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Research Article

Analysis of Two Decades Variations in Urban Heat Island Using Remotely Sensed Data in Nguru Local Government Area, Yobe State, Nigeria

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Abstract

The effects of Urban Heat Islands (UHI) have received a lot of attention because they have a huge impact on human health and environmental resource sustainability. A key moment in the history of mankind has been urbanization, and there is no doubt that the world is rapidly urbanizing, which is causing temperature changes. The relationship between climate change and rapid urbanization in Nguru Local Government Area, Yobe State, Nigeria, is investigated in this paper. The study used remote sensing data to reveal the extent of urban microclimate change trends over the next two decades (2001 - 2021). Thus, the microclimate temperature increased by nearly +5.32 °C in 2021 (39.39°C) compared to 34.07°C in 2001. Furthermore, the minimum temperature in 2001 was 22.33 °C, while that of 2021 was 23.36°C. The built-up area increased by 556.73%, from 446 hectares in 2001 to 2,483 hectares in 2021. Accelerated urbanization and the city's blue and green facilities, which are not preserved or safeguarded due to a poor planning system, are to be blamed for these modifications to the urban climate and design. The study aimed to determine the relationship between urbanization and urban heat islands in Nguru local government area, Yobe State, Nigeria. The picture of the situation in Nguru sheds light on the enormous challenges that cities in developing countries encounter in dealing with local and global climate change-related risks. Indeed, this situation necessitates an integrated strategy to address climate change both within and outside of cities. Policymakers must increase spending on urban planning, fund, an adaptation of approaches through urban planning, and strengthen urban planning institutions.

Keywords: Climate change, Land use land cover, Remote sensing, Temperature

Introduction

Rapid population growth, industrial growth, and social and economic activities are now centered in urban areas because of rapid urbanization, altering urban morphological characteristics and energy proportion over time. Urbanization is defined as the gradual transition in human population residence from rural to urban areas. It is among the most cumbersome human behaviors, with permanent effects on the planet's surface as well as the biosphere (UN, 2018). The concept known as "Urban Heat Island" refers to the higher temperature in the city center, in contrast to its surrounding area (Synnefa *et al.*, 2008; Adinna *et al.* 2009). The effects of Urban Heat Islands (UHI) are defined as temperature increases in metropolitan areas, particularly at night, when compared to surrounding rural areas. The temperature change is higher at night compared to during the day, and it is more noticeable when the winds are light.

According to Benali et al. (2012), Land Surface Temperature (LST) is a good indicator of the net surface energy balance caused by long-wave surface radiation emissions. Thermal Infrared (TIR) spectral measurements taken by ground-based, airborne, or satellite-based sensors typically yield LST. The urban heat island can be determined through the study of the land surface temperature of the area under study. UHI is most noticeable during the Harmattan and rainy season transition periods. This explosive increase in the exponential form of 'Population Growth' has wreaked havoc on urban human life Uwadiegwu *et al.*, (2011). This can be attributed to two major factors: human activity and land use. Urbanization has been the most significant class of land use/land cover alteration in human existence, which is the changing of other types of land to uses related to population and economic growth (Zhang *et al.*, 2008). Geometrical patterns and high-rise buildings in numerous urban centers that have multiple surfaces for sunlight absorption, reflection, and improved heating effectiveness in cities, are also causes of UHI, and this is known as the "canyon effect." The major effects of these are a consistent rise in temperature and decreased humidity in the urban environment (Oke, 1979; Efe, 2002; Burak et al., 2004).

The visible temperature increase in urban centers is referred to as the "Urban Heat Island (UHI)" (Oguntoyinbo, 1981; Figuerola and Mazzeo, 1998). Many cities, including Paris (Dettwiller, 1970), London (Derek, 1992), Madrid (Gómez et al. 1993), and Barcelona, have taken an interest in studying urban climate (Moreno-Garcia, 1994). Benin (Efe and Eyefia, 2014), Kaduna (Mande and Abashiya, 2020), Kano, Abuja (Isioye, Ikwueze, and Akomolafe, 2020), and Lagos (Isioye, Ikwueze, and Akomolafe, 2020; Bassett et al., 2020). The thermal level of comfort was assessed by using the Urban Thermal Field Variance Index (UTFVI) by Isioye, Ikwueze, and Akomolafe (2020), who quantitatively evaluated the effects of UHI on urban life in their study in Abuja, Nigeria. Their findings revealed that the Land Surface Temperature in Abuja city varies from nearly 19°C and 39°C, with UHI discovered in the city's eastern and northern parts. According to the UTFVI map attributed with UHI, the city's outskirts are more environmentally friendly than its core. Similarly, approximately 40% of the city suffers from ecologically harmful or scarier UHI effects, implying the importance of ongoing UHI mitigation efforts.

Mande and Abashiya (2020) used Landsat TM satellite imagery in their study in Kaduna town. The land cover classification showed a rise in residential areas by +15.93%, a -27.21% decline in grasslands, a +11.19% growth in bare land, and a +0.09 increase in water bodies between the years 2000 and 2018. For LST, NDVI analysis revealed a +0.02 and +0.17 expansion of the maximum and minimum intervals, as well as +2.16 and -7.76 variations in the ranges of maximum and minimum temperatures. Furthermore, the researchers concluded that urban expansion has a significant effect on urban climate, specifically the increase in land surface temperature, which enables cities to become hotter and drier.

Lagos, which tripled in size between 1984 and 2016, is one of the cities with the fastest growth rates in the world, claim Bassett et al. (2020). Because of the lack of data, the authors used an ensemble approach and the WRF numerical model to examine UHI effects in Lagos. Similarly, their findings showed that the region is influenced by the urban heat island effect, which is sharply expanding.

The UHI intensity (UHII) within Lagos' urban outline is also expanding, and the city is warming the rural region’s downwind. There is also a 0.448°C rise in nighttime ensemble-time-mean (ETM) UHII between the years 1984 and 2016, using a rectified, month-long set of meteorological conditions for each case. Between 1984 and 2016, the peak modeled UHII levels increased by 0.948 degrees Celsius per hour, reaching 4.138 degrees Celsius. The region in which ETM UHIIs exceeded 18C was discovered to sharply increase, showing the impact's true spatial extent. Due to a strong southwesterly wind that also transported the warmth of the city into nearby rural areas, the highest UHIIs were discovered in each case to the northwest of the study area.

Derek (1992) in his study in London observed that urban heat islands cause average yearly temperatures in the city to be about 1.5 degrees Celsius greater than in rural areas. This is a result of a diverse combination of factors such as the presence of air pollutants in the air, the removal of vegetative cover and substituting it with things such as concrete and tarmac, motor vehicle emissions, and anthropogenic heat emission. In their study in Benin City, Efe and Eyefia (2014) discovered an urban bias of about 4.4°C and temperature variability of 5.5°C within the urban canopy, confirming the presence of an urban heat island. It also revealed a 0.5°C temperature difference between rural and urban areas, indicating a 2% urban warming over rural areas. The daily temperature suggests that weekdays are warmer than weekends.

The increase in temperature was caused by a high rate of socioeconomic activities, which fueled the development of urban heat islands. In most Nigerian cities, the climatic irregularity in cities has expanded as low, single-story buildings have been replaced by multistory buildings. Also, asbestos, zinc, and aluminum roofing sheets result in net radioactivity spreading across multiple land uses, causing shifts in surface radiation patterns. Likewise, the height of such building structures and how they are positioned impact the nighttime egress rate because the sun's energy is absorbed by construction material during the day (Oguntoyinbo, 1981). Similarly, Samuels (2006) noted that the harmful effects of urban heat island scenarios are now widely known, spanning from the escalating community, regional, and microclimatic weather extremes to a diverse array of severe health problems, as well as involving the consumption of limited energy resources.

The countries of Sub-Saharan Africa have been portrayed as being the area most susceptible to the effects of global climate change (IPCC, 2014). The "variations in urban heat islands" have not been the focus of earlier studies (Adeyeri, 2009; Hassan, 2017; Yusuf, 2017; Zemba, 2018) related to climate change in the region. This study fills a gap in the literature by investigating the urban heat island in Yobe State's Nguru Local Government Area to prove the existence of climate change. Numerous studies have examined the spatial and temporal patterns of temperature in Nigeria and found that the nation is warming up (Adefolalu, 2007; Ikhile, 2007; Odjugo, 2010; Oguntunde, 2000; Sawa, 2015). Interestingly, no such study has been conducted in Nguru LGA despite its significance as the site of the Nguru wetland, which is why this research seeks to fill a knowledge gap by examining UHI between 2001 and 2021 in the study area.

Literature review

Several scholars (Efe, 2002; Mazzeo, 1998; Ayoade, 1993; Landsberg, 1981; Omere, 2001; Livingstone, 2006; Das, 2022; Philipps,et al., 2022; Çolakkadıoğlu, 2023) have used the concept of urban heat islands in both temperate and tropical regions across the globe. According to these studies, the climate of a city shifts as it grows. Several other urban climate studies in Nigeria have investigated the urban implications on climate elements such as global radiation (Ojo, 1980), net radiation (Ojo, 1980), temperature, and albedo (Oguntoyinbo, 1981; Oguntoyinbo, 1970). These studies found that, while urban net radiation and albedo values are lower than rural values, temperatures are lower in rural areas than in urban areas. These studies, regrettably, are constrained because they are descriptive, rely on archive data that is point determined, and fail to measure the spatial and periodic spatiotemporal trends of these climate characteristics over the urban canopy. They did, notwithstanding, call for regular studies of urban climate in other major Nigerian cities. Nwilo et al. (2012) discovered that land surface temperature reduces as one moves from the urban core to its outskirts and that surface temperature within urban areas can also differ due to disparities in land use and land cover. The approach used in this research included data collection, datum standardization, land cover (LC) extraction, land surface temperature (LST) determination, the generation of LST inventory, and a connection to land cover. Additionally, between 1984 and 2015, they observed an overall upward trend in surface temperatures. The greatest increase in average land surface temperature was witnessed in Ifako Ijaiye LGA (2.314°C), Eti-Osa LGA (2.071°C), Alimosho LGA (2.812°C), and Ikorodu LGA (2.320°C). Zaharaddeen (2016) conducted a similar study to determine the land surface temperature of Kaduna metropolis utilizing images from the United States Geological Survey's website captured in 2001, 2006, 2009, and OLI 2015 using the Landsat ETM+ satellite. An image of the Normalized Difference Vegetation Index (NDVI) was created. The final Land surface temperature was calculated by the researcher using surface emissivity based on NDVI.

According to his observations, the temperature in Kaduna metropolis ranged from 18.76°C to about 37.73°C in 2001, 15.67°C to around 48.01°C in the year 2006, 17.66°C to 36.03°C in 2009, and 28.14°C to 45.65°C in 2009. With a mean value of 39.42 and a standard deviation of 1.92, the year 2015 has the highest mean value. This suggests that urban growth does increase land surface temperatures by substituting vegetative cover with non-evaporating, non-transpiring surfaces like metal, tar-cemented buildings, concrete, and bare land (soils). In the summer, higher urban heat islands have devastating effects on tropical and arid areas. People who live in the middle of the city find it uncomfortable. People with limited physical endurance are susceptible to heat stress because of the extreme heat, which can result in sickness and even death (Voogt, 2004). However, the UHI effect tends to make people feel more comfortable during the hotter weather of the harmattan season (Shahmohamadi et al., 2010; Voogt, 2004).

Materials and Methods

Study Area

Nguru is a local government area in Yobe State, Nigeria. Its headquarters are situated at 12° 52′ 45″N, 10° 27′ 09″E, in the town of Nguru. The area is bordered by Jigawa, Bauchi, Gombe, and Borno states and shares an international border with the Niger Republic to the north. The town of Nguru was most likely founded in the fifteenth century. The three dominant tribal groups in the region—Hausa, Kanuri, and Fulani—consist of farmers, herders, and fishermen who solely rely on the Nguru wetlands for their subsistence (Birdlife International, 2015; Kaugama and Ahmed, 2014). The "Sand Dunes," a semi-desert area, is one of many different landscape types in the region. Its area is 1023.45 km2, and as of 2021, its population was estimated to be 314,360.

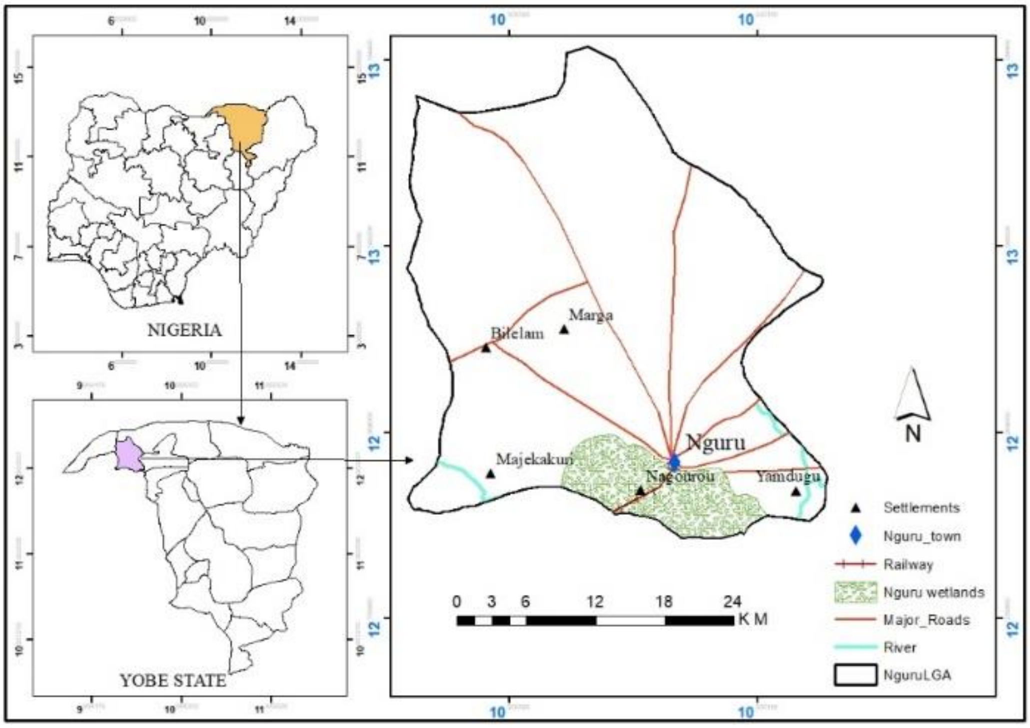

Fig. 1. The study area

A network of channels connects the permanent lakes and periodically flooded pools that make up the Hadejia-Nguru Wetlands (HNWs), which are part of the local government, and the area also has a college of education and legal studies. The wet season, which lasts from May to September, and the dry season, which lasts from October to April, are the two distinct seasons in the area. In the area, annual rainfall totals fall between 500 and 600 mm (Ogunkoya and Dami, 2007). The vegetation of the area is primarily Sudan's savanna.

The average monthly temperature ranges from a minimum of 12°C in December and January to a maximum of 40°C in April (Ogunkoya and Dami, 2007). A network of channels connects the ecosystem's permanent lakes and periodically inundated pools. The ecosystem is a crucial location for species diversity, particularly for migratory water birds from the Palearctic. Additional vital advantages of the wetland include crop production, pasture resources, quasi-forest products, fuel wood, and fishing, which all contribute to essential revenue and nutritive value (Ramsar, 2007).

Method of Data Collection

The collection of all of the relevant data used in this study came from diverse sources. The GLOVIS portal (http://glovis.usgs.gov/) was used to download Landsat satellite images of the years 2001 and 2021. Decheng *et al.* (2018) used Landsat images, they were considered suitable and downloaded for this evaluation. He observed that about 53% of scientists have utilized either one or numerous Landsat satellite images in their UHI research because:

i. It is considered the longest-operating undisrupted Earth observation satellite program (Decheng *et al.* 2018).
ii. Furthermore, thanks to a change in policy made in 2008, scholars now have free access to Landsat images.
iii. With a 185km - 18 km coverage swath, Landsat 5, 7, and 8 obtain the Earth's surface data on a 16-day continuous cycle. Table 1 summarizes the high-resolution images used in this study.

Table 1: Details of the images used

S/N	Data	Sensor	Band	Path and rows	Resolution	Date
1	Landsat 7	ETM	6	Path 187, row 51	30m	2001-09-24
2	Landsat 8	ETM+	10	Path 187, row 51	30m	2021-09-19

Table 2: Land use Land Cover types and descriptions

S/N	Land Cover Type	Description
1	Forest	Areas covered by thick vegetation and tall trees
2	Built-up areas	Public, commercial, residential, manufacturing, infrastructure-related, and recreational urban areas
3	Bare land	Open areas, a landfill, unprotected soil, and desolate land
4	Green areas	All land areas covered by grasses, short shrubs, and riparian vegetation
5	Waterbody	Rivers, Streams and other waterbodies

Tools for analysis

The images in this study were analyzed using the software mentioned below. ArcMap 10.7.1, Erdas IMAGINE, and Idrisi Terraset.

Data Processing

The images downloaded were processed in two stages: pre-processing and processing.

Pre-processing

This is done before the analysis. It comprises the following steps:

i. Clipping: Path 187 and row 51, as well as each of the years 2001 and 2021, were overlaid to create a single image that functions as a whole.
ii. Mosaicing: This was accomplished by superimposing the study area's administrative map over the downloaded satellite imagery.
iii. Extracting: A shapefile of the administrative map of the area was used to cut the Area of Interest (AOI) using the Extract by Masking function of ArcGIS 10.7.

Processing

Classification of land use and land cover was done during the processing of the downloaded images. The Anderson classification method of 1976 was revised and implemented to obtain the required land covers for study. The images were subjected to supervised classification using Igun and William's (2016) maximum likelihood classification because the method includes a weighting that helps reduce errors caused by misclassification during the classification process. Table 2 shows the altered land cover/land use classification that was used.

Identification of Normalized Difference Vegetation Index (NDVI)

The NDVI was calculated using bands 5, 4, and 3 between 2001 and 2021. The following formula was used to calculate it:

NDVI = NIR – RED / NIR + RED… ***Equation 1***

Where,
NIR denotes near-infrared
RED denotes red reflectance

Land surface temperature (LST) retrieval.

A single window algorithm was used to obtain Land Surface Temperature (LST) from image brightness:
LST = TB / 1 + (λ + TB/ ρ) In ελ ----------- ***Equation 2***

Where;
λ represents the wavelength of the generated radiance which is equal to 11.5μm.
ρ represents h.c/σ,
σ r denotes Stefan Boltzmann's constant = 5.67 x 10-8 Wm-2 K -4,

h denotes Plank's constant (6.626 x 10 -34 J S) c represents the velocity of light (2.998 x 108 m/sec) and
ελ denotes spectral emissivity.

The map algebra function of Spatial Analyst in ArcGIS 10.7.1 software was utilized to measure all of the above techniques (for calculating land surface temperature).

Data Analysis

All satellite images are in raster format, and the count values were transformed into area counts to turn the pixels that each land cover occupies into polygons. Changes in land cover were determined by calculating the changes in hectares and percentages between 2001 and 2021.

Results

Accuracy Assessment

One of the most important tools for creating maps of land use and land cover is remote sensing, which uses a process called image classification. Due to the increased potential for error that digital imagery presents, accuracy assessment has become a crucial process (Congalton, 1991). For the image classification process to be effective and accurately represent the real situation, an accuracy assessment is carried out to determine how accurate the classification was. Assessing or validating accuracy is a crucial step in the processing of remote sensing data.

Table 3. Confusion matrix for 2001 satellite image

SN	Class	Thick vegetation	Waterbody	Greenland	Bare soil	Built-up areas	Total	U_Accuracy	Kappa
1	Thick vegetation	10	0	0	0	0	10	1	0
2	Waterbody	0	10	0	0	0	10	1	0
3	Greenland	0	0	9	1	0	10	0.9	0
4	Bare soil	1	2	2	79	1	85	0.929412	0
5	Built-up areas	0	0	0	0	10	10	1	0
	Total	11	12	11	80	11	125	0	0
	P_Accuracy	0.909091	0.833333	0.818182	0.9875	0.909091	0	0.944	0
	Kappa	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0.895522***

Table 4. Confusion matrix for 2021 satellite image

SN	Class	Thick vegetation	Waterbody	Greenland	Bare soil	Built-up areas	Total	U_Accuracy	Kappa
1	Thick vegetation	10	0	0	0	0	10	1	0
2	Waterbody	0	10	0	0	0	10	1	0
3	Greenland	0	0	9	1	0	10	0.9	0
4	Bare soil	2	1	1	90	0	94	0.957447	0
5	Built-up areas	0	0	0	0	10	10	1	0
	Total	12	11	10	91	10	134	0	0
	P_Accuracy	0.833333	0.909091	0.9	0.989011	1	0	0.962687	0
	Kappa	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0.925323***

Table 5: Land use land cover (LULC) 2001 – 2021

S/N	LULC Type	Area (Ha) 2001	Area (Ha) 2021	% Change 2021 - 2001
1	Forest	6,224	2,771	-3,453 (66.23%)
2	Waterbody	934	858	-76 (86.83%)
3	Green area	7,932	365	-7567 (19.26%)
4	Bare soil	86,818	95,877	-9,059 (5.20%)
5	Built-up area	446	2,483	2,037 (556.73%)
	Total	**102,345**	**102,345**	

The selection of a sample of spatial units is typically done using a pre-defined sampling protocol, commonly based on individual pixels (Stehman, 2009). The "true LULC class" is then assigned to these sample units to create a reference data set, for instance, by photo interpretation of extremely high-resolution images and/or field visits. After creating a confusion matrix, all sample units are compared to the map class and the reference class. From this matrix, accuracy indices can be obtained, including the user's and producer's accuracy per class and the overall accuracy (e.g., Stehman and Foody, 2019; Olofsson et al., 2014). Thus, the quality of the reference database is essential for evaluating the accuracy and may have a significant impact on the accuracy indices obtained (McRoberts et al., 2018; Foody, 2010). The overall classification accuracy for the 2001 image was 89.14%, while the overall classification accuracy for the 2021 image was 91.7%, with a kappa coefficient (K) of 0.90. Furthermore, all five classes had accuracy levels above 0.81% for the producer, and all classes have accuracy levels above 0.90% for the user accuracy.

Land Cover

Figure 2 and Table 5 show the imageries of the Nguru Local Government Area for the years 2021 and 2021, which were analyzed using the maximum likelihood classification. The result showed a +556.73% expansion in built-up areas and a -27.21% decline in vegetation. Forests are being destroyed on a large scale to meet the demand for various urban facilities. Less tree cover means less effective cooling. The environment is cooled by trees because they deflect the sun's heat and capture it for their photosynthetic process (Akbari *et al*. 2001). There are many multilayered buildings in urban areas. The urban canopy, which is made up of nearby taller structures, captures the heat reflected by a building (Mason 2006). UHI is made worse by the growth of urban canopies.

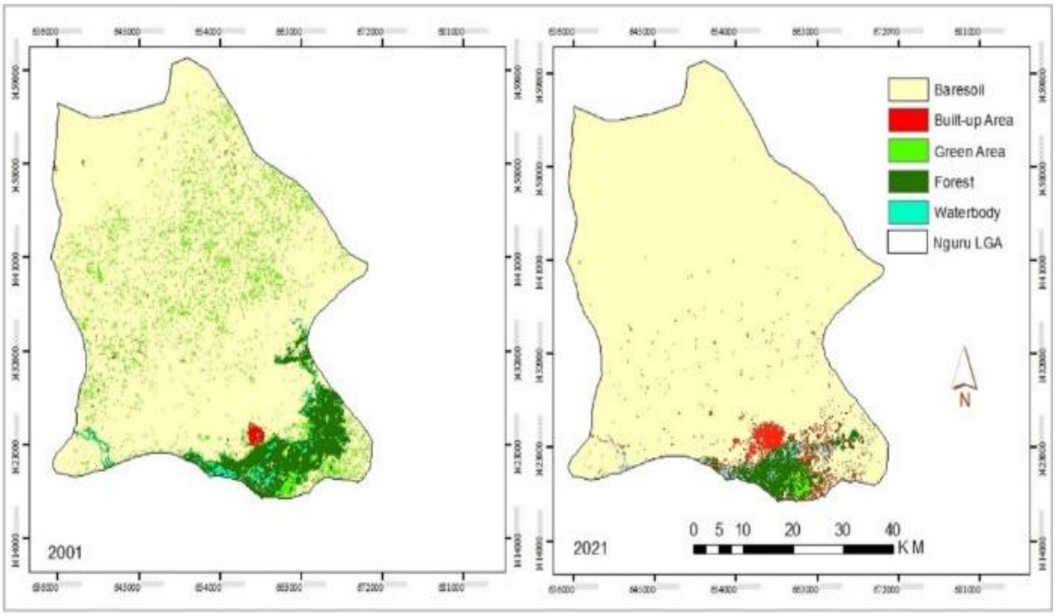

Fig. 2: Land use land cover (LULC) of 2001 and 2021

Land Surface Temperature

The LST retrieved to determine the UHI in Nguru shows a +5.32 ^{O}C increase and a +1.03^{O}C increase in the highest and lowest temperature between 2001 and 2021, respectively. Variations in minimum and maximum temperatures are alleged to have occurred within Nguru as a result of a massive drop in vegetative cover and an upsurge in built-up areas. The LST research findings are consistent with those of Ifatimehin (2007) who observed that Surface Urban Heat Island (SUHI) is higher in the city center and decreases as one moves outward, as well as the research findings of (Aslan and Koc-San, 2016; Khaled, *et al.*, 2015; Zaharadeen *et al*., 2016).

The causes of UHI, according to Santamouris *et al.* (2007) and Akbari and Oke (1987), are as follows: absorption of solar radiation because of low albedo; obstructing airflow because of higher rigidity; low evapotranspiration because of less vegetative cover; and high anthropogenic heat release. Sailor (2006) suggests two methods for lowering the urban heat island effect. The first involves using roofs with similar insulation qualities that are light in color because they do not absorb much heat from the sun, and the second involves increasing evapotranspiration. Similarly, one of the best ways to lessen the effects of urban microclimate is to increase the amount of vegetation. (Wilmers, 1988; Xua *et al.*, 2010).

Land Surface Temperature (LST) Response to Changes in land cover

To determine the response of Land Surface Temperature (LST) to changes in land cover, Table 1 was used to show the LST of Nguru in 2001 and 2021. The difference between the years was also calculated. The analysis showed a variability of +5.32^{o}C and +1.03^{o}C maximum and minimum temperature in the Nguru between 2001 and 2021 respectively, as shown in Table 6. The difference was found not to be sizeable in comparison to the studies by Ifatimehin (2007) and Qiquan and Jiayi (2017).

As depicted in Figure 3, the area with lower temperature is found at the Nguru wetland and its surrounding, this is the result of the presence of waterbody and vegetation at the location. The areas with high temperature.

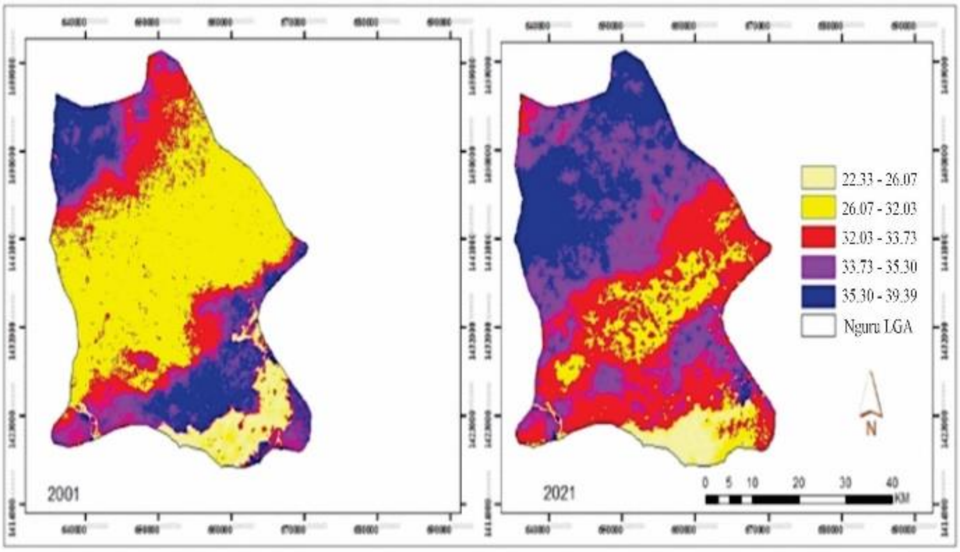

Fig. 3: Land Surface Temperature of Nguru Local Government Area of 2001 and 2021.

Table 6: LST in Nguru Local Government Area from 2001 – 2021

Temp (°C)	2001	2021	Difference (2021 - 2001)
High	34.07	39.39	+5.32 °C
Low	22.33	23.36	+1.03 °C

Table 7: LST by area in Nguru Local Government Area from 2001 – 2021

S/N	2001		2021	
	Temp (°C)	Area covered (ha)	Temp (°C)	Area covered (ha)
1	22.33 – 26.07	5,696	22.33- 26.07	4,278
2	32.03 – 32.03	49,151	32.03– 32.03	11,776
3	32.03 - 33.73	18,430	32.03 - 33.73	29,880
4	33.73 - 35.30	29,077	33.73 - 35.30	31,883
5	35.30 - 39.39	0	35.30 - 39.39	24,538

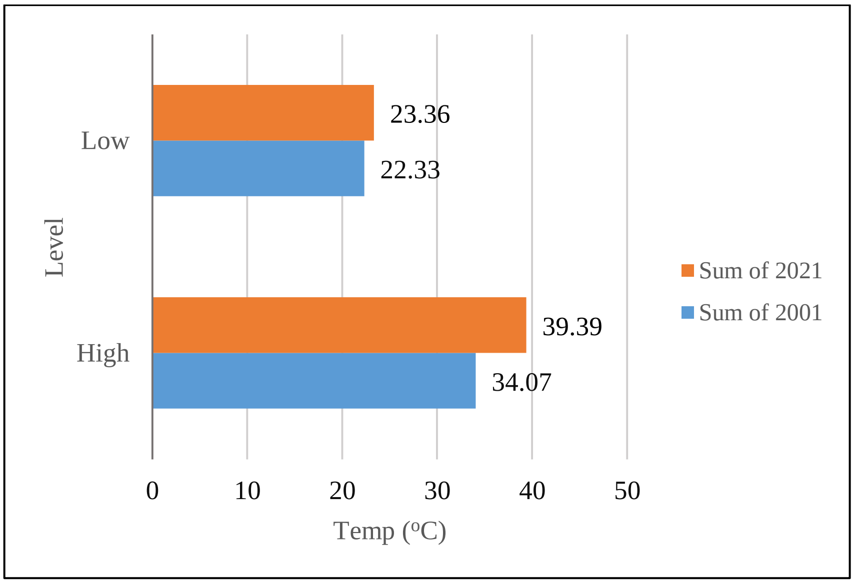

Fig. 4: Land Surface Temperature 2001 – 2021

However, Qiquan and Jiayi (2017) found that the correlation between Surface Urban Heat Islands and built-up class characteristics varied depending on the climatic zone in their study in China. Ifatimehin (2007) discovered that densely vegetated areas have the lowest temperature values, suggesting that a land cover's land surface temperature will be lowered provided it has higher biomass.

Discussion and Conclusion

Conducting this research revealed the connections between the different land covers under study, namely forest, built-up areas, grassland, water body, bare land, and land surface temperature in Nguru between 2001 and 2021. The research also discovered that urban growth greatly influences the local climate, notably because it raises the earth's temperature, which tends to generate urban heat. The findings of this study agreed with the results of other studies (Meenal and Rajashree, 2017; Zaharaddeen *et al.* 2016; Khaled *et al.* 2015) which also observed the existence of the relationship between urbanization and urban heat island.

To better inform their needs for adaptation and mitigation, it is evident that it is important to understand how hot Nigerian cities will be in the future. as temperatures in this region are expected to increase under all foreseeable climate conditions (IPCC, 2013), in addition to rapid UHI expansion. Nevertheless, the lack of observational data in Nigeria continues to be a problem despite continued efforts to enhance observational capabilities (Hussaini and Yakubu 2019). In an area that is warming up quickly and already inhabited by tens of millions, it is anticipated to double in size before the century ends. We hope that these results will be utilized to facilitate regional studies on climate change and to aid in sorting discoveries.

Replace impervious pavements that prevent water infiltration with pervious pavements that do (Sailor, 2006); it can be anticipated that this will possibly moderately lower the temperature. According to Robitu *et al.* (2006), an increase in water bodies may result in a decrease in temperature because of their evaporative effect and increased wind speed. Urban Design Urban planning done correctly can be extremely important in reducing the UHI effect. On the riverbank, an urban planning strategy was described by Yamamoto (2006). His recommendation is to construct the dwellings so that a winding path is made, allowing cool river air to flow into the city. Large-canopied shade trees can shield buildings and oncoming traffic from the sun's rays, keeping both groups of people relatively cool. Additionally, shade trees reduce the temperature through evapotranspiration Sailing (2006). Rooftop plants According to Wong (2005), between 21% and 26% of the total land area of cities is made up of roofs. To reduce the UHI effect, making the roofs green through vegetation will be extremely important. Green roofs draw in air and soak up heat, bringing the temperature down. (Getter, 2006).

Urban Heat Island dwellers ought to adopt a lifestyle of minimizing anthropogenic causes by using green and environmentally friendly appliances. Public enlightenment on the effects of urban heat islands should be done by the government in collaboration with civil societies and non-governmental organizations. Relevant laws prohibiting the indiscriminate cutting down of trees should be imposed upon the people living in the area.

Conflict of interest disclosure

The authors declare that no conflicts of interest exist.

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