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Sokoto Journal of the Social Sciences

(Formerly Journal of Social Science and Administration)

ISSN: 1595-2738

Vol 2: No. 2, December 2012

AN ASSESSMENT OF THE IMPACT OF URBAN GROWTH ON LAND SURFACE TEMPERATURE IN FCT, ABUJA USING GEOSPATIAL TECHNIQUE

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Abstract

Urbanisation *and economic dependence on land and its numerous resources have been the major driving force shaping various landscapes. This study employ the use of remote sensing and GIS techniques to identify the various land uses, their various transformations between 1986 and 2006 and measures the rate of urban expansion and loss of vegetation cover in the study area. It also analysed the changes in Land Surface Temperature over Abuja area using Landsat TM and ETM+ satellite data for 1986, 2002 and 2006. The variability of the Land Surface Temperature has been investigated with respect to different land use/land cover (LU/LC). Types determined from the Landsat Visible and Near Infrared (NIR) channels. The emissivity per pixel is retrieved directly from satellite data and has been estimated as narrow band emissivity at the satellite sensor in order to have the* *least error in the surface temperature estimation. Strong correlations were obtained between high surface temperature and negative NDV1 values. The study also revealed that the built up area has expanded by 17.88% of the total land area of Abuja in 1986 to 27.02% in 2006, vegetation covers reduced from 47.23% to 37.79%. The implication of this unprecedented growth is the resulting environmental and ecological problems associated with unplanned urban growth and development such as flooding, urban heat island, etc. However, greening and due adherence to development control were suggested as amelioration to the impending environmental crisis.*

1. Introduction

Urbanisation, the conversion of land to uses associated with growth of populations 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 buildings, 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 the surrounding rural areas. This thermal difference, in conjunction with waste heat released from urban houses, transportation and industry, contributes to the development of Urban Heat Island (UHI). The temperature difference between urban and rural areas are rising to several degrees with special urban, topographical and meteorological conditions (Dash, 2005).

It is very important to acquire wide area temperature information when the thermal environment problems of the city are being investigated. Satellite data is also useful for providing information on land cover. The recent development of high-resolution satellite images means that detailed analyses can now be achieved. Brightness temperature information from satellite data together with simultaneous satellite land use/cover data is very useful to understand surface conditions of urban areas. It is possible to evaluate the relationship between the ground cover situation and city temperature using satellite data. It has now become possible to obtain detailed knowledge of the land cover that determines the high-temperature of an urban area by utilizing information from a wide area (Goward, 1981).

The brightness temperature observed by satellite images is very useful for assessing area-wide temperatures distributions for the study of thermal environmental problems of urban areas. Studies on surface temperature characteristics of urban areas using satellite remote sensing data have been conducted primarily using NOAA AVHRR data (Gallo *et al*.., 1993; Ifatimehin, 2007; Adinna, 2009). The spatial resolution of NOAA (1.1 km) data is found suitable only for small-scale urban temperature mapping. The much higher resolution (120m) Landsat TM and (60m) Landsat ETM+ thermal infrared data were seldom used to derive surface temperature.

In Abuja, land use/cover patterns have undergone a fundamental change due to accelerated growth since 1979. Urban growth has been sped up, and extreme stress to the environment has occurred. This is particularly true in the city where massive agricultural land is disappearing each year, converting to urban or related uses. Evaluating the magnitude and pattern of growth of all the urban centres in Nigeria is an urgent need. Furthermore, because of the lack of appropriate land use planning and the measures for sustainable development, random urban growth has been creating severe environmental consequences. Thus, there also is a need to assess the environmental impact of the rapid urban growth (Jinqu, 2008).

The integration of remote sensing and geographic information systems (GIS) has been widely applied and has recognised as a powerful and effective tool in detecting urban land use and land cover change. Satellite remote sensing collects multi-spectral, multi-resolution and multi-temporal data and turns them into information valuable for understanding and monitoring urban land processes and for building urban land cover datasets. GIS technology provides a flexible environment for entering, analysing and displaying digital data from various sources necessary for urban feature identification, change detection and database development (Zubair, 2006).

2. Aim and Objectives

Aim

To assess the impact of urban growth on land surface temperature in FCT, Abuja using geospatial technique.

Objectives

- To determine the spatial extent of UHI in the area between 1986-2002;
- To assess the temperature variations associated with different land use/land cover types in the study area.

3. Materials and Methods

3.1 The Study Area

3.1.1 Location, position and extent

Abuja is located in the centre of the country in the Guinea savannah between latitudes 8°25"N and 9°25"N and longitudes 6°45"E and 7°45"E and occupies an area of about 8000 square kilometers. It is bordered in the north by Kaduna state, to the east by Nassarawa state, to the west by Niger state and to the south by Kogi state. It became the new administrative capital of Nigeria in 1976 after Lagos but the actual development and movement into Abuja started in 1980, after the master plan was completed by the

International Planning Associates (IPA) in 1979.

The beauty of the FCT is in its landscape profiled by rolling hills, isolated highlands and gaps with low dissected plains (NASRDA, 2007). Topographically, the area is typified by gentle undulating terrain interlaced with riverine depressions, and generally, the relief from hilltops to valley bottom varies around 50 m. The southwest section contains the flood plain of Gurara River eastward of the elevation of about 915 m above mean sea level. The soil structure of the area is thin with texture generally stony to gravelly sand with smaller occurrences of loam basically Alluvial and Luvisols. The annual rainfall is about 1,631.7 mm and the annual mean temperature ranges between 25.8°c and 30.2°C (Balogun, 2009).

3.1.2 Weather and Climate

Abuja under Köppen climate classification features a tropical wet and dry climate. The FCT experiences three weather conditions annually. This includes a warm, humid rainy season and a blistering dry season. In between the two, there is a brief interlude of harmattan occasioned by the northeast trade wind, with the main feature of dust haze, intensified coldness and dryness (Malik, 2004).

The rainy season begins from April and ends in October, when day-time temperatures reach 28°C to 30°C and nighttime lows hover around 22°C to 23°C. In the dry season, daytime temperatures can soar as high as 40°C and nighttime temperatures can dip to 12°C. Even the chilliest nights can be followed by daytime temperatures well above 30 °C (86.0 °F). The high altitudes and undulating terrain of the FCT act as a moderating influence on the weather of the territory. 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 from March to November every year (Malik, 2004).

3.1.3 Vegetation

The FCT falls within the Guinean forest-savanna mosaic zone of the West African sub-region. Patches of rain forest, however, occur in the Gwagwa plains, especially in the rugged terrain to the south southeastern parts of the territory, where a landscape of gullies and rough terrain is found. These areas of the Federal Capital Territory (FCT) form one of the few surviving occurrences of the mature forest vegetation in Nigeria (Malik, 2004).

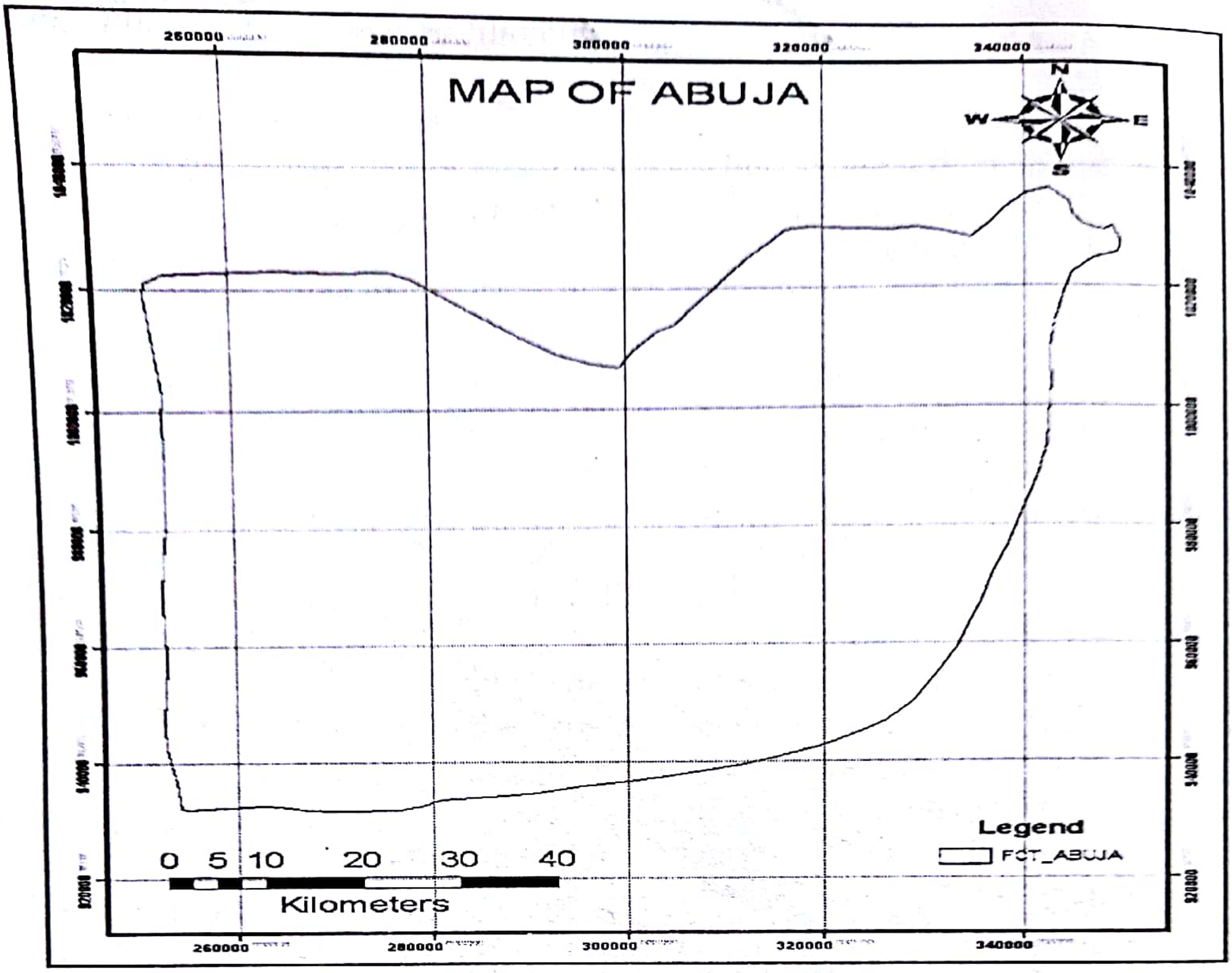


Figure 1: Map of the Study Area

3.2 Data

The digital data used in this study were collected by Landsat TM and ETM+, and their spectral and spatial characteristics as well as acquisition dates are shown in Table 1. Also, National, State and Local government boundary maps were obtained from the National Space Research and Development Agency (NASRDA), Abuja.

Table 1: Satellite Imageries used in the Study

Sensor	Date of acquisition	Number of reflective bands	Number of thermal bands	Resolution of reflective band	Resolution of the thermal band	Source
TM	21-12-1987	6	1	30m	120m	GLCF
ETM +	27-12-2001	6	1	30m	60m	GLCF
ETM +	09-12-2006	6	1	30m	60m	GLCF

Source: *Authors' Work, 2012*

3.3 Methods

3.3.1 Detection of Urban Growth

From remote sensing perspective, Impervious Surfaces (ISs) are usually referred to as built-up areas (buildings, roofs, paved roads, etc.). In this study, the IS will be an indicator for urban growth and be one land cover category.

Firstly, the satellite data were classified using Maximum Likelihood Classification Algorithm into five main types of land cover, including IS, bare surface, vegetation, cultivated and water body with the aid of ILWIS 3.3 academic software after the imageries have been enhanced using histogram equalization, rectified to a common UTM coordinate system (WGS84). The supervised classification method showed that IS was well separated from water and moist land, but some bare land was included. In highly vegetated areas, the NDVI typically ranges from 0.1 to 0.6, while urban IS and water value is negative. NDVI image then was used for establishing a threshold, where the NDVI value less than '0' usually represent urban IS and water types. For change evaluation of IS, the study carried out the post classification comparisons (Rahman, 2007).

3.3.2 Derivation of Land Surface Temperature (LST)

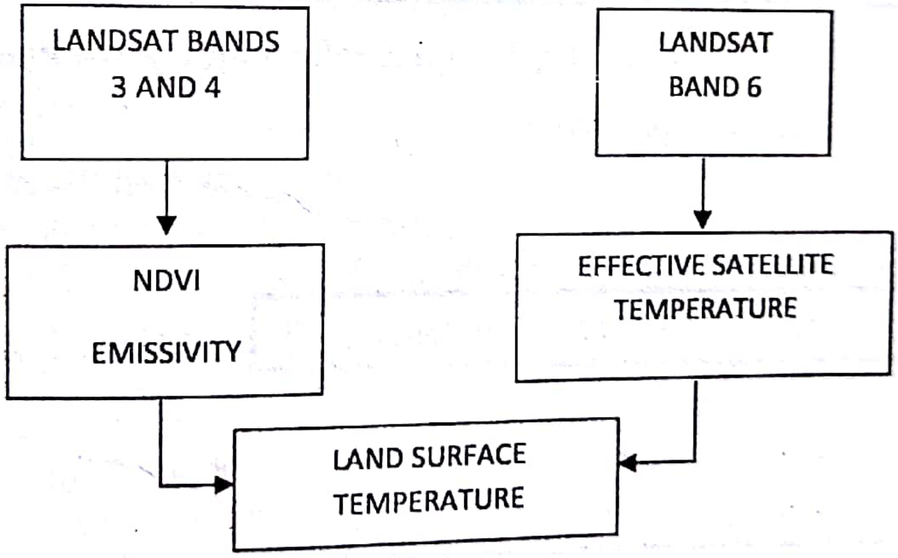


Figure 2: Flowchart of estimating surface temperature adopted from Weng, 2003

The radiometrically corrected Landsat TM and ETM band 3, 4 and the thermal infra-red (TIR) data (band6) will be used for this purpose. The following method will be adopted sequentially.

- Step 1: extraction of digital number(DN) from the TIR image;
- Step 2: conversion of DN to spectral radiance using

$$\boxed{L\lambda = 0.0370588 \times DN + 3.2} \qquad \text{..........................} \ (3.1)$$

Where Lλ is the spectral radiance

- Step 3: calculate the effective satellite Temperature using

$$\boxed{T_{Es} = (K_2)/\ln\{(K_1/L_\lambda) + 1\}} \qquad \text{..........................} \ (3.2)$$

Where K2 and K1 are constants and the values are

	Landsat TM	Landsat ETM	
K1	607.76	666.09	mWcm^2
K2	1260.56	1282.71	K

- Step 4: calculate the NDVI

$$\boxed{NDVI = (R_{\text{band }4} - R_{\text{band }3})/(R_{\text{band }4} - R_{\text{band }3})} \qquad \text{..................} \ (3.3)$$

R band 4 and R band 3 are the land surface reflectance in the near infra-red and the visible bands respectively;

- Step 5: calculate Emissivity (ε) from the NDVI

$$\boxed{\text{Emissivity } (\varepsilon) = 1.094 + 0.047 \times \ln(NDVI)} \qquad \text{..................} \ (3.4)$$

- Step 6: compute the surface temperature (Ts)

$$\boxed{T_s = (T_{Es})/\{1 + [\lambda \times (T_{Es}/\rho)]\ln\varepsilon\}} \qquad \text{..................} \ (3.5)$$

Where λ is the wavelength of the emitted radiance = 11.5μm (Markham and Baker, 1985); and ρ = hc/σ = 1.438 x 10^2 mK; σ =Stefan Boltzmann constant (5.67 x 10^-8Wm^-2K^4), h = Planck's constant (6.626 x10^-34Js) and c =2.998 x 10^8 m/s.

4. Results and Discussion

The results of this study are presented in form of maps, charts and statistical tables.

4.1 Analysis of Urban Growth (Land Use Land Cover Change)

Urban growth is usually detected with the analysis of Land Use Land Cover (LULC) change. In this study, urban areas which includes all impervious surfaces such as building, roads and all other man-made or artificial constructions are referred to as settlement while dense forests and crop-lands are referred to as vegetation, and also bare-surface are used to denote bare-grounds and rock outcrops (Voogt, 1997). The classification of the images of the study area at different epochs was necessary in the detection of changes which has occurred in the various land use land cover observed within the study area over the study period. Thus, the LULC distributions for each study year are clearly shown in the Table 2 below:

Table 2: Land Use Land Cover Distribution (1986, 2002, 2006)

CLASSIFICATION CATEGORY	1986		2002		2006	
	AREA (km^2)	AREA COVERED (%)	AREA (km^2)	AREA COVERED (%)	AREA (km^2)	AREA COVERED (%)
BARE SURFACE	1204.608	34.88	1217.658	35.26	1215.157	35.19
SETTLEMENT	617.351	17.88	786.087	23.64	932.957	27.02
VEGETATION	1631.012	47.23	1449.226	41.09	1304.857	37.79
TOTAL	3452.971	100	3452.971	100	3452.971	100

Table 2 reveals that as at 1986, Bare-surface and Vegetation constituted the largest LULC categories in Abuja collectively occupying an area of 3835.62 km^2 representing 86.22% of the total land cover of the study area with settlement being the least land cover type occupying an area of 617.315 km^2 representing 13.78% of the total land cover of the study area. Statistics for the year 2002 shows that there was settlement increase from 617.315 km^2 (13.78%) in 1986 to 786.087 km^2 (17.34%) in 2002, vegetation decreases from 58.80% of the total land cover to 54.03% while bare-surface increased from 27.42% to 28.63%. Also between 2002 and 2006, settlements grew from 786.087 km^2 (17.34%) to 932.957 km^2 (20.80%) while there were losses of vegetation and bare surface.

The changes in the LULC are also described in terms of number of pixels for each classification category. The number of pixels for the different classes and years are clearly represented by the chart below.

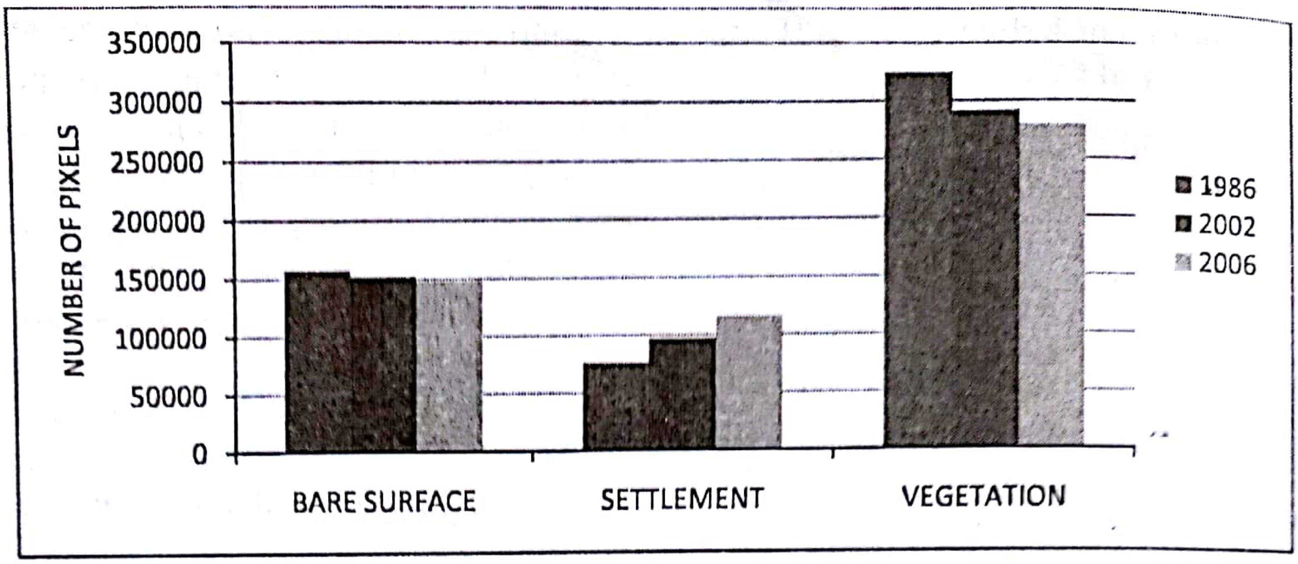


Figure 3: Pixel Information of the Different LULC of Abuja

Result shows that the study area has experienced significant gains in its settlement from 1986 to 2006 with an increment from 617.315 km² to 932.957 km² which makes up a per centage increase of 51.13%. Table 3 and Figure 4 show the gain and per centage increase in settlement for the different years considered.

Table 3: Settlement Gains and Percentage Increases

YEAR	SETTLEMENT AREA COVER (km²)	GAIN IN SETTLEMENT (km²)	PER CENTAGE INCREASE (%)	PER CENTAGE INCREASE (%) FROM 1986
1986	617.351	-	-	-
2002	786.087	168.736	27.33	27.33
2006	932.957	146.87	18.68	51.13

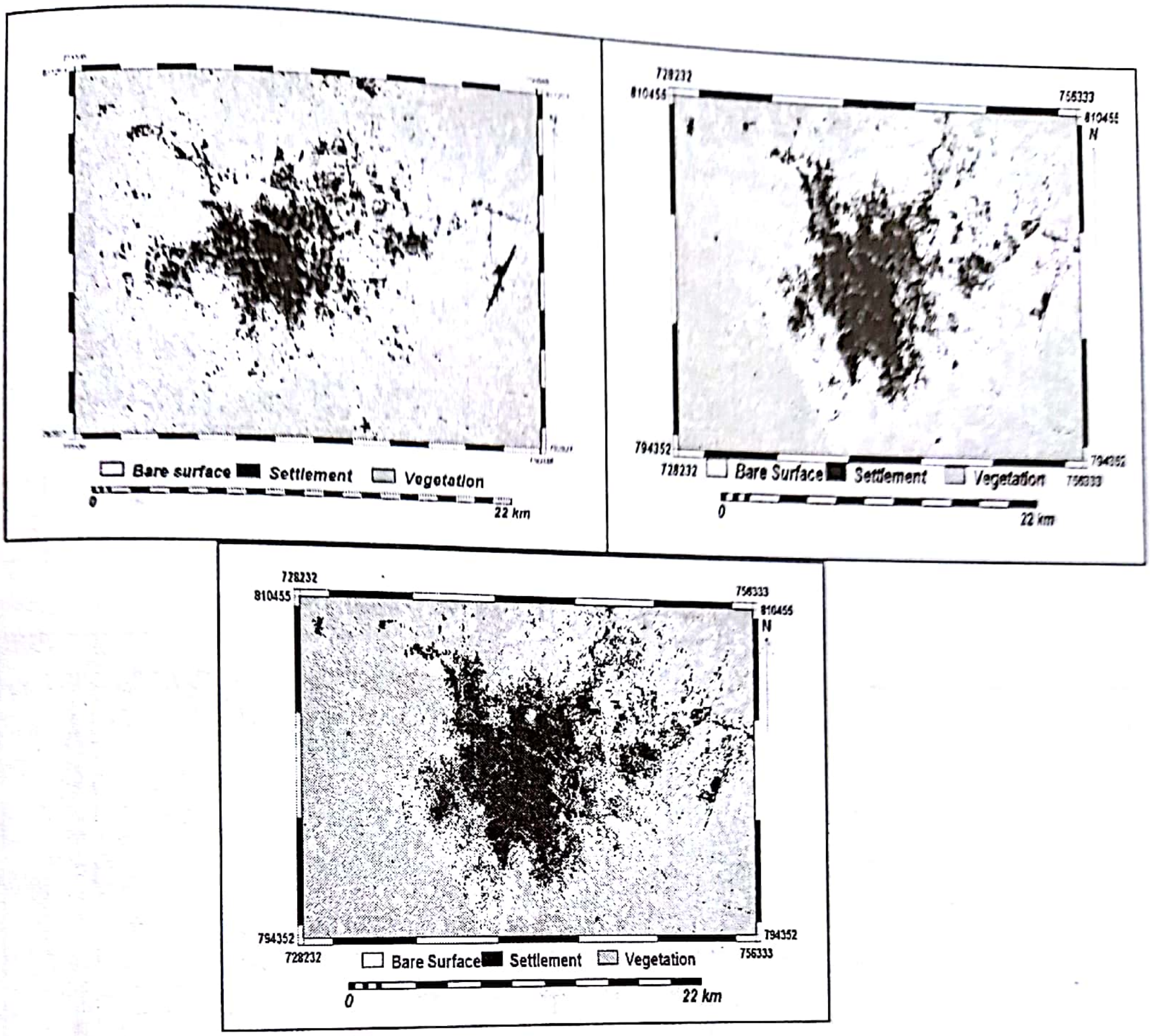


Figure 4: Landuse / Landcover Maps of Abuja, 1986, 2002 and 2006

4.2 Trends in NDVI

Normalised Difference Vegetation index (NDVI) is a measure of the vegetation density of an area and tends to reduce with increase in the alteration of natural surfaces and replacing them with impervious surfaces. The NDVI values as shown in Table 4 are in the range of -0.39 and 0.39 for the years considered. It is observed that lower NDVI corresponds to the developed settlements while high NDVI values corresponds to the less developed natural surfaces all through the year as shown in the Figure 5 (a, b and c) below, 1986 has the highest NDVI value while 2006 has the lowest which indicates that the NDVI of an Area tends to decrease with Urban growth.

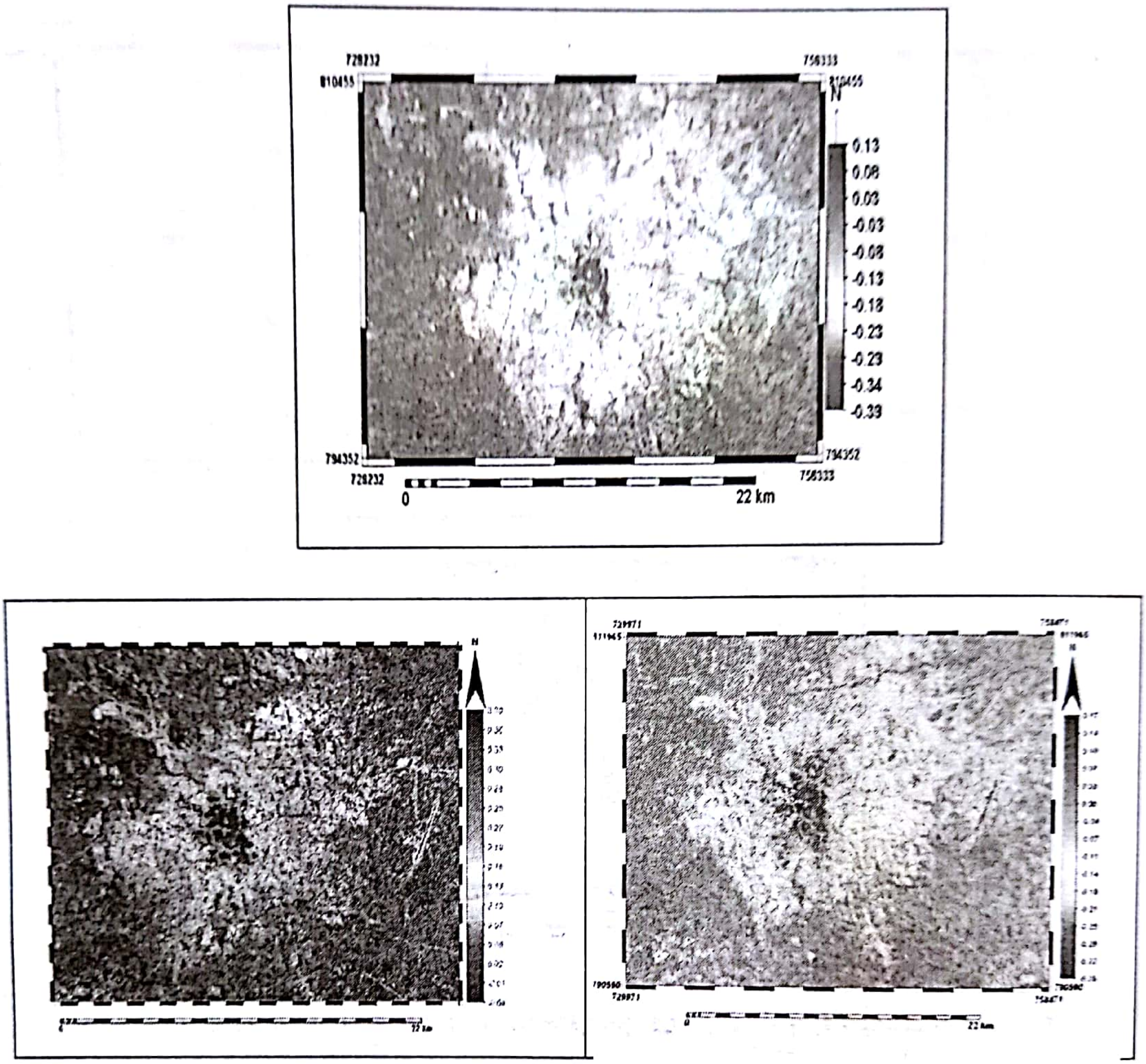


Figure 5 (a, b, & c): NDI Maps of Abuja in 1986, 2002 and 2006 respectively

4.3 Land Surface Temperature (LST) Distributions

In this study, LST was estimated using the Radiative Transfer Method and the results are shown in the table below. The result shows that Land surface Temperature increases with increasing the rate of urbanisation.

Table 4: LST values obtained for different years

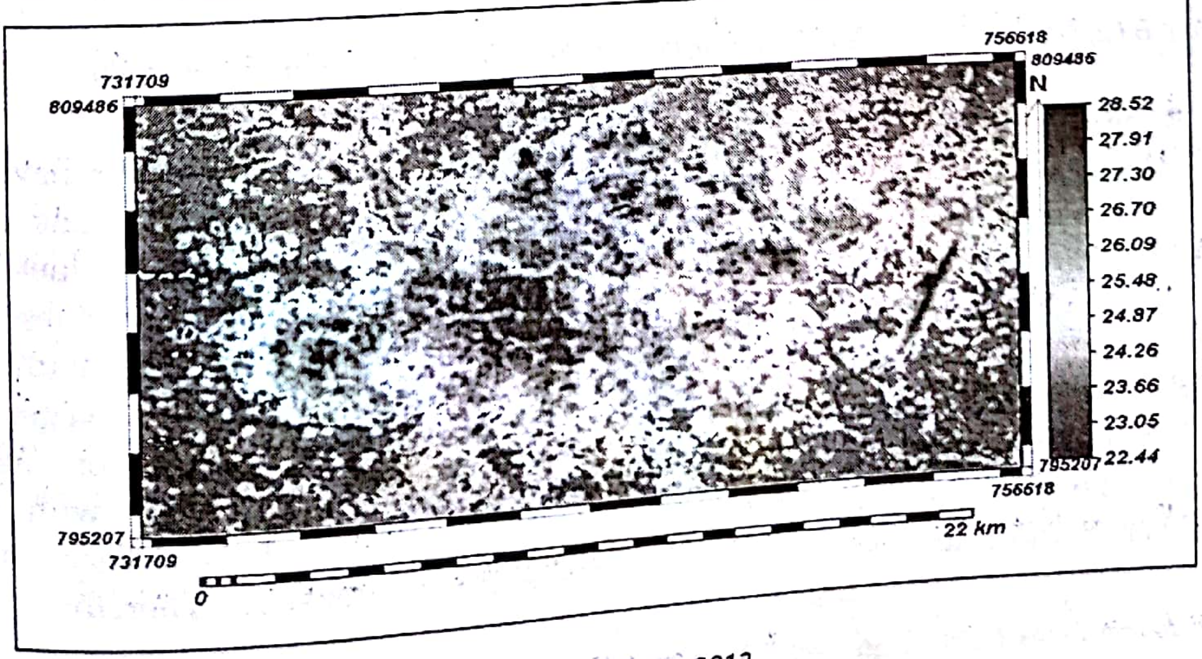
Years	1986	2002	2006
Maximum Temperature (°C)	28.52	37.32	38.42
Minimum Temperature (°C)	22.44	24.60	25.23

Table 4 shows that LST over Abuja has increased from 28.52°C in 1986 to 38.92°C in 2006 which constitutes an increase of 9.9°C within 20 years resulting into an average annual increase of 0.495°C. The rapid increase in the values of LST over the years of study can be attributed to the rapid increase in urbanisation the city has witnessed. The population of the city has increased from 120,531 in 1980 to 486,569 in 2006 and this has led to a considerable amount of natural surface and replacing them with impervious surfaces such as roads, pavements and other materials with the capability of retaining heat and thereby causing serious environmental stress which in-turn affect our urban micro-climate.

This study also examines the temperature variations associated with the different Land use Land cover types considered and the table5 show the mean LST of the three features considered:

Table 5: Temperature variation associated with different LULC types

LULC TYPE	1986	2002	2006
Settlement	28.52	37.32	38.42
Bare ground	24.87	30.92	30.88
Vegetation	23.66	24.60	25.23



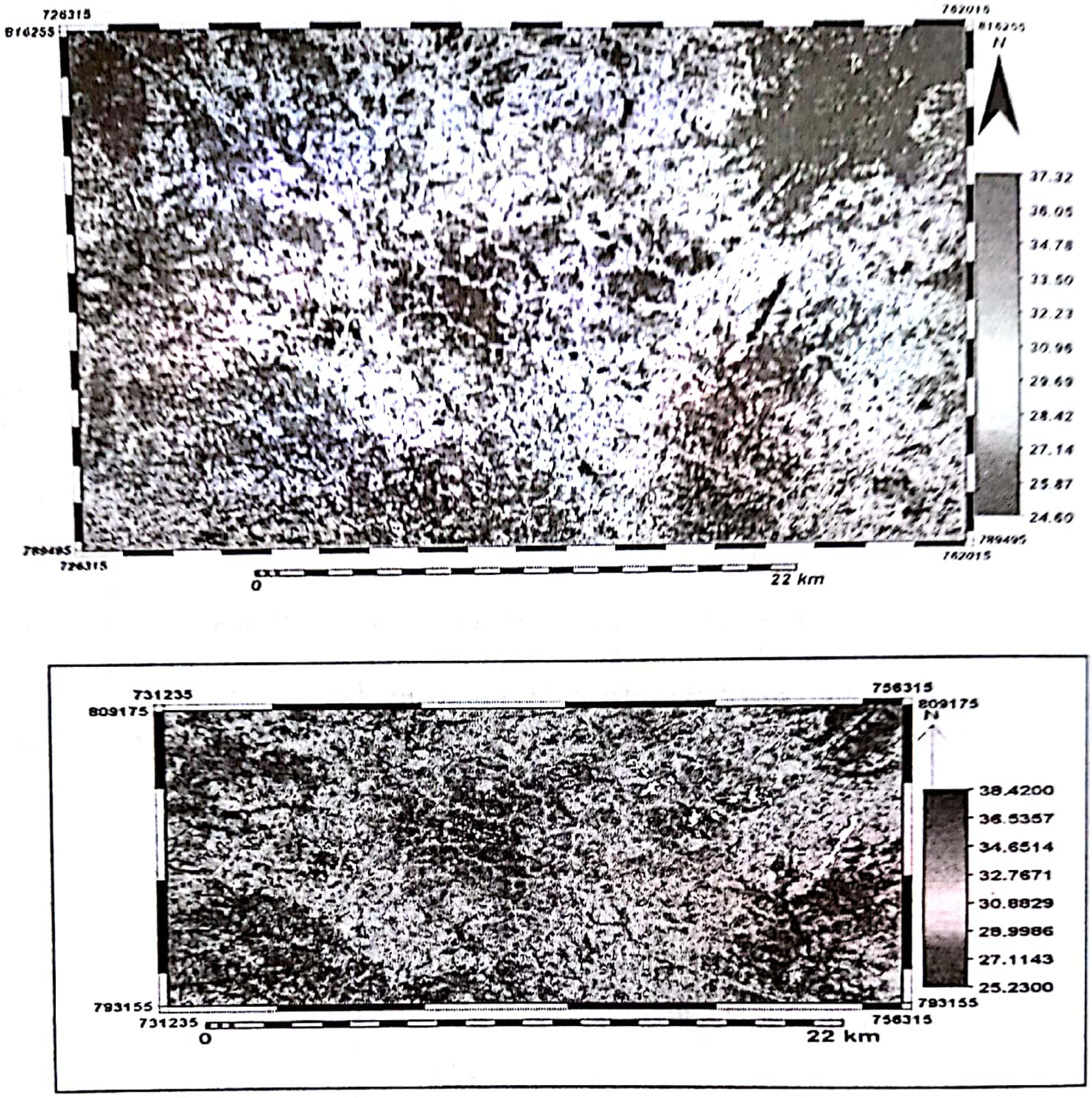


Figure 6 (a, b and c): *LST Maps of Abuja in 1986, 2002, and 2006 respectively*

4.4 Relationship between Vegetation Density (NDVI) and LST

It is well known that areas with high NDVI values have low LST values and vice-versa. This is further established in this study as the study tries to establish a relationship between LST and NDVI. Figures 6 (a, b and c) shows that LST is highly negatively correlated to NDVI, it indicates that features in pixels with high NDVI values have low surface temperature values and those in regions with low NDVI values have high surface temperature values. This also implies that regions with low NDVI values have less vegetation density as a result of urban development and regions with high NDVI values have very thick vegetation density. Therefore, LST increase with decreasing vegetation density.

Strong correlation between surface temperatures with NDVI is observed, which assures a potential of using linear regression to predict surface temperature if NDVI values are known. Hence surface temperature can be predicted with reasonable accuracy using NDVI.It is seen that the NDVI values decreases from 1986 to 2006 due to urban growth which has led to decrease in population of green vegetation due to clearing.

Spatial variation of NDVI is not only subject to the influence of vegetation amount, but also topography, solar radiation availability, and other factors (Weng, 2005). NDVI is commonly used as a measure of land surface greenness based on the assumption that NDVI values are positively proportional to the amount of greenness in an image pixel area (Voogt, 1997).

Table 6 below shows the relationship between Vegetation density and Land surface temperature.

Table 6: Relationship between Vegetation density and LST

YEAR	NDVI MINIMUM	NDVI MAXIMUM	LST MINIMUM	LST MAXIMUM	CORRELATION (R^2)
1986	-0.04	0.39	22.44	28.52	-0.963
2002	-0.35	0.17	24.60	37.32	-0.966
2006	-0.39	0.13	25.23	38.42	-0.974

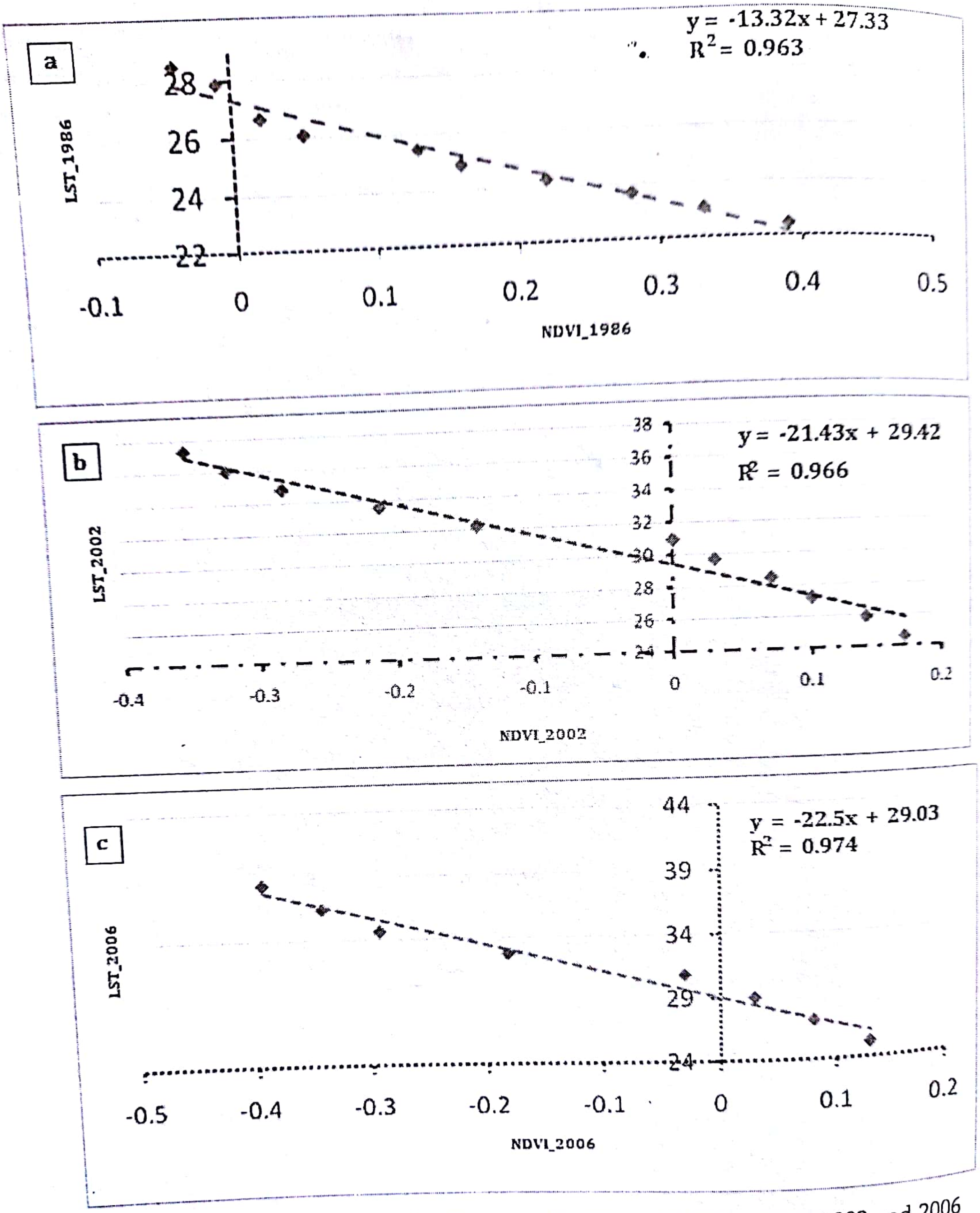


Figure 7 (a, b and c): Relationship between NDVI and LST for 1986, 2002 and 2006 respectively

5. Conclusion

This study exploits the possibility of Remote Sensing and Geographic Information Systems (GIS) techniques in the drive towards sustainable environmental development with particular respect to urban growth, vegetation loss and also on the exploitation of other environmental natural resources.

In this study, some of the major findings include:

- There has been fast transformation of savannah vegetation, range land, wetland vegetation cover to other land uses such as bare lands and built-up area.
- Bare lands and Built-up area have increased more than any other land uses.
- The study reveals vegetation cover has reduced more significantly.
- Growth of the urban area is highly related to the socio-economic and industrial potentials of the city.

This study identifies, that the surface temperature of Abuja increases day by day, due to many human activities. Population, Floor area density, Land use and Land Cover are the factors mostly affecting the surface temperature of the city.

5.1 Recommendations

Finally, despite the fact that loss of vegetal cover to urban growth cannot be totally halted, but sustainable planning and management will go a long way towards reliable and sustainable way of protecting the vegetal cover which always serves as the ecosystem service provider to the urban centers and also policy makers should incorporate afforestation and establishments of green belts and parks into the city planning schemes.

References

Adinna E. N. (2009). Assessment of Urban heat island and possible adaptation in Enugu Urban Metropolis using Landsat-ETM. *Journal of Science, Technology and Mathematics*, 7 (1): 108-118.

Balogun A.A. (2009). Observed Characteristics of the Urban Heat Island during the Harmattan Monsoon in Akure, Nigeria. *8th Conference on the Urban Environment*. AMS 9th Annual Meeting, 11-15 January 2009, Phoenix, AA, Paper JP 4.6.

Dash P. (2005). Land surface temperature and emissivity retrieval from satellite measurements. *Journal of Environmental Science*, 1 (1): 85-90.

Gallo, K.P. McNab, A.L, Karl, T.R., Brown, J.F. Hood, J.J and Tarpley, J.D.(1993). The Use of a Vegetation Index for Assessment of the Urban Heat Island Effect. *International Journal of Remote Sensing*. 14: 2223-2230.

Goward, S.N. (1981). Thermal Behaviour of Urban Landscapes and the Urban Heat Island, *Physical Geography*. 2: 19-23.

Ifatimehin.O.O. (2007). An Assessment of Urban Heat Island in Lokoja Town and Surroundings Using Landsat ETM data. *Dala Geographer*, 2: 129-134.

Jinqu Z (2008). Study of the Relationships between the Spatial Extent of Surface Urban Heat Islands and Urban Characteristics Factors Based on Landsat ETM + Data. *Hazards*, 3:5, 234-245.

Malik Z. H (2004). Estimating Surface Temperature form Satellite Data. *Journal of Applied Sciences*, 4: 126-129.

NASRDA News (2007). "Implication for Nigeria for Sustainable Development", 1 (3): 12-14.

Oke T.R. (1982). The Energetic basis of urban heat Island. *Quarterly Journal of the Royal Meteorological Society*, 108: 1-24.

Rahman A. (2007). An Assessment of Urban Environmental Issues Using Remote Sensing and GIS Techniques – An Integrated Approach: A Case Study of Delhi, India. *NISER Proceedings*.

Voogt, J.A. (1997). Complete Urban Surface Temperature, *Journal of Applied Meteorology*, 36: 1117-1131.

Weng Q. (2005). Urban Classification using full Spectral Information of Landsat TM + Imagery in Marion County, Indiana. *Hazards*, 3:2, 235 239

Zubair A. O. (2006). Change Detection in Land Use and Land Cover Using Remote Sensing Data and GIS. A B.Tech Dissertation, Dept of Geog, FUT Minna.