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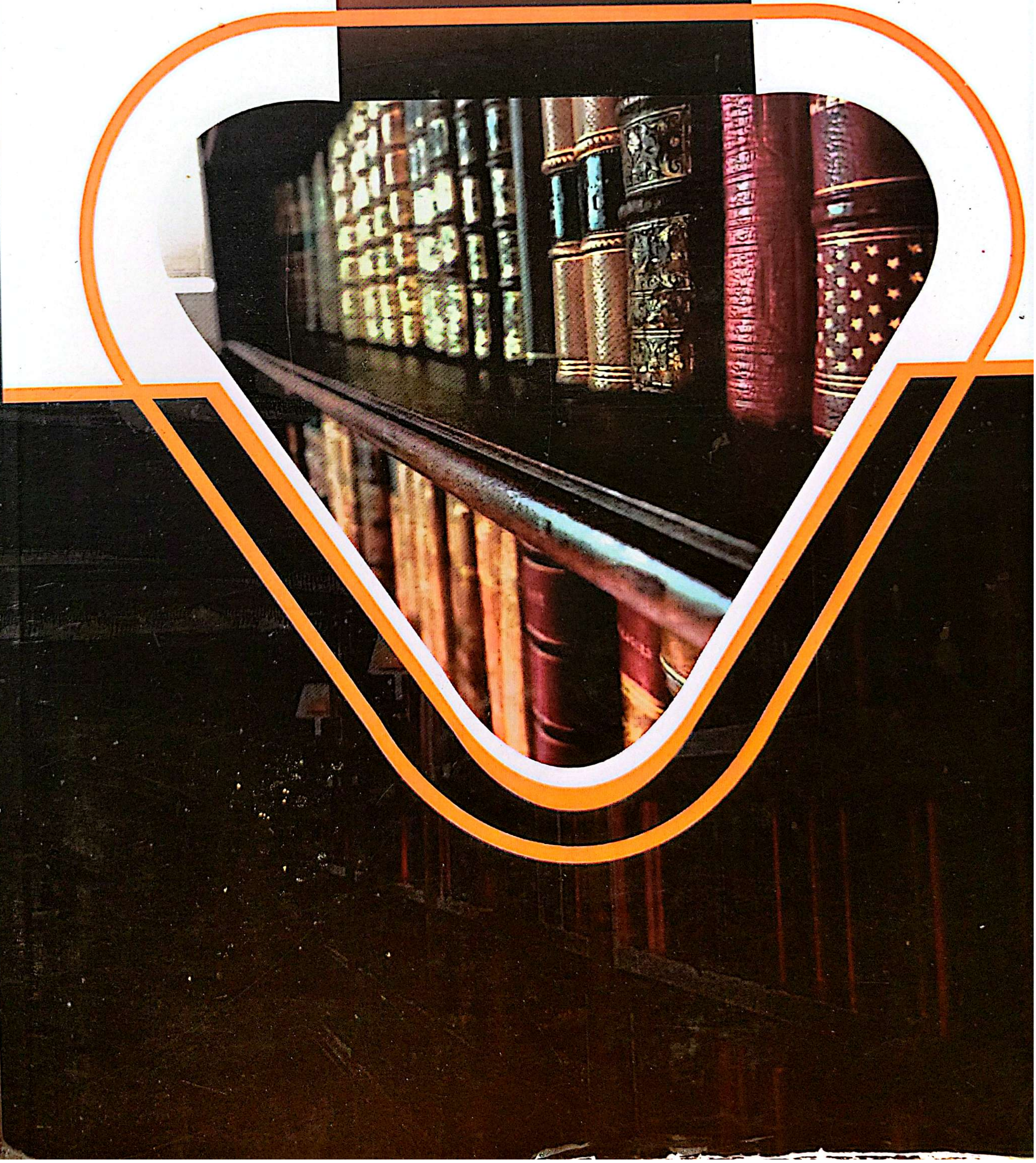
20th Academic Conference

Reintegration and Rebuilding Sub-Sahara African Nations for Sustainable Development: Multi-disciplinary Aproach



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:d by Prof. Azar, A. T.; Prof. Nordin, R. B.; and Dr. Yakub, H.

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The 20th Academic Conference
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Theme
Reintegration and Rebuilding Sub-Sahara African Nations for Sustainable Development: Multidisciplinary Approach

Sub-themes

Reintegration and Rebuilding Sub-Sahara African Nations toward Agriculture and Agricultural Science

Reintegration and Rebuilding Sub-Sahara African Nations toward Sustainable Development

Reintegration and Rebuilding Sub-Sahara African Nations Medical, Pharmaceutical and Biological Science

Reintegration and Rebuilding Sub-Sahara African Nations Environmental Design and Construction Management

Reintegration and Rebuilding Sub-Sahara African Nations toward Engineering and Renewable Technologies

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EFFECT OF URBAN GROWTH ON SURFACE TEMPERATURE VARIATION IN ABUJA, ABUJA

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Abstract

Urbanization can also be seen as the concentration of human activities in specific locations and regions promotes the development of large cities and other forms of urban settlement. The growth and transformation of cities are driven by the forces of attraction between specific locations. This paper aimed at assessing the effect of urban growth on land surface temperature variation in some major urban centres in FCT, Abuja. Landsat Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+) and Landsat-8 Operational Land imager (OLI) images of 1980, 2000 and 2021 respectively were utilized. Land use land cover maps were generated using supervised classification. The study revealed that for the past 40years, FCT has been experiencing accelerated urban growth. The study showed that built up is increasing at an annual rate of over 100% while the LST has been on an increase of 5.3□, 8.8□, and 9.75□ in surface temperature within FCC, Kubwa, and Gwagwalada between 1980-2021. The study also recommends that green roofing should be encouraged as it an ideal heat island reduction strategy, providing both direct and ambient cooling effects.

***Keywords**: urban growth; land surface temperature; remote sensing*

Introduction

Nigeria is notably Africa's most populous nation with a population of over 170 million people (World Bank, 2016). It is expected to rise to about 300 million people by 2050 (World Population Prospect, 2017; Adegoke, 2017). Nigeria as of 2012 had a GDP growth rate of 7% per year and is amongst the highest in the world (David, 2015). The increased urbanization trend has various environmental impacts and it seems to be never-ending with a continuous and rapid increase throughout the last decades and still projected to increase even faster (Azeem *et al.*, 2016). Consistent development of urban areas results in the formation of more and more impervious surfaces which has been considered as a predominant driving force towards the alteration of the natural ecosystem (Zhou *et al.*, 2010). With the advent of vegetal cover, loss in our cities, which has resulted in higher surface temperature due to built-up impervious surfaces and high-rise buildings constructed through the heavy use of metal as compared to surrounding rural landscapes characterized by land cover and pervious surfaces. This phenomenon is known as an Urban Heat Island (UHI), which is a manifestation of land use/cover modification (Xiao & Weng, 2007). UHI analysis is closely associated with the spatial patterns of land surface temperature, which primarily depends on the physical properties of LULC (Singh *et al.*, 2014). UHI emerges through the modification of land surface in a way that favours heat storage and trapping (reduced vegetation), the anthropogenic heat release from vehicles, industries, and buildings (Sailor & Lu, 2004). It is one of the perilous environmental issues, which can cause a negative impact on humans and the environment (Grimmond, 2007). It degrades air, influences local climate, increases ground-level ozone production, and ultimately affects the quality of life. In view of the trend of land surface temperature increase within and around the city of Abuja, as result of physical development has posed serious threat to environmental, socioeconomic and health wellbeing of the inhabitant of Abuja. Therefore, the study intends to study assess the effect of urban growth on land surface temperature changes within and around major urban centres in FCT, Abuja.

The Study Area

The Federal Capital Territory (FCT), covers an area of about 8,000sqkm; with coordinates 9°4°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

The Concept of Land Surface Temperature

The term Urban Heat Island (UHI) generally relates to the presence of several micro and mesoscale climates that are hotter than the initial temperature at that mount, and that of neighboring territories (Zhou & Wang, 2011). According to (Streutker, 2003), states that UHI is a paradox where a metropolitan or urban territory is considerably hotter than its agricultural zones. Voogt (2004) further, well-described three types of urban heat island, namely: Canopy Layer Heat Island, Boundary-Layer Heat Island, and Surface Heat Island. The profile of the urban heat islands is shown in Figure 1.

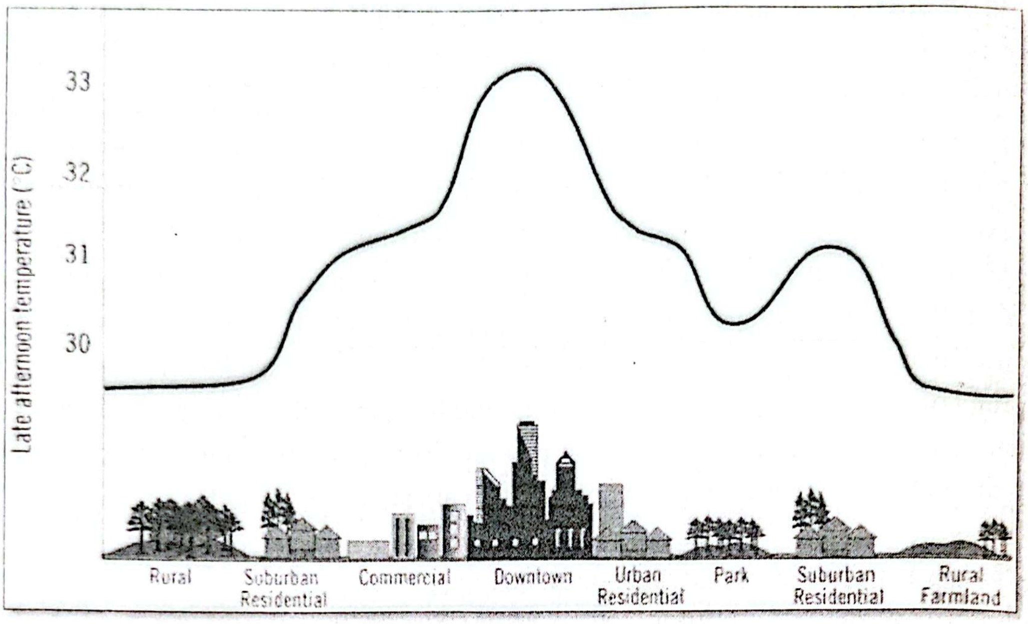


Figure 1: Profile of Urban Heat Island
Sources: European Environment Agency (2003).

The Concept of Urbanization

Urbanization describes the surge in the population of urban spaces compared to rural spaces (Deepika, 2020). It is also a geographical phenomenon. Urbanization is a process through which changes in the social structure of human settlements are caused by population density, concentration, and growth. Structurally, urbanization is characterized with the transformations of socio-economic structures and demographic functions, which alter the structure of urban spaces. The growth and transformation of cities are driven by the forces of attraction between specific locations. These changes are accelerated by the development of transport networks as well as the benefits that arise from the spatial agglomeration of resources, including human resources.

Urbanization and Effect of Land Surface Temperature

Urbanization is the spatial expansion of the built environment (human-constructed elements, such as buildings, roads, runways) that is densely packed by people and their socio-economic activities (Wu, 2010, 2014). During urbanization changes in land use to build cities and to support the demands of urban populations also drives environmental changes such as local and global alterations of biogeochemical cycles, climate, hydro-systems, and biodiversity altering the structure and functioning of ecosystems (Vitousek *et al.*, 1997; Grimm *et al.*, 2008). Urban areas expansion implies an increase in impervious land area which affects both geomorphological and hydrological processes, thus causing changes in water and sediment fluxes (Grimm *et al.*, 2008; Wu, 2008a). These impervious surfaces and the generation of heat from various combustion processes in urban areas modify the microclimate and air quality (Alberti, 2010).

Zhou *et al.* (2011) examined the relationship of LST to urban growth, using Landsat images between 1992-1996. They did a correlation analysis between LST and the NDBI. The authors results showed that LST increased about 3.4°C and 1.9°C, respectively, for forest and agricultural land that was converted into built-up areas. Me-ead & McNeil (2019) in their study pattern and trend of night Land Surface temperature in Africa. Their findings show evidence of temperature variation in the African continent from 2000 to 2014. Moreover, the land areas over the Sahara and semi-arid parts of southern Africa warmed by 1.6°C up to 2050s and the equatorial African countries warmed at a steady rate of about 1.4 C per year. Dewan & Corner (2014) opined that the expansion of urban built-up surface over natural land cover such as floodplain and agricultural land has become conspicuous, significantly affecting the spatial and temporal distribution of surface temperature. Annual mean land surface temperature estimation has shown that urban built-up surface consistently has the highest, ambient radiant temperature. Decrease in vegetation cover and subsequent increase in urban land cover were found to be associated with increased LST, suggesting an amplification of the UHI effect with time.

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 (FCC, Kubwa and Gwagwalada), photographs, maps, planning schemes. Instrument of data collection includes: Satellite image of the study area, Land use map of the study area (FCDA, AGIS), Data on temperature trend in the study area (NIMET and NBS), Records from relevant literatures, Questionnaires (Questionnaires were administered to the residents of the study area), Newspapers, Handheld Global Positioning System (GPS) and Camera. The questionnaire that was 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

Analysis of Land Surface Temperature of the Study Area

The Spatio-temporal pattern of LST of the study during the three (3) selected periods, (1980, 2000 and 2021) reveals that the study area exhibited higher LST.

Spatio Temporal Pattern of LST Dynamics in the Year 1980-1990

Figure 2 revealed that the variation in land surface temperature (LST) of the study area. In FCC, vegetal cover for was 3238.47 ha with recorded LST of 39.5°C. By the year 1990 the city loss 61% of its vegetal cover (-5055.49 ha) which give rise to LST of 0.2°C.

This shows that the Federal capital city is still densely vegetated with pockets of communities such as Takushara, Gwagwa, Kpepegyi, Kurudu, Orozo, Gwandara, and Jiwa prior to the construction phase of the city during that period, resulting in the low surface temperature observed in 1980. And the modest increase in surface temperature at the time was due to the destruction of approximately 845 villages throughout the region to make space for the nation's newly discovered capital (Olaitan *et al.*, 2004 and Obiadi *et al.*, 2018). The spatial pattern of LST increased from the northern part of the city (areas such as; Northwest (Gwagwa, Deidei, Dakwa, and Jiwa); Southwest (Lugbe, Aleita, Gosa,) and Northeast (Mpape).The research revealed that vegetal cover account for 19.2% of the total land coverage as against 6.0% for built up area in 1980.

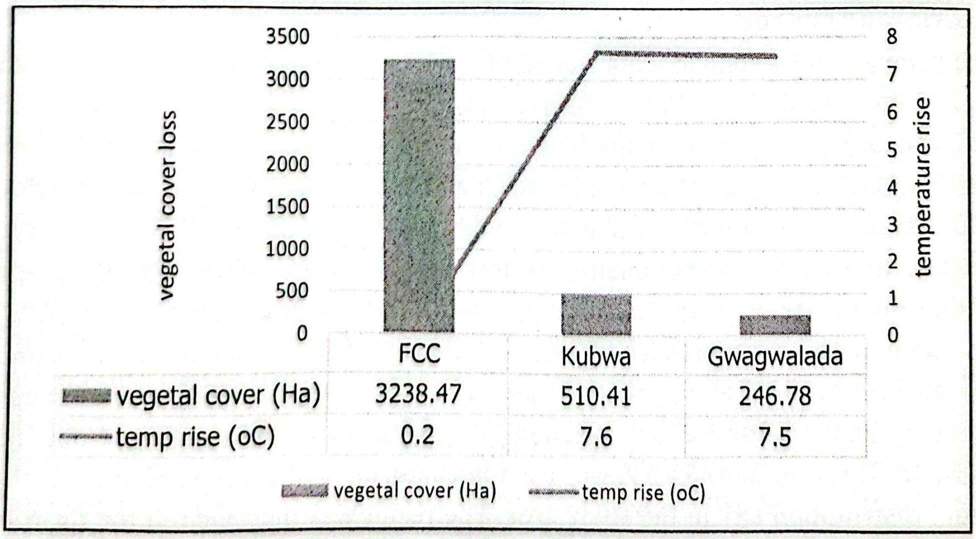
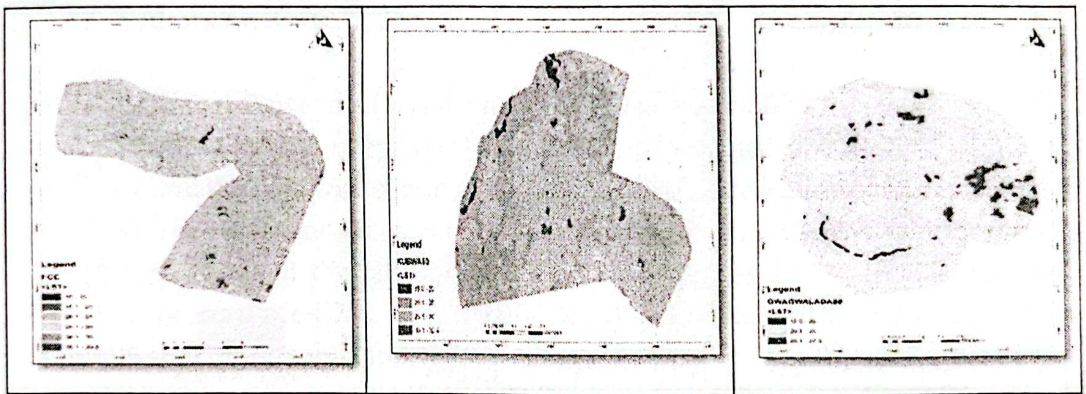


Figure 2: Variation in LST and Vegetal Cover Loss (1980-1990)
Source: Authors Analysis, 2021

In the Kubwa, the vegetal cover was 614.5 ha in 1980 with LST of 32.4°C. The vegetal cover decline by 17% (-104.09 ha), as result of this decrease the LST rise by 7.6°C in 1990. This is due to the resettlement scheme that was initiated by Federal Government of Nigeria and United Nations to resettle Gbagyi tribe within the FCC areas of Garki, Maitama, Jabi, and Kukwaba villages (Abumere, 1981 and Sylvester, 2014). The vegetal cover of Gwagwalada in 1980 was 838.36 ha with LST of 27.5°C. The town witnessed drastic loss in its vegetal cover by 71% (-591.58 ha) and 7.5°C rise in LST in 1990. This implies that the Gwagwalada area of the FCT was still a very small village with less population growth. Figures 3 Shows the composite spatio-temporal distribution of LST for the study area.



FCC	Kubwa	Gwagwalada

Figure 3: Composite Map of LST of the study area in 1980
Source: Authors Analysis, 2021

Spatio Temporal Pattern of LST Dynamics in the Year 1990-2000

Figure 4 revealed that the variation of LST and vegetal cover between 1990 and 2000. The vegetal cover for FCC in 2000 suffers decline by 12% (-385.38 ha) and had an increase in LST of 4.3°C as compared to 0.2°C of LST experienced in 1990. 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 Utako, Jabi, Gwarinpa, Apo, Durumi and Kado districts. This implies that depletion of vegetal cover in the city is as result of urbanization that is taking place. Thus, studies from Priyankara *et al.* (2019); Wang *et al.* (2015); Barsi *et al.* (2014); Sobrino *et al.* (2004a) and Weng *et al.* (2004) 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.

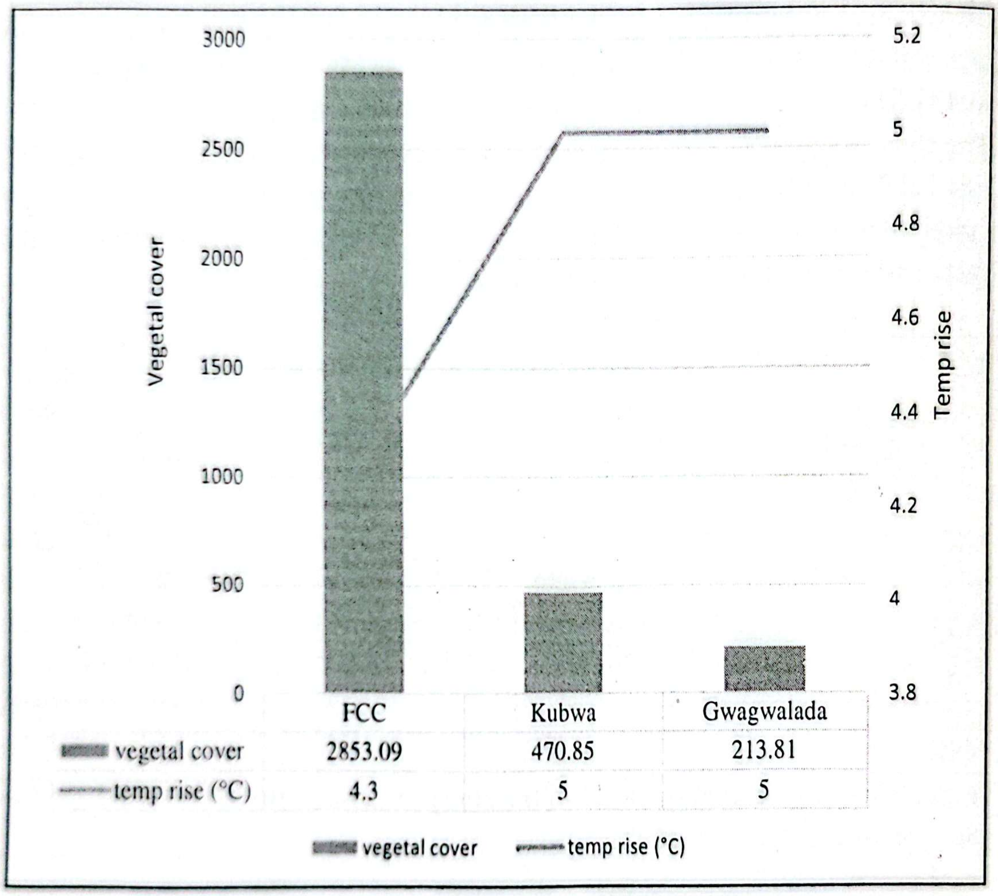
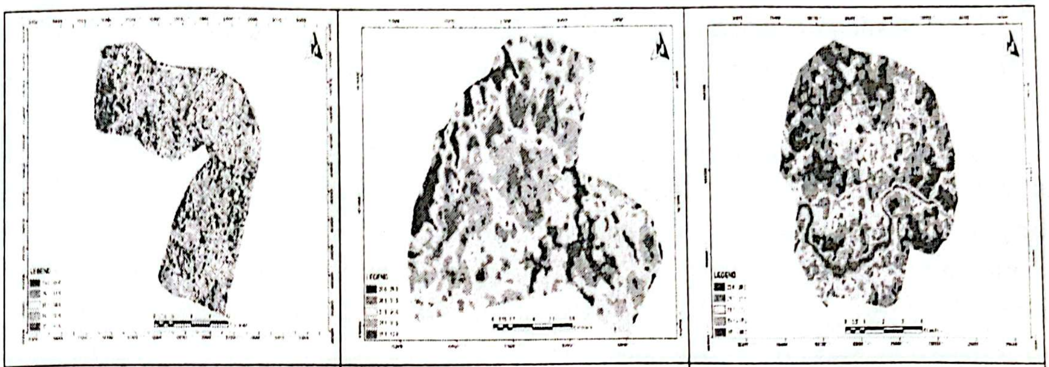


Figure 4: Variation in LST and Vegetal Cover Loss (1990-2000)
Source: Authors Analysis, 2020

In Kubwa, vegetal cover decreases from 510.41 ha in 1990 to 470.85 ha (-8%) in 2000 with LST rise of 5°C. Also, the vegetal cover for Gwagwalada was 246.78 ha in 1990 but witnessed 13% decrease (-32.97 ha) in 2000 with LST rise of 5°C. This implies that the increasing urbanization in Kubwa and Gwagwalada engenders the replacement of natural landscape elements (vegetation cover, waterbody, etc.) with artificial elements (built-up area and other non-vegetative features), and in response to this, surface energy balance is usually altered resulting in rising temperature (Santamouris *et al.*, 2011; Alavipanah *et al.*, 2015; Adeyeri *et al.*, 2017 and Xiao *et al.*, 2008). This explains the scattered temperature hotspots observed within the study area. The spatial distribution of LST for the year 2000 is shown in Figures 5.



FCC	Kubwa	Gwagwalada

Figure 5: Composite Map of LST of the study area in 2000

Source: Authors Analysis, 2021

Spatio Temporal Pattern of LST Dynamics in the Year 2021

Figure 6 shows that in the year 2021, the LST values range from 20-40°C within the study area, and the composite map of spatiotemporal distribution of LST is shown in figure 7. The Federal capital city recorded LST values from 20.1-25°C which occupies 0.1% (43.30742ha) of the land area; 25.1-30°C occupies 13.7% (5933.11654ha); 30.1-35°C occupies 64.7% (28019.90074ha) and 35.1-40°C occupies 21.5% (9311.0953ha) of the total land area coverage.

Meanwhile, Kubwa being one of the satellites two towns recorded an LST value of 25.130°C which covers 2.4% (99.68184ha); 30.1-35°C covers 5.1% (211.82391ha), and 35.1-40°C covers 92.5% (3841.90425ha) of the land area. Also, Gwagwalada was not left out, as the LST of the township were observed to be 25.1-30°C which covers 4.1% (284.16321ha); 30.1-35°C covers 38.1% (2640.63861ha) and 35.1-40°C covers 57.8% (4006.00818ha) of the total cover of the area. This implies that population explosion, climatic change, and rapid urban growth are the main drivers of the increase in surface temperature within the study area.

It is evident that the process of urbanization leads to an increase in the urban temperature by 2-5□ in Bahrain (Radhi *et al.*, 2013) and decrease in the vegetal cover is a result of the rapid rate of urbanization and that these alterations had given rise to an average increase of 2.2°C in surface radiant temperature in Awka, Nigeria (Nzoiwu *et al.*, 2017). The increase in temperature is enhanced by urban activity such as on-going construction processes, mining activities, a decrease in vegetal cover, and illegal logging in the FCT, Abuja. This is in line with the study of Adesola and Afolabi (2013) which revealed that Abuja is experiencing an increasingly high level of land transformation and conversion due to the increased rate of urbanization. The high rate of depletion of the vegetated resources at the expense of non-evaporated land uses such as concrete, asphalt and other impervious materials are seriously contributing to the rise in surface temperature in the Federal Capital Territory, Abuja.

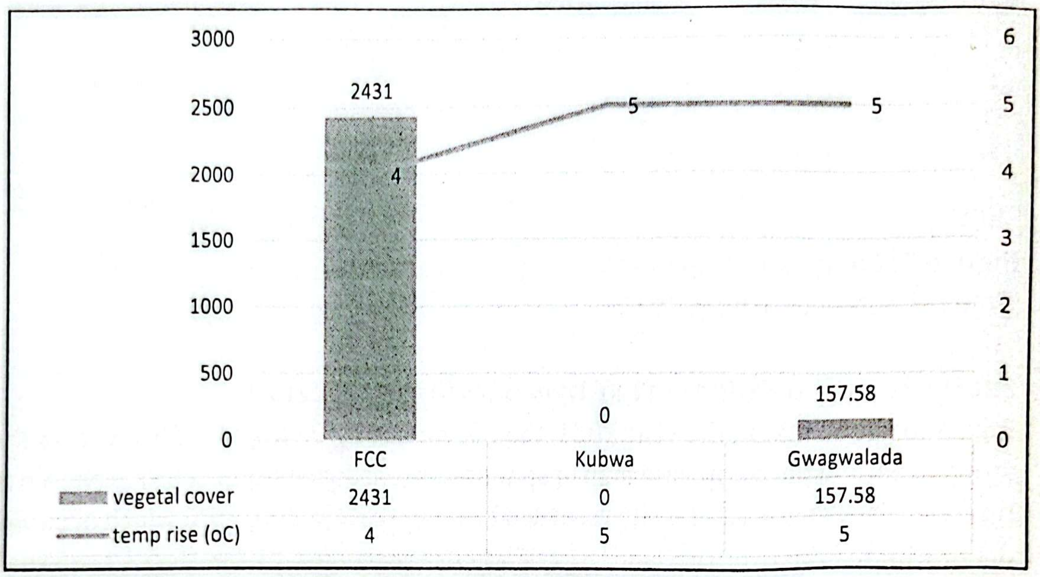


Figure 4.6: Variation in LST and Vegetal Cover Loss (2010-2020)
Source: Authors Analysis, 2021

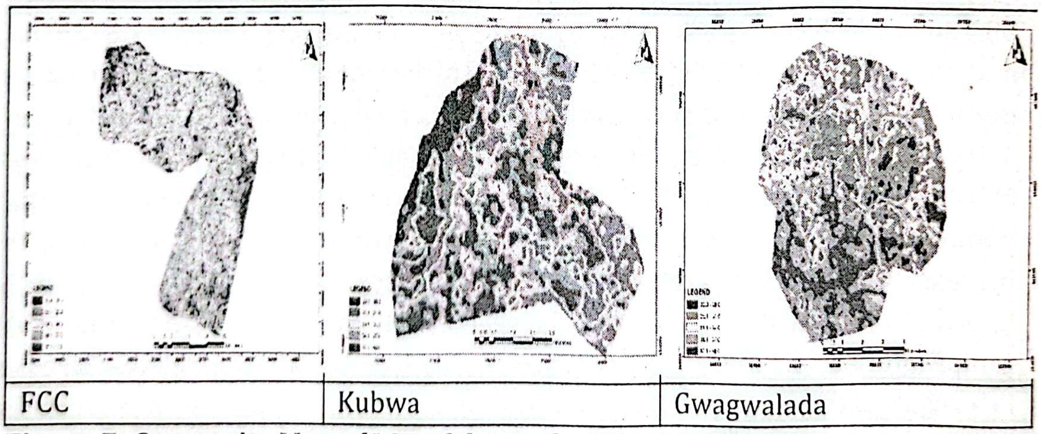


Figure 7: Composite Map of LST of the study area in 2021
Source: Authors Analysis, 2021

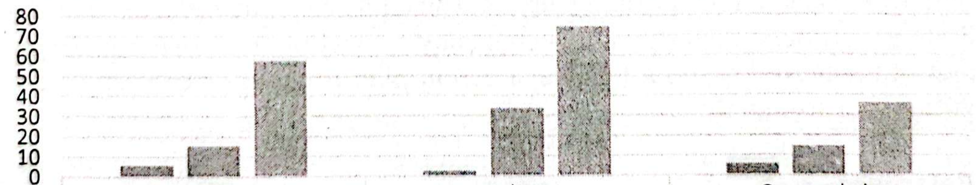
Percentage of Changes in Built Up Area from 1980 to 2021

Figure 5 showed the rate of change in the built-up areas within the FCC between 1980 to 2021, which demonstrated a significant increase in the built-up areas due to its experienced dramatic urban expansion over the time period. There was 9.5%

increase between 1980 to 2000, and the 2020 recorded a development rate of 42.6% due to high infrastructural development. This collaborated with the findings of Herold *et al.* (2003); Lambin *et al.* (2003) and Yue *et al.* (2013) which stated that population increase could be an indispensable factor that causes urban expansion.

Similarly, Kubwa being the satellite town developed by the FCTA administration to carter for the housing need of the people due to the infrastructural development and population influx that was happening in the FCC then recorded a tremendous development between the 1980 and 2000 with a rate of 31% and over 40.9% from 2000-2021.

Also, Gwagwalada urban area experienced a high turn of development from the 1980 with a growth rate of 9.5% in 2000. The town also, witnessed another exponential growth again by 31% in 2020. From this study, it is evident that population pressure is one of the major drivers of land use and land cover changes through the destruction of forest and vegetation cover for the purpose of urban expansion and demand for daily needs. This sporadic urban growth was speculatively caused by the rising price of land closer to the city center because all land within the city is increasingly expensive compared to areas outside of the ring road (Toffin, 2010). The growth of industries at the margins of the city limits has also contributed to this growth (Thapa *et al.*, 2009). With the industrial growth, many residents who traditionally would have looked for work in the heart of Abuja will now have the ability to work and live on the outskirts of the city. This is in line with the findings of Zeleke and Hurni (2001); Amsalu *et al.* (2007) and Haregeweyn *et al.* (2012) which stated that population growth coupled with migration from rural to cities leads to expansion of urban areas at the expense of vegetation cover.



	FCC	Kubwa	Gwagwalada
1980	6	2.8	5.8
2000	15.5	33.8	14.5
2021	58.1	74.7	36

1980 2000 2021

Figure 5: Rate of built up in the study area

Source: Authors Analysis, 2021

Discussion

From the study carried out in the FCT, Abuja revealed that in 1980, the minimum and maximum LST of the Federal capital city were 10□ and 39.5 □ with a mean of 24.75□. Whereas, the minimum and maximum LST of Kubwa was 15□ and 32.4□ with a mean value of 23.7□ and minimum and maximum LST of Gwagwalada was 15□ and 27.5□ and mean of 21.25□ respectively. A similar, trend was experienced in the study in the year 2000, with FCC having minimum and maximum LST of 20□ and 44□ with a mean of 32□; minimum and maximum LST of Kubwa was 25□ and 35□ with mean of 30□, while the minimum and maximum LST of Gwagwalada was 25□ and 40□ with mean of 32.5□. Similarly, the minimum and maximum LST of FCC in the year 2021 was 20.1□ and 40□ with a mean of 30.05□; Kubwa with minimum and maximum LST of 25□ and 40□ with mean of 32.5□ and Gwagwalada with minimum and maximum LST of 27□ and 35□ with a mean of 31□ respectively. The study shows that there has been an increase of 5.3□, 8.8□, and 9.75□ in surface temperature within the FCC, Kubwa, and Gwagwalada between 1980-2021.This reiterate the fact that urban growth is a function of land surface temperature variation changes of such localities.

Conclusion

The study revealed that for the past 40years, FCT has been experiencing accelerated urban growth. The result from the analysis showed that built up is increasing at an annual rate of over 100% while the LST has been on an increase of 5.3□, 8.8□, and 9.75□ in surface temperature within the FCC, Kubwa, and Gwagwalada between 1980-2021. Therefore, urbanization has proved to have a significant impact on the climate of cities resulting to land surface temperature effect and its magnitude depends on the degree of urbanization. The study also recommends that green roofing should be encouraged as it an ideal heat island reduction strategy, providing both direct and ambient cooling effects. The study also recommends that National / State government departments, meteorological institutes and emergency response departments to develop a heatwave action plan to monitor temperature changes within and around the city.

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