Spatio-temporal Variability of Landuse Landcover and its Impact on Land Surface Temperature in Zaria Metropolis, Nigeria

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Abstract

This paper assessed the spatio-temporal variability of land use land cover (LULC) and its impact on Land Surface Temperature (LST) in Zaria and environs. Multi-temporal Landsat data; Landsat 5TM, 7ETM$^+$ and 8OLI of 1988, 2003 and 2018, respectively, at an interval of 15 years were obtained. These data were processed and classified into various classes using the supervised classification. It was also used to determine the LST of the area. The results of the classification revealed that, apart from built-up area which increased consistently from 15.353 km^2 in 1988 to 32.8623km^2 in 2018, all other LULC decreased within the study period. The LST ranges from 1.5 to 35.9ºC across the study period. The relationship between LULC and LST was investigated and result showed that LST had positive correlation of 0.608 with built-up area indicating that LST increased with increase in built-up areas. However, dense vegetation, light vegetation and bare land had negative correlations of -0.976, -0.851 and -0.708, respectively, with LST indicating that LST increase with decrease in vegetation and bare land. The implication of this unprecedented changes is the resulting environmental and climatic problems such as urban heat island and desertification which have become very common in the study area. It was suggested that the LULC of Zaria metropolis should be controlled and afforestation be encouraged to enhance a healthy living condition of the area.

Keywords: Land Surface Temperature, Land Use Land Cover Change, Landsat

INTRODUCTION

The earth surface continuously undergo changes propelled by both natural and anthropogenic activities (Fall *et al.,* 2009). Anthropogenic activities include farming, cattle rearing, settlements and industry amongst others (Azua, 2018b). These activities otherwise refer to as land uses by most researchers (Kang *et al.,* 2010; Zhang *et al.,* 2010; Bu *et al.,* 2014; Azua, 2018a) are on the increase due to increase in the human population across the globe. Nigeria for instance had a population of 140 million in 2006 (NPC, 2006). Today, her population has risen to over 190 million (USCB, 2019). This has led to the expansion in settlements, farmland and deforestation as well as increase in demand for food, water and other natural resources. This result in series of environmental and climatic consequences that affects the wellbeing of man, plants and animals as well as the ecosystem in general.

Land Surface Temperature (LST) is one of the climatic parameters that is affected by changes in land use land cover. It refers to the temperature of the air near the surface of earth (Saini and Tiwari, 2017). Increase in LST can lead to an increase in urban heat island which causes an urban area to be warmer than its surrounding rural areas (Voogt and Oke, 2003).

There is need to assess the changes LULC from time to time because these changes are very vital in the monitoring and management of environment and its resources, for human wellbeing (Oyinloye and Kufoniyi, 2011; Nzoiwu *et al.*, 2017; Daramola and Eresanya, 2017).

Several studies have been conducted on the analysis of LULC of Zaria. Azua (2010), Grace *et al.* (2015) and Okewu (2016) studied the changing pattern of LULC in Zaria metropolis. However, it appears that no study assessing the impact of LULC on LST has been carried out in Zaria. The aim of this study therefore, is to analyse the impact of anthropogenic activities on LST in Zaria and its environs, with the view of providing better understanding on the biophysical composition of the earth for effective planning and management. The objectives of this study are to; determine the land use land cover dynamics and LST in the study area; determine the link between land use land cover dynamics and LST in the area; and to discuss the implications and suggest possible ways of reducing the impacts of these changes on the populace.

The Study Area

Zaria is the second largest city in Kaduna State located in northern parts of the state. It lies within Latitude 10°5' and 11°6' North of the equator, and Longitude 7°4' and 8°5' east of the Greenwich meridian (Figure 1). Zaria is located on the central plains of the Hausa high land standing at a height of about 670m above Mean Sea Level (Azua, 2010). It is drained by Kubanni, Galma and Saye Rivers all of which converge on River Kaduna. Zaria comprises of two Local Government Areas (LGAs) namely Sabon Gari and Zaria LGAs and has a population of about 1, 364,942 (Okewu, 2016). The study area has many institutions and industries which have attracted many people from different parts of the country to the area in search of shelter, better education and white-collar jobs leading to high population (Kugu, 2018).

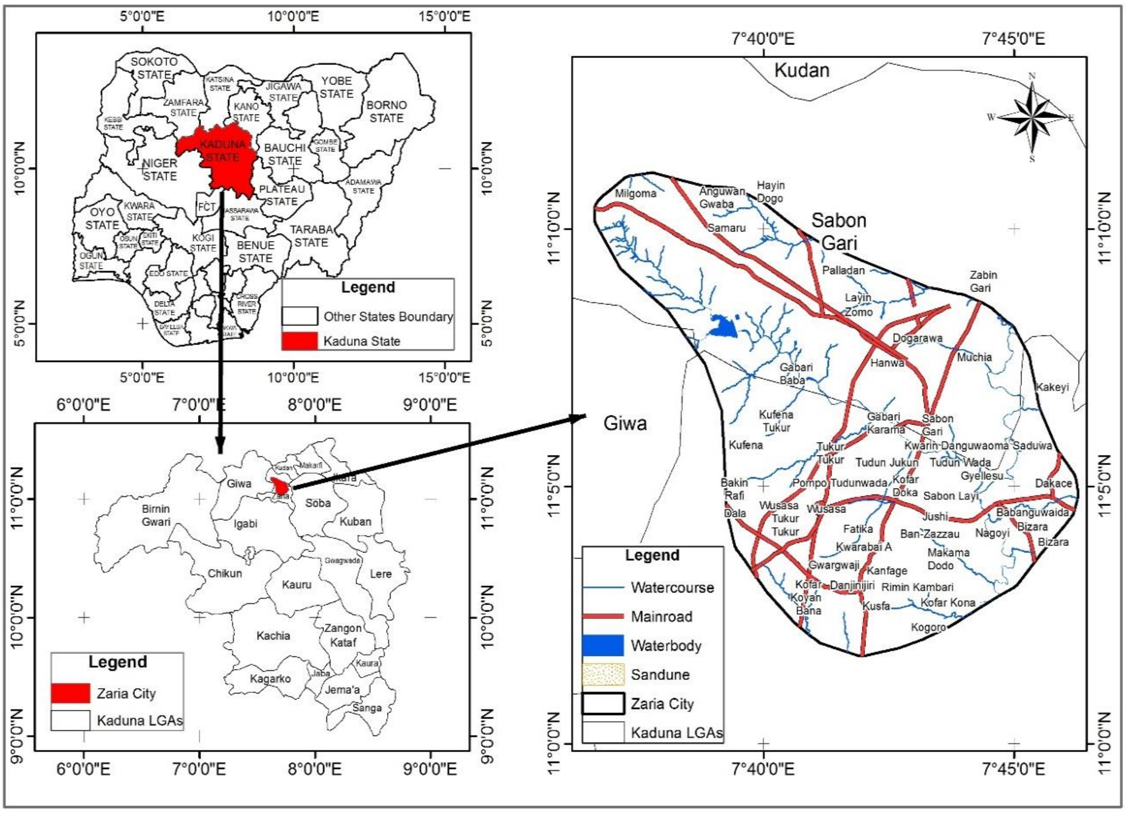

Figure 1: The Study Area.

The climate of the area is tropical continental comprising of two seasons namely, wet and dry seasons (Azua, 2010; Grace *et al.*, 2015). The wet season extend from April to October having an average of about 1100mm per annum. The dry season extend from November to March having daily maximum temperature rising from 33°C in January to the peak of about 40.6°C in April (Azua, 2010). The vegetation of the area was forest savannah however, due to settlement expansion, agricultural activities and other land uses, the natural vegetation has changed to guinea savannah.

The economic activities of the indigenes were primary production which involves the direct exploitation of the natural resources for immediate use. Hence, activities such as fishing, farming, hunting and mining of iron ore for the production of tools were very common in the area. These activities have changed tremendously due to urbanization.

MATERIALS AND METHODS

Materials

The Landsat data acquired for this study include Landsat 5 Thematic Mapper (TM), Landsat 7 Enhance Thematic Mapper plus (ETM+) and Landsat 8 Operational Land Imager (OLI) and their respective thermal bands. The data were obtained from the data archive of the United States Geological Survey (USGS) (glovis.usgs.gov) with the following characteristics as stated in Table 1. All the satellite images were acquired in January to avoid cloud cover and to ensure high accuracy. The images were acquired for a period of 30 years at an interval of 15 years. These images were registered and geo-corrected before been made available for use by the public (Azua *et al.*, 2018b).

Table 1: Data Types and Sources

Data Types	Path/Row	Bands used	Year	Resolution (m)	Date acquired by Satellite
Landsat 5 TM	P189/R52	2, 3, 4 & 6	1988	30	12th January, 1988
Landsat 7 ETM$^+$	P189/R52	2, 3, 4 & 6	2003	30	27th January, 2003
Landsat 8 OLI/TIRS	P189/R52	3, 4, 5 & 10	2018	30	21st January, 2018

Methods

Land Use Land Cover Classes

After forming the False Colour Composites (FCCs), the images were clipped to the boundary of the study area and subjected to digital image processing using histogram equalization, to enhance the image contrast. Supervised classification was employed to classify the FCCs into various classes based on their spectral properties using maximum likelihood algorithm in ERDAS Imagine 9.2 environment. The results were subjected to accuracy assessment using error matrix and kappa coefficient to ensure that the results meet the required standard for classification.

Extraction of Temperature Data

LST was extracted from Landsat 5 and 7 using bands 6 and Landsat 8 OLI using TIRS band 10. The top of atmospheric (TOA) spectral radiance (L) was computed using equation 1 (Barsi *et al.*, 2014; Avdan and Jovanovska, 2016):

(a) Conversion from Digital Number to Spectral Radiance

Eqn. 1 is applicable to only Landsat 5 TM and 7 ETM+ while equation 2 is applicable to Landsat 8OLI

$$L = \frac{(L_{\max} - L_{\min}) * (Q_{cal\max} - Q_{cal\min})}{(Q_{cal\max} - Q_{cal\min})} \quad (1)$$

Where L is the Spectral radiance at the sensor aperture (watt m^{-2} $ster^{-1}$), L_{max} is the Spectral radiance scaled to Q_{calmax} (watt m^{-2} $ster^{-1}$), L_{min} is the Spectral radiance scaled to Q_{calmin} (watt m^{-2} $ster^{-1}$), Q_{cal} is the Quantized calibrated pixel value DN, Q_{calmin} is the Minimum quantized calibrated pixel value corresponding to L_{min}, Q_{calmax} is the Maximum quantized calibrated pixel value corresponding to L_{max}, L_{max} and L_{min} value was acquired from Landsat post callibration dynamic range table

$$L = M_L * Q_{cal} + A_L - O_i \quad (2)$$

where, M_L is the band - specific multiplicative rescaling factor, Q_{cal} is the Band 10 image, A_L is the band - specific additive rescaling factor, and O_i is the correction for Band 10.

(b) Conversion from Spectral Radiance to Reflectance (at-satellite reflectance)

$$r = \frac{\pi * L * d^2}{E_{sun} * Cos\theta * dr} \quad (3)$$

where, r is the Planetery reflectance (unitless), L is the Spectral radiance at the sensor aperture (watt m^{-2} $ster^{-1}$ μm^{-1}), dr is the Inverse square of earth - sun distance (astronomical unit) Esun is the Mean solar exoatmospheric irradiances (watt $m^{-2}\mu m$,), θ is the Solar zenith angle (degree) and d is the distance from the earth to the sun.

(c) Computing NDVI using Landsat bands in reflectance

NDVI is calculated using the following expression (Azua *et al.*, 2018b; Alemu, 2019):

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \quad (4)$$

where, RED is the visible red reflectance and NIR = Near Infrared reflectance

(d) Land surface emissivity

Alemu (2019), defined land surface emissivity (ε_λ) as the “ratio of energy emitted from a natural material to that of a perfect emitter (black body) at the same temperature”. The author further stated that a surface used for emissivity is assumed to consist of bare soil and vegetation and the computation can be done using the mathematical expression in equation 5 as follows:

$$\varepsilon_\lambda = \varepsilon_{v\lambda} + P_v + \varepsilon_{s\lambda}\left(1 - P_v\right) + C_\lambda \quad (5)$$

where, ε_v is the band emissivity value for vegetation, ε_s is the band emissivity value for bare soil, C is the surface roughness taken as a constant value of 0.005, P_v = proportional vegetation that shows the extent of vegetation cover

p_v can be derived from NDVI as follows:

$$P_v = \frac{(NDVI_v - NDVI_s)}{(NDVI_v + NDVI_s)} \qquad (6)$$

where, $NDVI_v$ *is the NDVI value for full vegetation cover,* $NDVI_s$ *is the NDVI value for bare soil. The* $NDVI_v$ *and* $NDVI_s$ *of 0.5 and 0.2 were adopted as contained in Alemu (2019).*

(e) Computation of Temperature Data

LST was computed from Landsat 5 and 7 using bands 6 and Landsat 8 OLI using TIRS band 10. The top of atmospheric (TOA) spectral radiance ($L\lambda$) was computed using equation 2 (Barsi *et al.*, 2014; Avdan and Jovanovska, 2016).

(f) Conversion of Radiance to At-Sensor Temperature

The TIRS band data was converted from spectral radiance to brightness temperature (BT) using the thermal constants provided in the metadata file as shown in equation 7 (Avdan and Jovanovska, 2016):

$$BT = \frac{K_2}{ln\left[\left(k_1 / L\lambda\right)+1\right]} - 273.15 \qquad (7)$$

where, k_1 *and* k_2 *are the specific thermal conversion constants from the metadata.(For obtaining the results in Celsius, the radiant temperature is revised by adding the absolute zero (approx. - 273.15°C))*

The last step of retrieving the LST or the emissivity-corrected land surface temperature is computed as follows:

$$T_s = \frac{BT}{1 + (\lambda \beta T / \rho) \ln \varepsilon_\lambda} \qquad (8)$$

where, T_s *is the LST in Celsius* $(°C)$, *BT is at sensor BT* $(°C)$, λ *= the wavelength of emmitted radiance (for which the peak response and the average of the limiting wavelength (*$\lambda = 10.895$*) will be used) and* ε_λ *is the emissivity calculated.*

RESULTS AND DISCUSSION

Land Use Land Cover

The result identified five (5) LULC classes in the area namely, built-up, dense vegetation, light vegetation, bare lands and water body as shown in Figures 2,a-c. Table 2 showed the breakdown of various classes in each year of study. The accuracy assessment showed that, the overall accuracy for Landsat 5, 7 and 8 were 82%, 85% and 90%, respectively while the Kappa coefficients were 75%, 78% and 92% in the same order.

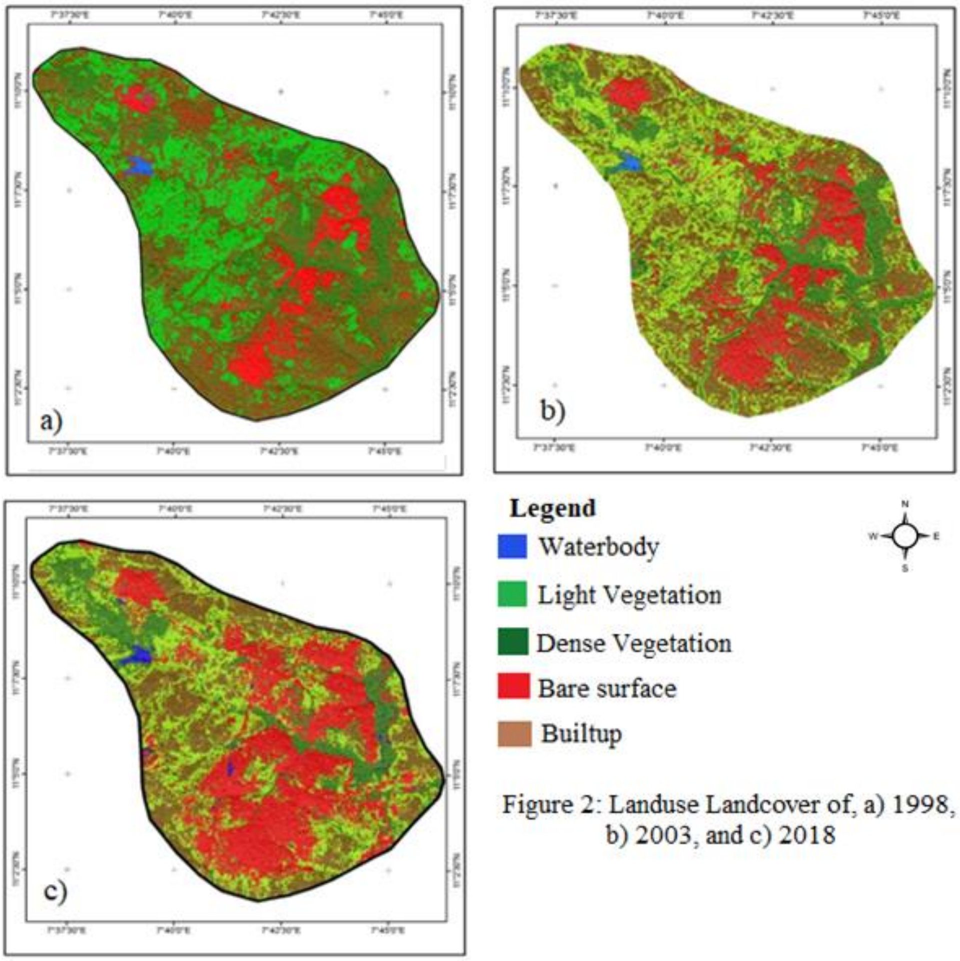

Figure 2: Landuse Landcover of, a) 1998, b) 2003, and c) 2018

Table 2 revealed that built-up area has been on the increase, expanding from 15.353 km^2 in 1988 to 23.030 km^2 in 2003 and 32.862 km^2 in 2018. This may be attributed to the influx of people in the area due to change in the socio-economic condition of the area. This result agrees with Azua (2010) who reported similar findings in the area. Some of the areas that witnessed expansion in built-up include PZ, Zaria City, Sabon Gari, Grace Land and Kabama Layout amongst others. Dense vegetation on the other hand increased from 21.950 Km^2 in 1988 to 34.675 km^2 in 2003 gaining about 9.8 km^2 and then decreased to 14.801 km^2 in 2018. The increase and decrease in dense vegetation observed between 1988 and 2018 seems abnormal, however, it could be due to various anthropogenic activities associated with the increase in

Table 2: Land Use Land Cover

Class Name	1988 (Km^2)	Percentage (%)	2003 (Km^2)	Percentage (%)	2018 (Km^2)	Percentage (%)
Unclassified	134.443	44.3	134.439	44.3	202.745	66.9
Built-up	15.353	5.1	23.030	7.6	32.862	10.8
Water Body	0.929	0.3	0.489	0.2	1.306	0.4
Dense Veg.	21.95	7.2	34.675	11.4	14.801	4.9
Light Veg.	50.787	16.8	48.397	16.0	26.535	8.7
Bare Land	79.825	26.3	62.248	20.5	25.028	8.3
TOTAL	303.277	100	303.277	100	303.277	100

population and expansion in settlement within the study area. This agrees with Okewu (2016) who reported similar findings in Zaria. Light vegetation also experienced decrease from

50.787 km^2 in 1988 to 48.397 km^2 in 2003 and 26.535km^2 in 2018 losing about 21.800 km^2. This may not be unconnected with the increase in population and the demand for fuel wood and agricultural activities amongst others.

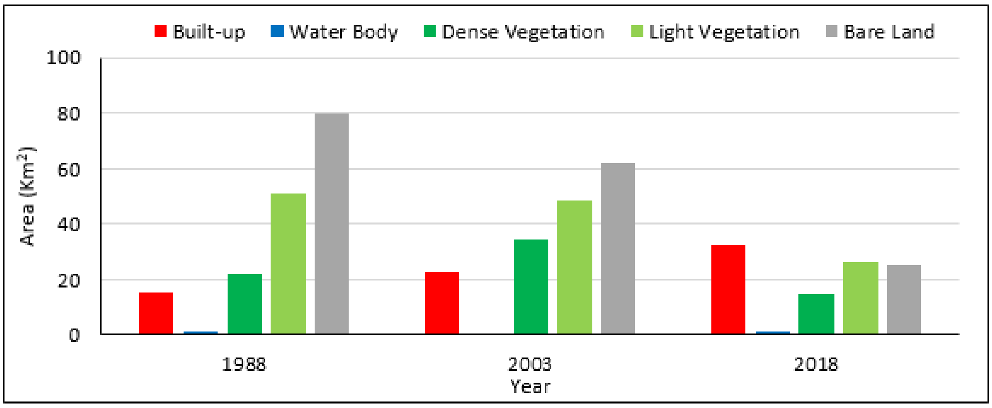

Figure 3: Graphical Representation of Land Use Land Cover of Zaria

The areas affected are mostly those that witness expansion in settlement and agricultural activities. The increase in population of Zaria could be attributed to the expansion in both governmental and non-governmental organizations, including banks, manufacturing firms, service sectors, and educational institutions. Tertiary institutions such as the Ahmadu Bello University, Zaria, Nigerian College of Aviation Technology, Zaria and Nigerian Institute of Transport Technology, Zaria amongst others have attracted many people in Zaria which increased the demand for land and other natural resources in the area.

Similarly, bare lands also decreased from 79.825 km^2 in 1988 to 62.248 km^2 in 2003 and then 25.028 km^2 in 2018. This may also be attributed to the expansion in settlement and other anthropogenic activities which converted the bare lands into other land uses. Additionally, water body experienced decrease from 0.929 km^2 in 1988 to 0.4887 km^2 in 2003 and then increased to 1.306 km^2 in 2018. This may be due to the increase in demand for land used for settlement, agriculture and other human activities in the area. This result is also similar to Okewu (2016) who observed fluctuations in the water level in the area.

Spatio-temporal Analysis of LST

The result of LST for the study period is presented in Figures 4a-c. The spatial distribution of LST of Zaria and environs showed temperature ranges between 14.74 and 25.58°C in 1988, 15.1 and 32.00°C in 2003 and, 16.55 and 35.94°C in 2018. Figure 4d revealed that, the area covered by low temperature increased slightly from 1988 to 2003 and then decreased in 2018. However, the area covered by moderate temperature decreased consistently from 1988 to 2003 and then to 2018, while that of high temperature on the other hand increase consistently from 1988 to 2003 and then to 2018. These changes may not be unconnected with the LULC dynamics observed in the study area leading to decrease in area covered by low temperature and increase in area covered by high temperature values. Thus, high temperature areas are shown in the shades of red and correspond to built-up areas, bare lands and low vegetated areas. Low temperature areas are shown in shades of green and correspond to vegetation and water bodies.

Validation of LST

The LST obtained from Landsat data was compared with the ground-based method obtained from Nigerian Meteorological Agency (NiMET), Institute of Agricultural Research (IAR), Ahmadu Bello University, Zaria (Table 3). The comparison revealed that, the values are almost the same, thus, indicating that, the LST obtained from Landsat data are accurate and reliable. The slight differences observed might be due to radiometric error caused by atmospheric error and satellite platform.

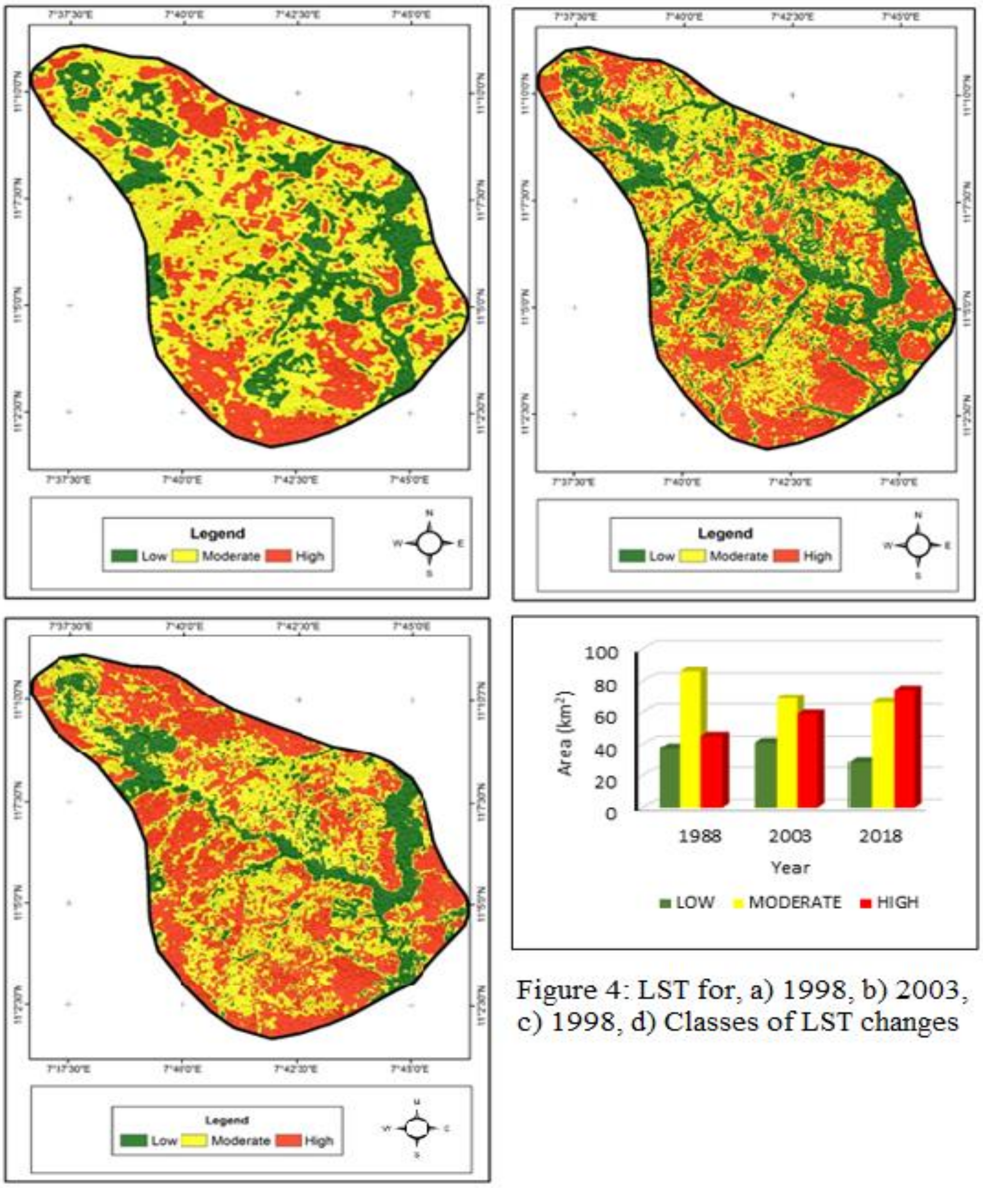

Figure 4: LST for, a) 1998, b) 2003, c) 1998, d) Classes of LST changes

Analysis of Relationship between LULC and LST

It is a fact that built-up areas exhibit higher LST than vegetated areas (Amiri *et al.*, 2009; Takeuchi *et al.*, 2010; Nzoiwu *et al.*, 2017). Table 4 revealed that, the highest mean temperature of 28.55ºC with standard deviation of 1.81 was obtained in 2018. This may not be unconnected with the expanse of built-up area in the study area. This means that, the replacement of natural vegetation with other surfaces such as cemented buildings, pavements, metal, tarred roads and

Table 3: Validation LST

	1988		2003		2018	
	Satellite	Ground based	Satellite	Ground based	Satellite	Ground based
Minimum	14.7	10.0	15.1	17.0	16.6	15.0
Maximum	25.6	25.0	32.0	31.0	35.9	31.0

concrete among others induce LST. This accounted for the variation of LST in Zaria and environs, thus high LST values were notably observed in PZ, Sabo, Grace Land, Samaru and Zango amongst others. It was also observed in Table 4 that, the mean LST dropped from 21.11ºC in 1988 to 15.06ºC in 2003. This may be due to the increase in dense vegetation from 21.95 km^2 in 1988 to 34.675 km^2 in 2003. Vegetation as it is already stated, reduces LST through transpiration and evaporation. This explains why the decrease in light vegetation correspond to the increase in LST from 1988 to 2003. Thus low LST values were observed at Ahmadu Bello University, Zaria and Gaskiya Danmagaji communities, amongst others.

Table 4: LST Statistics

Year	Mean Temp (ºC)	Standard Deviation	Built-up (km^2)	Dense Vegetation (km^2)	Light Vegetation (km^2)	Bare Land (km^2)	Water Body (km^2)
1988	21.11	1.02	15.353	21.95	50.787	79.825	0.929
2003	15.06	1.55	23.0301	34.6752	48.3966	62.2476	0.4887
2018	28.55	1.81	32.8623	14.8014	26.5346	25.0283	1.3059

The correlation between LST and LULC showed that, built-up area is positively correlated (0.608) with LST which implies that increase in built-up area results in high LST. This agrees with Adeyeri and Okogbue (2014) who reported similar findings in Abuja, Nigeria. Further, it was also observed that dense and light vegetation have strong negative correlation (-0.976 and -0.851, respectively) with LST. This indicates that, pixels with high vegetation content have low surface temperature values. This agrees with the findings of Daramola and Eresanya (2017) who reported similar findings in Akure, Ondo State.

Implications of the study

The findings reveal that LULC dynamics have negative effect on LST by increasing the LST of the area under study. This causes urban heat island that leads to high temperature values that are unfavourable to human wellbeing. This increase the demand for power supply for use of fans, air conditioners and other means of cooling the temperature. Unfortunately, the power supply is very epileptic thus, not sufficient for use during heat period. This can lead to severe health challenges that may even result in death. Hence the need to control the LULC of Zaria and environs is emphasized and afforestation should be encouraged to attenuate the rate of change of LST in the area.

CONCLUSION

This study has successfully analysed the relationship between LULC dynamics and LST in Zaria. The results revealed that built-up area has increased consistently within the study period. This causes significant increase in LST of the area. It was also established that vegetation is decreasing in the area due to the increase in human activities which has resulted in the increase in LST. Bare land also decreased consistently within the study period accounting for substantial increase in LST. In general, apart from the built-up area, all other land uses in the area are decreasing thus paving way for increase in LST. It is therefore recommended that LULC of Zaria and environs should be controlled and afforestation should be increased to enhance a healthy living condition of the area.

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