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ASSESSMENT OF THE RELATIONSHIP BETWEEN URBAN GROWTH AND SURFACE TEMPERATURE IN ABUJA MUNICIPAL AREA COUNCIL

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ABSTRACT
AMAC experienced growth in built-up areas during the past 30 years. The influx of people brought modification in Land Use Land Cover leading to expansion in urban area and conversion from one LULC to another. This has implications on climate of the area. This study assessed urban growth effects on Land Surface Temperature (LST) of AMAC from 1986 to 2016, using remote sensing and Geographic Information System (GIS).ERDAS Imagine 2014 and ArcGIS 10.4.1 softwares were used for processing and classification of the multi-date (1986, 2001 and 2016) satellite imageries. It also used LST data derived from Landsat imageries as well as rate of change in LULC. Simple linear regression was used to establish relationship between urban growth and LST. Results show that the period between 1986 and 2016 witnessed changes in LULC as bare surface increased by 24.28%, built-up areas by 16.43%. However, vegetation decreased by 40.46%, water body by 0.06 % and rocks by 0.19%. The implication of urban growth on LST is an increase in mean LST of built-up areas to27^{o}C, 33^{o}C and 36^{o}C for 1986, 2001 and 2016 respectively with the highest value at city centre due to sparse vegetal cover. LST also increased across different LULC during the three epoch years. In the relationship between LST and urban growth, LST and NDBI revealed strong relationship with coefficient of determination (R^2) of 0.9610 for 1986; 0.9576 for 2001and 0.9732 for 2016. These results call for implementation of policies to control rapid urban growth and preserve vegetal covers.

Keywords: Land Surface Temperature, Land Use Land Cover, Relationship, Satellite Imageries, Urban Growth

INTRODUCTION

Globally, there has been an unprecedented increase in human population concentration in urban areas which has led to rapid urban landscape changes (Vernon, 2002). Urban area is an area with increase in human population as well as in density of human created structures in comparison to the areas surrounding it. Recent studies have shown that about 50% of the world population lives in urban areas (Herold, Liu, and Clarke, 2003). As reported by Montgomery and Hewett (2005), the highest rate of urbanization and associated land use or cover changes have been observed in the developing countries. Likewise a recent projection by the United Nations as reported by Civco and Chabaeva (2005) shows that the urban population of developing nations is now growing at the annual rate of 2.3% and is predicted to double in 30 years that is a rise from 1.94 billion in the year 2000 to 3.88 billion in 2030. Based on these predictions, it implies that cities in developing countries will likely double their built up or impervious surface areas to accommodate the increasing population. This growth is a very crucial issue stressing urban planners because of the escalating problems of urban congestion, poor housing, traffic congestion, climatic variability, lack or inadequate basic services, low educational standards and unemployment (Lynch, 2005). Thus, increasing population and introduction of various forms of poor land use practices such as deforestation, inappropriate irrigation techniques are the major threats to the present day environment (Vernon, 2002).

Globally, the estimated annual urban population growth rate of 1.78% is nearly double that of the global population and if this trend continues, it entails that 5 billion people out of a total world population of 8.1 billion will reside in urban centres by 2030 (Civco and Chabaeva, 2005). Hence, with this rapid increase in population, cities have to expand both in physical size and features bringing about a total change in morphology; agricultural land being converted to industrial layouts, open spaces being built on, forest diminish as more land is used for housing/shelter to accommodate people and property, and vegetation (e.g. grassland for grazing, park land etc.) becoming scarce in some cases (Civco and Chabaeva, 2005). Therefore, it is no surprise that these urban areas are conflict zones due to economic growth and the preservation of the environment. Urban centres in different parts of the world suffer from several environmental problems: ranging from higher temperature in the form of heat island to air pollution, traffic jams and high levels of ambient noise, empty houses and derelict lands all of which affect the health and quality of life of the urban dwellers (Deng and Wu, 2013).

In several parts of the world, the relationship between Land Use Land Cover and Land Surface Temperature has been examined by some authors; For instance, Karl., Diaz and Kukla (1988) estimated urbanisation effects on the United States climate by using climate records obtained from meteorological stations and population data obtained from census boards, their results revealed that areas with high population were warmer than less populated areas. Though, this housing density parametre often derived from census data has several limitations in its application. For instance, census blocks were often too coarse and not timely for monitoring purposes. This is because the census block is updated at decadal intervals which might complicates studies on urban expansion by introducing spatial mismatch between boundaries of different datasets (Hammer, Stewart, Radeloff and Voss, 2004). Similarly, Carlton (1992) was able to prove that warmer than surrounding thermal features are associated with urban land use and could be identified from infrared radiative surface temperature observed from satellite data. Remotely sensed data have equally been used to carry out similar study. For instance, Xian and Crane (2006) used Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper plus (ETM+) data to analyse the influence of urbanisation on surface temperature in Tampa Bay Florida. Besides Landsat data, LST can also be estimated using Moderate Resolution Imaging Spectroradiometer (MODIS) or ASTER satellite data. LST estimation based on MODIS data were made by Ma., Zhou., Zhang and Dai (2016) for studying the effect of the urban heat island in Shanghai, China. Another study carried out by Yang et al (2016) estimated LST using combined MODIS and ASTER datasets. In addition, Rasul and Ibrahim (2016) carried out a similar in Dohuk City, Iraq and appraised that the highest temperatures were associated with barren land and built-up areas, ranging from 47ºC, 50ºC, 56ºC while lower temperatures were related to water bodies and forests, ranging from 25ºC, 26ºC to 29ºC respectively, in 1990, 2000 and 2016. The study titled urban land use land cover changes and their effect on Land Surface Temperature revealed that Normalized Difference Built up Index (NDBI) correlates positively with high temperatures.

In Nigeria, similar studies have been carried out by several researchers. Notable among them is Oguntoyinbo (1970) that studied the albedo and reflection fluxes of urban and rural surfaces in Ibadan. According to the researcher, a mean albedo of 12% for urban surfaces and 6% for rural surfaces in the study area was obtained. In another instance, Oguntoyinbo (1973) used in-situ equipment like thermo-hygrographs and whirling hygrometer to obtain temperature and relative humidity data across Ibadan. This was done to examine the impact of urbanization on the climate of Ibadan. Other researchers such as Nduka (2011) and Abdulhamed (2011) deviated a little and focused on Urban Heat Island using ground based measurement from meteorological stations and in-situ equipment such as digital temperature loggers. Specifically, Nduka (2011) used digital temperature loggers to assess the urban canopy heat island variation and Land Use Land Cover in Onitsha Metropolis. Abdulhamed (2011) also carried out a similar study in Kano using the same equipment.

It is pertinent to state that the method used in these previous studies can be both costly and time consuming. This is because it may involve purchasing or hiring in-situ equipment for the study. In addition, it is also limited in its representation since it only reflects the temperature surrounding a particular location at a particular time. It is also important to note that air temperature data, obtained from meteorological archival records are inadequate for urban climate studies. This is especially true in the case of Nigeria where nearly all meteorological stations in the country are usually located at airports and often cited at the periphery of cities. These locations could serve as 'rural' sites but the problem of obtaining climatic data representative of the urban sites still arises because of the heterogeneous nature of urban surfaces. As a result of the above situations, remote sensing might be a better alternative to the aforementioned methods. Othe advantages of using remote sensed data are the availability of high resolution, reliable and repetitive coverage and proficiency of measurements of earth surface conditions (Ifatimehin, Ujoh and Magaji 2009).

Land Surface Temperature estimations using remote sensing and GIS techniques in an urban area were made by Ifatimehin, Ujoh and Magaji (2009). They evaluated the effect of land use/cover change on the surface temperature of Lokoja town, Nigeria. As the built-up area increased in size (2667.6%) so was the surface temperature (6.48ºC) and others like vacant land (872%, 9.65ºC), cultivated land (104.4%, 1.2ºC) and water bodies (64.3%, 0.94ºC) while the surface temperature on vegetation cover increased by 2.44ºC and its area extent decreased (316.7%). It is clear from this result that built up has a high surface temperature compared to other classes. Ifatimehin., Ishaya and Fanan (2010) also carried out a similar study in Lokoja and noted that, the built up and vacant areas had the highest Land Surface Temperatures of 59.5ºC and 58.5ºC respectively, while vegetation, water bodies and cultivated land had the least with 26.5ºC, 28.5ºC and 34ºC respectively. The study carried out by Zaharaddeen, Ibrahim and Zachariah (2016) in Kaduna, shows that NDVI is found to have negative correlation with LST. Equally**,** Babalola and Akinsanola (2016) analyzed the spatial distribution of changes in temperature and land cover using Landsat images in Lagos. The result revealed that the vegetal cover has decreased rapidly over 30 years period from 70.043% to 10.127%; this change contributed to the variations in the microclimate, and the urban and bare areas correlated positively with high land surface temperatures.

A similar study was carried out in Federal Capital City by Usman (2009), where the researcher stated that LULC was found to have increased (18.57%) in areal extent for built up between 1987 and 2001 while by 2006, a 2.31% decrease for built up was recorded, showing changes in urban growth and consequently on surface temperature with a rise in mean LST from 26ºC in 1987 to 34ºC in 2006. The study failed to state the method used to confirm urban growth as one of the causes of increase in LST in AMAC as an area council. In other words, the study failed to establish a direct linkage between urban growth and LST in AMAC. In addition, accuracy assessment was not conducted for the Land Use Land Cover and the method used to determine the Land Surface Temperature (Radiative transfer method) is obsolete. Hence, less attention was focused on the use of the relatively new technology - the Geographic Information System (GIS), and its complimentary technologies such as latest versions of GIS software and Landsat 8 imagery. Therefore, a better approach such as this current study is needed to consolidate on aspects of previous methods, in order to get better data and results. This is a gap that this research intends to fill.

Also, Nigeria being a developing country and the most populous in Africa, the country has reached a state where urbanisation and its related challenges such as traffic congestion and slums development seems to be assuming uncontrollable rates and dimensions. Also, previous studies have shown that urban areas differ substantially in their micro-climates (Adebayo and Zemba, 2003; Ifatimehin, 2007). These differences are caused by the alteration of the earth's surface by human activities such as agriculture, industries and construction. These activities result in concrete, asphalt and glass that replace natural vegetation. These changes affect the absorption of solar radiation, evaporation rates, storage of heat, the turbulence and wind pattern of cities and the surface temperature (Voogt, 2004). With increase in urban population and activities, the increasing rate of emissions of heat, water vapour and pollutants directly impact the temperature of atmosphere above cities. Abuja, being the Federal Capital Territory of Nigeria, is not an exception to this observed Land Use Land Cover (LULC) changes. Analysis of Land Use Land Cover (LULC) in Abuja Municipal Area Council (AMAC) of Nigeria showed increasing trend in urban growth and change in land cover (Nkeki and Ojeh, 2014). The causes of the rapid growth of Abuja have been a major concern to researchers. Essentially, the two causes mostly referred to in literatures have been the continued rural-urban migration and the rate of natural increase (Muhammad, Abubakar and Shehu, 2013). Chen, Zhao, Li and Yin (2006), Adeyeri, Okogbue, Ige and Ishola (2015) and Hamdi (2010) reported separately, that another significant effect of this urban expansion is the variation in Land Surface Temperature (LST). LST means the skin temperature of the land surface and is one of the important parametres in urban climate as it serves as an indicator for measuring Urban Heat Island (UHI) (Voogt and Oke, 2003; Feizizadeh and Blaschke, 2013). It has a significant influence on air temperature, especially the canopy layer that is closest to the surface (Zhang and Wang, 2008). Furthermore, the replacement of the vegetation and other natural surfaces by unnatural or man-made materials like asphalt, concrete, metal, in urban areas have environmental implications that include reduction in evapo-transpiration, rapid run-off and increase in surface temperatures leading to creation of Urban Heat Island (Singh, Grover and Zhan, 2014). All these may be contributing to climate change as the air temperature is being affected. For instance, there is a general increase in mean minimum temperature of 3ºC per decade in Nigeria as observed by Inyang and Esohe (2014). On the other hand, Nigeria has witnessed a rapid increase in human population as the yearly percent change rose from 1.9% in 1960 to 2.65% in 2016 (United Nation, 2016). This indicates a likely relationship between urban growth and Land Surface Temperature in Nigeria. This has necessitated the aim of this study, which is to assess urbanization effects on the surface temperature of AMAC. The specific objectives of the study include to:

i. examine the urban Land Use Land Cover changes for the study area.
ii. determine the characteristics of Land Surface Temperature in AMAC from 1986 to 2016.
iii. identify Land Surface Temperature change of each LULC types from 1986 to 2016.
iv. establish the relationship between urban growth and Land Surface Temperature during the study period.

MATERIALS AND METHODS

Abuja is the capital city of Nigeria which is located between latitudes 8º 25' N and 9º25' N of the Equator and longitudes 6º 45' E and 7º39' E of the Greenwich Meridian (Figure 1). It is a planned city in the centre of the country bordered to the north by Kaduna State, to the east by Nassarawa State, to the south-west by Kogi State and to the west by Niger State. The area under study is the Abuja Municipal Area Council (AMAC), one of the area councils in Abuja. AMAC is the largest, most urbanized and developed of the six area councils of Abuja(Touristlink, 2013). The bulk of the built-up areas of AMAC made up the Federal Capital City. AMAC is located between latitudes 8º36´ N and 9º21´ N of the Equator and longitudes 7º07´ E and 7º33´E of the Greenwich Meridian. It covers about 1,500 sq km of the total land area (38.8%) of the Federal Capital Territory (FCT) (Balogun, 2001). The area is considered the most ideal and conducive for human habitation and settlement development within the FCT (Mabogunje, 1976). It is made up of 12 political wards namely; City Centre, Wuse, Gwarinpa, Garki, Kabusa, Gui, Jiwa, Gwagwa, Karshi, Orozo, Karu and Nyanya(Touristlink, 2013).

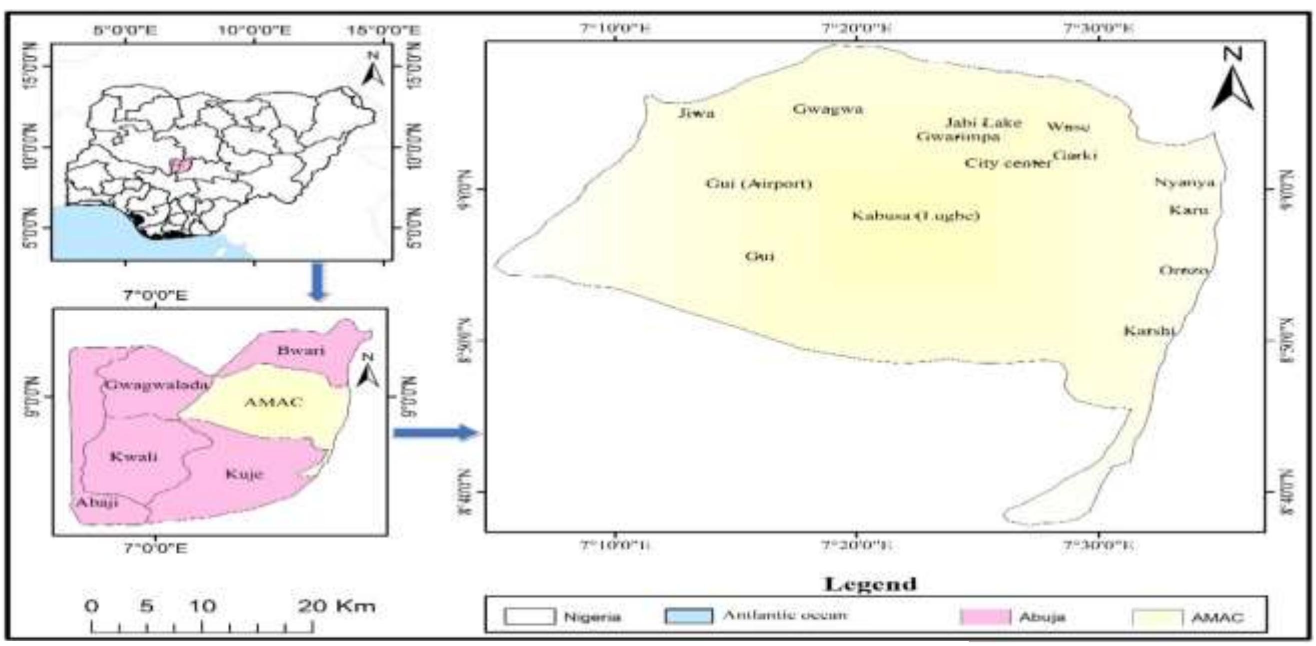

Fig. 1: Abuja Municipal Area Council Major Residential Areas.

Adapted from: Encarta Premium, 2015.

Abuja has a climate classified by Koppen as tropical wet and dry (Aw). The area experiences two seasons annually. These are warm, humid rainy season and a cold dry season. Fortunately, the high altitudes and undulating terrain of the FCT act as moderating influence on the weather of the territory. The rainy season begins from April and ends in October, when day-time temperature vary between 28°C and 30°C and night time temperature vary between 22°C and 23°C (Adeyeri., Okogbue., Ige and Ishola, 2015). In the dry season, day time temperature can soar as high as 38°C and night time temperatures can drop to 12°C. Even the chilliest nights can be followed by day time temperatures well above 30°C (Adakayi, 2000). Rainfall in the FCT reflects the territory's location on the windward side of the Jos Plateau and the zone of rising air masses with the city receiving frequent rainfall during the rainy season. The total annual rainfall varies between 1100 mm and 1600 mm while relative humidity is about 30% in dry season and 70% in wet season (Malik, 2004). The prevailing direction of wind for the months of June/July and December/January are south to south westerly and north easterly respectively. Average daily wind speed is about 89.9 km/hr or about 3.0 and 4.6 Knots in the months of June/July and 1.5 to 3.7 knots for December/January (Mahmoud, 2016).The daily pressure hovers between 1001mb and 101mb. The length of the day does not vary substantially over the course of the year, with duration of 12 hours almost throughout year (Mahmoud, 2016). The climatic elements of Abuja highlighted above directly or indirectly affect its surface temperature.

There is a marked difference between the highest and lowest elevation within AMAC. The highest elevation is 213.3 metres to the North (which is largely urbanised) and 142.2 metres to the South (which is largely rural) of the area council (Touristlink, 2013). The area council is therefore characterized by a hilly dissected terrain and is the highest part of the FCT with several peaks that are 760 metres above sea level (Balogun, 2001). Within AMAC is located the famous Aso Rock, Katempe Hill and Asokoro rock outcrops. The upper Niger Valley is located in the Western and South-Western portions of the FCT study area. It contains the lowest elevations within the FCT, less than 60 metres (200 feet) at the territory's southwest corner (Mahmoud, 2016). The height of the elevated areas also plays a role in the surface temperature. This is because areas with high elevation tend to enjoy lower temperature (lapse rate effect) while plains experience the opposite. Also areas close to Jabi Lake, may enjoy the benefit of breeze from the water bodies thereby modifying the surface temperature. Jabi Lake is the major notable natural body of water in AMAC along with seasonal streams during the wet season. The lake offers speed boats rides, canoe rides as well as fishing avenue (Secureafrica, 2012).

AMAC is located within the savanna zone vegetation of the West African sub-region. It has patches of rain forest consisting of trees like *Antirisem Africana, Anthocleista ceiba, pentandra, celtis spp, chotorophora, grandifondlia ar*ound the Gwagwa plains, specifically in the gullied terrain to the south and the rugged south-eastern parts of AMAC (FCDA, 1979). Basically, the savanna vegetation in the area can be divided into three (3) types; the park or grassy savanna that constitutes about 53% land area of the area; the savanna woodland covers about 12.8% of the area while the shrub savanna covers about 12.9% of the land area (FCDA, 1979).The removal of this vegetation can cause a change in its surface temperature. This is because vegetation and forests in particular serve as carbon sink that help to lower the temperature of an area.

The 2006 National Population and Housing Census put the population of AMAC at 778,567, the highest within Abuja. The 2017 estimated population of AMAC is about 1,967,500 (National Bureau of Statistics, 2017). The indigenous inhabitants of Abuja are the Gbagyi, Bassa, Gwandara, Gade, Ganagana, Koro and so on. The increasing rate of settlement expansion in AMAC is very likely to influence surface temperature due to increase in human activities like deforestation, road construction and pollution from industries (Touristlink, 2013). The area council is accessible by land and air mode of transportation. The principal mode of transportation in the study area is land transportation and the common type of land transportation is by road. This involves the use of cars, tricycle, motorcycles and bicycles. The Nnamdi Azikiwe International airport is located in AMAC (Adakayi, 2000). The area council is therefore accessible from other parts of the country by roads through Abuja-Suleja road on the north, on the east through the eastern arterial keffi-nyanya road and through the Lokoja-Gwagwalada road on the west. Water transportation is used in limited places in the study areas. Jabi Lake is mainly used for sporting activities.

In addition, some of the economic activities carried out by the inhabitants of AMAC are fishing, farming, lumbering, trading, people working in public and private sectors as well as other activities like; carpentry, hair dressing, brick laying, taxi driving and so on. This is made possible due the presence of General markets in Wuse, Garki, Utako, and Gudu .Also various Industries. Ministries, agencies and educational institutions are located in AMAC (Secureafrica, 2012). AMAC also is the location of the Presidential Complex, National Assembly, and the Supreme Court, and it also houses the headquarters of the Economic Community of West African States (Touristlink, 2013).All these structures, have encouraged the human activities mentioned above. These activities result in the release of heat into the environment that modifies the weather and climate (including elements like temperature) of AMAC.

Reconnaissance survey was carried out in order to have a general knowledge of the study area. This knowledge was very useful during visual image interpretation process before and after image classification. The data used for this study were obtained through primary and secondary sources. The primary data source that was used for the study include field data that was collected via visual observation and Global Positioning System coordinates obtained for ground truth purpose (accuracy assessment). The secondary data used in the study include Google earth images, and AMAC shape file obtained from National Space Research Development Agency and Landsat imageries. Hence, this study employed the use of cloud free remotely sensed Landsat TM, ETM and OLI satellite imageries of AMAC for 1986, 2001 and 2016 covering path 189 and row 54 downloaded from United States Geological Survey (USGS) archives (Table 1).

Table 1: Description of Landsat Image Data

Satellite	Sensor	Spatial Resolution	Date Acquired	Source
Landsat 5	TM	Composite Bands (30m) Thermal Band (120m)	26/12/1986	USGS
Landsat 7	ETM+	Composite Bands (30m) Thermal Band (100m)	27/12/2001	USGS
Landsat 8	OLI _TIRS	Composite Bands (30m) Thermal Band (100m)	28/12/2016	USGS

Source: United States Geological Survey 2016.

ERDAS Imagine2014 software was used in Land Use Land Cover (LULC) classification and ArcGIS 10.4.1 software was used to extract Normalized Difference Built-up Index (NDBI), Land Surface Temperature value and embellish necessary maps. In addition, Microsoft office 2013 (Word and Excel) were used for reporting and analysis.

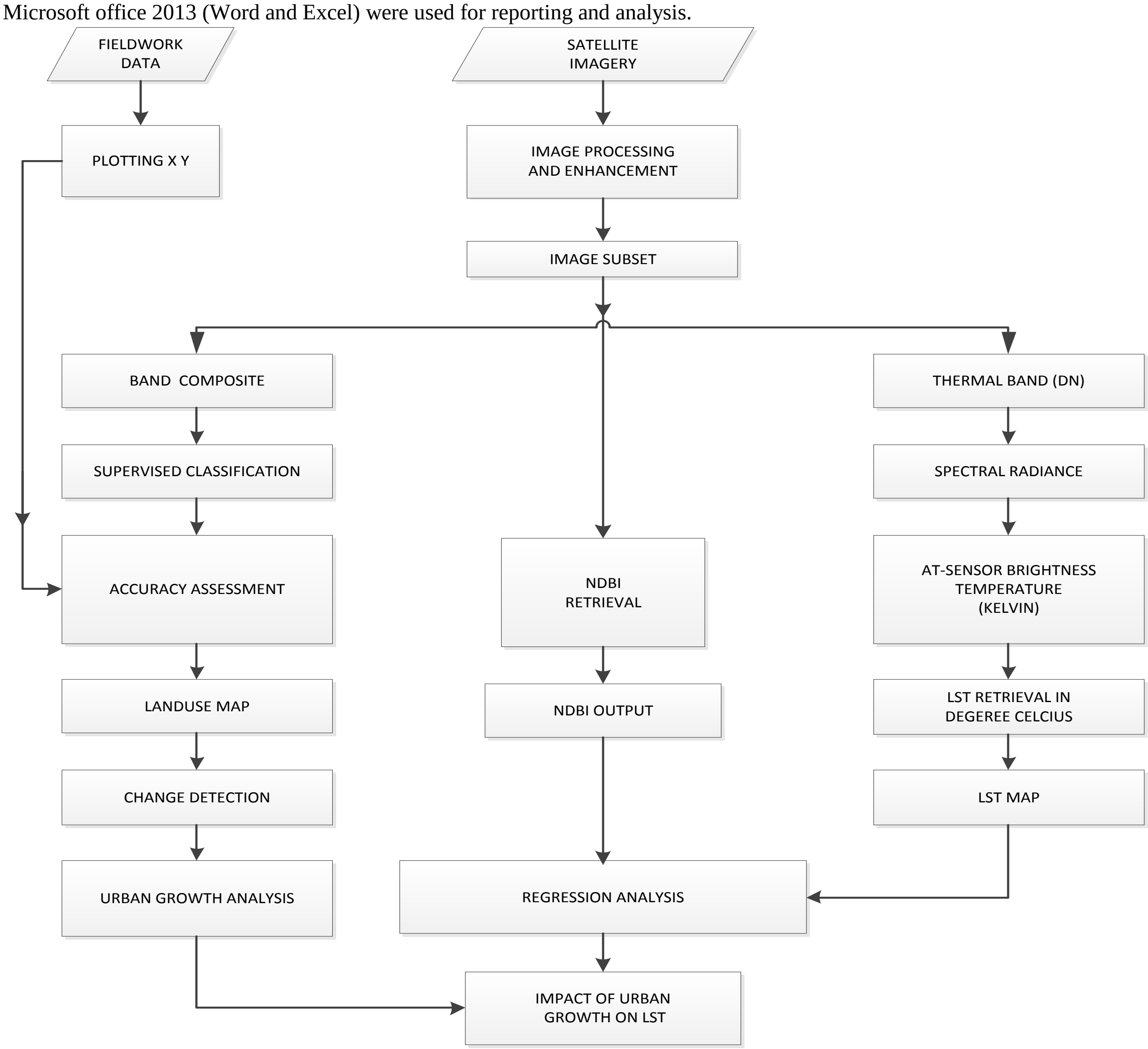

Fig. 2: Flow Chart Indicating Procedures Followed in LULC and LST Analysis.

The downloaded satellite images for this study were ortho-rectified/georeferenced L1T (terrain corrected) product from source (United States Geological Survey). However, the geometric accuracy was verified by overlaying and comparing with existing maps. However, coordinate system verification and projection to UTM zone 32, WGS1984, Minna Datum was ascertained. Radiometric correction was performed on the thermal bands by converting the digital numbers (DN) to at-sensor radiance using the raster calculator in Arc GIS in conjunction with the provided metadata in the header file. In addition, the satellite imageries used were enhanced using histogram equalization to aid image interpretation.

According to Richards (1993), supervised classification is the essential tool used for extracting quantitative information from remotely sensed image data. Using this method, it was possible to have sufficient known pixels to generate representative parameters for each class of interest. This step is called training. There are two prominent color composite namely; the natural color composite (RGB) and false color composite. In this study, the false color composite was adopted owing to its good visual discrimination advantage. The chosen color composite for Landsat 5 TM, 7 ETM+ (band 4, 3 and2) and Landsat 8 OLI (band 5, 4 and 3) were used with training sample sites for land cover classification. This composite provided better visualization and recognition of LULC. The training sites developed for this research were based on the reference data and ancillary information collected from various sources. Once trained, the classifier is then used to attach labels to all the image pixels according to the trained parametres. The most commonly used supervised classification Algorithm is Maximum Likelihood Classification (MLC), which assumes that each spectral class can be described by a multivariate normal distribution. Thus, supervised classification with a Maximum Likelihood Algorithm was used to classify the land use and land cover classes; built-up areas, bare surface, vegetation, water body and rock out crop (Table 2).

Table 2: Land Use/Land Cover Classes

LULC Classes	Description
Built-up areas	The residential and commercial area made up this class
Bare surface	This includes uninhabited land, mainly desert area or features.
Vegetation	This is made up of forest, scrublands and agricultural land.
Water body	Includes rivers, lakes, streams and water shed.
Rock	Rocks of various origin found in AMAC.

Source: Fieldwork, 2018.

The essence of accuracy assessment is to complete the classification process. The study used error matrix because it is the most widely used approach which makes comparison between classified images and referenced data easy and it can be carried out by selecting random points in order to test the accuracy assessment. In addition, for representing the differences among changes in the agreement and the reality, Kappa coefficient was calculated. In this study for each satellite imagery, 100 random points were selected and created in the ERDAS Imagine software for accuracy assessment of year 1986 and 2001, while fieldwork data was used for assessing the accuracy for 2016 classification. Image of the study area on Google Earth map was used for proper field validation and confirmation of training sites selected during image interpretation and analyses. Rate of change in the LULC describes and quantifies differences between images of the same scene at different times. The classified images of the three dates were used to calculate the area of different land covers and observe the changes that took place in the span of data. This analysis was helpful to identify various changes that occurred in different classes of land use such as increase in urban built-up area or decrease in vegetation.

Detection of Urban Growth

From remote sensing perspective, impervious surfaces are usually referred to as built-up areas (buildings, roofs, paved roads). In this study, the impervious surfaces served as an indicator for urban growth and are part of the LULC. As a result, urban land uses for 1986, 2001 and 2016 were extracted from the classified images. After the extraction, the urban land use images were then overlaid and a spatial analysis was performed to obtain an image of urban growth areas. This urban growth image showed areas which experienced urban growth during the period of investigation.

Derivation of Land Surface Temperature

Land surface temperature was retrieved from the thermal infrared band of Landsat images (band 6 of Landsat 5 and 4 then band 10 and 11 of Landsat 8). The basic steps for the derivation of LST given below are based on the guidelines provided in Landsat Data Users Handbook published by USGS.

1. Conversion of pixel values (DN) to spectral radiance (Lλ)

For Landsat 5 and 7:

$L_\lambda = (LMAX_\lambda - LMIN_\lambda)/(QCALMAX - QCALMIN))*(QCAL - QCALMIN) + LMIN_\lambda$

Where;

L_λ = Spectral Radiance at the sensor's aperture in watts/(meter squared * srad * µm)

Q_{CAL} = the quantized calibrated pixel value in DN

LMINλ = the spectral radiance that is scaled to QCALMIN in watts/(meter squared * srad * µm)

LMAXλ = the spectral radiance that is scaled to QCALMAX in watts/(meter squared * srad * µm)

QCALMINλ = the minimum quantized calibrated pixel value (corresponding to LMINλ) QCALMAXλ = the maximum quantized calibrated pixel value (corresponding to LMAXλ)………………………………………………………………………**(1)**(Jacob, 2015)

For Landsat 8:

$L_\lambda = M_L * Q_{CAL} + A_L$

Where:

M_L= the band-specific multiplicative rescaling factor

A_L= the band-specific additive rescaling factor

Q_{CAL} = the quantized calibrated pixel value in DN ....**(2)(**Jacob, 2015)

2. Conversion of spectral radiance (Lλ) to temperature in Kelvin

$T_B = K_2/Ln\ (k_1/L_\lambda+1)$

Where;

T_B= At-Satellite brightness temperature (K)

L_λ= Spectral radiance spectral radiance in W/ (m^2* srad*µm)

K_1= pre-launch calibration constants from metadata

K_2= pre-launch calibration constants from metadata**…………………...(3)(**Jacob, 2015)

3. Land Surface Temperature retrieval (ºC)

The LST in Celsius (˚C) was calculated by Conversion of temperature in Kelvin to Celsius with the following equation:

LST (ºCelsius) = LST (Kelvin) – 273.15**…………………………………..…(4)**(Jacob, 2015)

Computation of Normalized Difference Built-Up Index (NDBI)

The Normalized Difference Built-up Index (NDBI) is an approach used to strengthen the robust extraction of built-up from urban areas as well as built-up information. Given that the NDBI is a good indicator of built-up feature in urban areas due to its high reflectivity in the mid-infrared (MIR) band than the NIR band. The values of NDBI and NDVI can vary from -1 to +1(Raynolds., Comiso., Walker and Verbyla, 2008). It was calculated using the Equation below:

NDBI = MIR band – NIR band /MIR band +NIR band

Where;

NDBI = Normalized Difference Built-up Index

MIR band = Mid Infrared band of Landsat imagery

NIR band = Near Infrared band of Landsat imagery**……………………….(5)(**Raynolds., Comiso., Walker and Verbyla, 2008).

Analysis of Land Surface Temperature and Urban Growth

Statistical tables and charts were used for data analysis. Zonal Statistics as Table (ZSAT) was also used to identify Land Surface Temperature changes of each LULC types in the study area. This was implemented in Arc GIS 10.4.1 based on the vectorized LULC which is categorical and LST is continuous. With the aid of ZSAT, a set of statistics were calculated such as the minimum, mean and maximum statistics of LST derived based on LULC maps. This was done to identify the Land use with the highest surface temperature in AMAC. In addition, simple linear form of regression analysis was used to establish the relationship between LST and NDBI. The LST was the dependent variable while the NDBI served as the predator/independent variable. This was done in order to determine if the relationship between the variables is statistically significant. To achieve this, 12 points were generated from the LST and NDBI where the NDBI served as an indicator for urban growth. The Microsoft Excel software was used for the regression analysis. The formula of regression analysis is;

y=a + bx +e

Where;

y= the estimated value the dependent variable

x = the value the independent variable

a = the y intercept i.e. where the regression line touches the y axis

b = the regression coefficient

e = the residual or random error term**………………………………………....(6)(**Mahmoud, 2016)

RESULTS AND DISCUSSION

Land Use Land Cover Distribution of AMAC from 1986 to 2016

The study area (AMAC) satellite imagery was grouped into five different classes namely vegetation, built up areas, rocks, water body and bare surface with an overall classification accuracy assessment of 91.14%, 88.71%, and 90.32% for 1986, 2001 and 2016 respectively. Thus the Land Use Land Cover (LULC) maps of AMAC for 1986, 2001 and 2016 are presented in Figures 3, 4 and 5 respectively. The most significant changes are the transitions from vegetation to built-up areas and bare surface probably as a result of human interference.

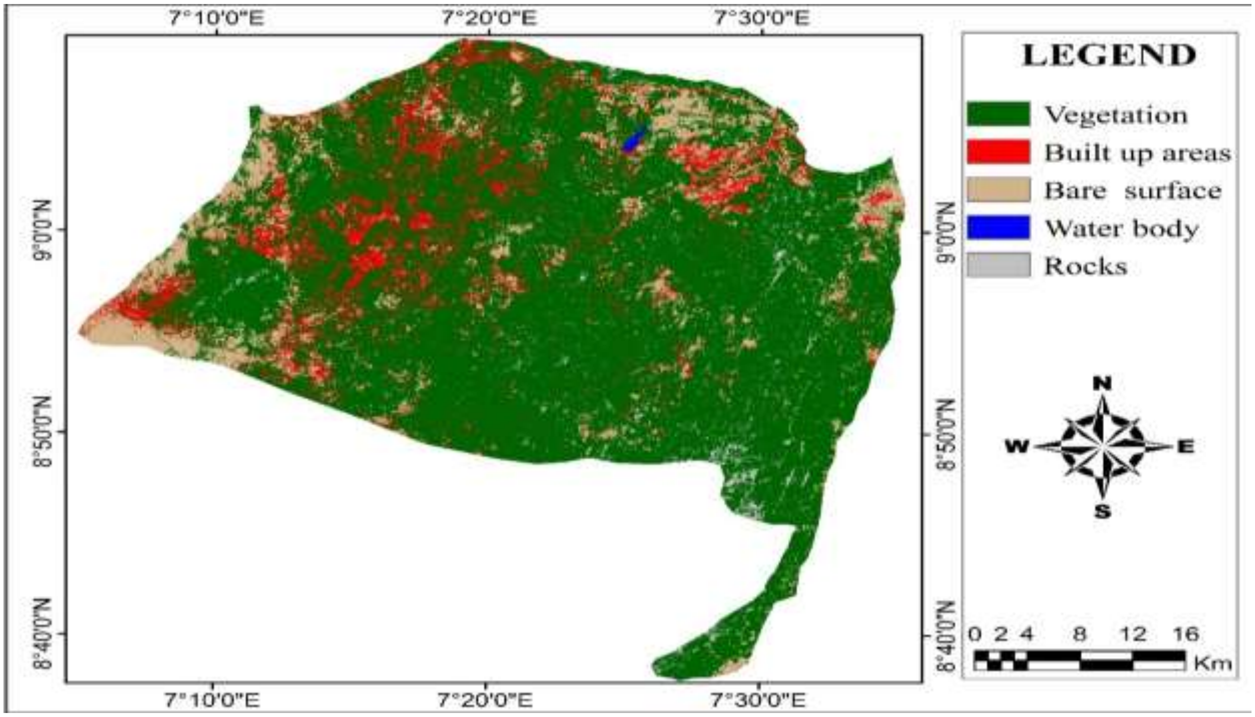

Fig. 3: Land Use Land Cover of AMAC in 1986.
Source: Authors' Analysis, 2018.

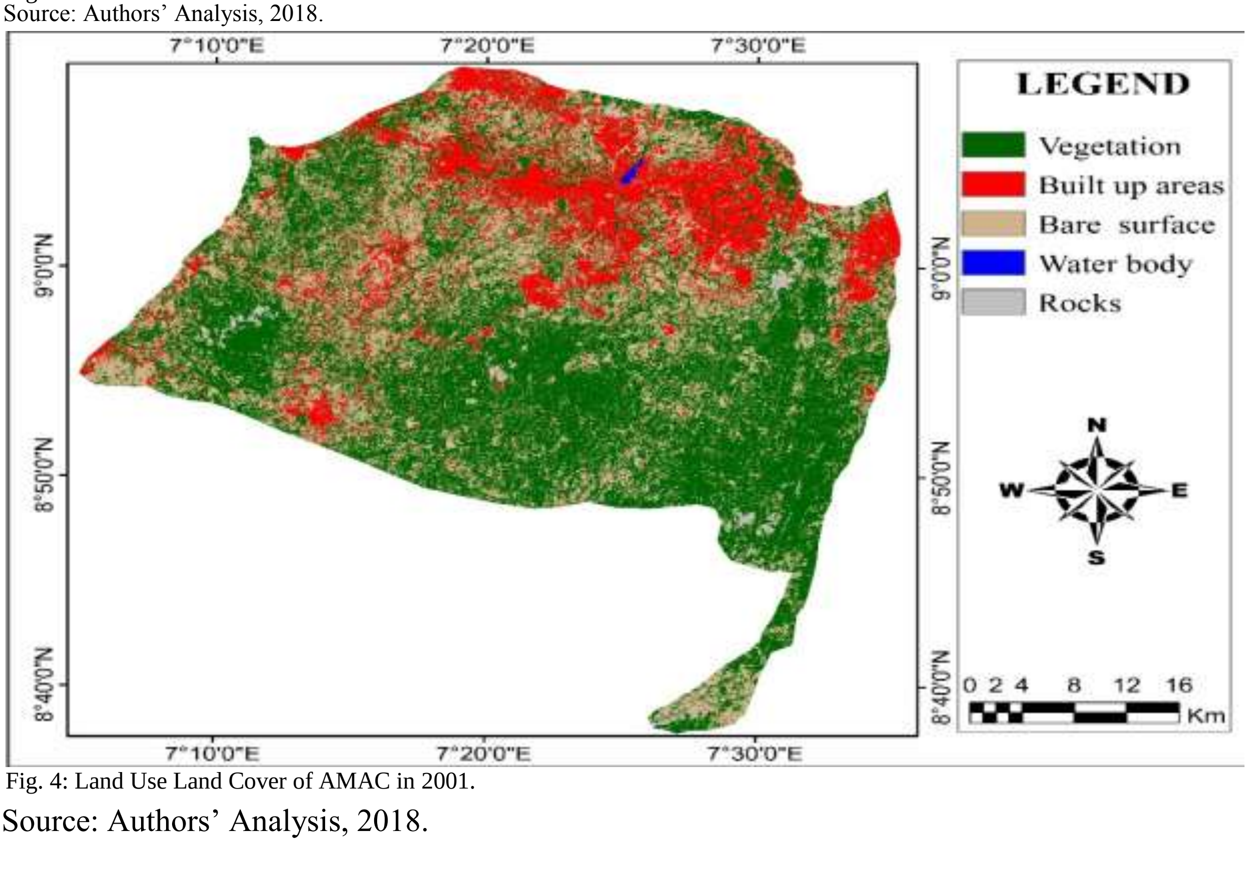

Fig. 4: Land Use Land Cover of AMAC in 2001.
Source: Authors' Analysis, 2018.

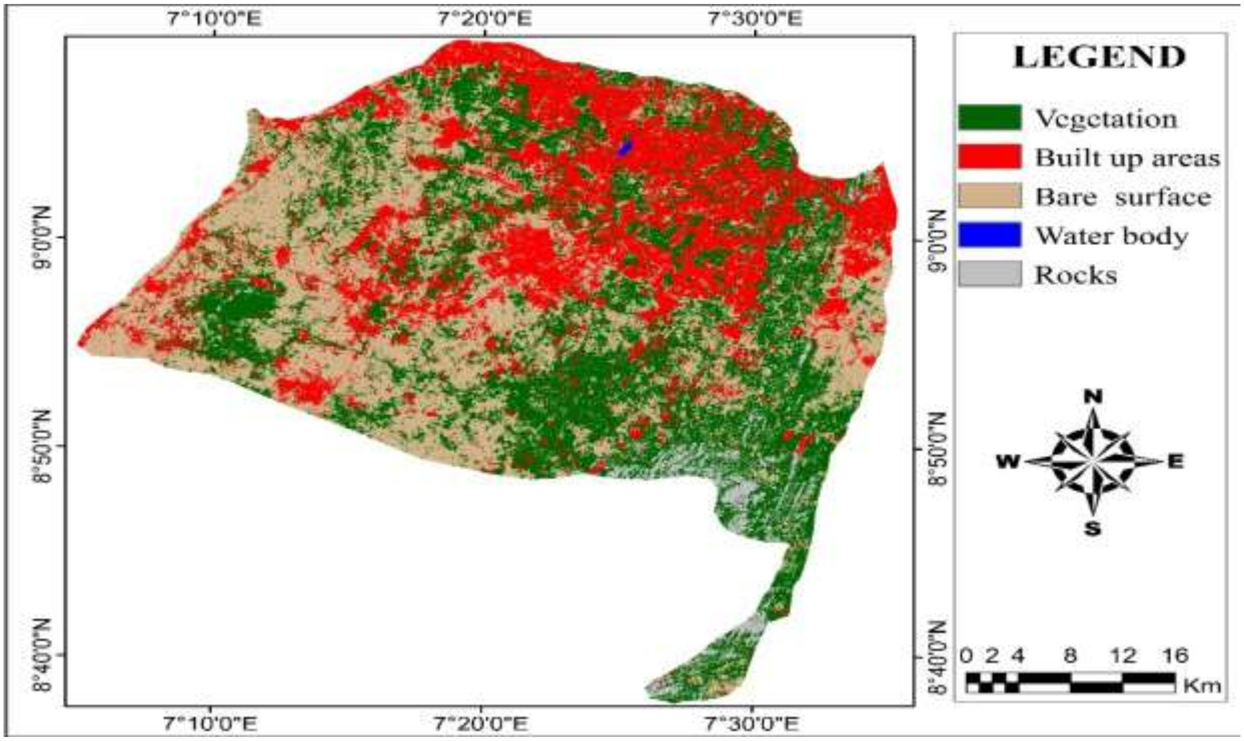

Fig. 5: Land Use Land Cover of AMAC in 2016.
Source: Authors' Analysis, 2018.

Table 3: LULC Analysis for AMAC from 1986 to 2016

	1986		2001		2016	
LULC	**Area (km^2)**	**Percentage (%)**	**Area (km^2)**	**Percentage (%)**	**Area (km^2)**	**Percentage (%)**
Vegetation	1201.46	75.99	800.36	50.62	561.78	35.53
Bare surface	189.67	12	475.81	30.09	573.61	36.28
Water body	1.61	0.1	1.06	0.07	0.67	0.04
Built-up areas	146.78	9.28	263.09	16.64	406.46	25.71
Rocks	41.57	2.63	40.77	2.58	38.57	2.44
Total	1581.09	100	1581.09	100	1581.09	100

Source: Fieldwork, 2018.

The distribution of the LULC for 1986 by area in kilometre squares (Table 3) and the classified Landsat TM satellite imagery (Figure 3) revealed that the vegetative covers (encompassing forest, scrubland and farmland) dominated majority of LULC of the study area compared to the other LULC. Hence vegetation accounted for 75.99%, followed by bare surface which occupied 12%; built-up areas occupied 9.28%; while rocks and water body amounted to 2.63% and 0.1% respectively. The factor responsible for this LULC distribution then, was probably because AMAC was inhabited by mostly indigenes that engaged in activities like farming, fishing, trading and hunting. These were activities with low human interference with nature, because they were carried out at subsistence level. The image classification results retrieved from 2001 Landsat ETM satellite imagery (Figure 4 and Table 3) also showed that there was tremendous change in the LULC of AMAC from 1986 to 2001. On the other hand, vegetation still remained the major Land Use Land Cover but with a decrease from 75.99% to 50.62% of the total land area, due to the clearance of the formerly vegetated areas probably for construction purposes. Whereas there was a significant increase in bare surface, as it rose to 30.09%while built-up areas also increased to 16.64%; rocks and water body percentages decreased. Generally, the transfer of the Federal Capital Territory of Nigeria from Lagos to Abuja in 1991 could be regarded as a dominant factor responsible for the LULC distribution experienced during this period.

The LULC results generated from 2016 Landsat 8_OLI satellite imagery (Figure 5) revealed that, LULC in 2001 differed slightly from 2016 LULC distribution as shown on Table 3. This may be due to increase and modification by anthropogenic activities like construction of roads, bridges, industrial location and deforestation. The decline in vegetation to 35.53%was probably because of the increase in bare surface and built-up areas, as forested areas are cut down for construction purposes. The bare surface increased to 36.28%. This may be attributed to bush clearing for farming and construction activities that took place in the study area then. This was obvious as built-up areas increased to 25.71% and rocks decreased due to extraction for engineering construction purpose (quarry). The extent of water body declined from 0.07% to 0.04%. Furthermore, the results as shown in Table 3 revealed that, the LULC distribution of AMAC for the three epoch years has undergone rapid changes (Figure 6) that may likely have resulted in both negative and positive environmental impacts like increase in surface temperature of the area and physical and economic development induced by urban growth.

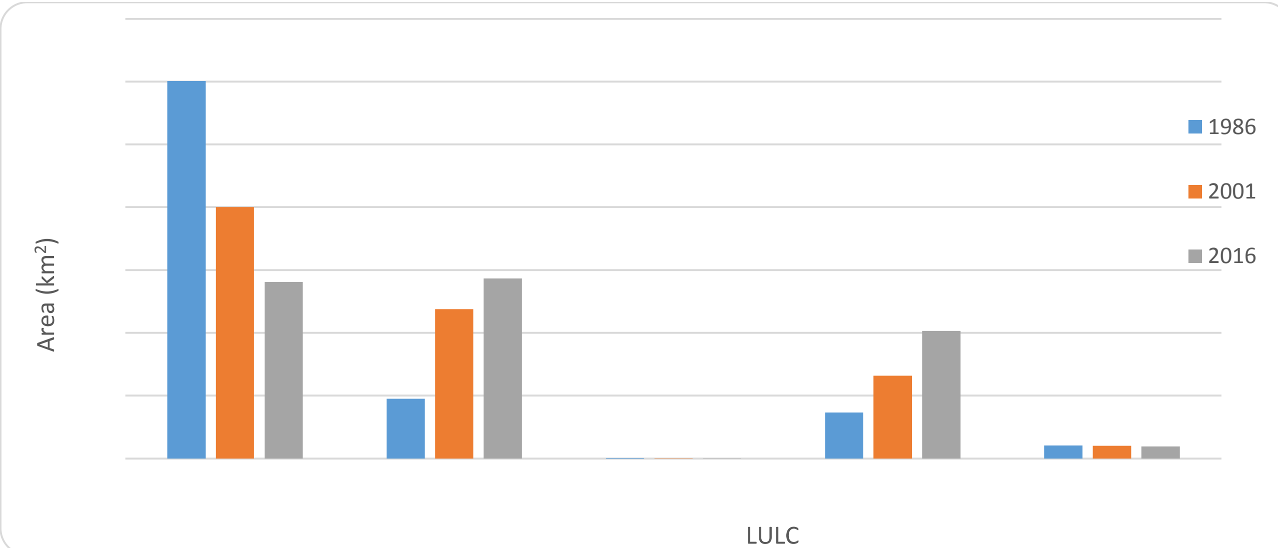

Figure 6: LULC of AMAC from 1986 to 2016.

Source: Fieldwork, 2018.

The rate of change in Land Use Land Cover in the three epoch years depict the extent of expansion in built-up areas which served as an indicator for urban growth in AMAC for this study. Both positive and negative changes in LULC (Table 4) were experienced during the study period. During the first period (1986-2001) the land use change was characterised by abrupt rise in bare surface by approximately 18.09% and built-up areas increased at the rate of 7.36%. On the other hand, vegetation decreased by 25.37%, water body and rocks by 0.03% and 0.05% respectively. This means there was no significant change in water body and rocks due to less human interference when compared to the other LULC types. Generally, the changes experienced during this period may be due to the change in the status of AMAC from a rural settlement to an area council when Abuja was made the Federal Capital Territory of Nigeria in 1991. Similarly, in the second period (2001-2016), bare surface increased at the rate of 6.19% and built-up areas increased at the rate of 9.07%. On the other hand, vegetation decreased by 15.09%, water body by 0.03% and rocks by 0.14%. In general, the period between 1986 and 2016 witnessed tremendous changes in LULC types of AMAC (Table 4) as bare surface increased at the rate of 24.28%, built-up areas increased by 16.43% whereas vegetation decreased by 40.46%, water body by 0.06%, and rocks by 0.19%. The built up area which is the primary concern of the study and was used to depict extent of expansion witnessed a rapid change between 1986 and 2016 (Figure 6) due to increase in housing and infrastructural development such as roads, health and educational buildings that have modified the morphology and extents of the area council. These results as discussed above agree with the findings of Babalola and Akinsanola (2016) in their study titled an analysis of change detection in Land Surface Temperature and Land Use Land Cover over Lagos metropolis, Nigeria.

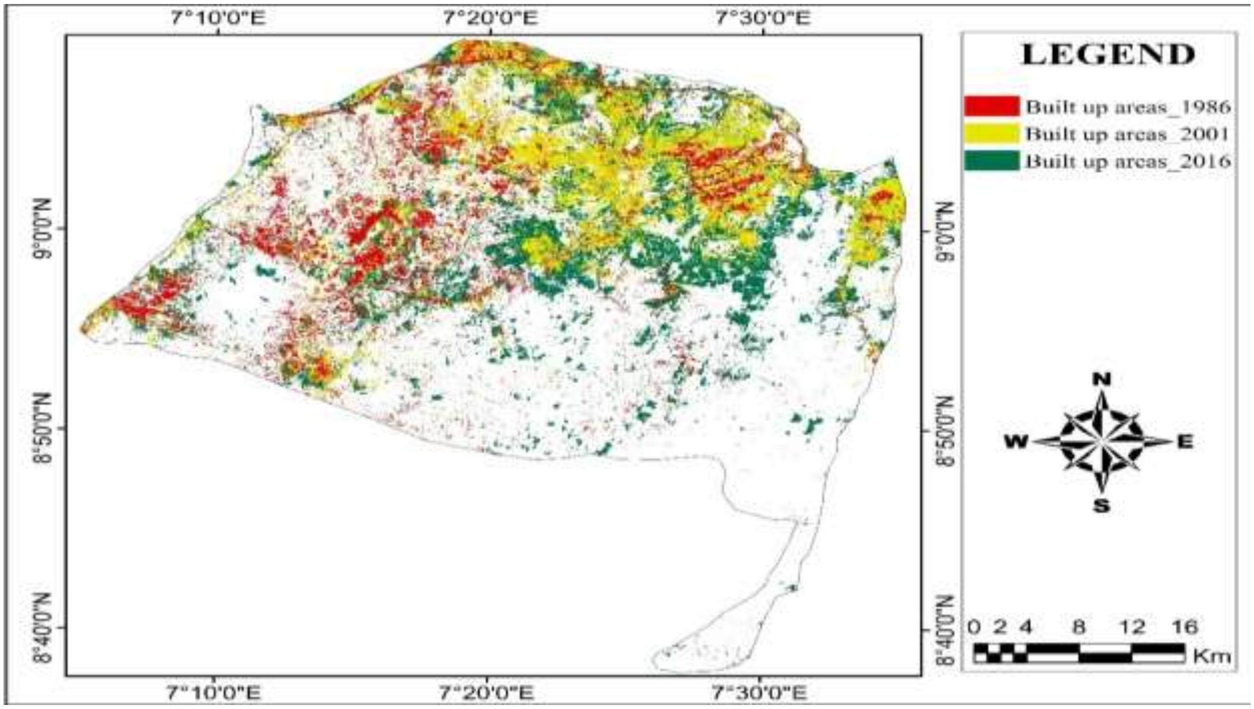

Fig. 7: Extent of Urban Growth in AMAC.

Source: Authors' Analysis, 2018.

Derived Land Surface Temperature Maps

The Land Surface Temperature retrieved from the thermal infrared band of Landsat imageries depicts an increase in LST with increasing rate of urbanization in the area council. The computed LST map is illustrated in Figures 8, 9 and 10 for the years 1986, 2001 and 2016 respectively. Essentially, this study revealed that in 1986 the minimum LST was 16°C while the maximum LST was 31°C. However, from 1986 to 2001, the LST changed as the minimum LST rose to 17°C while the maximum LST was 39°C. This can be attributed to the modification of LULC by human activities, as built up areas and bare surface increased at the expense of vegetation (Table 4). The LST in 2016 also differed from 2001, as the minimum LST rose to 22°C while the maximum LST was 40°C (Table 4).

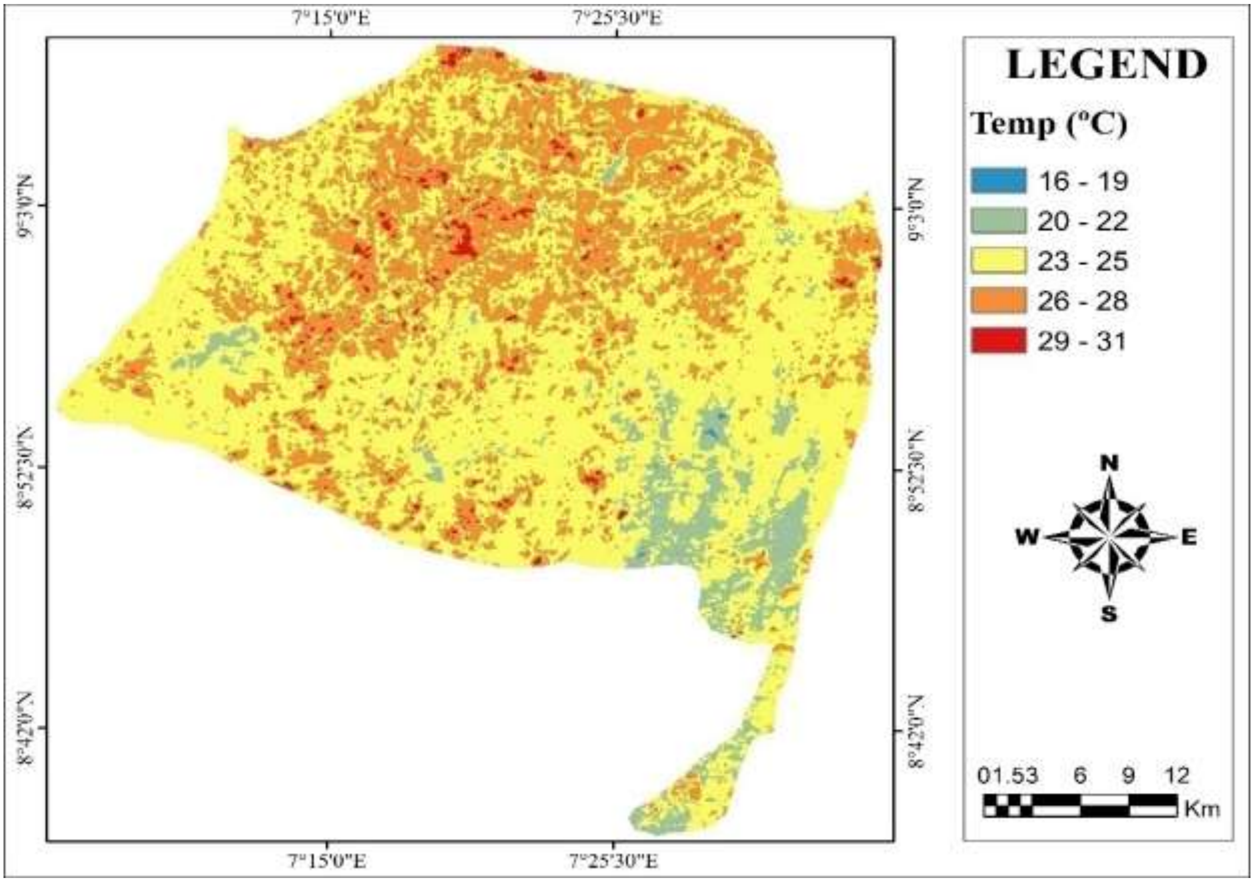

Figure 8: Derived Land Surface Temperature for 1986.

Source: Authors' Analysis, 2018.

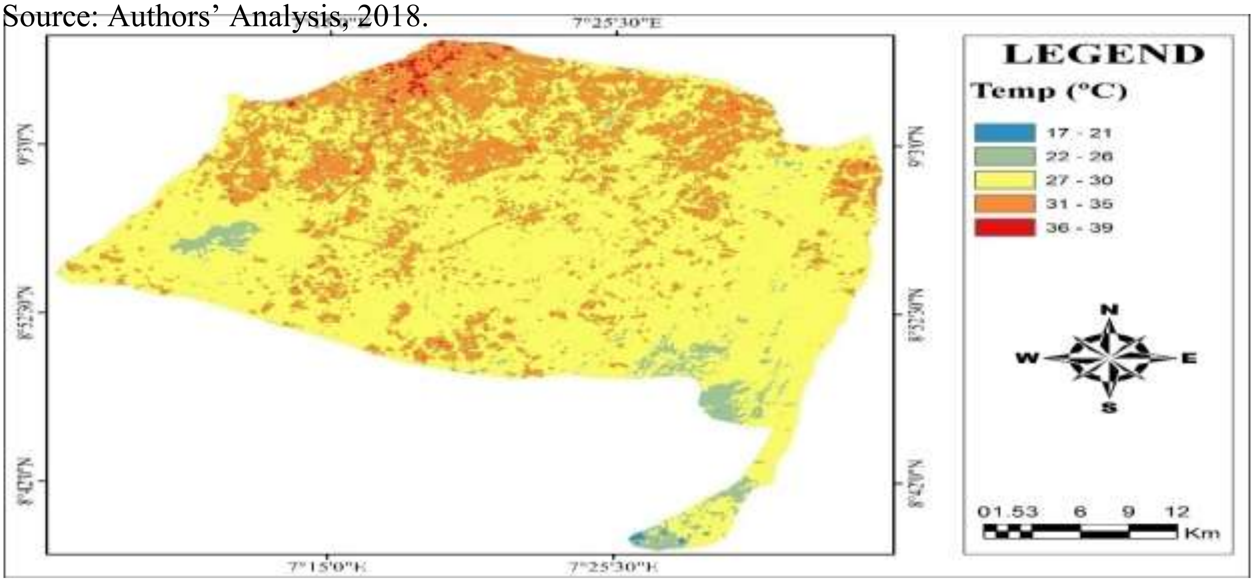

Figure 9: Derived Land Surface Temperature for 2001.

Source: Authors' Analysis, 2018.

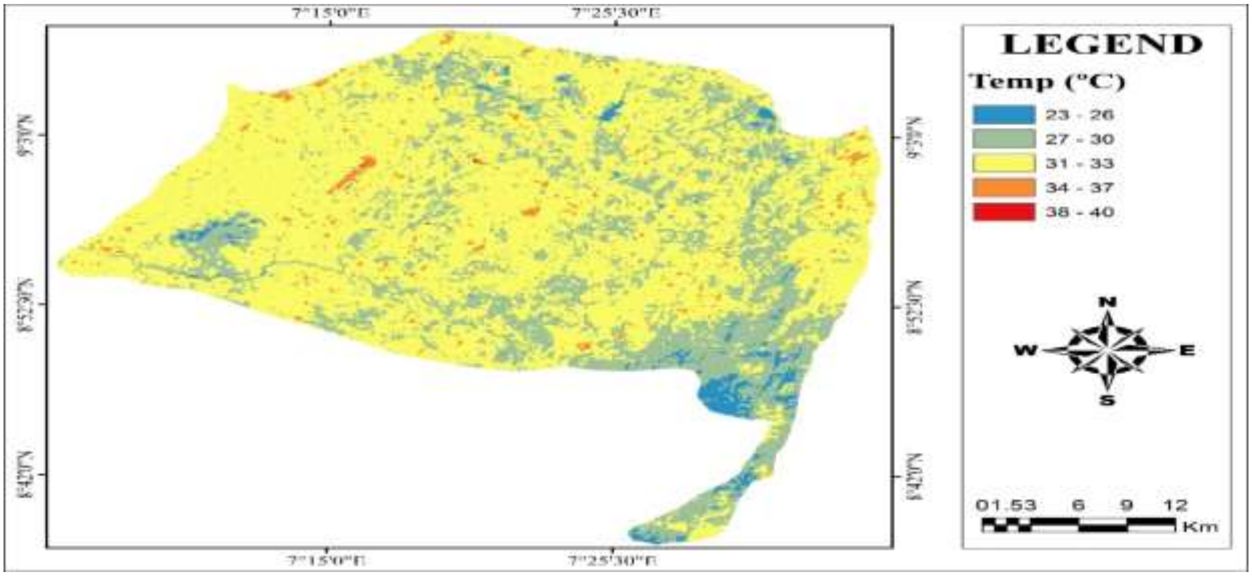

Figure 10: Derived Land Surface Temperature for 2016.

Source: Authors' Analysis, 2018.

Land Surface Temperature Changes of each LULC Types

Table 4 shows the Land Surface Temperature changes of each LULC types in the study area that were derived with the aid of Zonal Statistics as Table (ZSAT) in ArcGIS 10.4.1 software

Table 4: LST Statistics of each LULC Types

	1986 LST (°C)			2001 LST (°C)			2016 LST (°C)		
LULC	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Vegetation	16	28	22	17	34	26	22	36	29
Bare surface	16	30	23	17	39	28	26	39	33
Water body	19	30	25	24	30	27	24	29	27
Built-up areas	23	31	27	27	39	33	31	40	36
Rocks	18	30	24	17	35	26	23	33	28

Source: Fieldwork, 2018.

From the results obtained (Table 4), it was revealed that built-up areas exhibited the highest mean LST which could be attributed to its rapid change at the rate of 7.36% between 1986 to 2001; 9.07% between 2001 to 2016 and 16.43% between 1986 to 2016. This might have been so because built-up areas are characterised with high concentration of buildings, people, roads, pavements, machines and high rise structures, that contribute to higher LST due to the modification of reflective (albedo), absorptive, storage and emissive characteristics of the urban LULC (Voogt, 2004). In 1986, 2001, and 2016 the values of LST exhibited by bare surface were 23°C, 28°C and 33°C respectively. Bare surface exhibited relatively higher LST values than other Land Use Land Cover probably because they tend to have sparse or complete absence of vegetation. It is also evident from Table 4 that vegetation showed considerably low mean LST during the three periods when compared to built-up areas and bare surface. Thus, it can be deduced that the decline in vegetative cover as shown in Table 4 could be a contributory factor for the rise in LST in the area council. Similarly, the increase in mean LST exhibited by water body and rocks from 1986 to 2016 were 2°C and 4°C respectively. Essentially, urban growth (built-up areas) which is the primary concern of this study experienced a rapid increase in LST from 1986 to 2001, 2001 to 2016 and 1986 to 2016 as the LST of built-up areas increased by 6 °C, 3 °C and 9 °C respectively. As stated earlier, the alteration of vegetation cover is one of the likely factors responsible for the rise in LST. This is because it (especially trees and forest) serves as carbon sinks which help to radiate cooling thereby modifying the microclimate of an area (EPA, 2009). Also, increase in LST can also be induced by properties of urban materials, arrangement of buildings (urban geometry) and anthropogenic heat generated from activities such as bush burning, vehicles, industrial activities and so on.

Relationship between Urban Growth and Land Surface Temperature in AMAC

It is evident from the results obtained, that from 1986 to 2016 there was 16.43% increase in urban growth (built-up areas) with corresponding increase in the Land Surface Temperature of AMAC by 9 °C. This means that the built-up areas of AMAC are on the increase as well as the LST (Table 4.1). For instance, in the year 1986 when the built-up areas occupied 9.28% of the land area of AMAC, the mean LST was 27 °C. Similarly, in the year 2001 when there was an increase in built up areas, the mean LST of AMAC increased from 27 °C to 33 °C (an increase of 6

°C). Additionally, in the year 2016 when there was an increase in built-up areas there was a corresponding increase in the Land Surface Temperature of AMAC from 33 °C to 36 °C (that is by 3 °C). In essence, the rate of change in built-area from 1986 to 2001 was 7.36% which relates to 6 °C increase in LST for that period. Also, the rate of change in built-areas from 2001 to 2016 is 9.07% which relates to 3 °C increase in LST for that period.

Table 5: Data Used For the Regression Analysis

NDBI_1986	LST_1986 (°C)	NDBI_2001	LST_2001 (°C)	NDBI_2016	LST_2016(°C)
0.03	17.91	0.03	19.22	0.15	25.94
0.07	19.28	0.1	22.32	0.2	27.21
0.1	20.17	0.15	24.54	0.24	28.22
0.13	21.48	0.2	25.78	0.27	29.09
0.16	22.79	0.24	27.02	0.29	29.9
0.19	23.68	0.27	28.35	0.31	30.57
0.21	24.52	0.3	29.59	0.33	31.24
0.23	25.35	0.33	30.74	0.35	31.84
0.24	26.24	0.36	31.98	0.36	32.44
0.27	27.49	0.38	33.22	0.4	33.18
0.29	28.75	0.4	34.82	0.5	34.59
0.44	30.83	0.67	39.16	0.77	40.02

Source: Authors' Analysis, 2018.

Table 6: Output of Regression Statistics on Microsoft Excel

Year	Model	Multiple R	R Square	Adjusted R Square	Standard Error	P-Value
1986	1	0.9798	0.9610	0.9561	0.8261	2.57628541385732E-08
2001	2	0.9786	0.9576	0.9534	1.2037	3.42454896185263E-08
2016	3	0.9865	0.9732	0.9705	0.6433	3.4700688090086E-09

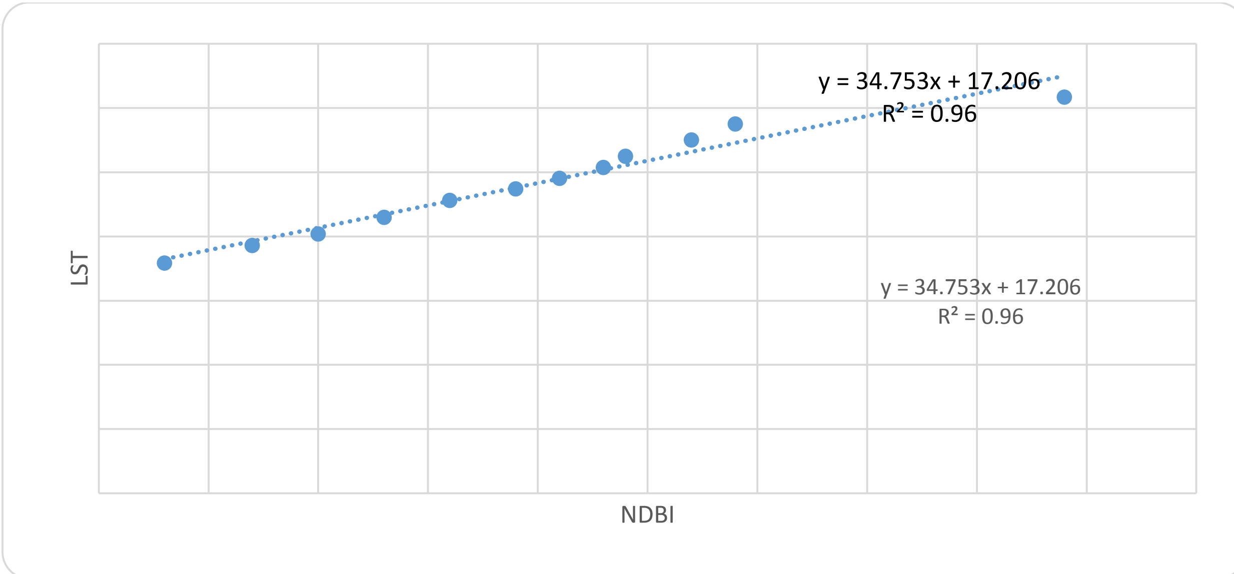

Figure 11: Effects of Urban Growth (NDBI) on LST for 1986.

Source: Authors' Analysis, 2018.

Results of linear regression analysis for 1986 (Figure 11 and Table 6) showed that there was a significant relationship between urban growth and Land Surface Temperature with correlation value (R) being 0.9798 while coefficient of determination (R^2) was 0.9610. This is because the p-value of the predictor (NDBI) in 1986 was lower than the significance level of 0.05 as determined using the data shown on Table 5. Thus it can be deduced that urban growth may likely be responsible for the rise in LST in the study area. The results from the linear regression for 2001 indicated a positive correlation between NDBI-derived built-up fractions and the LST, as shown in Figure 12 with correlation value (R) of 0.9786 while coefficient of determination (R^2) was 0.9576 (Figure 12)

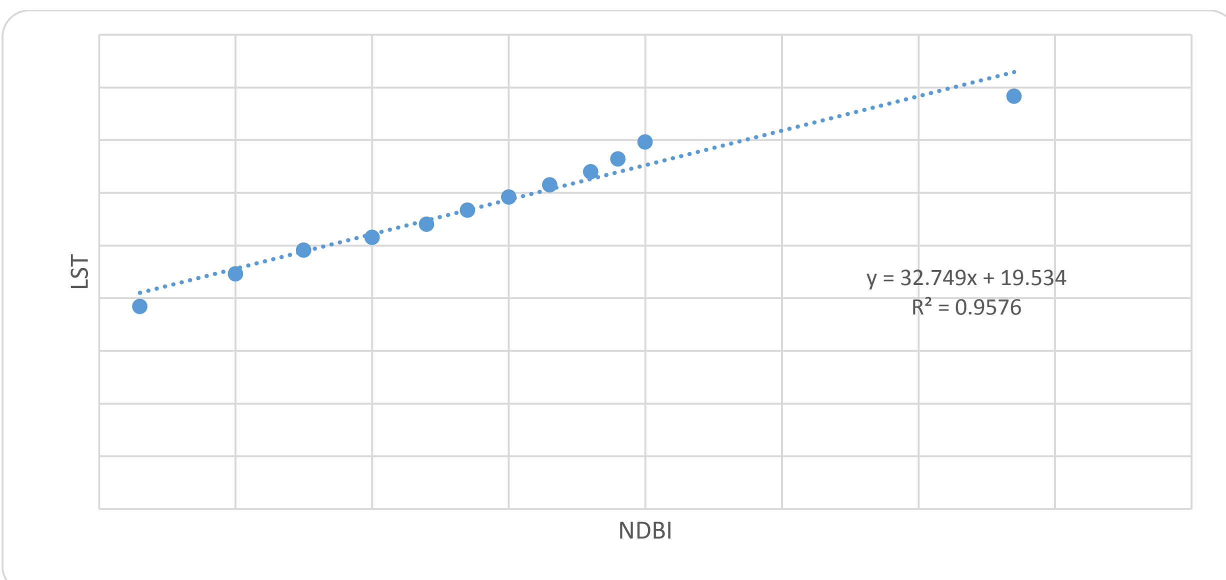

Figure 12: Effects of Urban Growth (NDBI) on LST for 2001.

Source: Authors' Analysis, 2018.

Similarly, the results of linear regression analysis for 2016 (Figure 13 and Table 6) showed that there was a significant relationship between urban growth (NDBI) and Land Surface Temperature with correlation value (R) being 0.9865 while coefficient of determination (R^2) was 0.9732. In essence, it is clear from the results obtained that higher LST values were obtained towards the densely populated parts of the study area with many structures/buildings and higher anthropogenic influences due to high influx of people probably from other states into the city. These results agree with the findings of Balogun and Samakinwa (2015) on geospatial assessment of urban expansion and Land Surface Temperature in Akure, Nigeria. In addition, it is a well-known fact that areas with high NDBI values (more built areas) have high LST value and vice versa (Raynolds., Comiso., Walker and Verbyla, 2008). This has been further established in this study as a strong relationship was established between the density of human created structures (NDBI) and Land Surface Temperature. This also implies that areas with high LST values have a corresponding high NDVI values and less vegetative cover due to rapid rate of urban development. Thus, there is a need to implement Abuja master plan and other urban growth policies to control the rapid rate of urbanisation being experienced in AMAC in order to minimize its effects on Land Surface Temperature.

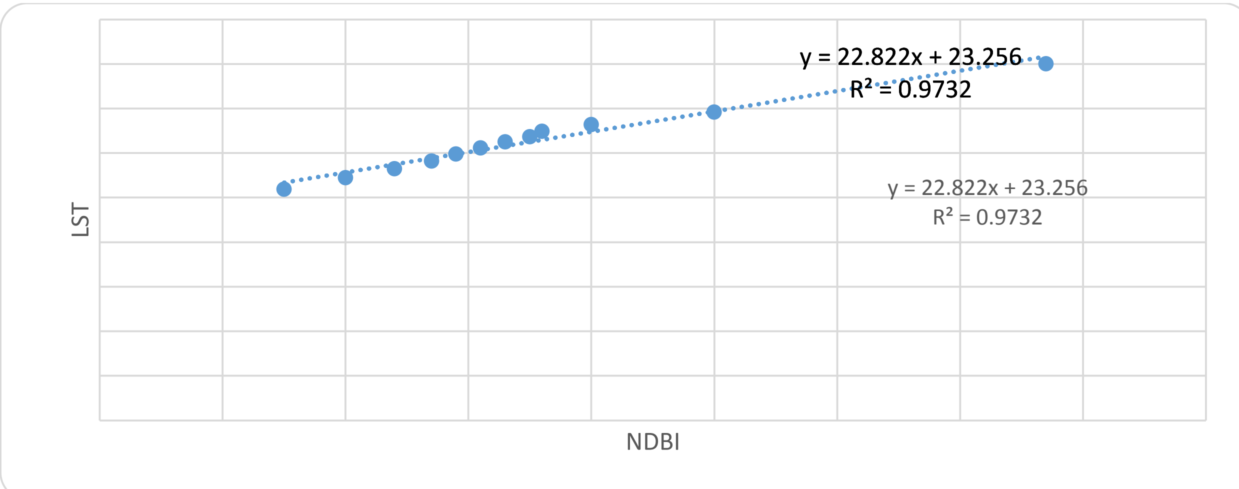

Figure 13: Effects of Urban Growth (NDBI) on LST for 2016.

Source: Authors' Analysis, 2018.

CONCLUSION

This study has demonstrated that the recent advancements in remote sensing and GIS technologies provide powerful tool for mapping and detecting changes in Land Use Land Cover which is often used as an indicator for urban growth. The study revealed high rate of urban growth in AMAC which may be attributed to the high influx of people from other states into the city and as a result of natural increase (difference between birth rate and death rate). Thus, the rapid urban growth has both negative and positive environmental impacts like increase in surface temperature of the area, physical and economic development. Ultimately, if the built up continues to increase and vegetation continue to decline, LST will be on the high side and this may bring about urban heat island which is responsible for thermal discomfort in urban areas.

This study highlight that the variations in Land surface temperatures of the Land Use Land Cover types of AMAC suggest that urban growth is a major factor responsible for LULC distribution experienced in the study area. The rise in the surface temperature of AMAC may likely have several negative implications on both the health of residents and the natural environment. Hence, the following recommendations are suggested. There should be a constant monitoring of urban growth resulting from high influx of rural dwellers into the urban areas. This may be achieved by providing basic infrastructural facilities and services in rural areas. Also, there is a need to implement the various development and master plans designed by the urban planners to ensure orderly development. There is a need for forest conservation and encouragement of afforestation schemes. This is because, the presence of trees and forest serve as carbon sinks that aid in modifying the micro climate of an area thereby lowering its LST.

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