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ANALYSIS OF THE EFFECT OF POPULATION GROWTH ON LAND SURFACE TEMPERATURE IN LOKOJA METROPOLIS

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Abstract

Understanding the impact of population growth on trends in Land Surface Temperature (LST) necessitates a comprehensive examination of changes in Land Use and Land Cover (LULC). As populations expand, various land covers undergo alterations to meet escalating demands. This study seeks to evaluate the hypothesis that population growth influences LST trends. Population data for Lokoja spanning 1991-2021, sourced from the United Nations World Population Review, was analyzed alongside LULC changes utilizing Landsat 5TM, 7ETM+, and Landsat 9 OLI/TIRS images. Five classes—Built-up areas, Vegetation, Waterbodies, Rock outcrops, and Bare land surface—were classified to signify population growth and changes. LST trends were derived using the Radiative Transfer Method, with yearly averages calculated. Analysis revealed a remarkable urban growth of over 200% in Lokoja from 1991 to 2021, juxtaposed with a declining natural vegetation cover of -18%. Built-up areas showed commensurate growth, driven by increased housing demand. Regression analysis confirmed a significant relationship between population growth and LST trends (multiple R = 0.905), with strong coefficients indicating this association. The study underscores the substantial population increase and consequential land cover alterations in the region, alongside observable shifts in LST trends. Notably, built-up areas emerged as prominent contributors to LST, prompting recommendations for the adoption of reflective roofing materials to mitigate urban heat islands and the preservation of green spaces to counterbalance urbanization effects.

Keywords: Land surface temperature, Population growth, Urban heat island

INTRODUCTION

The unprecedented growth of the global human population has led to a remarkable expansion of urban areas, causing significant alterations to land use patterns and ecological systems. This expansion, driven by factors such as improved economic opportunities and better living conditions in urban areas, has resulted in the transformation of natural landscapes into built environments, leading to changes in climatic conditions (Azar, 1986).

According to Azar (1986), Changes in climatic conditions, including alterations in land surface temperature (LST), are influenced by both natural and anthropogenic factors. The rapid population growth has created demands for various necessities such as food, shelter, and transportation infrastructure, resulting in the modification of the natural environment. These changes altered the chemical composition of the atmosphere and changes in the temperature leading to changes in the thermal and hydrological properties of the earth's surface and also the aerodynamic roughness parameters, for instance, marshes are drained, local vegetation is removed and soil is turned as natural surfaces are replaced by more impervious surfaces such as pavements, tarred roads, and building roofs (Ngie et al., 2017). In summary, these modifications, including the replacement of natural surfaces with impervious materials like roads and buildings, contribute to changes in LST and other climatic parameters (Pickett & Pearl, 2001).

The most significant characteristics of man's induced changes in the urban environment are the variation in thermal properties of the built-up land surfaces, soil, and impervious surfaces which result in more solar energy being stored and converted to sensible heat, and also the removal of shrubs and trees which serve as a natural cooling effect of shading and evapotranspiration (Pickett & Pearl, 2001) thus, contributing to the reduction in outgoing longwave radiation by hindering the loss of sensible heat and distribution of heat (Oke, 1982).

Land surface temperature (LST) is a key parameter for surface energy balance and urban climatology studies. LST is affected by the characteristics of the land surface such as vegetation cover and its type, land uses land cover, and surface imperviousness (Khandelwal et al, 2017). This then leads to the increase in sensible heat flux at the expense of latent heat flux, thereby forcing the development of meteorological events such as increased precipitation, which poses a threat to the environment and the human population (Zhao & Wang, 2001). It exacerbates urban air pollution, alters rainfall patterns in and around urban centres, and changes the composition of biodiversity (Nowak et al, 2002) However, it also contributes to global warming (Changnon, 1992). The importance of Land Surface Temperature is being increasingly recognized because many of the changes on the Earth's surface are caused by changes in temperature as greenhouse gases in the atmosphere increase in proportion to the temperature of the surface increases. This will result in the melting of glaciers and ice sheets and affect the vegetation of that area (Kamaran, 2015).

With remote sensing and GIS, it has become very cost-effective to study and analyze land surface temperature (LST) from satellite images, it has become more attractive because remotely sensed data are almost in real-time, and cover a large area (Ngie et al., 2017). Technological advancements and free availability of these satellite data have translated into a growing base of studies through the LST estimation establishing the existence of the UHI phenomenon within cities across the globe. With remote sensing and GIS one can easily acquire Landsat images from the internet and analyze changes in land cover as a population continues to increase over time, also using Landsat images to estimate and relate the way these changes influence land surface temperature, this is what this research will be looking to study.

Statement of Problem

The rapid growth of Lokoja town in recent years, fueled by a burgeoning human population and extensive infrastructural development, has triggered significant changes in its land use/cover patterns. The natural vegetation that once characterized the environment is being displaced by materials with high thermal properties, such as tarred roads, concrete walls, and pavements. This transformation raises concerns about the potential escalation of temperature trends within Lokoja, as indicated by recent studies (Laosuwan et al., 2016).

As the administrative hub of the state, Lokoja's land use dynamics are further compounded by increased human activities, including manufacturing, fossil fuel consumption, and construction. These factors contribute to the altering of the town's temperature profile over time, exacerbating the urban heat island effect and potentially impacting local climate conditions.

To address these challenges, leveraging the capabilities of remote sensing and Geographic Information Systems (GIS) emerges as a promising approach. By harnessing multi-spectral, multiresolution, and multi-temporal data from Landsat images, GIS and remote sensing techniques offer a powerful means to analyze and monitor changes in land use/cover. The objective of this study is to explore the complex interplay among population growth, changes in land use patterns, and shifts in surface temperature trends within Lokoja. These findings hold significant importance in guiding sustainable urban planning efforts and mitigating the negative impacts of swift urban expansion on the local climate environment.

The primary goal of this study is to assess how population growth has influenced the surface temperature trend of Lokoja over the past three decades. To accomplish this goal, the following specific objectives are outlined:

i. To analyze the effects of population growth on changes in land use and land cover within the region during the last three decades.
ii. To investigate the trends in surface temperature within the region over the past three decades.
iii. To ascertain the relationship between population growth, changes in land cover, and their combined impact on surface temperature trends over the last three decades.

Conceptual Framework

The conceptual framework of this study revolves around understanding the intricate dynamics of population growth and distribution, and their influence on land use/land cover patterns and surface temperature trends.

Population Growth

Population growth, as defined by the United Nations, refers to the increase in the size of a population over time, driven by factors such as innovations, industrialization, and advancements in energy, food, water, and medical care availability (United Nations, 2015). The global human population has experienced rapid growth, with significant implications for climate and temperature trends.

Population distribution, on the other hand, according to Boruah (2011), pertains to the spatial pattern of population dispersal, agglomeration, and linear spread across regions. Regional variations in population densities are influenced by factors such as physical conditions, socioeconomic opportunities, demographic trends, and political factors. The factors influencing population growth and distribution can be broadly categorized into physical, socio-economic, demographic, and political factors (Lonkham, 2011).

Physical factors include climate, topography, water availability, soil quality, and accessibility of a place. Climate, for instance, influences agriculture, vegetation, and the distribution of flora and fauna. Topography affects the availability of arable land and influences population density. Adequate water supply and soil quality are essential for supporting agriculture, a significant source of livelihood for many populations. In summary, physical factors play a significant role in shaping the characteristics of a place, including its ecosystem, population, and economy. They are interrelated and their effects can often be seen in the lifestyle and activities of the people living in the area. (Lonkham, 2011).

Social and economic factors also heavily influence population distribution. Economic activities, such as agriculture and industry, serve as drivers of population growth, particularly in urban areas where employment opportunities are abundant (United Nations, 2015). Demographic factors such as migration, fertility, and mortality rates also play a significant role in population dynamics (United Nations, 2015). These factors according to Wears, (2013), alongside political factors such as war, political conflicts, and government policies, can significantly impact population growth

Understanding these factors is essential for analyzing the impact of population growth on land use/land cover dynamics and surface temperature trends. By examining how these factors interact and influence each other, researchers can gain insights into the complex relationships between human activities, environmental changes, and climate dynamics.

Land Use and Land Cover (LULC)

Land cover refers to the physical material at the surface of the Earth, including natural vegetation, crops, water bodies, and human-made structures. Land use, on the other hand, refers to the activities and functions humans engage in on the land cover, such as agriculture, urban development, and infrastructure (Fresco et al., 1994). Changes in land use and land cover have profound effects on the natural environment, including interactions with the atmosphere, aquatic systems, and surrounding land. These changes can occur through conversion from one land cover category to another or alterations within a specific land cover category (Wiliam et al., 1992). Human activities such as agriculture, deforestation, urbanization, and construction have significantly altered land cover globally, with vegetation cover being particularly impacted (Ifeoluwa et al., 2011; Adesina et al., 1999).

The increasing global population has led to a significant migration of people to urban areas. It is projected that by the mid-21st century, nearly two-thirds of the world's population will reside in urban areas, with a considerable portion in developing countries experiencing rapid urbanization (UNDP, 1994).

Urbanization has resulted in the transformation of natural landscapes into built environments, characterized by the clearing of vegetation and the construction of roads and buildings. This alteration in land cover leads to changes in land surface temperature (LST), as urban areas tend to have higher temperatures compared to natural environments due to the heat-retaining properties of built surfaces (Gill et al., 2007). Liu & Zhang (2011), opined that understanding the dynamics of urban temperature trends is crucial due to their implications for local climate dynamics and human health. Remote sensing and geographic information system (GIS) techniques offer valuable tools for studying these trends by estimating land surface temperatures from satellite data. By analyzing the relationship between land cover types and LST, researchers can assess the impact of land use changes on temperature trends over time.

In summary, the relationship between population growth, land use/land cover changes, and land surface temperature trends underscores the need for sustainable urban planning practices to mitigate the adverse effects of urbanization on local climates and ecosystems.

Study Area

Lokoja, known as the "confluence city," serves as the administrative capital of Kogi State. Situated between latitudes 7°45'N and 7°51'N and longitudes 6°41'E and 6°45'E, Lokoja lies within the lower Niger trough, proximate to the confluence of the Niger and Benue Rivers (see figure 1). It encompasses an estimated landmass of approximately 63.82 square kilometres. Positioned amidst two prominent geographical features—the Niger River and Mount Patti—Lokoja's terrain varies from about 300 meters near the Niger-Benue confluence to elevations ranging from 300 to 600 meters above sea level in the uplands. The town shares boundaries with Niger, Kwara, and Nasarawa states, as well as the Federal Capital Territory to the north; Benue state to the east; and Kehi and Kabba Bunu Local Government Areas (LGAs) to the south and west, respectively (Adeoye, 2012).

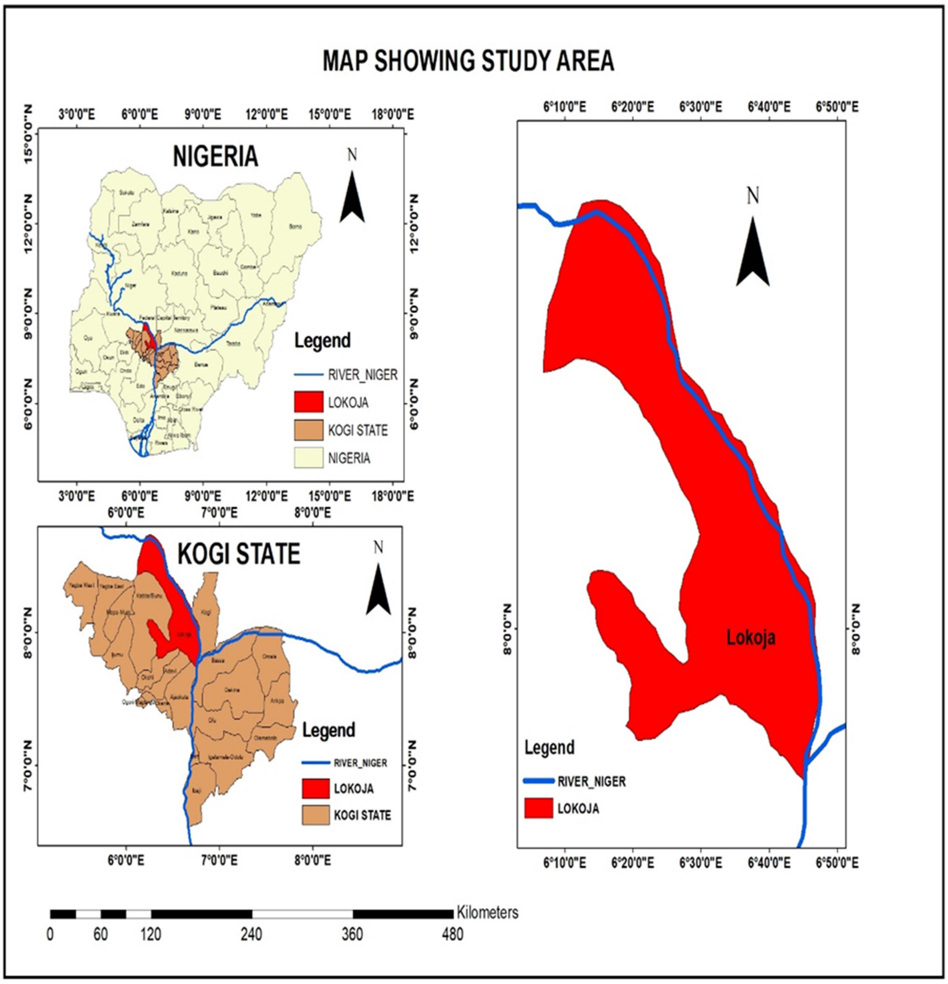

Figure 1: Map of the study area

METHODOLOGY

The methodology for this research aims to provide a comprehensive understanding of how population growth influences surface temperature trends in Lokoja, enabling informed decision-making for sustainable development and climate resilience.

Data Collection

i. Population Data: Historical population data for Lokoja spanning the last three decades from reputable sources such as national census reports, and municipal records, was obtained.
ii. Surface Temperature Data: The surface temperature data for Lokoja over the same period from reliable sources such as satellite imagery which is a remote sensing dataset was

acquired. The temperature data capture variations across different seasons and land cover types.

iii. The digital data that was used for the calculation of land surface temperature is the thermal band, which was sourced from Landsat 5 TM, Landsat 7 ETM, and Landsat 9 OLI/TIRS sensors.

Land Use/Land Cover Analysis

Remote sensing techniques and Geographic Information System (GIS) tools were used to analyze changes in land use and land cover in Lokoja over the study period. The satellite imagery was processed to classify land cover types, including Built-up areas, Vegetation, Water bodies, Bare Rock surface and bare land surface. The extent of urbanization, deforestation, agricultural expansion, and other land use changes influenced by population growth were determined.

Land Use/Cover Classification Methodology

The land use/cover classification was conducted using ArcGIS 10.8 software. The process involved the utilization of Landsat satellite imagery, specifically Landsat 5TM, Landsat 7ETM, and Landsat 8OLI/TIRS images. A supervised classification approach was adopted to accurately delineate and classify different land cover types within the study area.

Procedure

i. Image Selection: Landsat imagery spanning the study period was acquired and pre-processed to ensure uniformity and compatibility across different sensors.
ii. Band Combination: The spectral bands ranging from Band 1 to Band 7 were selected for each Landsat image. These bands were combined in an optimized sequence to enhance the discrimination of various land cover features.
iii. Supervised Classification: A supervised classification algorithm was implemented in ArcGIS to classify the combined Landsat images into distinct land cover classes. Training samples representing each land cover class were selected based on spectral signatures and ground truth data.
iv. Selection of Land Cover Classes: Five primary land cover classes were identified and classified within the study area: Built-up areas, Vegetation, Water bodies, Bare rock surface, Bare land surface
v. Training and Validation: Training sites were designated within the study area to teach the classification algorithm to differentiate between different land cover types. Additionally, validation points were randomly selected to assess the accuracy of the classification results.

The accuracy of the land cover classification was evaluated using error matrices and confusion matrices. This involved comparing the classified land cover map with reference data or high-resolution imagery to quantify the classification accuracy.

The land use/cover classification methodology employed ArcGIS software and Landsat satellite imagery to accurately delineate and classify different land cover types in the study area. This approach enabled the identification of key land cover classes, including built-up areas, vegetation, water bodies, bare rock surface, and bare land surface, contributing to a comprehensive understanding of land use dynamics and environmental changes over time.

Methods of Deriving Land Surface Temperature (LST)

In this study, the Radiative Transfer Method was employed to derive Land Surface Temperature (LST). For this, the following sequential steps were adopted:

Step 1: Calculation of Top of Atmosphere (TOA) Spectral Radiance: The TOA spectral radiance was calculated using the following equation: TOA = (ML * Qcal) + AL

Where TOA is the top of atmosphere spectral radiance, ML is the band-specific multiplicative rescaling factor from the metadata, Qcal corresponds to band 10, and AL is the band-specific additive rescaling factor from metadata. This equation was solved using the raster calculator tool in ArcMap.

Step 2: TOA to Brightness Temperature Conversion: After converting DN (digital number) values to at-sensor spectral radiance, the TIRS, TM/ETM band data will be converted to brightness temperature (BT) using the following equation: BT = (K2 / ln((K1 / L) + 1))

Where L is the spectral radiance of the thermal band, BT is the brightness temperature; K1 and K2 are calibration constants;

Step 3: Calculation of Normalized Difference Vegetation Index (NDVI): NDVI will be calculated to identify different land cover types within the study area. NDVI ranges between -1.0 to +1.0 and will be calculated on a per-pixel basis using the formula: NDVI = (NIR - Red) / (NIR + Red)

Where NIR is the near-infrared band (0.85-0.88 µm); Red is the red band (0.64 - 0.67 µm).

These methods enabled the derivation of Land Surface Temperature (LST) and the assessment of vegetation cover within the study area, contributing to a comprehensive understanding of surface temperature dynamics and land cover characteristics.

RESULT AND DISCUSSION

Analysing population growth about changes in land use/ land cover in Lokoja

Through extensive research and analysis carried out, it is evident that Lokoja town has undergone significant expansion and development between 1991 and 2021 as shown in the results below.

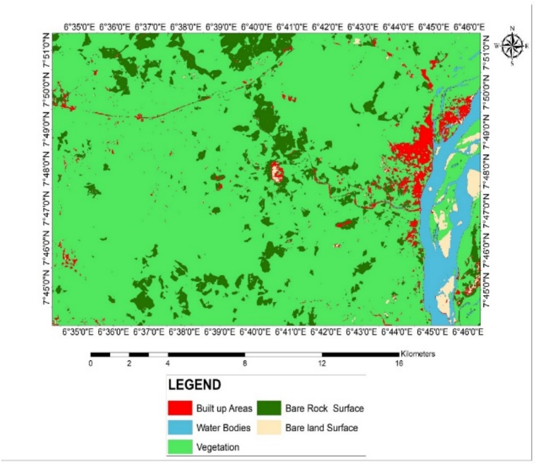

Figure 2: 1991 LULC
Source: 1991 Landsat 5TM imagery

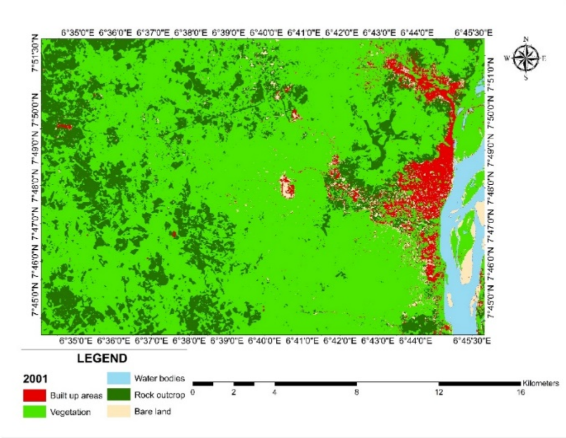

Figure 3: 2001 LULC
Source: 2001 Landsat 7 ETM imagery

The Landsat imagery classification conducted for Lokoja between 1991 and 2001 revealed notable changes in land cover, particularly in built-up areas and vegetation. The findings are in tandem with that of Timothy et al., (2023). In 1991 (Figure 2), the built-up area covered approximately 10.73 sqkm, while by 2001 (Figure 3), it expanded to 13.6 sqkm. Conversely, vegetation coverage decreased from 301.6 sqkm in 1991 to 255.5 sqkm in 2001. Water bodies reduced from 18.4 sqkm in 1991 to 13.4 sqkm in 2001. Additionally, the bare rock surface expanded from 38.1 sqkm in 1991 to 78.4 sqkm in 2001, while the bare land surface increased from 5.6 sqkm to 9.7 sq km during the same period.

This land cover distribution paints a picture of Lokoja in the early 1990s as a small town situated at the confluence of the River Niger and River Benue. At this time, Lokoja had recently been designated the capital of Kogi state, with a relatively low population of about 75,715 and a growth rate of 8.70%. Agricultural activities, particularly farming and fishing, were the primary occupations and sources of livelihood (Areola, 2004). However, by 2001, the town's population had surged to approximately 161,921, with a growth rate of 8.06%. This population growth was attributed to increased administrative activities and employment opportunities stemming from the town's new status as the state capital, attracting migrants from across the state. Consequently, the expansion of built-up areas mirrored the population growth, as indicated in Table 1.

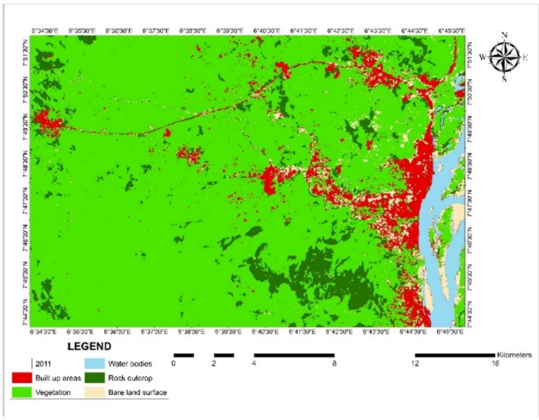

Figure 4: 2011 LULC
Source: 2011 Landsat 7 ETM imagery

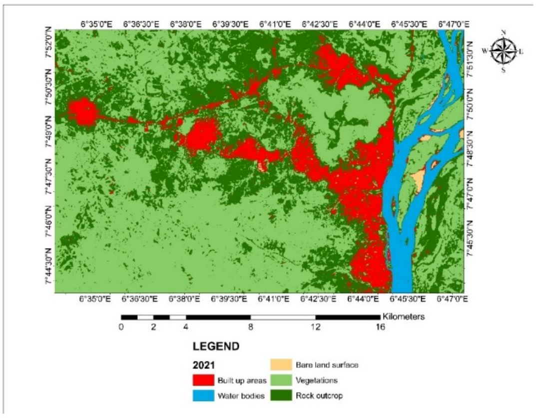

Figure 5:2021 LULC
Source: 2021 Landsat 9 OLI/TIRS imagery

In 2011, Lokoja witnessed a substantial surge in its population, soaring from 161,921 in 2001 to approximately 348,798 in 2011, reflecting a growth rate of 8.07%. This significant population increase is anticipated to create a demand for residential spaces. Consequently, there was a corresponding expansion in the extent of built-up areas to accommodate the burgeoning population, as depicted in Figure 4.

Table 1: Population of Lokoja (1991-2021)

YEAR	SIZE	GROWTH RATE
1991	75,715	8.70%
2001	160,921	8.05%
2011	347,798	8.07%
2021	741,482	7.08%

Source: World population review.

Table 2: Land Use/Land Cover For Lokoja From 1991-2021 (SqKm)

	Area (SqKm) and Percentage(%)							
Classes	**1991**	**%**	**2001**	**%**	**2011**	**%**	**2021**	**%**
Built up areas	10.73	2.87	13.6	3.67	22.4	7.21	42.6	9.29
Vegetations	301.6	80.54	255.5	68.94	234.1	75.3	246.4	53.8
water bodies	18.6	4.91	13.4	3.61	13.5	4.34	24	5.24
Rock outcrop	38.1	10.18	78.4	21.16	32.5	10.45	142.1	31
Bare land surface	5.6	1.5	9.7	2.62	8.4	2.7	3.1	0.67
TOTAL	374.43	100	370.6	100	310.9	100	458.4	100

Source: Fieldwork (2021)

Table 3: Percentage Change (1991-2021)

	Year and Percentage					
CLASSES	**1991-2001**	**%**	**2001-2011**	**%**	**2011-2021**	**%**
Built up areas	2.87	26.7	8.8	64.7	20.2	90.2
Vegetation	-46.1	-15.3	-21	-8.4	12.3	5.1
Water bodies	-5	-28	0.1	7.5	10.5	77.8
Rock outcrop	40.3	105.8	-45.9	-58.5	109.6	337.2
Bare land surface	4.1	73.2	-1.3	-13.4	-5.3	-63.1

Source: Fieldwork (2021)

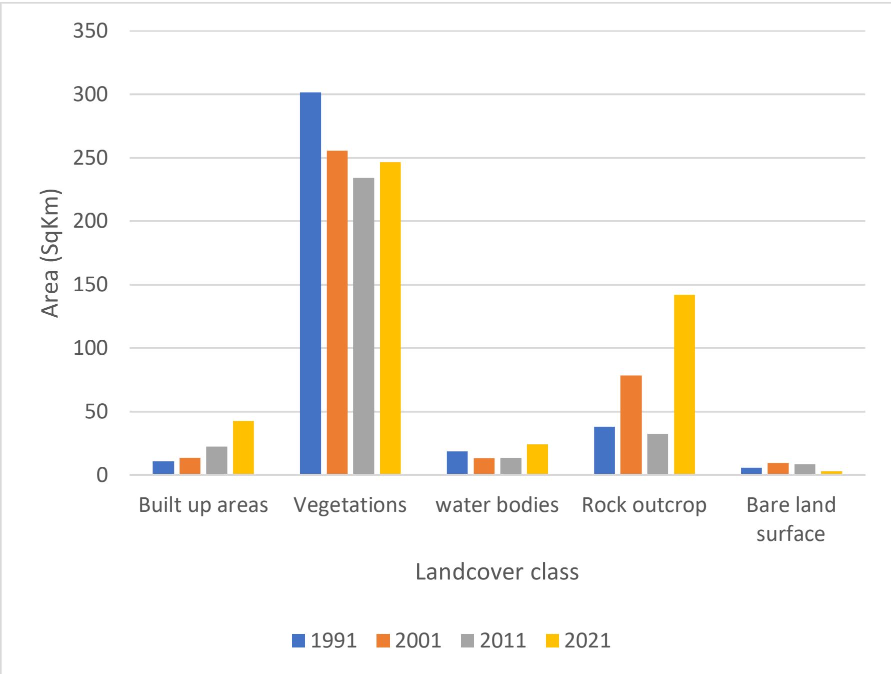

Figure 6: Land Use/Land Cover For Lokoja From 1991-2021 (Sqkm)

Source: Fieldwork (2021)

The built-up areas expanded from 22.4 Sqkm in 2011 to 42.6 sqkm in 2021, while vegetation covered 234.1 Sqkm in 2011 and slightly increased to 246.4 Sqkm in 2021. Water bodies occupied 13.5 Sqkm in 2011 and expanded to 24.0 Sqkm in 2021. Additionally, the bare rock surface extended from 32.5 Sqkm in 2011 to 142.1 Sqkm in 2021, whereas the bare land surface decreased from 8.4 sqkm in 2011 to 3.1 Sqkm in 2021.

The rise in population size has driven the growth of Lokoja, resulting in increased demand for housing and subsequent expansion of built-up areas. This expansion has led to the clearing of natural vegetation, contributing to land degradation.

Over 30 years from 1991 to 2021, the population of Lokoja surged dramatically from 75,715 to an estimated 741,482, representing a remarkable increase of 666,000 individuals. This population growth has significantly impacted the town's landscape, with notable alterations observed in various land cover categories.

Between 1991 and 2001, built-up areas increased by 26.7%, vegetation decreased by 15.3%, water bodies decreased by 28.0%, bare rock surface increased by 105.8%, and bare land surface increased by 75.2%. The period from 2001 to 2011 witnessed further substantial changes, attributed to Lokoja's emergence as a major commercial hub due to its strategic road network linking various parts of the country. During this period, built-up areas expanded by 64.7%, vegetation decreased by 8.4%, water bodies increased by 7.5%, bare rock surface decreased by 58.5%, and bare land surface decreased by 13.4%.

From 2011 to 2021, the trend continued with a 90% increase in built-up areas, a 5.1% increase in vegetation cover, a 77.78% increase in water bodies, a significant 337.2% increase in bare rock surface, and a notable 63.1% decrease in bare land surface. These changes reflect the ongoing urbanization and development of Lokoja, characterized by intensified construction activities and land use transformations.

Land Surface Temperature Trend In Lokoja Over The Study Period Of 1991-2021.

The analysis of Landsat images reveals a gradual rise in land surface temperature in Lokoja throughout the study period. Details of the data are presented in Table 4.

Table 4: Land Surface Temperature Trend

	Land Surface Temperature Trend (°C)		
	Low	**High**	**Average**
1991	21	34.1	27.5
2001	21.5	37.6	29.6
2011	21.8	39.1	30.5
2021	25	38.5	31.8

Source: Fieldwork (2021)

According to the data provided in Table 4.4, the land surface temperature in 1991 ranged from a low of 21.0°C to a high of 34.1°C, averaging 27.5°C. In 2001, the temperature showed a low of

21.5°C and a high of 37.6°C, with an average of 29.6°C. By 2011, the temperature range was from 21.8°C to 39.1°C, with an average of 30.5°C. In 2021, there was a noticeable increase, with a low of 25.1°C, a high of 38.0°C, and a higher average of 31.8°C, indicating a discernible shift and overall rise in the average temperature.

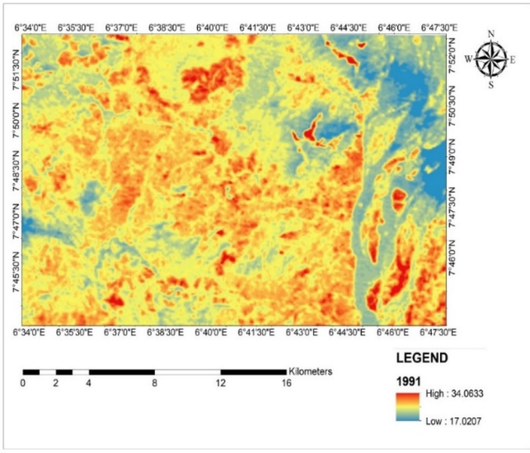

Figure 7: 1991 LST
Source: 1991 Landsat 5TM imagery

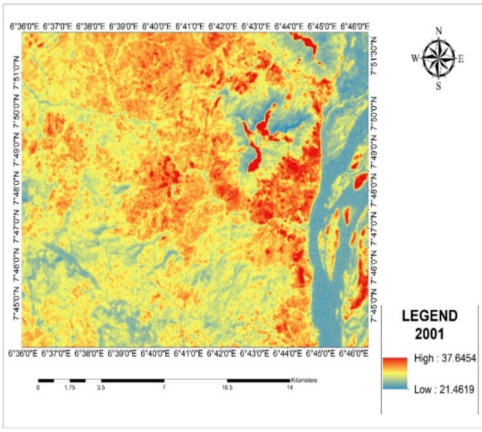

Figure 8: 2001 LST
Source: 2001 Landsat 7ETM imagery

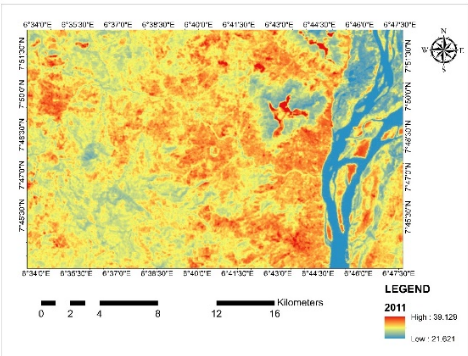

Figure 9: 2011 LST
Source: 2011 Landsat 7ETM imagery

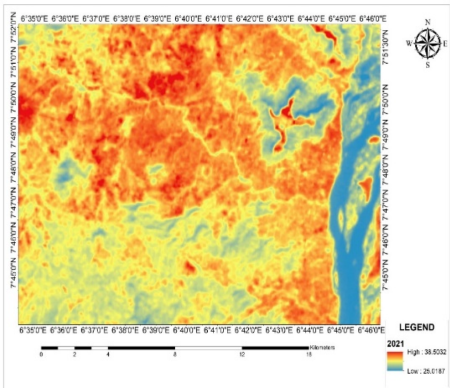

Figure 10: 2021 LST
Source: 2021 Landsat 9 OLI/TIRS imagery/

Between 1991 and 2021, there has been a notable 12% change rate in land surface temperature. This change is closely linked to significant alterations in land use and land cover patterns observed in Lokoja. Particularly, the ongoing expansion of built-up areas coupled with the decline in vegetative cover has played a crucial role in influencing the trend of land surface temperature (LST) in the area. Analysis of heat maps from Figure 4.6 to Figure 4.9 reveals a conspicuous correlation between built-up areas and LST, with these areas depicted by a prominent red colouration on the maps.

In 1991, when the population size was relatively low at 75,715, built-up areas covered a mere 2.87% of the land, resulting in a relatively even and low-temperature distribution. However, with the substantial increase in population to approximately 741,482 by 2021, built-up areas underwent a staggering 90% expansion, encompassing 42.6 sq km of land. This expansion is reflected in the 2021 LST map (Figure 4.9), where built-up areas emerge as major contributors to the heightened surface temperature trend.

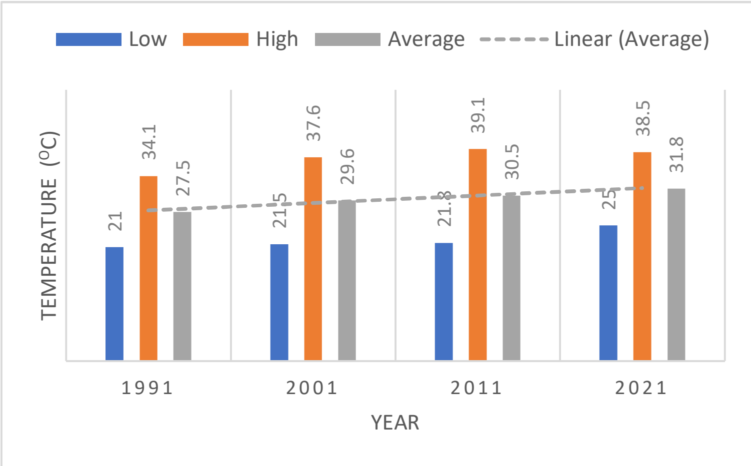

Figure 11: LST
Source: Landsat LST imagery analysis

Relationship between Population Growth and Land Surface Temperature Trend between 1991 and 2021

The analysis below reveals a correlation between the rising population and an upward trend in Land Surface Temperature (LST). In 1991, with a population size of 75,715, the average land surface temperature was recorded at 27.5°C. This period exhibited a considerable amount of vegetative cover, contributing to the regulation of surface temperature, along with a limited extent of built-up areas.

Table 5: Relationship between Population Growth and Land Surface Temperature

YEAR	POPULATION	TEMPERATURE
1991	75,715	27.5°C
2001	160,921	29.6°C
2011	347,798	30.5°C
2021	741,482	31.8°C

Source: Adapted from World Population Review and Landsat imagery LST Analysis

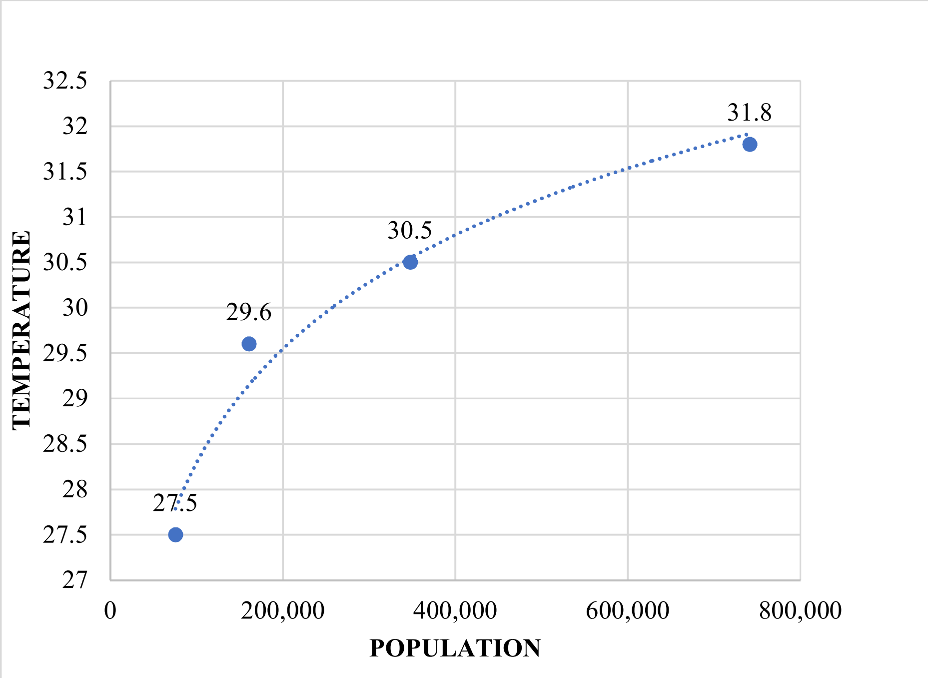

Figure 6: Lokoja Population against LST(1991-2021)

Source: Landsat LST imagery analysis

The depicted graph unmistakably illustrates a positive correlation between population growth and the trend in Land Surface Temperature (LST). This relationship underscores the notion that as the population expands, accompanied by alterations in land cover and land use, the Land Surface Temperature trend also experiences an increase. This observation aligns with numerous studies highlighting the intricate interplay between population dynamics and environmental factors, including land surface temperature (Liu & Zhang 2011). The burgeoning population exerts pressure on land resources, leading to changes in land cover patterns such as urbanization and deforestation, which subsequently influence surface temperature dynamics (Seto et al., 2012; Wu et al., 2014). Therefore, understanding the linkages between population growth and LST trends is pivotal for effective land management and climate change mitigation strategies.

CONCLUSION

Urban growth, driven by the surging demand for residential spaces amidst rapidly expanding populations, stands out as a significant contributor to the escalation of land surface temperature. The research underscores that urban growth and expansion in Lokoja have witnessed a remarkable surge between 1991 and 2021, marked by an astonishing growth rate exceeding 200%. Concurrently, the natural vegetation cover has experienced a notable decline, registering a change rate of -18% over the same study period. This trend is intricately linked to the burgeoning population, which fuels the demand for housing and other urban amenities.

As population numbers soar, the built-up areas undergo substantial expansion, reflecting the need to accommodate the burgeoning populace. This phenomenon is closely associated with the observed changes in land surface temperature. The surge in population triggers a cascade of demands for housing and infrastructure, prompting the displacement of natural vegetation that plays a crucial role in regulating and mitigating surface temperatures. Consequently, the displacement of natural vegetation by impervious surfaces such as pavements and buildings contributes significantly to the observed rise in land surface temperature.

This nexus between urban growth, population dynamics, and land surface temperature trends underscores the complex interplay between human activities and environmental changes. Understanding these relationships is pivotal for devising effective urban planning strategies aimed at mitigating the adverse impacts of urbanization on local climate and ecosystem dynamics (Seto et al., 2012; Liu & Zhang 2011). Additionally, incorporating sustainable land management practices and green infrastructure initiatives can help alleviate the urban heat island effect and promote environmental sustainability in rapidly growing urban centres (Heisler, 2014; Song et al., 2018).

RECOMMENDATIONS

Based on the findings highlighting the significant relationship between urban growth, population dynamics, and land surface temperature trends, several recommendations can be proposed to address the challenges posed by urbanization-induced heat islands and environmental degradation:

i. Implement Sustainable Urban Planning: Adopting sustainable urban planning practices is essential to manage urban growth and mitigate the adverse impacts on land surface temperature. This includes zoning regulations, land use planning, and infrastructure development that prioritize green spaces, reduce impervious surfaces, and promote compact urban forms to minimize heat retention (Beatley, 2011).
ii. Preserve and Enhance Natural Vegetation: Efforts should be made to protect and enhance natural vegetation cover within urban areas. Urban forestry initiatives, such as tree planting programs and green corridors, can help mitigate the urban heat island effect by providing shade, reducing surface temperatures, and improving air quality (Nowak et al., 2006).
iii. Enhance Climate Adaptation and Resilience: Develop and implement climate adaptation strategies and resilience measures to address the impacts of climate change on urban areas. This includes enhancing drainage systems, fortifying infrastructure against extreme weather events, and integrating climate considerations into urban planning processes (UN-Habitat, 2019).
iv. Foster Community Engagement and Education: Engaging local communities through public awareness campaigns, education programs, and participatory planning processes fosters collective action and promotes environmental stewardship. Empowering residents

to adopt sustainable practices, such as water conservation, waste management, and energy efficiency measures, can contribute to mitigating urban heat island effects and enhancing environmental sustainability (Bulkeley & Betsill, 2005).

v. Invest in Research and Innovation: Support research and innovation in sustainable urban development, climate adaptation, and environmental conservation. Foster collaboration between academia, government agencies, and private sector entities to develop innovative solutions, technologies, and best practices for addressing the complex challenges associated with urbanization and climate change (Bulkeley et al., 2019).

By implementing these comprehensive strategies, policymakers, urban planners, and stakeholders can effectively address the challenges posed by population growth on land surface temperature trends, promote sustainable urban development, and enhance resilience to climate change in Lokoja and across Nigeria.

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