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Relationship between Urban Growth and Temperature Rise in Gwagwalada, Abuja, Nigeria

Y.A. Abbas, O.O Morenikeji, M. Dalil and H.D. Musa
Department of Urban and Regional Planning, Federal University of Technology, Minna, Niger State, Nigeria

Abstract
Urbanization can be seen as an increase in the proportion or share of the population residing in urban area as opposed to rural areas. The spatial dimension of urban growth pattern could be perceived to as negative which could have irreversible impact on the sustainability of the environment and human. This paper aimed at assessing the relationship between urban growth temperature rise in Gwagwalada area of Abuja. Landsat Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+) and Landsat-8 Operational Land imager (OLI) images of 2010 and 2021 were used. Land use land cover maps were generated using supervised classification. The study revealed that for the past 12 years, Gwagwalada has been experiencing tremendous urban growth. The study showed that built up is increasing at an annual rate of over 8.7% while the land surface temperature (LST) has increase by 5℃ between 2010 and 2022. The study also recommends that biophilic design should be adopted by the Federal Capital Territory Administration (FCTA) administration in Gwagwalada revised master plan to help mitigate LST and improve the livability of the resident.

Keywords: Urban Growth, Land Surface Temperature, Remote Sensing, Built up Area.

Introduction
Most cities in Nigeria are growing faster which brings up rapid expansion due to rise of population, increasing demand for additional on natural resources (Aliyu and Amadu, 2017). Due to this acceleration of urbanization in Federal Capital Territory, Abuja with the need for housing, industries and construction materials increases has brought about several environmental problems including loss of arable land, habitat destruction, decline in natural vegetation cover and climatic change (Mohan *et al.*, 2011). This process is an indicator of

development which generally has a negative impact on the environmental health of the area due land use change phenomena that is taking place. The advent of vegetal cover has resulted in increasing surface temperature in modern cities due to built-up impermeable surfaces and high-rise buildings constructed with heavy metal use as opposed to neighbouring rural landscapes characterized by land cover and pervious surfaces. However, the rapid depletion of vegetated resources at the expense of non-evaporated land uses such as concrete, asphalt, and other impermeable materials is significantly contributing to the rise in surface temperature in Abuja. According to a European Environment Agency (2003) investigation on the effect of temperature rise in big European cities, any city with a population of one million or more is likely to suffer an increase in the average temperature of 1°C -3°C as a result of urban expansion. It is one this premise the study tends to study the relationship between urban and temperature rise in Abuja.

The Study Area

The Federal Capital Territory (FCT), covers an area of about 8,000sqkm; with coordinates 9º4°0 'N and 7°29°0"E. The capital shares its boundary with Niger, Kaduna, Nassarawa and Kogi State from which the FCT was carved out. The FCT, therefore, shares some of the attributes of the two zones, thus making it a fascinating area for urban development. The quest for a new Federal Capital began on the 9th August 1975 with the setting up of the then Aguda Panel to examine the dual role of Lagos as the Federal and State capital and was advised on the desirability or otherwise of Lagos holding that role as state and federal capital. The Aguda Panel was, among other things, to recommend which of the two governments, Federal or State, should move to a new location in the circumstance of finding Lagos unsuitable for its dual role (Obateru, 2004). Where they decided that the Federal should move, a suitable location should be recommended. The report declared Lagos as unfit and no longer capable of shouldering the dual role of being the commercial and industrial nerve centre of the country. It recommended that the Federal Capital be moved from Lagos and sited in a vast virgin territory in the country's heartland. The decision to move the federal capital to Abuja was taken in 1976 by the then Federal Military Government after accepting the panel report (FCDA, 2009).

The Abuja Master Plan, conceived the Federal Capital City to accommodate an estimated population of 157,750 people upon its inauguration in 1986, then 485,660 persons in 1990, 1,005,800 persons in 1995 and 1,642,100 persons in 2000 and it's expected to reach its maximum estimated population of 3.1 million by 2009 (FCDA, 1979). Between the year 2000 and 2010 made Abuja the fastest growing city in the country, with an annual growth rate of 9.3% (Udeh, 2010). The factors responsible for the choice of Abuja where central location and easy accessibility from all parts of the country, healthy climatic conditions, and low population density, availability of land for future expansion, physical planning convenience and ethnic accord. The population of the FCT and livelihood indices are shown in Table 1.

Table 1: Population Distribution in FCT

Area Council	2006	2016 *Projection	2022 **Projection
Abaji	58,642	148,000	257,930
AMAC	776,298	1,959,272	3,414,558
Bwari	229,274	578,656	100,8464
Gwagwalada	158,618	400,330	697,682
Kuje	97,233	245,403	427,681
Kwali	86,174	217,491	379,037
Total	**1,406, 239**	**3,549,152**	**6,185,352**

Source: NPC, 2006; NBS, 2016

Conceptual Framework and Literature Review

Conceptual Framework of Urbanization and Urban Heating

The built environment refers to material, spatial, and cultural product of human labour that combines physical elements and energy informs of living, working and playing (Wu *et al.*, 2014; Li *et al.*, 2018). Humans have altered more than half of the Earth's surface as a result of rising human population and increased demand for resources such as minerals, soil, and water (Hooke & Sandercock, 2012). Changes in land use to develop cities and meet the demands of urban populations induce environmental changes such as local and global changes in biogeochemical cycles, temperature, hydro-systems, and biodiversity, which alter ecosystem structure and function (Grimm *et al.*, 2008). By modifying land use patterns and, as a result, surface radiation regimes and energy balance, urbanisation can have a considerable impact on local and regional climate (Wu *et al.*, 2014). Babalola & Akinsanola (2016), found out that the vegetal cover loss leads to LST. This alteration has influenced the intensity of UHI and contributed to microclimate changes. According to the study, urbanisation has significantly impacted climatic variability, which has a regional impact on climate and socio-economic development. A similar study was carried out in Awka, by Nzoiwu *et al.* (2017), the decrease in LULC is due to a high rate of urbanisation, could result to an average increase of 2.2°C in surface radiant temperature. Due to extensive urban expansion, rising temperatures in over-developed areas could have a detrimental influence and enhance living discomfort within the city (Linda & Oluwatola, 2015).

Relationship between LST and LULC

Ejaro & Abdullahi (2013) conducted a study in Suleja on Spatiotemporal analysis of LULC and found that urbanisation is mostly responsible for substantial changes and adjustments in LULC. This backs with Tyubee and Anyadike's (2012), conclusion that urbanisation is the primary driver of surface and atmospheric temperatures. Also, using remote sensing and GIS, Ishaya, Ifatimehin, and Okafor (2008) investigated urban expansion and loss of vegetative cover in Kaduna using Landsat imageries from 1990 to 2000. The findings revealed that Kaduna town has been changing over the last few decades as a result of population growth, which has resulted in vegetation loss and the expansion of the built-up area. Balew and Korme (2020), conduct a study on LST monitoring in Bahir Dar and its environs, finding that the vegetation cover had a mean LST of 32.22°C in 1987 and climbed to 33.91°C in 2002. As a result of urbanisation, paved surfaces had a mean LST of 1.6°C higher than in 1987 and 36.62°C in 2002, according to their research. According to Me-ead and McNeil (2019), climate change is the leading driver of LST increases in the Sahara and semi-arid portions of Southern Africa by 1.6°C in the 2050s and 1.4°C per year in equatorial African countries.

Material and Method

Both primary and secondary data were employed in the study. The first step in data acquisition included satellite imageries of the study area. photographs, maps, planning schemes. Instrument of data collection includes: Satellite image of the study area, Data on temperature trend, Records from relevant literatures, Global Positioning System (GPS) and Camera. The questionnaire administered was coded in numbers and entered into the IBM Statistical Package for Social Sciences (SPSS) spread sheet. Statistical analysis carried out included interpretation of the readings from the handheld GPS, also ArcGIS 10.7, was used in capturing and analysis of data on the spatial distribution LST in the study area. The result was displayed in the form of maps, tables, graphs and charts.

Result and Findings

Land Use/Land Cover of the Study Area in the Year 2010-2022

Table 2, revealed that in the year 2010, Gwagwalada area the total land coverage is 6930.8 hectares, the built-up area covers 1889.9 hectares (27.3%), bare surfaces covers 4762.8 hectares (68.7%), vegetation occupies 184.5 hectares (2.7%) and water body covers 93.6 hectares (1.4%). While in the year 2022, the built up area has increased by 8.7% from 1889.9 hectares to 2494.9 heactares, bare ground reduces -8.2%; vegetation increased by 0.4% and water body decreased by 0.2% (see figure 1). This implies that anthropogenic activities such as road construction, bridge construction, industrial location, deforestation, and population growth contributed to the increase and change of bare surface in the study area. This is in line with Mundia and Aniya's (2006) findings, which revealed that economic growth and proximity to transportation lines were the two most important factors in fostering urban expansion inside a city.

Table 2: LULC of the study area

	2010			2022		
Landcover	Area (ha)	Coverage	Percentage (%)	Area (ha)	Coverage	Percentage (%)
Built-up	1889.9		27.3	2494.9		36.0
Bareground	4762.8		68.7	4193.01		60.5
Vegetation	184.5		2.7	157.58		2.3
Water body	93.6		1.4	85.32		1.2
Total	6930.8		100.0	6930.81		100.0

Source: Authors Analysis, 2023

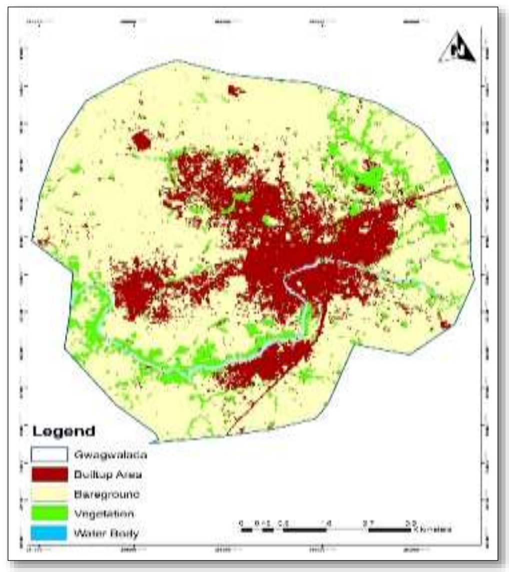
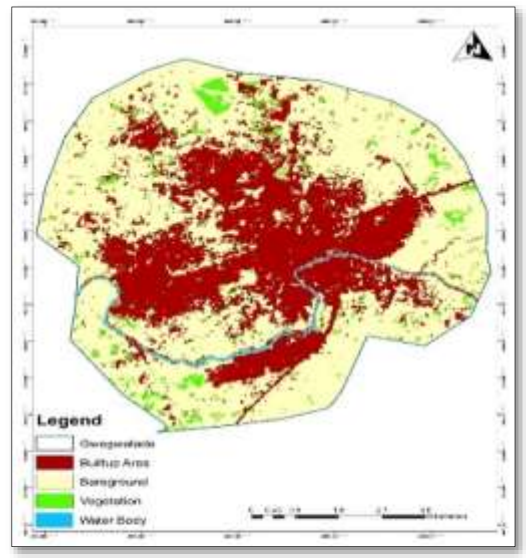
	
2010	2022

Figure 1: Land Use/Land Cover Map of the study area
Source: Authors Analysis, 2023

Urban Surface Temperature Variation based on Vegetal Cover Changes in the Study Area

The normalized vegetation index (NDVI) is a dominant factor in LST derivation processes and it is used invariably in any LST study. The role of NDVI is to reveal where the vegetation is thriving or under stress, as well as changes in vegetal cover due to human activities NDVI is directly used in the determination of LST emissivity and thus a significant factor for LST estimation. Spatio-temporal pattern of LST of the study area during the two temporal periods, (2010-2022) revealed that the study area exhibited higher LST as shown in Table 3. Gwagwalada had 184.5 ha of vegetal cover with a recorded LST value of 35°C in 2010. And 157.53 ha with recorded LST of 35°C respectively. The loss of vegetal cover and the rise in LST was due to infrastructural and housing development which give way for the emergence of settlements like Phase I, Dukpa and Custom Quarters. This implies that depletion of vegetal cover in the city is as result of urbanization that is taking place. Thus, studies from Wang *et al.* (2021); Priyankara *et al.* (2019) and Barsi *et al.* (2014) shows that LULC transformation is a common phenomenon in the expansion of impervious surfaces like buildings, concrete roads, asphalt, and parking lots. And the rapid expansion of these impervious surfaces at the expense of other land-cover types like vegetation, wetlands, and water bodies increases the thermal accumulation of an area. These extreme LULC changes are the main indicator of urbanization and it is the driving factors to increase LST. Figure 2 illustrate the composite map of LST spatial distribution of the study area.

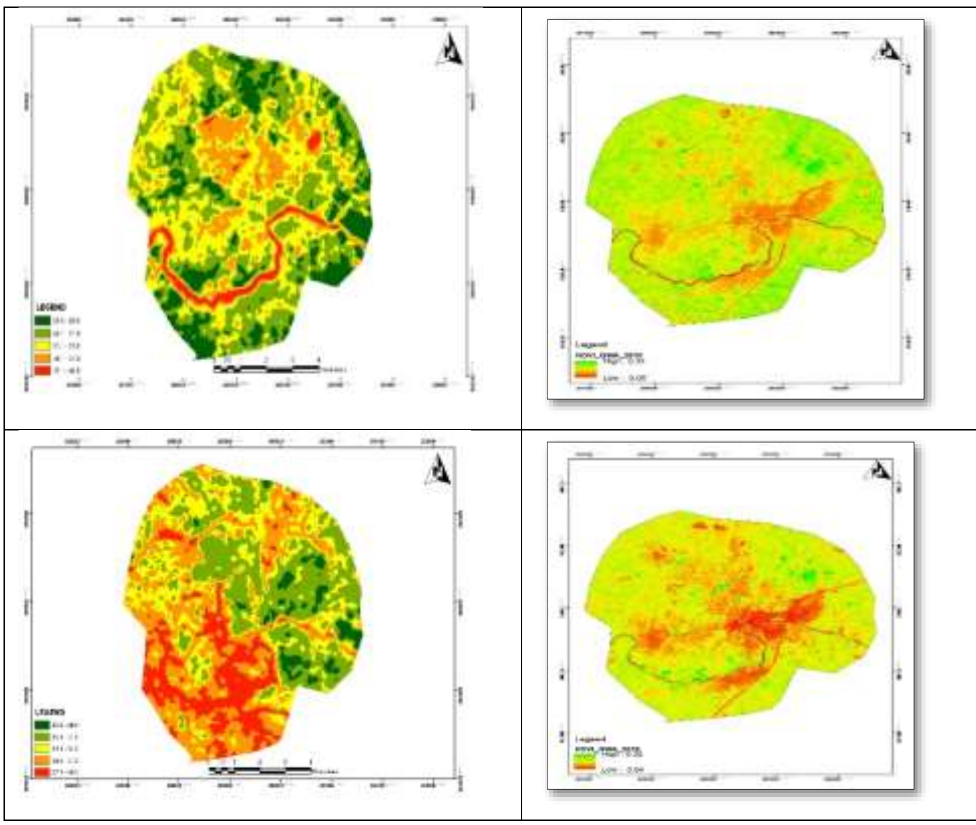
Table 3: **Urban Surface Temperature Variation based on Land Cover Changes in FCT**

Year (s)	Gwagwalada			
	LST (°C)	VC (Ha)	decrease in VC (Ha)	LST rise (°C)
2010	35.0	184.5	-29.31	5.0
2020	35.0	157.53	-26.97	5.0

Source: Authors Analysis, 2023

Note:

VC: Vegetal Cover
LST: Land Surface Temperature
Ha: Hectares
°C: degree Celsius



2010

2022

Figure 2: Composite Map of LST of the Study Area
Source: Authors Analysis, 2023

Relationship between Built-Up Surface and Temperature Changes in the Study Area

The minimum temperature recorded in Gwagwalada is 27.2°C and maximum at 36.2°C. Table 4, revealed that built up area in 2010 was 1889.9 ha which account for 27.3% of the total land coverage. By the year 2022 the built area increased by 8.7% to 2494.9ha, as result of this increase the LST rose by 5°C. The increase in temperature was as a result of heavy infrastructural and massive housing development within the period under study. The study revealed that as the cities grow as a result of urban expansion, the heat island effect expands both in extent and intensity (Mavrakis *et al.,* 2015; and Nouri *et al.,* 2016). Also, the pattern of development features such as construction of road and housing and deforestation lead to temperature rise (Tan *et al.,* 2020; Chapman *et al.,* 2019; Orimoloye *et al.,* 2018; Adeyeri *et al.,* 2017 and Adegboyega *et al.,* 2016). Also, the study revealed the current state of land use dynamics and its potential implications on land surface thermal characteristics over the study area as well as the influence of human activities on the natural landscape, particularly the built-up areas. This is as a result of over time population influx and recent development in the region have given to land surface temperature of FCT, Abuja Nigeria.

Table 4: Built Up Area Effect on Temperature Changes

Years	**Gwagwalada**	
	Built up (Ha)	LST rise (°C)
2010	1889.9	5.0
2020	2494.9	5.0

Source: Authors Analysis, 2023

Correlation Between growth in the built-up Area and Temperature Changes with the Study Area

The correlation between built-up and temperature for the years under study; 2010, and 2020, is presented in Table 5. According to Cohen *et al.* (2013), the linear regression coefficient is determined centered on the strength of the correlation coefficient, where 0.31–0.5 signifies a weak correlation, 0.51–0.7 signifies a normal correlation, 0.71– 0.90 signifies a strong correlation and 0.91–1.0 signifies a strong correlation. The result revealed there is a strong positive relationship between temperature changes over time and built-up surfaces in the area under study. The study shows that the correlation matrix recorded an r-value of 0.8738, for the built-up area and temperature changes in the study area, shows a strong positive relationship between built area (urban growth) and temperature changes. The study implies that 87% of Gwagwalada built up have more of the variability in temperature changes than other built up in FCT. This study is in line with the study of Zhou *et al.* (2011), who examined the relationship of LST to urban growth. The findings show that there is strong correlation between surface temperature increase and urban growth. Zhou & Wang (2011), indicate that that rapid urbanization altered the local thermal environment, increasing the LST in zones within the urban core. The finding collaborates with Eliasson *et al.* (2003), in their study of spatial air temperature variations and urban land use in Goteborg, Sweden, found out that reduction in vegetative cover also had an impact on the local air temperature variation.

Table 5: Correlation matrix of built up and temperature changes

Variables	**Gwagwalada**	**Temperature**
Gwagwalada	1	
Temperature	0.8738	1

Source: Authors Analysis, 2023

Discussion

From the study carried out in the Gwagwalada, revealed that between 2010 and 2022. Built up area has increased by 8.7% from 1889.9 hectares to 2494.9 hectares, bare ground reduces -8.2%; vegetation increased by 0.4% and water body decreased by 0.2%. Also, the minimum temperature recorded were 27.2°C and maximum at 36.2°C with a mean of 31.7℃. The shows that Gwagwalada has more variability in temperature changes by 87% than any other part in with a LST of 5℃. This implies that urban growth is a major factor that lead to land surface temperature rise in the study area.

Conclusion

The study revealed that for the past 12years, Gwagwalada has been experiencing accelerated urban growth. The result from the analysis showed that built up is increasing at an annual rate of over 76% while the LST has been has an increasing 5℃, with period under study. However, the study has proved that extensive urban expansion, decrease in vegetal cover and rising temperatures could have a detrimental influence and enhance living discomfort of residents within the city. The study recommends that urban greening be introduced in Gwagwalada (Old Kutunku, New Kuntunku, phase 1, Angwandodo, Phase 3 and Dagiri) to help restore the depleted vegetal cover in the study area and introduction of biophilic design should be adopted by the FCTA administration in the proposed new area such as Custom quarters, phase 2 and Dukpa to help mitigate LST and improve the livability of the resident within the study area.

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