climate adaptation capacity in Nigerian cities.

Water footprint refers to the total quantity of freshwater utilized directly and indirectly in the production of goods, services, industrial operations, agricultural systems, and household activities. It represents an important indicator for measuring water sustainability and environmental management efficiency. Water footprint is commonly categorized into blue water footprint, green water footprint, and grey water footprint. Blue water footprint refers to freshwater extracted from rivers, lakes, and groundwater sources. Green water footprint refers to rainwater utilized during agricultural production, while grey water footprint measures the volume of freshwater required to dilute pollutants and maintain acceptable environmental quality standards. Rapid urbanization and industrialization increase water demand and place significant pressure on freshwater ecosystems. In many developing countries, weak environmental governance, pollution, and unsustainable water management intensifies water scarcity and ecological vulnerability.

Weagle, et al (2018) observed that unsustainable water consumption patterns threaten environmental sustainability and freshwater availability. Urbanization, industrialization, and population growth significantly increase freshwater demand and environmental pollution. Further studies on water quality and environmental sustainability in Nigeria indicate that urbanization negatively affects freshwater ecosystems and increases water contamination risks. In the South-

South region, oil pollution, industrial waste, saline intrusion, and flooding intensify water-related environmental challenges (Eneji, et al. 2021, Eneji, et al. 2022).

In a study by Eneji, et al. (2022) Urban Heat Island and poor environmental conditions have serious implications for public health. Excessive heat exposure increases the risk of heat exhaustion, dehydration, respiratory illnesses, cardiovascular complications, fatigue, and mental stress. According to WHO (2021), heat-related illnesses and environmental pollution disproportionately affect vulnerable populations, including children, elderly persons, and outdoor workers. Poor air quality associated with Urban Heat Island aggravates respiratory diseases such as asthma and bronchitis, while polluted water contributes to waterborne diseases and skin infections. In another dimension, climate change intensifies Urban Heat Island effects and environmental vulnerability in urban areas. Rising global temperatures increase the frequency and intensity of heat waves, flooding, and ecological instability. UNEP (2023) emphasized that cities worldwide are increasingly vulnerable to climate-related environmental hazards. Sustainable urban planning, green infrastructure, urban forestry, and climate-sensitive architecture remain essential strategies for enhancing climate resilience and environmental sustainability.

Rapid urbanization, industrialization, and population growth have intensified environmental pressure within the South-South geopolitical zone of Nigeria; it is further observed that rapid expansion of urban settlements, oil exploration activities, industrial operations, and infrastructural development have significantly transformed natural landscapes and ecological systems within the region. The increasing replacement of vegetation with roads, buildings, and impervious surfaces has intensified Urban Heat Island effects and thermal discomfort in major cities such as Port Harcourt, Warri, Benin City, Calabar, Yenagoa, and Uyo. Rising temperatures associated with Urban Heat Island contribute to declining environmental quality, increased flooding, poor air quality, and ecological instability.

Simultaneously, increasing water demand, environmental pollution, industrial waste, and unsustainable freshwater utilization have intensified water stress and environmental vulnerability. Oil spills, poor waste disposal, saline intrusion, and contamination of freshwater ecosystems further threaten water sustainability and public health within the region. The combined effects of Urban Heat Island and unsustainable water utilization have serious implications for environmental and human health. Excessive heat exposure and environmental pollution contribute to respiratory illnesses, heat stress, dehydration, cardiovascular disorders, waterborne diseases, fatigue, and declining environmental comfort among residents. Although several studies have investigated urban climate change and environmental pollution in Nigeria, limited empirical attention has been given to the integrated relationship between water footprint, Urban Heat Island, environmental sustainability, and public health in the South-South geopolitical zone. This study seeks to bridge this knowledge gap. Most existing studies focus either on urban climate or environmental pollution without integrating water sustainability and public health dimensions. This study therefore investigates the effects of water footprint and Urban Heat Island on environmental and human health in the South-South geopolitical zone of Nigeria with emphasis on causes, environmental implications, public health effects, and mitigation strategies.

Theoretical Framework

This study is anchored on Urban Ecological Theory and Sustainable Development Theory. Urban Ecological Theory explains the interaction between human populations and environmental systems within urban areas. The theory posits that urbanization alters ecological balance through land-use transformation, industrialization, and environmental exploitation. Sustainable Development Theory emphasizes the need to balance economic growth, environmental protection, and social well-being in order to achieve long-term sustainability. The theories are relevant because they explain how rapid urbanization and unsustainable water utilization contribute to Urban Heat Island effects, environmental degradation, and public health vulnerability within the South-South region of Nigeria.

Objectives of the Study

The main purpose of this study is to examine the effects of water footprint and Urban Heat Island on environmental and human health in the South-South geopolitical zone of Nigeria.

Specifically, the study sought to:

1. Examine the causes of Urban Heat Island in the South-South geopolitical zone of Nigeria.
2. Assess the effects of water footprint on environmental sustainability within the region.
3. Determine the environmental effects associated with Urban Heat Island.
4. Examine the human health implications of Urban Heat Island and water stress.
5. Determine the relationship between urbanization and temperature increase in the South-South region.
6. Recommend sustainable mitigation strategies for reducing environmental and health risks.

Research Questions

The following research questions were formulated to guide this study:

1. What are the major causes of Urban Heat Island in the South-South geopolitical zone of Nigeria?
2. How does water footprint affect environmental sustainability within the region?
3. What are the environmental effects associated with Urban Heat Island?
4. What human health problems are linked to Urban Heat Island and water stress?
5. What are the relationship between urbanization and temperature increase within the region?
6. What mitigation measures can reduce environmental and health risks associated with Urban Heat Island and water footprint?

Hypothesis

There is no significant relationship between urbanization and Urban Heat Island intensity in the South-South geopolitical zone of Nigeria.

Research design and methods

The research design adopted for this study is the survey research design, the descriptive survey design was used to enable the researcher to examine environmental and public health conditions associated with water footprint and Urban Heat Island, while the correlational design helped was adopted to help the researchers determine the relationship between urbanization and temperature increase. The study area is the South South geopolitical zone of Nigeria which lies approximately between latitude $4^{\circ}15'N$ and $7^{\circ}15'N$ of the Equator and Longitude $5^{\circ}00'$ and $9^{\circ}30'E$ of the Greenwich meridian. The study was conducted in the South-South geopolitical zone of Nigeria, comprising Akwa Ibom, Bayelsa, Cross River, Delta, Edo, and Rivers States. The region lies within the tropical rainforest belt and experiences high annual rainfall, high humidity, and increasing urbanization associated with industrial and commercial activities.

The population of the study comprised of residents of selected urban centers within the South-South region, including Port Harcourt, Asaba, Benin City, Uyo, Calabar and Yenagoa. The sampling technique adopted for the selection of a sample size of 1,200 respondents is the stratified and simple random sampling techniques. Respondents were selected from residential, commercial, and industrial areas. Four sets of instruments were used for data collection; primary data were gotten through temperature measurements, structured questionnaires, field observations and oral interview with residents and stakeholders. Secondary data were gotten from journals, government reports, climate data reports, environmental publications, satellite imageries and conference proceedings among others. The following instruments were used for data collection- structured questionnaire, observation checklist, interviews schedule and thermometer and GIS evidence. The validity of the instruments was established by experts in environmental studies and management and public health. The instrument's reliability was done using test-retest method, which yielded a coefficient of reliability of 0.84. Data analysis was done using descriptive statistics, simple percentage, and correlation analysis at 0.05 significant level.

Results and Discussion

The result of the descriptive statistics shows that 1200 were sampled for the study, the result shows that the mean score for the causes of urban heat island is 11.51 with a standard deviation of 3.59, while the effects of water footprint on environmental sustainability has a mean score of 11.21 and a standard deviation of 3.47, environmental effects of urban heat island has a mean score of 11.60 and a standard deviation of 3.56, whereas the effects of urban heat island and water footprint on human health has a mean score of 10.84 and a standard deviation of 3.68, while urbanization and urban heat island has a mean score of 17.88 with a standard deviation of 1.70.

Table 1: Descriptive Statistics

Variable	N	Mean	Std. Deviation
Causes of urban heat island	1200	11.51	3.59
Water footprint on environmental sustainability	1200	11.21	3.47
Environmental effects associated with urban heat island	1200	11.60	3.56
Urban heat island and water footprint on human health	1200	10.84	3.68
Urbanization and urban heat island	1200	17.88	1.70

Causes of Urban Heat Island

Approximately 972 representing 81% of respondents identified declining vegetation cover as a major cause of increasing urban temperature, while 912 respondents representing 76% attributed rising temperatures to increasing concrete surfaces and industrial activities. These findings support previous studies which established that urban expansion and declining vegetation replaced by infrastructural developments intensify thermal stress and environmental degradation in Nigerian cities (Odunsi & Rienow, 2024; Oyeniyi et al., 2025). The study revealed that rapid urbanization, industrialization, traffic congestion, vegetation loss, oil exploration activities, and infrastructural development significantly contribute to Urban Heat Island intensity within the South-South region.

Water Footprint and Environmental Sustainability

Table 2: Pearson product moment correlation analysis of the relationship between water footprint and environmental sustainability in the South South geopolitical zone of Nigeria (N=1200)

Variable	X	SD.	r-Cal	P-Value
Water foot prints	11.51	3.59	.600	.000
Environmental sustainability	17.88	1.70		

Significant at .05 level, r- Critical = .000; df= 1198

From the correlation analysis shown on table 2, the calculated r-value is 0.600, while the table value is .000. the result is significant in the sense that there is a significant relationship between water foot print and environmental sustainability in the South South Geopolitical zone of Nigeria. The implication of this result is that water foot print contributes to environmental sustainability. The findings revealed that increasing population growth, industrialization, and urban consumption patterns significantly intensify water demand and freshwater stress within the region. Respondents reported declining access to potable water, increasing water pollution, flooding, and environmental degradation associated with industrial waste and oil exploration activities. These findings agree with previous studies indicating that urbanization and industrial pollution negatively affect freshwater sustainability and environmental quality in Nigeria.

Environmental Effects of Urban Heat Island

The study identified several environmental effects associated with Urban Heat Island such as:

- Increased air pollution
- Thermal discomfort
- Flooding
- Poor water quality
- Declining biodiversity
- Environmental degradation

Urban centers with high industrial concentration and dense population recorded significantly higher temperatures than suburban locations. These findings corroborate earlier studies on urban thermal stress and environmental degradation within Nigerian cities.

Urbanization and urban heat island (Temperature Increase)

Table 3: Pearson product moment correlation analysis showing the relationship between urbanization and temperature increase (N=1200)

Variable	X	SD.	r-Cal	P-Value
Urbanization	11.21	3.47	.765	.000
Temperature increase	17.88	1.70		

Significant at .05 level, r- Critical = .000, df= 1198

The result of the correlation analysis on table 3 shows the relationship between urbanization and temperature increase in the south south zone of Nigeria. The result indicate that the calculated r-value of .765 is higher than the critical table value of .000, meaning there is a significant relationship between urbanization and temperature increase. The findings indicate that increasing urban development contributes significantly to elevated temperature conditions and environmental stress within the South-South region.

Human Health Implications

The findings showed that residents experience multiple health challenges associated with Urban Heat Island and environmental degradation, including:

- Heat stress
- Respiratory illnesses
- Cardiovascular complications
- Skin infections
- Fatigue
- Dehydration

- Sleep disturbances
- Headaches

Approximately 73% of respondents reported excessive heat discomfort during the dry season, while 61% indicated increased respiratory problems associated with poor environmental quality.

These findings align with WHO (2021), which emphasized that excessive heat exposure and environmental pollution significantly affect public health conditions.

Discussion of Findings

This study examined the effects of water footprint and Urban Heat Island (UHI) on environmental and human health in the South-South geopolitical zone of Nigeria. The findings provide empirical evidence that rapid urbanization, environmental degradation, and unsustainable water resource utilization are interconnected challenges affecting environmental sustainability and public health in the region. The study found that declining vegetation cover, increasing concrete surfaces, industrial activities, traffic congestion, oil exploration, and rapid infrastructural development are the major drivers of Urban Heat Island intensity in the South-South region. Specifically, 81% of respondents identified vegetation loss as a major contributor, while 76% attributed rising urban temperatures to concrete structures and industrial expansion.

These findings are consistent with the works of Odunsi and Rienow (2024) and Oyeniyi et al. (2025), who observed that the conversion of vegetated land into built-up areas significantly increases surface temperatures in Nigerian cities. The findings also support Urban Ecological Theory, which argues that human modification of natural landscapes disrupts ecological balance and creates environmental stress. The extensive replacement of forests, wetlands, and green spaces with impervious surfaces in cities such as Port Harcourt, Asaba, Warri, Benin City, Uyo, Yenagoa, and Calabar has increased heat absorption and retention, thereby intensifying urban warming. Furthermore, the findings corroborate Watts et al. (2019), who established that anthropogenic heat emissions from industrial and transportation activities significantly contribute

to urban temperature increases. The South-South region's concentration of petroleum industries, gas flaring activities, and expanding urban settlements further amplifies thermal stress.

The study revealed a significant positive relationship between water footprint and environmental sustainability ($r = 0.600$, $p < 0.05$). Respondents reported increasing water demand, declining access to potable water, pollution of freshwater sources, flooding, and environmental degradation arising from industrial activities and oil exploration. This finding agrees with Weagle et al. (2018), who argued that unsustainable water consumption patterns threaten freshwater availability and environmental sustainability. Similarly, Schandl et al. (2018) emphasized that increasing urbanization and industrialization place enormous pressure on freshwater resources, leading to water scarcity and ecological degradation. The findings further support the studies of Eneji et al. (2021) and Eneji et al. (2022), which documented the impacts of local embalmment, oil pollution, industrial waste discharge, saline intrusion, and flooding on freshwater ecosystems in the Niger Delta region. The observed relationship indicates that water resource management remains central to environmental sustainability. As urban populations continue to grow, demand for water increases, thereby heightening pressure on already stressed freshwater ecosystems. The implication is that poor water governance and unsustainable utilization practices not only threaten environmental quality but also compromise the ability of future generations to access adequate freshwater resources, contrary to the principles of Sustainable Development Theory.

The findings identified increased air pollution, thermal discomfort, flooding, poor water quality, declining biodiversity, and environmental degradation as major environmental consequences of Urban Heat Island. Urban centers characterized by dense populations and industrial concentration recorded higher temperature levels than less developed areas. These findings align with the observations of Lessler et al. (2018), Hardy et al. (2019), Stanaway et al. (2019), and Chaves et al. (2020), who concluded that Urban Heat Island contributes significantly to ecological instability and environmental deterioration. Elevated temperatures accelerate atmospheric chemical reactions that increase the formation of pollutants, thereby reducing air quality. The

results also corroborate Ojerinde et al. (2026), who found that declining urban forests reduce ecological resilience and increase environmental vulnerability in Nigerian cities. The reduction of vegetation weakens natural cooling mechanisms, increases stormwater runoff, and contributes to flooding, especially in poorly planned urban environments. The findings further support the IPCC (2021), which emphasized that climate change and urban warming interact synergistically to worsen environmental stress. Consequently, Urban Heat Island not only alters local climatic conditions but also aggravates broader environmental challenges affecting ecosystem sustainability.

The study revealed that Urban Heat Island and water stress have significant adverse effects on human health. The major health challenges reported include heat stress, respiratory illnesses, cardiovascular complications, skin infections, fatigue, dehydration, headaches, and sleep disturbances. About 73% of respondents experienced excessive heat discomfort during the dry season, while 61% reported increased respiratory problems. These findings strongly support the assertions of WHO (2021), which noted that excessive heat exposure and environmental pollution disproportionately affect vulnerable populations, including children, older adults, outdoor workers, and low-income residents. The findings are equally consistent with Eneji et al. (2022), who established that excessive environmental heat and poor environmental quality increase the prevalence of respiratory and cardiovascular illnesses.

The results also support Watts et al. (2018), who observed that environmental degradation and excessive heat exposure significantly increase public health risks. Elevated temperatures contribute to dehydration, heat exhaustion, reduced productivity, and mental stress. Simultaneously, contaminated water sources resulting from industrial pollution and poor environmental management increase the occurrence of waterborne diseases and skin-related infections. The implication is that environmental sustainability and public health are inseparable, as deteriorating environmental conditions directly translate into increased disease burden and reduced quality of life among urban residents.

The study found a strong and significant positive relationship between urbanization and temperature increase ($r = 0.765$, $p < 0.05$). This result led to the rejection of the null hypothesis, which stated that there is no significant relationship between urbanization and Urban Heat Island intensity in the South-South geopolitical zone. This finding confirms the works of Koko et al. (2021), Guo et al. (2022), Abimbola et al. (2025), and Odunsi and Rienow (2024), who demonstrated that urban expansion significantly contributes to rising land surface temperatures in Nigerian cities. The strength of the correlation suggests that urbanization is one of the most important determinants of temperature increase within the region.

The finding is also consistent with Urban Ecological Theory, which posits that urban development alters ecological systems through land-use changes and environmental exploitation. As cities expand, vegetation cover decreases while impervious surfaces increase, leading to greater heat absorption and retention. This strong relationship suggests that continued urban growth without adequate environmental planning will likely worsen Urban Heat Island effects and intensify environmental and health vulnerabilities in the South-South region.

Sustainable Mitigation Strategies

Based on the findings, sustainable mitigation measures are necessary to address the environmental and health challenges associated with Urban Heat Island and water footprint. The results support recommendations advanced by UNEP (2023), WHO (2021), and IPCC (2021), which advocate urban greening, climate-sensitive architecture, sustainable water management, urban forestry, improved waste management systems, and environmentally responsible industrial practices. The findings indicate that increasing vegetation cover, protecting wetlands, restoring urban forests, regulating industrial emissions, controlling oil pollution, and promoting efficient water-use practices can significantly reduce environmental and public health risks. These measures are essential for enhancing urban resilience and achieving sustainable development within the region.

This study demonstrates that Urban Heat Island and unsustainable water utilization constitute major environmental and public health challenges within the South-South geopolitical zone of Nigeria. Rapid urbanization, industrialization, and vegetation loss have significantly altered the thermal characteristics of urban environments within the region. The replacement of vegetation with impervious surfaces intensifies heat retention and environmental stress. Similarly, increasing water demand, environmental pollution, industrial waste, and oil exploration activities threaten freshwater sustainability and public health. The findings further reveal that climate change and local environmental degradation interact synergistically to intensify ecological vulnerability, thermal discomfort, and heat-related illnesses.

Conclusion

This study established that Urban Heat Island and Water Footprint are critical environmental sustainability and public health concerns in the South-South geopolitical zone of Nigeria. The findings demonstrated that rapid urbanization, industrialization, oil exploration activities, vegetation loss, and infrastructural expansion are major drivers of Urban Heat Island intensity in the region. The study further revealed that unsustainable water utilization, environmental pollution, and increasing freshwater demand contribute significantly to environmental degradation and water stress. The significant relationship between water footprint and environmental sustainability ($r = 0.600$) indicates that water resource management plays a crucial role in maintaining ecological balance and environmental quality. Similarly, the strong positive relationship between urbanization and temperature increase ($r = 0.765$) confirms that expanding urban development is a major factor responsible for rising temperatures and Urban Heat Island formation within the region.

The study also established that the combined effects of Urban Heat Island and water stress have serious consequences for environmental quality and human health, including air pollution, biodiversity loss, flooding, thermal discomfort, respiratory illnesses, cardiovascular complications, dehydration, and other heat-related health challenges. Overall, the evidence

suggests that environmental sustainability, water resource management, urban planning, and public health protection are closely interconnected. Therefore, achieving sustainable development in the South-South geopolitical zone requires integrated policies that promote climate-resilient urban planning, ecosystem conservation, sustainable water management, pollution control, and public health protection. Such interventions are essential for reducing environmental vulnerability and improving the quality of life of present and future generations.

Recommendations

1. State governments and local authorities should implement aggressive urban greening policies through the establishment of urban forests, green belts, parks, and roadside tree-planting initiatives. Since 81% of respondents identified vegetation loss as a major cause of Urban Heat Island, restoring green infrastructure will help reduce urban temperatures, improve air quality, conserve biodiversity, and enhance climate resilience in rapidly growing cities such as Port Harcourt, Uyo, Calabar, Benin City, Warri, and Yenagoa.
2. Urban planning authorities should make climate-responsive land-use planning mandatory by incorporating green spaces, permeable surfaces, green roofs, and environmentally sustainable building designs into city master plans. Given the strong relationship between urbanization and temperature increase ($r = 0.765$), future urban expansion should be guided by environmental impact assessments and sustainable development principles to minimize heat accumulation and ecological degradation.
3. Federal and state governments should develop comprehensive water footprint management frameworks aimed at promoting efficient water use in households, industries, agriculture, and commercial establishments. Water conservation technologies, rainwater harvesting systems, wastewater recycling, and sustainable groundwater management should be encouraged to reduce freshwater stress and enhance long-term environmental sustainability.

4. Environmental regulatory agencies should strengthen monitoring and enforcement of pollution control laws, particularly in oil-producing and industrial areas of the Niger Delta. Strict sanctions should be imposed on industries responsible for oil spills, untreated effluent discharge, gas flaring, and environmental contamination. This recommendation is necessary because the study identified industrial waste, oil exploration activities, and pollution as major contributors to water stress, environmental degradation, and public health risks.
5. Public health authorities should develop regional Heat Health Action Plans to protect vulnerable populations from heat-related illnesses. Such plans should include heat early-warning systems, public awareness campaigns, emergency cooling centres, community health surveillance, and occupational safety measures for outdoor workers. This is particularly important because 73% of respondents reported excessive heat discomfort and a significant proportion experienced respiratory and cardiovascular health challenges associated with environmental stress.
6. Governments should improve urban drainage systems, wetland conservation programs, and flood-control infrastructure to reduce flooding and protect water resources. Since Urban Heat Island effects were found to contribute to flooding, poor water quality, and environmental degradation, investments in climate-resilient infrastructure will enhance urban environmental sustainability and reduce disaster risks across the region.
7. Environmental sustainability programs should be integrated into school curricula, community development initiatives, and public awareness campaigns. Citizens should be educated on water conservation, waste management, urban greening, and climate adaptation practices. In addition, governments should support continuous research, GIS-based environmental monitoring, and data-driven policy development to track Urban Heat Island intensity, water footprint trends, and emerging environmental health challenges across the South-South region.

Policy Direction Summary

The findings of this study suggest that environmental sustainability and public health in the South-South geopolitical zone cannot be achieved without integrated policies that simultaneously address urbanization, water resource management, pollution control, climate adaptation, and ecosystem restoration. Policymakers should therefore adopt a multi-sectoral approach that links environmental management, urban planning, public health, and sustainable development in order to reduce Urban Heat Island intensity, improve freshwater sustainability, and enhance the well-being of present and future generations.

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