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Effects of Vegetation cover and Build-up area on Land Surface Temperature (LST) of Jimeta

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Abstract

This study analyzed the land surface temperature of Jimeta town which is a core factor in the formation of urban heat island phenomenon. Landsat 8 OLI images for the year 2014-2019 were used to determine the changes in land surface temperature of Jimeta over time. Six (6) samples points were selected randomly on NDVI, NDBI and LST where pixel values of each point were obtained. Correlation analysis was used to examine the relationship between NDVI, NDBI and LST. Result of the findings revealed that land use activities in Jimeta metropolis has increased progressively during the years; and this has influenced the urban heat island. Relationship between Normalized difference in Built-up index (NDBI) and the Normalized difference in Vegetation index (NDVI) with Land Surface Temperature (LST) reveal that there is a significant positive correlation between LST and NDBI for which an increase in built-up areas leads to a proportional increase in land surface temperature. NDVI and LST on the other hand showed a significant negative correlation at $p<0.01$with land surface temperature. Based on these findings, recommendations were made which include: provision of green landscapes in the urban areas, decongestion of areas of concentrated activities, heat prone areas should be giving more space for building and the occupancy ratio should be based on planning standard of 2 persons per habitable room.

Keywords: Vegetation cover; Build-up area; Land Surface Temperature; Jimeta

Introduction

Land surface as one of the earth systems is interconnected to many other components of the earth surface. Because of it interaction with other components, its temperature is being influence by these factors among which are; available water bodies, land-use change, rapid urbanization and transformation of natural landscapes to built-up areas (Alshaikh, 2015; Jenerette *et al*, 2015 and Yongjiu *et al*, 2019). Increasing this Land Surface Temperature (LST) makes some urban areas significantly warmer than the surrounding rural areas and that lead to a scenario known as Urban Heat Island (UHI).

Urban Heat Island (UHI) is a phenomenon that is generally acknowledged in most urban areas of the world. It occurs when the temperature of an urban area is higher than that of its relative surrounding neighborhood; this has been evident in the increased concentration of activities and population density in the urban areas and other anthropogenic activities (Nuruzzaman, 2015).

Urbanization contributes greatly to changes in the existing landscape, buildings, roads, and other supporting infrastructure which leads to warmer temperatures in the region compared to their adjacent rural surroundings (Bhargava, Lakamini and Bhargava 2017). Demand for more energy is another factor contributing to UHI. Increase in need for energy has increase the rate of fossil fuel burning which leads to high amount of greenhouse gasses emissions leading to UHI effect and climate change (Nuruzzaman, 2015). The geometry of the city and topography of the land also plays an important role in the spatial distribution of temperatures in the city (Kuttler *et al*., 1996). The emission of anthropogenic heat, Urbanization, pollution increase, among others determines the UHI intensity and varies with seasons (Stanhill and Kalma,1995).

Jimeta being an administrative town and also a commercial hub has experienced a significant and rapid increase in urbanization. For example, it was documented that, In recent times, Jimeta has risen as the premier commercial, industrial and transportation urban area of the northeastern Nigeria which recorded a rapid increase in population by 69% between 1973 and 1991and 58% between 1991 and 2006, and was projected to a total of 224,233 in 2010 (Ambrose *et al*., 2013; Yemi, 2013 and NPC, 2006). It has also been documented that, Jimeta has recorded an influx of population in the metropolis due to the increased in urbanization (Aminu et al., 2015). Similarly, the recent attack by Boko Haram in North-eastern Nigeria has displaced people from their locality to the nearby cities and other relatively peaceful towns which lead to population increase and environmental degradation. For example, study by Cook (2011) and Ishaq and Ekpo (2019) indicated that, the impact of Boko Haram in North-eastern Nigeria of which Jimeta is part has polluted the natural environment contributing to global warming. Against this background, this research is designed to;

i. Examine the land use/Land Cover pattern of Jimeta.
ii. Examine the NDVI, NDBI and LST of the study area.
iii. Examine the relationship between NDBI, NDVI and LST in Jimeta.

The study area, Jimeta Metropolis, is located between latitude $09^0 16'$ N and $09^0 30'$ N and longitude $12^0 18'$ E and $12^0 34'$ East of Greenwich meridian (Figure 1). It is situated in the Sudan savannah vegetation zone of the country. It is bounded by Girei and Yola South local government area to the South and eastern parts respectively. Like any other Nigerian cities, Jimeta comprises of so many land use types ranging from institutional, commercial and residential. The city is clearly stratified in terms of population densities (Ilesanmi, 1999). The Area has a total population of 198,247 as of 2006 national census and was projected to 211,598 in 2008, 217,824 in 2009 and 224,233 in 2010 (NPC, 2006 and Yemi, 2013). The Soil of Jimeta is derived from the basement complex rock. However, there is some alluvial soil along the Benue flood plains.

Jimeta/Yola has a tropical climate mark by two seasons; wet and dry. The rainy season begins in May and ends in October while the dry season lasts for mainly from November to April. The mean length of rainy season ranges from 120-210 days, while the mean annual rainfall ranges from 900-1000mm (Adebayo, 1999). The temperature in this climatic region is high throughout the year, however, there is usually a seasonal change. The seasonal maxima usually occur in April with a maximum temperature of 40ºC while the minimum can be as low as 18ºC between December and January (Adebayo, 1999).

River Benue is the major river in the area, it rises from the highlands of Cameroon republic and flows southwards into Nigeria joining the river Niger at Lakoja. The River Benue which is main river flows all year round with the peak in the months of August-October in the Wet season. Some of the tributaries that drain into Benue are Mayo in Faro and Chochi River which are all seasonal streams. The study area generally ranges from 152m to 213m above sea level. The area is characterizing by broadly flat topography with gentle undulation hill ranges.

Materials and Methods

Landsat 8 OLI for a period of 2014, 2017 and 2019 were downloaded from earthexplorer.usgs.gov. The images were downloaded at different period of time (14/03/2014, 07/04/2014 and 29/04/2019) based on the quality of images. All the images collected were analyzed based on the different methods required in extracting each parameter. The steps below were followed in extracting the parameters;

Retrieval and Determination of Land Surface Temperature (LST)

The land surface temperature for the study area was retrieved and determined through the use of satellite remotely sensed imageries alongside the use of Landsat 8 users' handbook. The band 10 and 11 of the Landsat 8 are thermal bands were used for the analysis. The procedures for the analysis involve the following steps.

Conversion of Digital Number (DN) to spectral radiance

The digital number (DN) of the thermal infrared band was converted into spectral radiance ($L\lambda$) using the equation supplied by the Landsat 8 users' handbook.

$$L\lambda = M_L Qcal + Al \quad (1)$$

Where: $L\lambda$= Spectral radiance, M_L= Band specific multiplicative rescaling factor,

Al= Band specific additive rescaling factor and Qcal= quantized and calibrated standard product pixel value (DN)

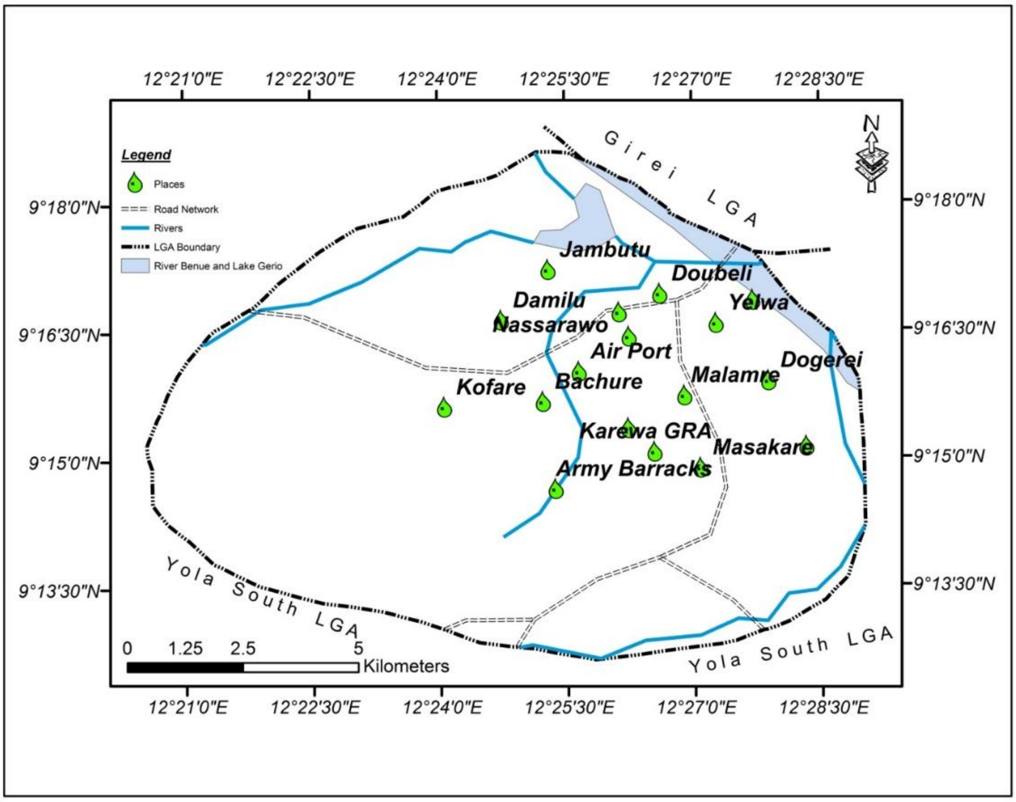

Figure 1: Map of the Study Area

Conversion of Radiance to At-satellite Brightness Temperature

The effective at sensor brightness temperature (T_B) also known as black body temperature is obtained from the spectral radiance using Plank's inverse function

$$T_B = \frac{K_2}{Ln(\frac{K_1}{L\lambda}+1)} \quad (2)$$

Where:

T_B = At- Satellite brightness temperature (K), $L\lambda$ = Spectral radiance, K_1 = Band specific thermal conversion (constant from the metadata) (K_1_ constant_ Band_ X, where x is the band number: 10 or 11), K_2 = Band specific thermal conversion (constant from the metadata) (K_2_ constant_ Band_ X, where x is the band number: 10 or 11) and Ln= Log number

Determination of Land Surface Emissivity (e)

Land surface emissivity affects the satellite measurements by three categories:

i) emissivity causes a reduction of surface-emitted radiance;
ii) non-black surfaces reflect radiance; and
iii) Anisotropy of reflectivity and emissivity might reduce or increase total surface radiance.

Emissivity as a function of wavelength is controlled by several environmental factors such as surface water content, chemical composition, structure, and roughness. For vegetated areas, emissivity varies significantly with plant species, areal densities, and growth rates. In fact, land surface emissivity is closely related to NDVI (Weng and Larson, 2005; Van and Bao, 2010). Therefore, the emissivity can be estimated from NDVI (Liu and Zhang, 2011). The land surface emissivity is determined by the formula

PV= (NDVI-NDVImin / NDVImax – NDVI min) 2 (3)

Pv= Proportional Vegetation and e = 0.004PV + 0.986

Determination of Land Surface Temperature (LST)

The land surface temperature is determined by the formula

LST= BT / 1 + W * (BT / P) * Ln (e) (4)

Where: LST= Land Surface Temperature, BT = at-satellite temperature, W = Wavelength of emitted radiance (11.5μm), P = h*C /S (1.438* 10^2mk), h = Plank's constant (6.626 * 10^-34 Js), S = Boltzmann constant (1.38 * 10^-34J/k) and C= Velocity of light (2.988 * 10^-8m/s)

Determination of Normalized Difference in Built up Index (NDBI)

The normalized difference built up index (NDBI) is used in the extraction and mapping out of built up areas. NDBI was extracted based on the fact that, increase in build-up area may has a tendency of increasing the LST, as such the equation below was used to determine the NDBI;

$$NDBI= \frac{(SWIR-NIR)}{(SWIR+NIR)} \quad (5)$$

Where:

SWIR= Short wave infrared and NIR= Near infrared

Determination of Normalized Difference Vegetation Index (NDVI)

The normalized difference Vegetation index (NDVI) was used in the extraction and mapping out of vegetation cover/areas. The NDVI has a relationship with surface temperature. Therefore, the vegetative index of the study area was analyzed to determine the relationship it has with the land surface temperature.

The NDVI is calculated by subtracting the Red band from the Near infrared band of the Landsat and dividing it by the Near infrared plus Red band.

Mathematically, $NDVI = \frac{(NIR-RED)}{(NIR+RED)}$ (6)

Correlation and Regression Analysis

In other to examine the relationship between NDVI, NDBI and LST, six (6) points were selected randomly from different classes of LU/LC and the points were overlaid on LST, NDVI and NDBI maps for all the three selected years. Data on LST, NDVI and NDBI were generated from them using the pixel value of each specific point on all the parameters and for all the three (3) Years. All the data generated were then subjected to correlation and regression analysis.

$$r = \frac{n(\sum Xy)-(\sum X)(\sum y)}{\sqrt{[n\sum X^2-(\sum X)^2][n\sum y^2-(\sum y)^2]}} \quad (7)$$

were

r= correlation coefficient

x= LST

y= NDVI and NDBI

Method of Data Presentation and Analysis

The data extracted were analyzed using different packages such as Arc GIS 10.2.2, Microsoft Excel and Statistical Package for Social Sciences (SPSS). Land use/land cover, NDBI, NDVI and LST were extracted using Arc GIS while total area of different classes of LULC were converted to percentage in excel. Statistical Package for Social Sciences (SPSS) on the other hand was used in analyzing the Correlation between the parameters.

Results and Discussions

Land Use/ Land Cover (LULC) of Jimeta Metropolis 2014-2019

LULC map of the area is presented in figure 1 and the aim of analyzing the land use/cover of the area is to determine the relationship between land use activities on Urban Heat Island (UHI). Two variables (vegetation cover and built-up areas) which were assumed to have a significant relationship with LST were analyzed to examine the relationship between the variables. The land use/ cover of Jimeta Metropolis was grouped into four different classes namely: vegetation cover, built-up areas, Water bodies and bare-surfaces.

It has been observed from the analysis that there is an increase in land use activities of which notable of them is the built-up areas. From the analysis, it has also been noticed that built-up areas have increases from 39.39% in 2014 to about 53.5% in 2019 of the total land areas; water bodies covered the smallest portion of the area but recorded a decrease of 0.23% from 2014 to 2019. In the same vein, Vegetation cover of the area has recorded a decrease of 5.77% from 2014 to 2019. Bare surface area on the other hand covered the large portion of the area and recorded a decrease of 8.11%. Following these entire trends, it is clear that the rate at which the built-up areas are growing is high and the consequences of these growths are not properly guided by the dynamics of planning. Over the years, the vegetation zones have gradually decrease and has been occupied either by built-up areas or bare surfaces which were meant to help in reducing the effect of much surface temperature on the environment. The table 1 below shows the LULC of Jimeta from 2014 to 2019.

Table 1: Land use/land cover of Jimeta for 2014, 2017 and 2019

	2014	2017	2019
`Built-up areas (%)	39.38	44.89	53.50
Bare Surfaces (%)	49.41	51.02	41.30
Vegetation cover (%)	9.68	2.64	3.91
Water bodies (%)	1.53	1.45	1.30

Source: Extracted from LULC map 2019

NDVI and NDBI of Jimeta from 2014 to 2019

Result of NDVI and NDBI is presented in figure 2 and 3. Analysis of the result revealed that water bodies and build-up areas recorded the lower value while places outside the build-up areas and near water bodies have high NDVI values. In the same vein, NDBI of the area revealed that the places outside the build-up area which are recognized to be bare surface in LULC analysis and are the area with high value while places occupied by water bodies and build-up areas haves high NDBI value.

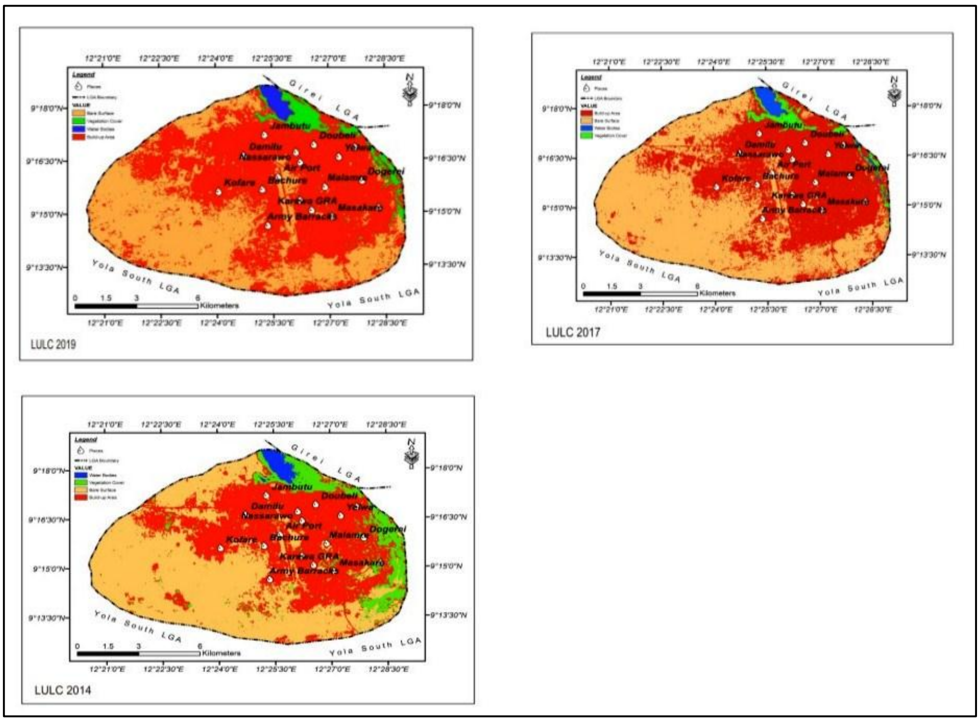

Figure 2: LULC map of 2014, 2017 and 2019

Land Surface Temperature Analysis from 2014 to 2019

Result of LST analysis in 2014 revealed that the temperature range of Jimeta metropolis in 2014 was between 27.02^{0}C and 41.0^{0}C, with a mean temperature of 36.46^{0}C. The land surface temperature was noticed to be higher in areas with high concentration of activities and built up areas. Areas close to the rivers and vegetative zones were observed to have a moderate temperature between 30.8^{0}C and 34.57^{0}C, water bodies from the analysis have been seen to have a moderate temperature of 27.02^{0}C, built up areas and commercial activities zone were noticed to have a temperature range between 38.35^{0}C and 42.12^{0}C. However, the result of the analysis also showed that open lands and bare surface had the highest impact of surface temperature. This have been attributed to the result of direct impact of solar radiation on the bare surface without any cover absorbing the impact of the radiating rays of the sunshine, also factors such as wind direction and topography (slope of the land mass) has been seen to have a direct effect on the cause of the high increase in the surface temperature of the bare-lands.

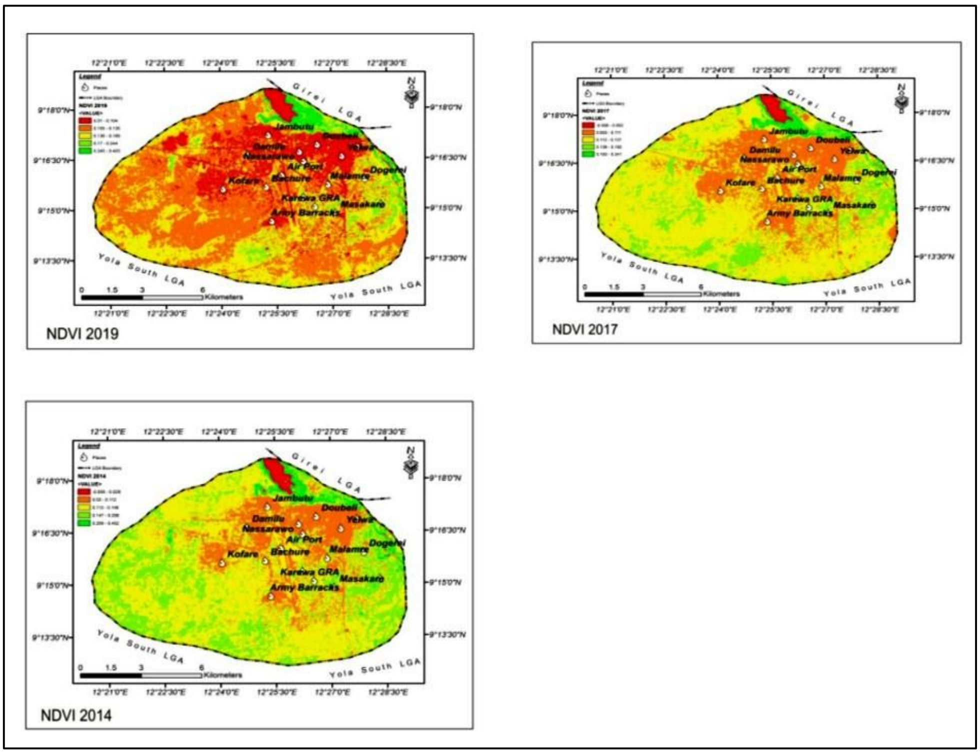

Figure 3: NDVI map of 2014, 2017 and 2019

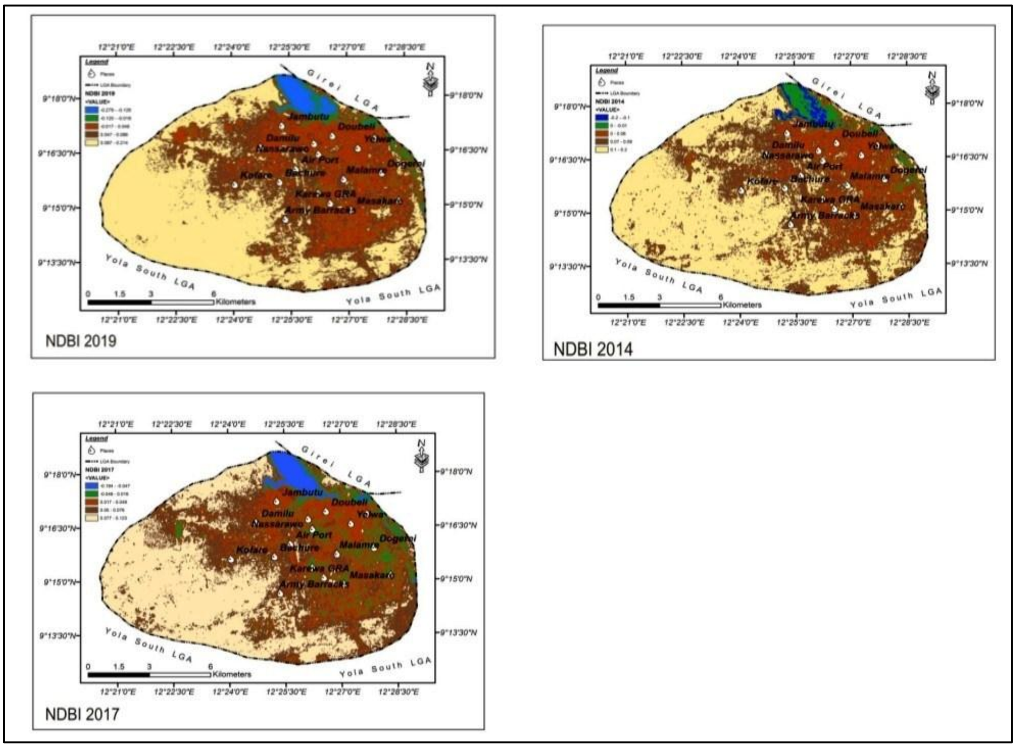

Figure 4: NDBI map of 2014, 2017 and 2019

Result of the 2017 analysis showed that the temperature range of Jimeta is between 23.37ºC and 37.40ºC. The land surface temperature was noticed to be higher in areas with high concentration of built-up activities while places closed to the river recorded low temperature of 29.86-30.8ºC than those within the heart of the city. Areas covered by vegetation have also been noticed to have a moderate temperature as a result of the impact of the green land that absorb the heat intensity and reduce the impact of radiation of solar energy. In the case of bare-surfaces, three categories of temperature range were identified; 30.12ºC, 33.6ºC, and 35.87ºC. The high temperature amount experience in this region can be attributed to wind direction, slope of the land mass among others.

Result of the 2019 analysis on the other hand reveals a temperature range of between 20.03^{0}C and 36.14^{0}C while the mean temperature was 28.09^{0}C. The surface temperature variation of Jimeta metropolis was noticed to be much higher in built up areas and bare lands while, areas which are close to the river have been noticed to have a relatively low temperature than those which are around areas of higher concentration of activities. Also, from the analysis, it has been observed that some wards like Karewa which have more trees and vegetation cover have low temperature of between 27^{0}C and 29^{0}C than the bare lands and areas around the market where activity concentrations are high.

Following all these results, it is clear that, variations in the land surface temperature in Jimeta metropolis are not static. Based on the analysis, it has also been observed that temperature of 2014 recorded high. However, it has been observed that Land use activities that constantly maintain high temperature is the built-up areas which encompasses various concentrations of land use activities and without proper implementation of planning standards. The green area zones which were meant to serve as a cooling catalyst and vegetative zone has gradually been encroached by the built-up activities. It has also been observed that open spaces have the highest temperature impact for 2014 and 2019. However, based on literature studies it has been observed that there are a variety of factors which contributes to the open land being hotter and higher in temperature range than the CBD's this include; slope of the land mass (topography of the area), Wind direction, cloud cover and absence of vegetation cover which leads to high emissivity in surface impact (Kuttler *et al*., 1996). The figure below show the LST map of the study area.

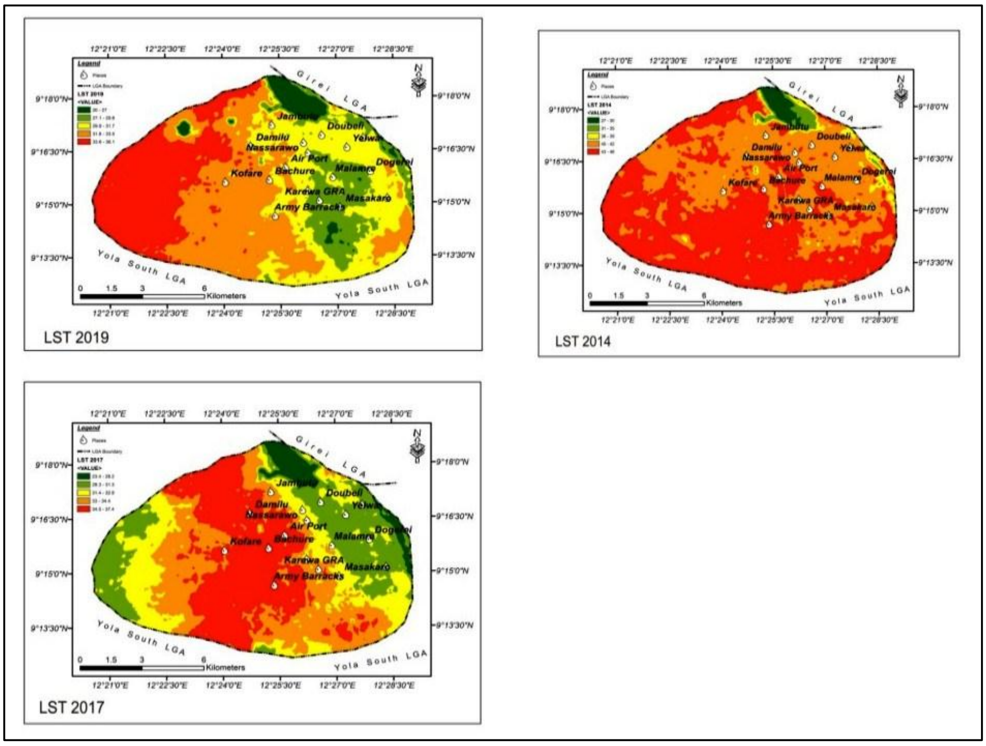

Figure 5: LST map of 2014, 2017 and 2019

Relationship between NDVI, NDBI and Land Surface Temperature (LST)

Relationship between LST, NDVI and NDBI for 2014, 2017 and 2019 as presented in Table 2 revealed that LST displayed a strong negative and significant relationship of 0.967, 0.995 and 0.995 for 2014, 2017 and 2019 respectively with NDVI at $p<0.001$. This result clearly implies that, as NDVI value increases the amount of LST decreases and reverse is the case. This is not surprising because positive increase in NDVI explained a positive increase in vegetation cover which suggests that the vegetation cover will reduce the amount of carbons released from human activities thereby reducing the amount of land surface temperature. This result agrees with the findings of (Leon *et al.*, 2019; Han *et al.*, 2018; Jenerette *et al, 2015* and Alshaikh, 2015). Unlike the NDVI, NDBI on the other hand revealed a strong positive and significant relationship of 0.979, 0.991 and 0.993 for 2014, 2017 and 2019 respectively at $p<0.001$. This result suggested that, increase in build-up area will lead to increase in land surface temperature. This relationship is obvious because increase in build-up implies an increase in impermeable and low albedo materials such as asphalt or concrete, increase in demand for energy (Fossil and wood fuel), increase commercial activities and industries. All these activities mentioned, either directly or indirectly have contributed greatly to increase in temperature as also observed by (Alshaikh, 2015)

Table 2: Relationship between LST, NDVI and NDBI for 2014, 2017 and 2019

	2014			2017			2019		
	LST	NDVI	NDBI	LST	NDVI	NDBI	LST	NDVI	NDBI
LST	1	-.967**	.979**	1	-.995**	.991**	1	-.995**	.993**
NDVI	-.967**	1	-.989**	-.995**	1	-.994**	-.995**	1	-.998**
NDBI	.979**	-.989**	1	.991**	-.994**	1	.993**	-.998**	1

** Correlation is significant at 0.01

Planning Implications of Findings

From the research findings, the study has showed that UHI are most noticed in concentrated built up and densely populated areas where vegetation covers and trees are not available so as to reduce the heating effect of solar radiation. The planning implications of these findings are briefly summarized below:

i. Lack of proper planning in the central urban areas where population density and urban activities are high will result to increasing UHI.
ii. Failure to ensure the planning standards for built up areas, market activities and space requirement of occupancy ratio will result to increasing effect of the Urban Heat Island phenomenon.
iii. Planning standards and criteria of occupancy ratio of 2 persons per habitable room are not adhered to which have contributed in the increase level of UHI.

Conclusion

Following the findings of this study, it was concluded that vegetation cover in the area is reducing while Build-up area is increases. It was also concluded that the effect of UHI in Jimeta is observed in the concentrated areas of Jimeta where commercial activities, population density and built-up area are concentrated. The negative correlation between LST and NDVI indicates that vegetation cover reduced the effects of UHI, while build-up areas increase the amount of LST which lead to increase in Urban Heat Island. In addition, it was concluded that build up area is taking over the vegetation cover of the study area thereby increasing LST of the area. Following the result obtained it is recommended that there is a need for control on vegetation destruction, also the need for proper planning in terms of building residential and other structures.

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