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* *less error in the surface temperature estimation. Strong correlations were obtained between high surface temperature and negative NDVI values. The study also revealed that the built up area has expanded by 17.86% 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 631.7 mm and the annual mean temperature ranges between 25.8ºc and .2ºC (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 governme[illegible] boundary maps were obtained from [illegible] National Space Research [illegible] Development Agency (NASRDA) [illegible]

Table 1: Satellite Imageries used in the Study

Sensor	Date of acquisition	Number of reflective bands	Number of thermal bands	Resolution of reflective band	[illegible]
TM	21-12-1987	6	1	30m	[illegible]
ETM+	27-12-2001	6	1	30m	[illegible]
ETM+	09-12-2006	6	1	30m	[illegible]

Source: *Authors' Work, 2017*

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)

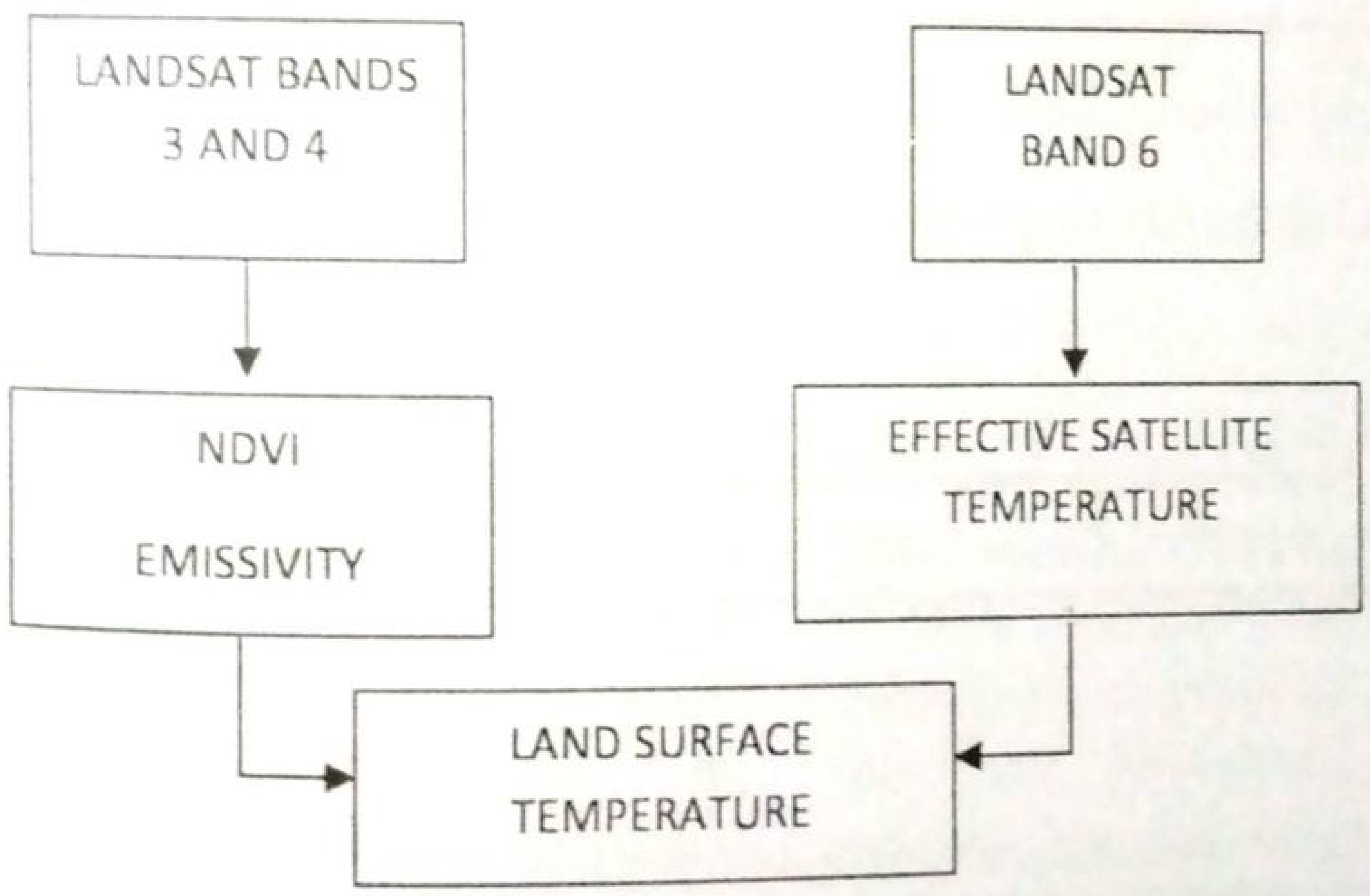

Figure 2: *Flowchart of estimating surface temperature adopted from Weng, 2003*

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

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

Where Lλ is the spectral radiance

- Step 3: calculate the effective satellite Temperature using

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

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

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

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

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

- Step 6: compute the surface temperature (Ts)

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

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

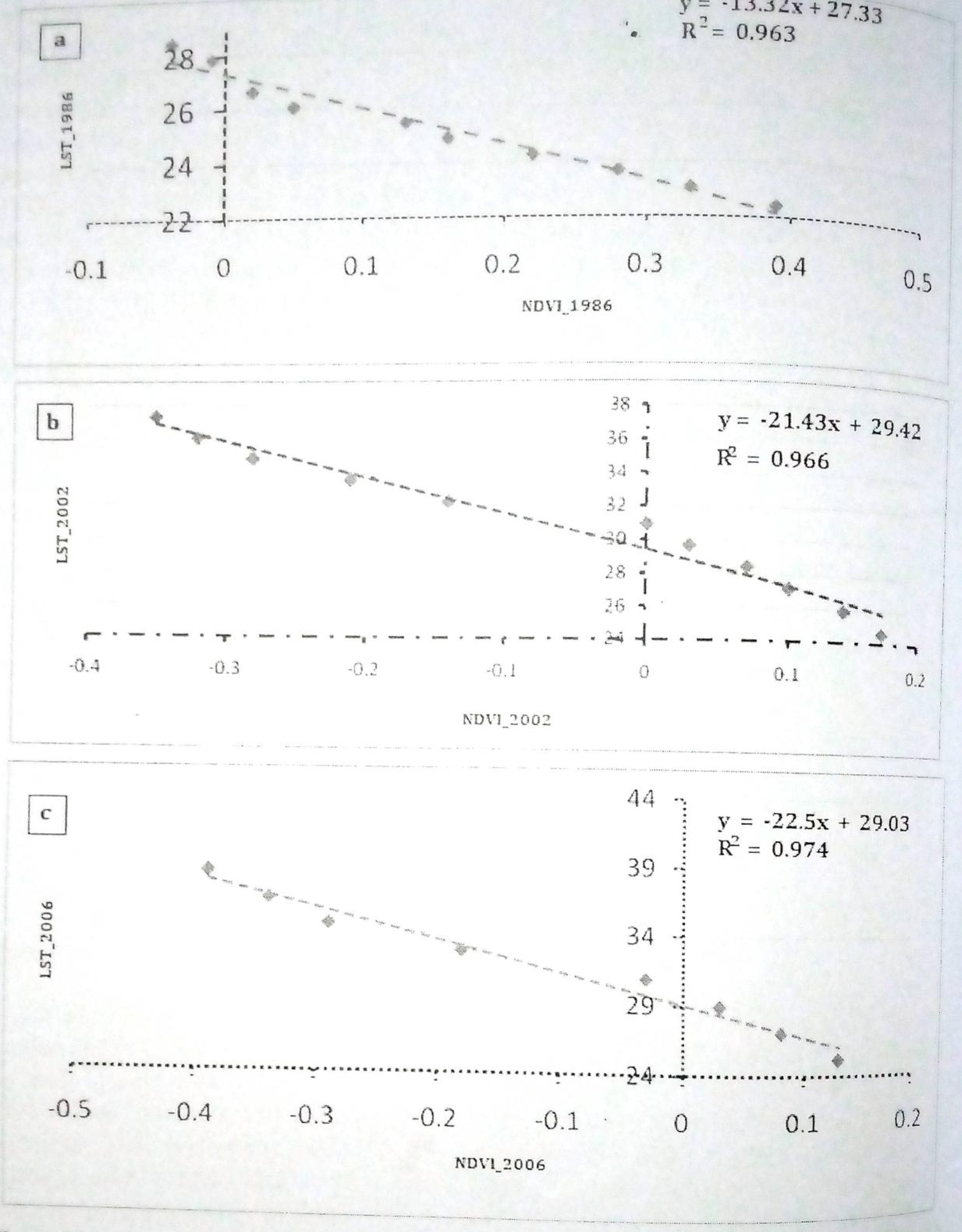

Figure 7 (a, b and c): Relationship between NDVI and LST for 1986, 2002 and 2006 respectively

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.

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