

Monitoring and Analysis of Urban Heat Island using Remote Sensing Data – A Case Study of Akure, Ondo State, Nigeria



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Abstract

This study aimed at using remote sensing and GIS to assess the urban heat island (UHI) in Akure town. A time series of Landsat data, from 1986 to 2014, were used in the present study to determine the urban growth and the intensity of urban heat island. The study also examines the spatial distribution of urban surface temperature and NDVI with remotely sensed data in the urban area. It was observed that the greatest urban growth occurred in Akure South with 54.22% and 58.96% in the two periods of study. Also, the greatest urban growth occurred in the second period with a total of 60.20km² compared to the total of 49.96km² in the first period. The urban growth over the entire study area showed a yearly increase of 47.79km².

Changes in LULC were accompanied by changes in NDVI and LST. In 1986, it was found that average NDVI (mean ± S.D.) in the non-built up area was 0.30 ± 0.07 and for the built-up area, it was 0.16 ± 0.09. However, this statistics reduced to 0.28 ± 0.06 and 0.13 ± 0.06 in 1999 respectively. Furthermore, the statistics was 0.24 ± 0.05 for non-built up and 0.06 ± 0.04 for built-up in 2014. It was found that average surface temperature (Mean ± S.D.) in the non-built up area in 1986 was 24.01 ± 1.21 and 27.28 ± 1.12 for the built-up area but this difference jumped to 26.52 ± 2.02 and 29.86 ± 1.66 in 1999 and further to 31.48 ± 2.03 and 33.82 ± 1.07 in 2014. It was also observed that the temperature differences between the urban/built-up and the non-built up significantly widened and this has led to the high intensity of urban heat island.

Keywords: Urban Heat Island; Remote Sensing; Land Use Land Cover Data; Normalize Difference Vegetation Index temperature

Abbreviations: UHI: Urban Heat Island; LST: Land Surface Temperature; TMs: Thematic Mapper Sensor; LST: Land Surface Temperature; LULCC: Land Cover Changes; NDVI: Normalized Difference Vegetation Index; DVI: Difference Vegetation Index; PVI: Perpendicular Vegetation Index; NDBI: Normalized Difference Built-up Index; LULC: land-Use-Land-Cover; TM: Thematic Mapper; NIMET: Nigeria Meteorological Agency

Introduction

This research focuses on urban heat island and urban development. It intends to close the gap left by previous studies in the use of remote sensing and GIS as conventional ways of carrying out urban climate studies. The study focuses on reviews by different researchers on these topics across the globe. Over the past century, there has been an increasing trend towards urbanization. In 1900, approximately 150 million people lived in urban areas with populations of 20,000 or more. This was less than 10% of the world's population. Today this population has grown to approximately 2.2 billion, which constitutes close to 50% of the world's population. High rates of urbanization have resulted in drastic demographic, economic, land use and climate

changes. The growth and expansion of our urban centers entail the construction of new roads, buildings, and other various human made structures to accommodate the growing population, and in turn, the destruction of the natural ground cover and landscape. This urbanization of the natural landscape can have profound meteorological impacts causing urban microclimates, referred to as urban heat islands, with elevated air temperatures of 2-8°F, increased energy demands, and elevated pollution concentrations compared to rural surrounding areas.

Most cities today exhibit heat island effects relative to predevelopment conditions, their individual intensities depend on a number of factors: geography, topography, land use,

population density, and physical layout. Urbanization is the conversion of other types of land use associated with growth of population and economy is a main type of land use and land cover change in human history. It has a great impact on climate. By covering with building, roads and other impervious surfaces, urban areas generally have higher solar radiation absorption and a greater thermal capacity and conductivity so that heat is stored during the day and released by night. Therefore, urban areas tend to experience a relatively higher temperature compared with surrounding rural areas. This thermal difference in conjunction with waste heat released from urban houses. Transportation and industry, contribute to the development of urban heat island Wang (2001). Urban development usually gives to a dramatic change of the earth's surface as natural vegetation is removed and replaced by non-evaporating and non-transpiring surfaces such as metal, asphalt and concrete. This alteration will inevitably result in the redistribution of incoming solar radiation and induce the urban rural contrast in surface radiance and air temperature

Today, two-thirds of all impervious area is in the form of parking lots, driveways, roads, and highways Getter and Rowe (2006). These increasing impervious areas consist of cities, towns, and suburbs. It is documented that urbanization can have significant effects on local weather and climate. Of these effects one of the most familiar is the UHI Streuter [1]. The increase of urbanization has greatly increased over the last century. Though it may seem the study of the UHI is fairly new, it actually was noticed and documented as far back as 1820. The UHI in a metropolitan area that is significantly warmer than its rural surroundings (Figure 1). The thermal characteristics of materials used in the city (asphalt, brick, concrete, glass, etc.) differ greatly from those found in the countryside (trees, grass, water bodies, bare soil, etc.).

During the day the energy is trapped by multiple reflections and absorption by the buildings Chapman [2]. This stored energy in urban areas is then reradiated as long-wave radiation less efficiently than in rural areas during the night Solecki et al. [3] keeping the urban areas warmer than the surrounding rural areas, while the buildings play a role in reducing wind speed. The combination of reducing wind speed and cloud cover aid in the UHI becoming magnified. Heat island magnitudes are largest under calm and clear weather conditions. Increasing winds mix the air and reduce the heat island. Increasing clouds reduce radiative cooling at night and also reduce the heat island Voogt [4].

The increase in urban temperatures can affect public health, the environment, and the amount of energy that consumers use in the summertime cooling. Summertime heat islands increase energy demand for air conditioning, raising power plant emission of harmful pollutants. Higher temperatures also accelerate the chemical reaction that produces ground level ozone and smog (EPA 2003). Over the next century, human induced warming is

projected to raise global temperatures by an additional 3 to 7°F Chicago Climate Task Force [5] adding to the Global Warming Effect.

Urban areas are spaces where the human transformations of environment are the greatest. Human action has changed land uses and vegetation cover, among other environmental parameters, introducing new elements and materials that are able to change locally the surface-atmosphere energetic fluxes. This fact may disturb climatic regional patterns in urban areas. One of the effects more studied is the temperature increment in the city Böhm [6] and the development of urban heat islands, a general characteristic of medium and large urban areas Landsberg [7].

One of the fundamental components that set a city apart from its rural surroundings is the climate that prevails over urban environments. In urban areas, buildings and paved surfaces have gradually replaced preexisting natural landscapes. As a result, solar energy is absorbed into roads and rooftops, causing the surface temperature of urban structures to become 50 - 70°F higher than the ambient air temperatures. Taha, Akbari & Sailor (1992). As surfaces throughout an entire community or city become hotter, overall ambient air temperature increases. This phenomenon, known as an "urban heat island," can raise air temperature in a city by 2 - 8 °F. Oke (1987) & World Meteorological Organization (1984).

The increase of global warming is believed to be resulted by Land use and Land Cover changes Landsberg [7]. One of the most general consequences of land use change and global warming is the urban heat island (UHI) Streuter [1] which is one of the straight representations of environmental issues Lu et al. [6]. UHI in a metropolitan area is importantly warmer than its neighboring rural areas. The higher urbanization leads to added distinct UHI with enormous temperature differences between urban and rural areas. The study on the UHI incident by satellite image derived by Land Surface Temperature (LST) measurements have been carried out by some researchers, mainly by using NOAA AVHRR data Streuter [1] for urban temperature mapping in local scale. Recently, Landsat Thematic Mapper sensor (TMs) and Enhanced Thematic Mapper sensor Plus (ETMs+), particularly, have been utilized for local scale mapping studies of UHI Weng [8]; Chen et al. (2002).

Some studies have revealed that anthropogenic stress resulting from population growth; urbanization and other social and economic activities have been the major drivers of increase in land surface temperature (LST) in the urban area Lu and Weng [9], Chen et al. (2006), Radhi et al. (2013). This has led to increase in local surface temperature in urban areas compared to the surrounding rural areas Chen et al. (2006a). Research on LST illustrated that the dividing sensible and latent heat fluxes and thus surface radiant temperature response was resulted by varying surface soil water content and vegetation cover Owen et al. [10]. This finding encourages research on the association

among LST and vegetation abundance Gallo et al. (1998), (1998), Hawkins et al. (2004).

The UHI intensity is related to patterns of Land Use / Land Cover Changes (LULCC), such as the composition of vegetation, water and built-up areas and change detection. The result of rural variability has been used for the calculation of UHI outcome Tian & Xiangjun (1998). Various vegetation indices can be obtained from remote sensing data which can be used in the measurement of vegetation cover qualitatively and quantitatively Purevdorj et al. (1998), Chen et al. (2002). Regression analysis can be used to create the relationship between different vegetation indices and percent vegetation cover Wang et al. (2004), e.g. Normalized Difference Vegetation Index (NDVI), Difference Vegetation Index (DVI) and Perpendicular Vegetation Index (PVI).

This study uses remote sensing methods since there are strong heterogeneity in Akure land surface characteristics; with several drainage, vegetation, built-up, soil and water bodies. Normalized Difference Vegetation Index (NDVI) will be used to represent the vegetative cover of the area, while Normalized Difference Built-up Index (NDBI) will be used to classify urban and built-up areas.

Urbanization and Land Use/Land Cover Change

There are different sources of information on existing land use and land cover and on changes that occur. Most planning agencies make use of detailed information generated during ground surveys which involves enumeration and observation. Interpretation of large-scale aerial photographs have been used widely for the purpose and satellite imagery also offers another source of getting accurate information on land use/land cover and on detecting changes that occur Anderson et al. [11]. According to Gabe [12], major effects of land use land cover in times past was deforestation, especially in temperate regions, more recent significant effects of land use include; soil erosion, soil degradation, salinization, desertification and, urban growth which is the focus in this research. Basically, land use/cover can be altered by either of two forces; Natural forces such as weather, climate fluctuations and eco-system dynamics and anthropogenic forces which largely points at human influence.

An alteration in land use produces a change in land cover hence the term land use/land cover change, this can be detected principally by the use of field survey and analysis of remote sensing imagery with a foremost result of the change being urbanization. The loss of marginal land around cities in most regions of the world as a result of urbanization has become a topic of global attention Zemba (2008). Researchers such as Wu and Jennerete (2001), Longely et al. (2001), Weng and Lu [9] all carried out extensive studies in an attempt to bring further attention to the situation by focusing on the social and eco-system implications associated with urbanization. Urbanization which involves changes in land use and land cover is one of the dominant demographic trends of our time; in 1900, 150 million

people lived in cities, by the year 2000, it was 2.9 billion people, a 19- fold increase. According to IAUC (2006), the year 2020 will see more than half of the world's people living in cities, making us for the first time, an urban species. Taking a cursory look at the situation in Nigeria, approximately 50% of Nigerians are urban dwellers with at least 24 cities having populations of more than 100,000 people (US Census Bureau, 2006).

The concept of urbanization has reached an important milestone in recent times. Even when it seems that majority of the Sub-Saharan population still live in rural areas, the average annual urban growth rate of 4.58 % between 1980 and 1993 has been more rapid in these areas than in any part of the world and is cause for great alarm World Bank, (1995). Globally, the estimated annual urban population growth rate of 1.78% is nearly twice as fast as that of the global population and if this trend continues 5 billion people out of a total world population of 8.1 billion will reside in cities by 2030 Van de Voordeet al. (2008). With this much increase in population density, the cities have had to expand both in size and features bringing about a total change in morphology; agricultural land is converted to industrial layouts, open spaces are built on, forests diminish as more land is needed for housing/shelter to accommodate people and property, and vegetation (e.g. grassland for grazing, park land etc) goes extinct in some cases. It is no surprise then that these urban areas are conflict zones between economic growth, society and the environment. Cities suffer from many environmental problems: ranging from higher temperatures in the form of heat islands to air pollution, traffic jams and high levels of ambient noise, empty houses and derelict lands all which undermine the quality of life of city dwellers and imprint a negative view of urban life.

Statement of Problem

There have been numerous changes in the land-use-land-cover (LULC) patterns in Akure, due to accelerated economic development and population increase over the years. Being the capital of the state, Akure has seen rapid increment in urban growth. The population of Akure has therefore increased drastically and there has been an increase level of urban development, which in turn increases the pressure on environment. As surfaces throughout an entire city become hotter, overall ambient air temperature increases. As a result of expanding population and industrial growth, there has been a rise in air pollution and heat, which has various level of harm on the population. The purpose of this project is to identify the effect of Urban Heat Island on Akure. The study entails the examination of land use, development of urban fabric analysis in which total vegetative, built-up areas, water bodies and bare soil are investigated and quantified.

Methodology

The methodology used in achieving the objectives set for this research are discussed further. The steps to be discussed are

the data acquisition, software to be used, image pre-processing, digital image processing, acquisition of land use land cover maps and the determination of the urban heat island of the study area.

The Study Area

The study area (Akure town) comprises of 2 local Government areas; Akure South and Akure North in Ondo State, South Western part of Nigeria. The State is bounded in the North by Kwara state, in the East by Edo and Kogi state then to the west by Oyo and Ogun state. It shares an international boundary with the Atlantic Ocean in the Southern part. The study area lies between on latitude 7° 4' and 7° 25' north of the equator and longitude 5° 5' 53'0" east of the Greenwich meridian. The study area is a medium sized metropolis in Nigeria judged by its tremendous rate of population growth. It is dominant in the national economy with wide range of urban problems.

The population of Akure in 1991 according to the population census was 239,124. The population kept growing and by projection the city's population was about 313,721 by year 2000 Okoko (2000). In 2002, it had risen to 353,211 NPC (2006). Ondo state exerts an influential role in Nigeria. The significance of this role is due partly to its historical and cultural background. It also owes its growth and development to bitumen discovery and oil producing influence. During the colonial era, there existed sharp contrast in the morphology and quality of housing between European, the educated elites and the indigenes. Each of the social groups selected in different quarters. The contrast can be seen as they existed in Akure. The Europeans lived at Oke-Eda (Alagbaka) area. The educated Nigerians lived behind the Europeans at Sijuwade areas were inhabited by indigenes.

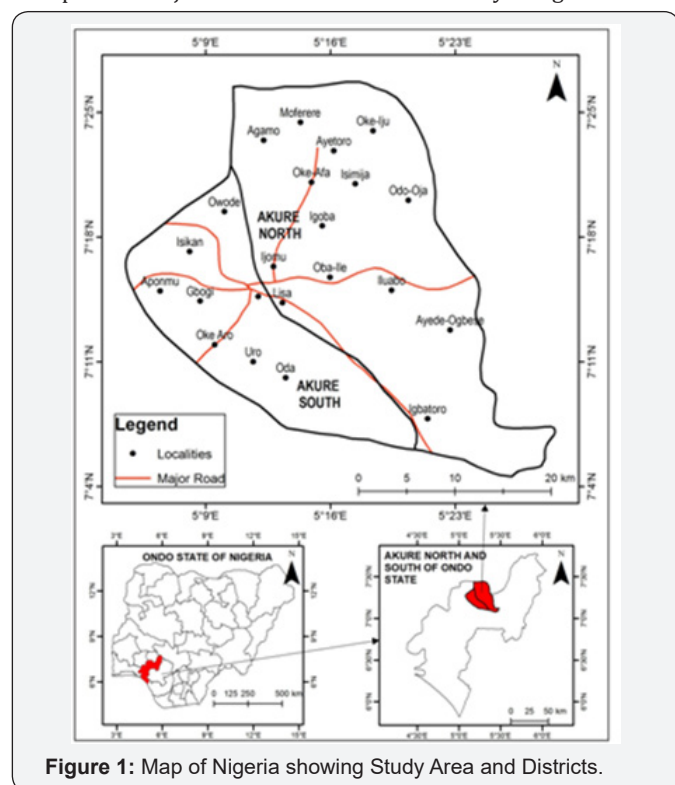


Figure 1: Map of Nigeria showing Study Area and Districts.

Geology and Climate

Akure is situated 250 metres Above Sea Level and Ado-Ekiti and Idanre hills. It is surrounded with large granite formations of volcanic origins. Akure is in the humid tropical region of Nigeria, with annual rainfall of over 1500 millimeters. During the months of December, January and February the cooler dry continental air from the north-east prevails. The rainy season lasts from March to October (Figure 1).

Data Acquisition

In the study, a series of multi-temporal Landsat data; Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+), The Landsat data used in this study all collected from the archive of US Geological Survey. The data set covers a period of 1986 and 2014. The Landsat data used in the research were taken in December Landsat data (1999) and (2014) and January Landsat data (1986). This signifies that the data were obtained in the peak of the dry season in the study area.

Image Pre-processing

The Landsat images used in the work were readily georeferenced, courtesy of the NASA Landsat program. The accuracy of the coordinate was tested by comparing the longitude and latitude of the image with that of the Google Earth coordinates of the study area. Radiometric and geometric corrections were performed on the image. Pre-processing helps to enhance and improve the quality of the image. Bands 2,3 and 4 of (Landsat TM) and 3,4 and 5 of (Landsat ETM) were subsequently combined to produce false-colour images. Since change in landcover is one of the drivers of intensity of Urban Heat Island, the colour composite technique was used to aid the visual interpretation of the images. Other preprocess like atmospheric correction, histogram equalization and spatial filtering were also done using the ENVI 4.7 tools (Table 1).

Table 1: Data used.

S/N Type of data	Source	Year	Spatial resolution
Landsat 5 (TM) p199/r055	Global Land Cover Facility Website	1986	30,120m
Landsat7 (ETM+) p199/r055	Global Land Cover Facility Website	1999	30,60m
Landsat 8 (OLI) p199/r055	USGS Earth Explorer Website	2014	30,100m
Temperature and Rainfall Data	NIMET (Nigeria Meteorological Agency)	1960-2012	N/A

Determination of Urban Growth in the Study Area

In order to detect and measure urban growth areas, land cover classification and change detection was performed. The three Landsat images of 1986, 1999 and 2014 acquired for this study were first geo-referenced and re-projected unto the UTM

Zone 31 WGS 84 coordinate system. Supervised classification was then used to classify the RGB 432 Color Composite of the individual Landsat images of 1986, 1999 and 2014 acquired for this study. The Maximum Likelihood Algorithm which classifies images according to the covariance and variance of the spectral response patterns of a pixel was the parametric rule used during the classification. Land use/cover for 1986, 1999 and 2014 was extracted from the classified images.

Studies of land use and land cover structure change usually needs development and definition of more or less homogeneous land use/land cover units before the analysis is started. These have to be defined and spatially differentiated using the available data sources (e.g. remote sensing) and any other relevant information and local knowledge. Hence, the land cover classes used in this research are defined based on the Anderson [11] according to Table 2. After the classification, the three urban land cover areas in the three years were then overlaid and change detection was performed to obtain an image of urban growth areas. These urban growth images showed areas which experienced urban growth during the period of investigation.

Table 2: Land covers classification scheme and Land cover classes Descriptions.

Built up	This classes includes urban fabric, industrial, commercial, transport units and other related built up areas of non-agricultural, vegetated areas
Agriculture	Crop, pasture, irrigated land and plantation are included in this class, heterogeneous agricultural areas and agro-forestry areas
Vegetation	It comprises forest land, shrub and other mixed forest land, herbaceous
vegetation associations	
Bareland	Open spaces with little or no vegetation, beaches, dunes sands, bare rocks

Subsequently, the study area was divided into two zones (Akure North and Akure South) to enable further analysis of urban growth within each of the two local government areas. The amount of urban growth within each local government was determined by cross tabulating the urban growth image with the two zones of the study area. Derivation of Land Surface Temperature and Normalized Difference Vegetation Index.

Land Surface Temperature

Image-based method was used to retrieve LST from Landsat TM/ETM+ in this research. Although there are other algorithms, such as the mono-window and the single-channel algorithm have been used in the literature Qin et al. (2001), Jiménez-Muñoz and Sobrino (2003), Anderson et al. [11], but recent studies Li et al. [13], Li and Yin 2013, Zhang et al. [14] have reported that the image-based method provides better and accurate results. The first task in this research was to convert Landsat TM and ETM+ thermal bands to temperature. Two steps were taking in the

retrieving LST from Landsat data. In the first step, the DN values were converted to spectral radiance using spectral radiance scaling method. The formula used in this process is as follows:

$$L_{\lambda} = ((L_{MAX} - L_{MIN}) / (QCAL_{MAX} - QCAL_{MIN})) * (DN - QCAL_{MIN}) + L_{MIN} \dots \dots \dots 3.1$$

Where L_{MAX} = spectral radiance scaled to $QCAL_{MAX}$ in $W/(m^2 * sr * \mu m)$

L_{MIN} = spectral radiance scaled to $QCAL_{MIN}$ in $W/(m^2 * sr * \mu m)$

$QCAL_{MAX}$ = maximum quantized calibrated pixel value (corresponding to L_{MAX}) in $DN=255$

$QCAL_{MIN}$ = minimum quantized calibrated pixel value (corresponding to L_{MIN}) in $DN=1$

The second step involves the conversion of radiance to degrees kelvin using the relation below:

$$TB = K2 / \ln((K1) / (L\lambda + 1)) \text{ (Unit in Kelvin)} \dots \dots \dots (3.2)$$

Where TB is the at-sensor brightness temperature in degrees Kelvin,

$L\lambda$ is the spectral radiance at-sensor ($Wm^{-2}sr^{-1}\mu m^{-1}$),

$K1$ and $K2$ are constants. Usually $K1 = 607.76$ and 666.09 ($Wm^{-2}sr^{-1}\mu m^{-1}$),

$K2 = 1260.56$ and 1282.71 (K) for Landsat TM and ETM+, respectively.

The at-sensor brightness temperature was calculated using Equation 3.2.

Normalised Difference Vegetation Index (NDVI)

The NDVI model used to compute the vegetation indexes in this present study was carried out in ENVI environment using Equation below:

$$NDVI = (BAND4 - BAND3) / (BAND4 + BAND3) \dots \dots \dots 3.3$$

Where Band 3 = the reflectance in the red region of the electromagnetic spectrum

Band 4 = the reflectance in the near infrared spectral region.

The value of this index ranges from -1 to +1. It has been shown in the literature that -1 value are generally from ice or cloud on the image, Zero values stand for areas with no vegetation and +1 values signify the maximum potential density and greenness of leaves. The common range for green vegetation is 0.2 to 0.8.

Determination of Correlation between Urban Growth and Climate variation

Temperature obtained from Landsat thermal infrared band is the brightness temperature (also known as blackbody temperature). It differs from air temperature that is controlled

by both atmospheric conditions and radiation from the sun and the earth surface Xian et al. [15]. The climate data collected Nigeria Meteorological Agency (NIMET) was used to investigate climate change correlation with urban growth in the Study area. Records including annually averaged temperature and rainfall have been analyzed for the study area.

Results and Discussion

This chapter discusses the results obtained in the research. The estimation of surface temperature depends on two factors: the surface emissivity and the reference blackbody temperature. The NDVI is also very important in the research as the surface emissivity parameters are dependent on the NDVI.

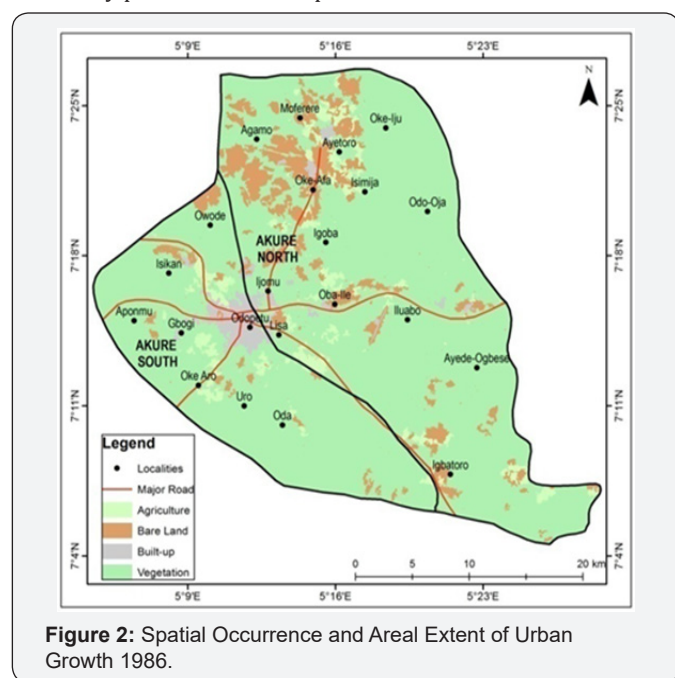


Figure 2: Spatial Occurrence and Areal Extent of Urban Growth 1986.

Urban Growth In The Study Area

Table 3 shows the area extent of land use/cover in the study area. It is evident from this table that, there has been a significant urban growth in the metropolis for the 28 year period. Built-up areas increased from 2.76% in 1986 to 7.37% in 1999 and 12.17% in 2014. Places that used to be villages or small towns in 1975 are emerging as big towns. These places portray an increase in built up area signifying an aspect of rural-urban migration. The demand for food and other resources by the growing population made cultivated lands increased from 4.61% in 1986 to 29.57% in 1999. However, by 2014, agricultural lands dropped to 19.39% as more people increasingly leave farms for white collar jobs in Akure town. Increased settlements means higher population of people which amounts to more activities that lead

Table 3: Urban Growth in the Study Area.

Land cover	1986	%	1999	%	2014	%
Agriculture	46.87	4.61	300.42	29.57	197.02	19.39
Bareland	95.85	9.43	85.47	8.42	214.40	21.10

to the degradation of vegetation in the study area. Vegetation decreased from 83.20% in 1986 to 54.65% in 1999 and further to 47.34% in 2014. This is in agreement several authors that the activities of man has been known to be one of the major threat to the forest because, man always wants to make himself more comfortable and hence tries to use whatever is available to him within his environment (Table 3) (Figures 2-4).

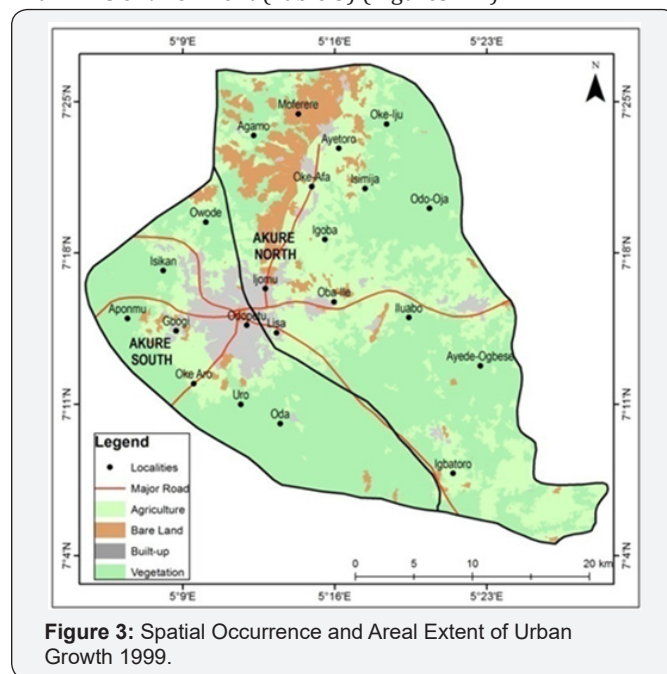


Figure 3: Spatial Occurrence and Areal Extent of Urban Growth 1999.

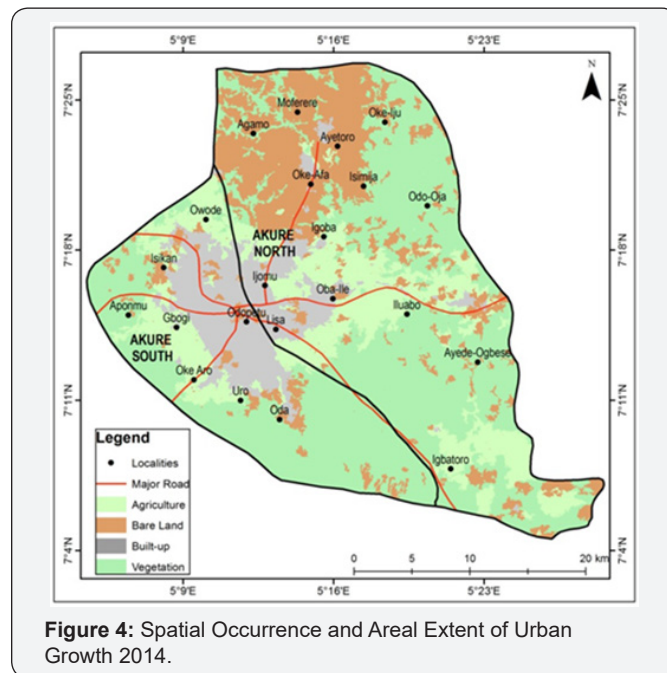


Figure 4: Spatial Occurrence and Areal Extent of Urban Growth 2014.

Built-up	28.03	2.76	74.90	7.37	123.61	12.17
Vegetation	845.38	83.20	555.25	54.65	481.02	47.34
Total	1016.13	100.00	1016.05	100.00	1016.04	100.00

Table 4: Effect of urban growth on Land surface/Greenness in Akure.

	1986	1999	2014
Land cover	MEAN ± STD	MEAN ± STD	MEAN ± STD
Non- Built-up	0.30 ± 0.07	0.28 ± 0.06	0.24 ± 0.05
Built-up	0.16 ± 0.09	0.13 ± 0.06	0.06 ± 0.04

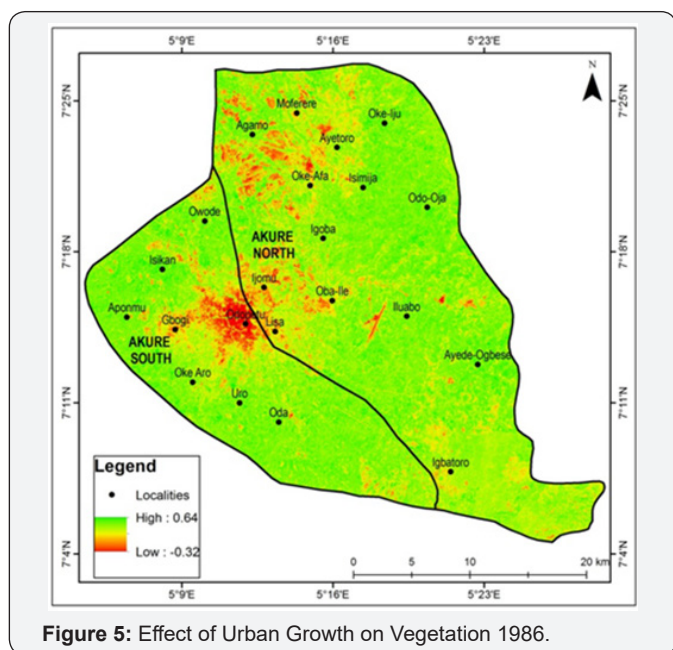


Figure 5: Effect of Urban Growth on Vegetation 1986.

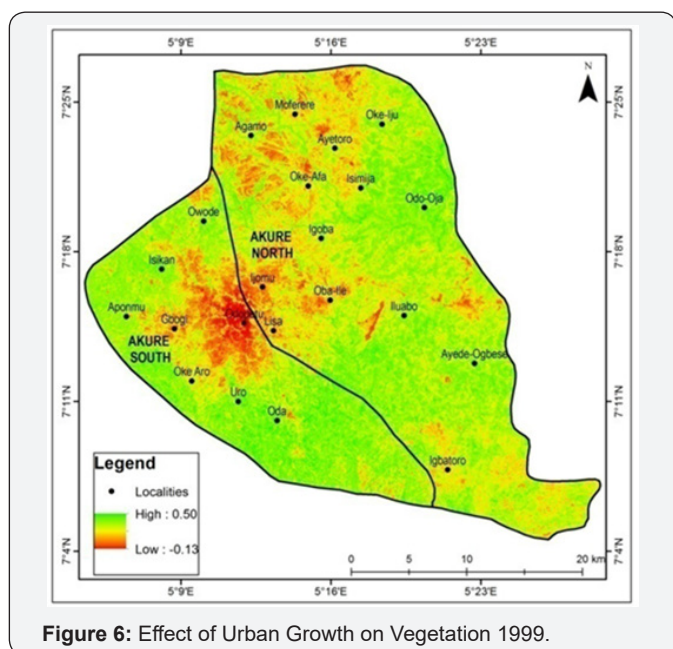


Figure 6: Effect of Urban Growth on Vegetation 1999.

Effect of urban growth on Land surface/Greenness in Akure

Generally, urban areas exhibit smaller NDVI values than non-urban areas, with consistent decrease in the mean NDVI as the

mean LST increases. Indeed there is a consistent decline in NDVI with increased level of urban development. NDVI maps for the three dates are shown in Figures 3 & 4. In 1986, it was found that average NDVI (mean ± S.D.) in the non-built up area was 0.30 ± 0.07 and for the built-up area, it was 0.16 ± 0.09 . However, this statistics reduced to 0.28 ± 0.06 and 0.13 ± 0.06 in 1999 respectively. Furthermore, the statistics was 0.24 ± 0.05 for non-built up and 0.06 ± 0.04 for built-up in 2014. This explains the fact that there was less vegetation cover as the built-up area increased because vegetation landscapes in urban areas are interspersed with the variegated developed urban structures (Table 4) (Figures 5-7).

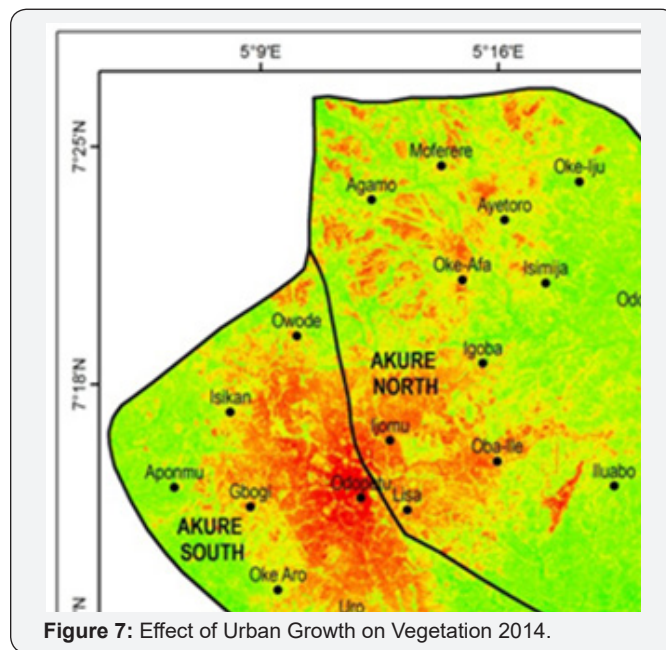


Figure 7: Effect of Urban Growth on Vegetation 2014.

The effect of land-use-land-cover changes on LST

It was found that average surface temperature (Mean ± S.D.) in the non-built up area in 1986 was 24.01 ± 2.21 and 27.28 ± 1.12 for the built-up area but this difference jumped to 26.52 ± 2.02 and 29.86 ± 1.66 in 1999 and further to 31.48 ± 2.03 and 33.82 ± 1.07 in 2014. Figures 4 & 6 shows the increasing extent of LST over the study period. In 1986, the areas with higher surface radiant temperature were mainly located in the central urban area and the bare rock areas however; temperatures began to increase around the built-up area in 1999 and 2014 in areas that are non-built- up. This mean that urban growth increase surface temperature since natural vegetative cover is replaced with non-

transpiring non-evaporating impervious surfaces such as metals, concrete and stone Weng (2001). The small deviations of surface temperature for urban areas indicates that, urban or built-up

area do not undergo a wide variation in surface temperature because of the dry nature of urban materials (Table 5) (Figures 8-10).

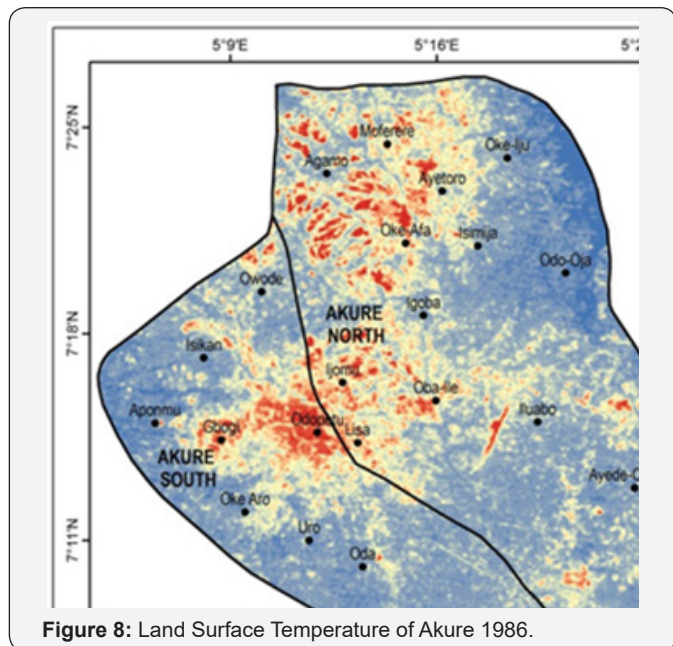


Figure 8: Land Surface Temperature of Akure 1986.

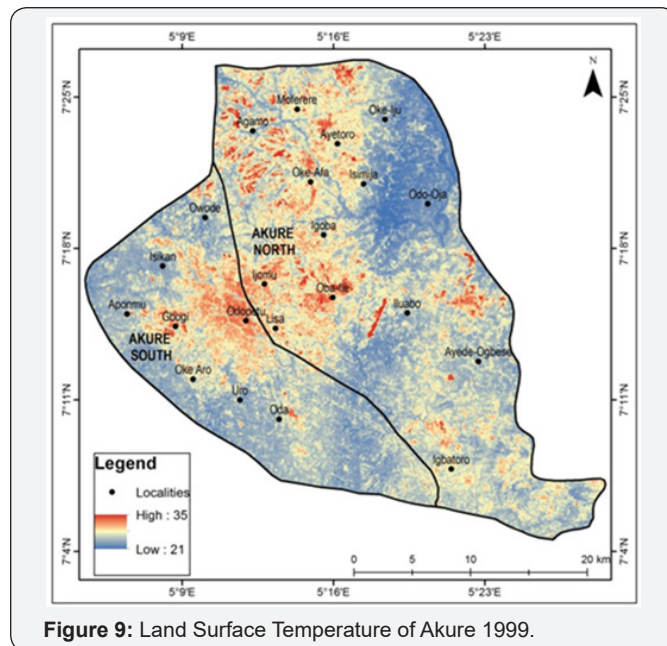


Figure 9: Land Surface Temperature of Akure 1999.

Table 5: The effect of land-use-land-cover changes on LST.

	1986	1999	2014
	MEAN ± STD	MEAN ± STD	MEAN ± STD
Non-Built up	24.01 ± 2.21	26.52 ± 2.02	31.48 ± 2.03
Built up	27.28 ± 1.12	29.86 ± 1.66	33.82 ± 1.07

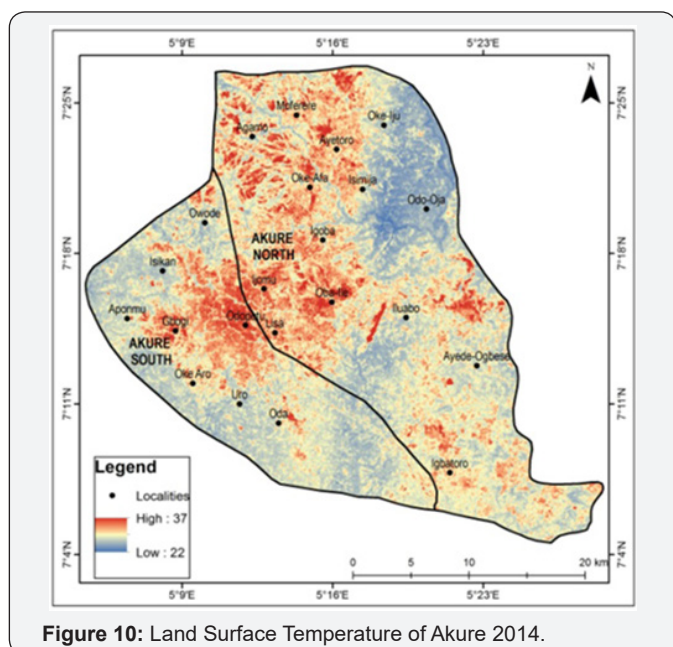


Figure 10: Land Surface Temperature of Akure 2014.

Conclusion

This study shows great increase in urban growth in Akure south with 54.22% and 58.96% in the periods of study. Also, an increase in urban growth occurred in the second period with a

total of 60.20km² compared to the total of 49.79km² in the first period. The urban growth over the entire study area showed a yearly increase of 47.79km² [16]. Changes in LULC were accompanied by changes in NDVI and LST. In 1986, it was found that average NDVI (mean ± S.D.) in the non-built up area was 0.30 ± 0.07 and for the built-up area, it was 0.16 ± 0.09. However, this statistics reduced to 0.28 ± 0.06 and 0.13 ± 0.06 in 1999 respectively. Furthermore, the statistics was 0.24 ± 0.05 for non-built up and 0.06 ± 0.04 for built-up in 2014. It was found that average surface temperature (Mean ± S.D.) in the non-built up area in 1986 was 24.01 ± 1.21 and 27.28 ± 1.12 for the built-up area but this difference jumped to 26.52 ± 2.02 and 29.86 ± 1.66 in 1999 and further to 31.48 ± 2.03 and 33.82 ± 1.07 in 2014 [17]. These increases in temperature have also cause the increase of intensity of surface urban heat island in Akure over these periods of time.

It was also observed that the temperature differences between the urban/built-up and the non-built up significantly widened. This could lead to an increase in temperature in the built-up areas and also the intensity of the surface urban heat island. The abundance of vegetation was an important factor influencing LST. This demonstrated that the decrease of biomass primarily triggered the impacts of urban expansion on LST. This research has demonstrated that the intensity of

urban development has a significant impact on radiant surface temperature and increase in urban heat of the study area. The application of remote sensing and GIS proved to be an efficient way to detect the key driver in intensity of urban heat island in Akure and the effect of urban growth.

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