ISSN No:-2456-2165

Geospatial Assessment of Urban Development on Land Surface Temperature in Abuja, Nigeria

O. O. Ajayi*, O. M. Adepoju[1], G. K. James., Dr. I. Jega[1], V. T. Salami[1], O.M Aderoju[1], O. I. Adedeji[1]
Strategic Space Applications Department,
National Space Research and Development Agency,
Abuja, Nigeria

Abstract:- This dissertation investigates assessment development in urban on land surface temperature using geospatial technique with land use land cover and variation between 1986 and 2016. The aim of this study is to examine the effect of urbanization on land surface temperature using GIS and Remote Sensing technique. Satellite images used for this dissertation were Thematic Mapper ™ acquired on 1986, Enhance Thematic Mapper plus (ETM+) acquired on 2001 and Operational Land Imager (OLI) acquired on 2016. All satellite data have 30-meter resolutions, Thematic Mapper and Enhance Thematic Mapper plus images have spectral range of 0.45 to 2.35 micro meters (μm) with 8 bands, while the Operational Land Imager extends to band 12. The images were used to produce land use/land cover map of Abuja Municipal Area Council (AMAC) for effective analysis of land surface temperature for three epochs to know the feature contributes most to surface temperature and changes over time. Results of land use/land cover shown that there is significant increment of Built-up from 36.74 per square kilometer to 283.7 per square kilometer between 1986 and 2016, water body from 1.21 to 1.32 per square kilometer and bare surface from 571.5 to 607.5 per square kilometer. There is also sharp decrement in vegetation from 714.4 to 452.34 per square kilometer and rock outcrop from 132.52 to 111.48 between 1986 and 2016. There is little rise in surface temperature from 1986 to 2016. Temperature rise from 15 to 26 degree Celsius (0C), built up, contributed most to surface temperature.

Keyword:- *Remote sensing, land use land cover, surface temperature and GIS.*

I. INTRODUCTION

Temperature influences human activity in many waysinclude the survival of man and his social-economic activities such as business, income, agricultural practices, civil servant jobs and reproduction among others activity. Land surface temperature (LST) is a favorable indicator for the study of environmental conditions, and the use of LST indicators as a useful research object in regional energy change discussion is also increasing. As the infrastructure construction of the strip land, the roads will have an impact on the LST of the area along the roads due to the construction of it and the subsequent occupation due to the land occupation and itself. In addition, with the continuous development of social needs, the mileage of road networks is increasing, and the LST within the road's domain will also change due to the influence of the road itself, thus affecting the surrounding environment (Hegerl et al, 2007).

At present, most of the studies on regional LST are to study a large scope of urban areas, but there are fewer studies on LST changes within the road areas. As an important indicator of environmental change, most LST researchers use it as an important characterization object for surface energy involvement and environmental change (Marland et al, 2003; Islam and Islam 2013. However, in addition to the use of real-time monitoring and measurement methods, researchers have made it more convenient to adopt satellite data to study regional LST wherefore, numerous researchers use satellite data for regional LST analysis, not only from the inversion algorithms to explore and make improvement but also in the selection of source data in different aspects of screening (Srivastava et al, 2010). For example, some researchers have summarized and analyzed several major LST inversion methods and compared their accuracy. However, different parameter selection on the inversion algorithms will also cause differences in accuracy.

However, as an important part of the development of social foundation, attention should be paid to the sustainable development in the continuous development process of road, (Reducing urban heat islands 2008), and in-depth research and analysis should be conducted due to its own changes. Its retrieval from remotely sensed thermal-infrared (TIR) data provides spatially continuous LST measurements with global coverage to examine the thermal heterogeneity of the Earth's surface, and the impact on surface temperatures resulting from natural and human-induced changes (Oke, 1978Daytime land surface temperature is more tightly coupled with the radiative and thermodynamic characteristics of the Earth's surface than standard air temperature measurements. LST is also more sensitive to changes in vegetation density and captures additional information on the biophysical controls on surface temperature, such as surface roughness and transpiration cooling. However, this study used remote sensing and GIS approach to address effect of land surface temperature in AMAC.

- The objectives are
  - Examination of spatial distribution of land surface temperature in Abuja.
  - Identification of land surface temperature change from 1986 to 2016.
  - Determination of land-use and land cover and their contribution to surface temperature in the Abuja.
  - Determinationof relationship between surface temperatures acquired from satellite imageries and land-use/land-cover impact.

ISSN No:-2456-2165

II. THE STUDY AREA

Abuja, the Federal Capital of Nigeria is located at 8.823^0 N and 9.187^0 Nof the Equator and 7.24^0 and 7.56^0 E in (figure 1). According to the 2006 population census the Federal Capital Territory (FCT) has total population of 1,402,201 (2006 population census)and land area of 1,769 square kilometres (km^2).

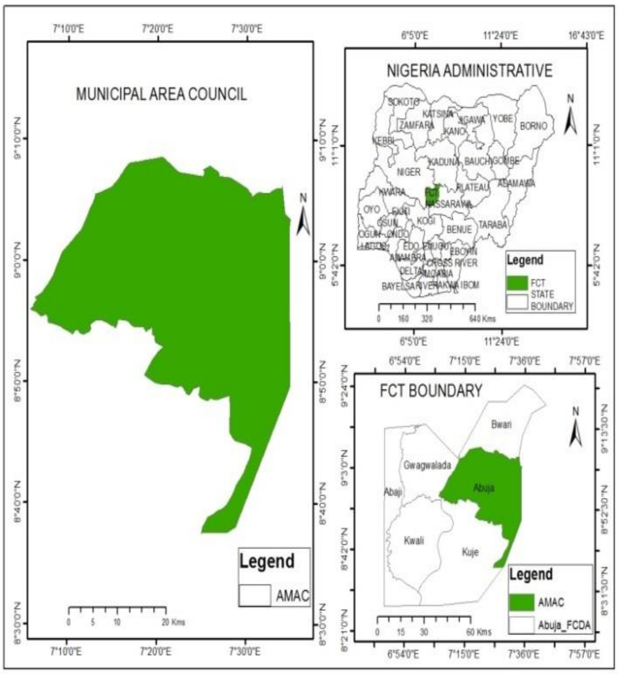

Fig. 1: Abuja Study Area Map

- Climate and Weather

The Abuja municipal Area Council (AMAC), experiences two climate seasons, wet and dry season with a brief of Harmattan, occasioned by the movement of the northeast trade wind, with the main features of dust haze, intensified coldness, and dryness. Rainfall in the AMAC starts by March and end in October. Humidity in raining season is high and also temperature around this time is moderate. The dry season stars by November and end in April, humidity in this period is very low and the temperature is high due to free cloud cover Balogun (2001).The soil in Abuja Municipal Area Council is good for agriculture as it good for cash crop.

III. METHODOLOGY

- Data Acquisition and Source

The Landsat data was acquired from the global land-cover website at the University of Maryland, USA. The images are thematic mapper (TM) image acquired on 18th December 1986, Enhance Thematic Mapper plus (ETM^+) image acquired on 6th February 2001 and the Operational land Imager (OLI) acquired on 5th of February 2016 as shown in Table 1. The satellite data have 30m spatial resolutions and the TM and ETM Plus images have spectral range of 0.45-2.35 micro meter with bands 1,2,3,4,5,6,7 and 8 while the Operational Land Imager (OLI) extends to band 12.

s/n	Data Type	Date	Spatial Resolution
1	Landsat 4-5 (TM)	1986	30meters
2	Landsat 7 (ETM)	2001	30meters
3	Landsat 8 (OLI)	2016	30 meters

Table 1: Shows characteristics of Landsat Imagery

IV. METHODS

A. Data Pre-Processing

The satellite imageries were pre-processed in order to correct the error during scanning, transmission and recording of the data. The pre-processing steps used were:

- Radiometric correction to remove effects of atmosphere error ;
- Geometric correction i.e. to correct image distortion by establishing a projection matches a specific projection surface or shape ; and
- Noise removal to remove any unwanted noise during acquisition or transmission process.

B. Image Classification[3.2.2]

The false Colour Composite was the first and foremost layer stack; the three bands (4, 3 and 2) were combined for thematic mapper and Enhance Thematic mapper, while bands (5, 4 and 3) were combined for Operational Land Imager. These false colours were classified using the maximum likelihood classification algorism (pixel classification process). This was carried out by selecting sample representative sites of known cover type called Training Sites or Area. So also, Google Earth map was used to validate classification where necessary. The computer algorithm then uses the spectral signatures from these training areas and classifies images into; residential, bare-surface, water-body, vegetation, road-network and rock-outcrop. All the images for these classifications were acquired in 1986, 2001 and 2016 respectively.

C. Derivation of Land Surface Temperature[3.2.3]

Single-Channel Algorithm (SC)

The SC algorithm developed by Jiménez-Muñoz et al. (2014) for the estimation of LST. The mathematical structure of SC algorithm is:

$T_s = У\,[1/\varepsilon\,(\Psi_1 L_{sen} + \Psi_2) + \Psi_3] + Ϭ$………….1

Where ε is the surface emissivity and (y, Ϭ) two parameters given as

$Y = T^2_{sen}/by\,L_{sen};\; Ϭ = T_{sen} - T^2_{sen}/by$……….2

Where T_{sen} is the at-sensor brightness, temperature, Ψ_1, Ψ_2 and Ψ_3 are atmospheric function, given as

$\Psi_1 = 1/t;\; \Psi_2 = -L_d - L_u/t;\; \Psi_3 = L_d$……………..3

V. RESULTS AND DISCUSSION

A. Results

The analyses and results of this work was carried outfrom satellite images, for three epochs of different years in mapping and monitoring of surface temperature in Abuja Municipal Area Council. Table 2 shown reports of land use and land cover for different decades for which surface temperature was measured. Figures 2, 3 and 4 present land use and land cover maps of the study area in 1986, 2001 and 2016 of three decade and Figures 5, 6 and 7 present land surface temperatures map for 1986, 2001 and 2016 respectively.

Classes	1986 Epoch Area KM^2	2001 Epoch Area KM^2	2016 Epoch Area KM^2
Water Body	1.210	1.140	1.320
Built Up	36.740	98.50	283.70
RockOutcrop	132.520	115.20	111.480
BareSurface	571.50	522.50	607.50
Vegetation	714.40	718.70	452.340
Total	1456.380	1456.320	1456.340

Table 2: Results of land use and land cover of study area for 1986, 2001 and 2016

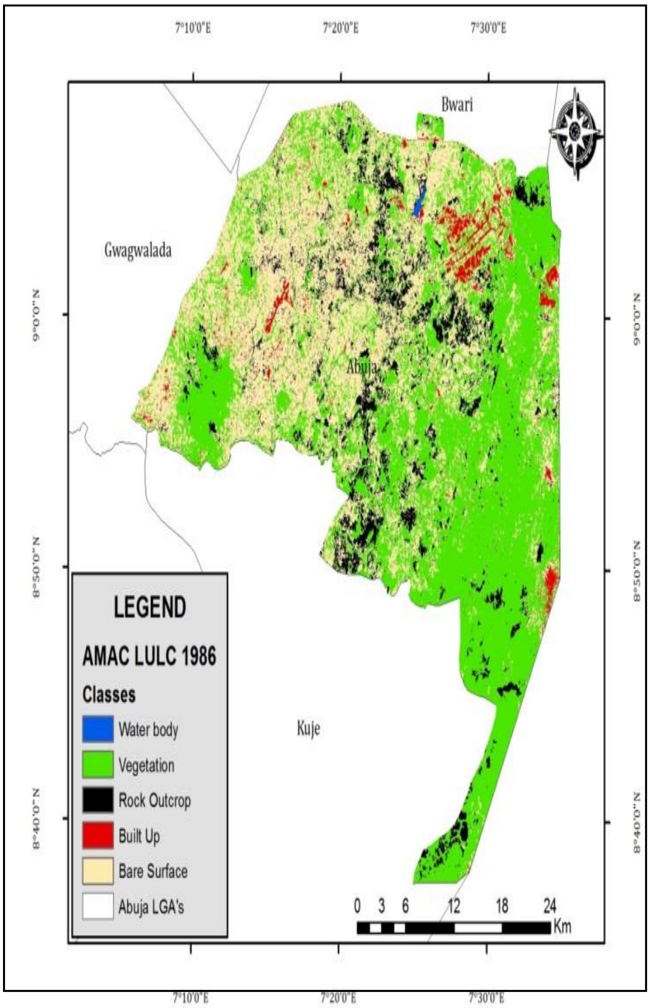

Fig. 2: AMAC land use land cover 1986

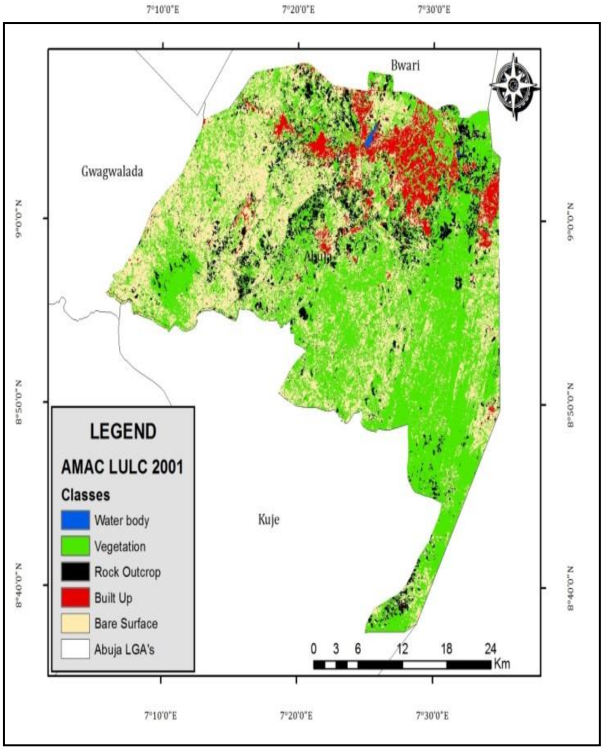

Fig. 3: AMAC land use land cover 2001

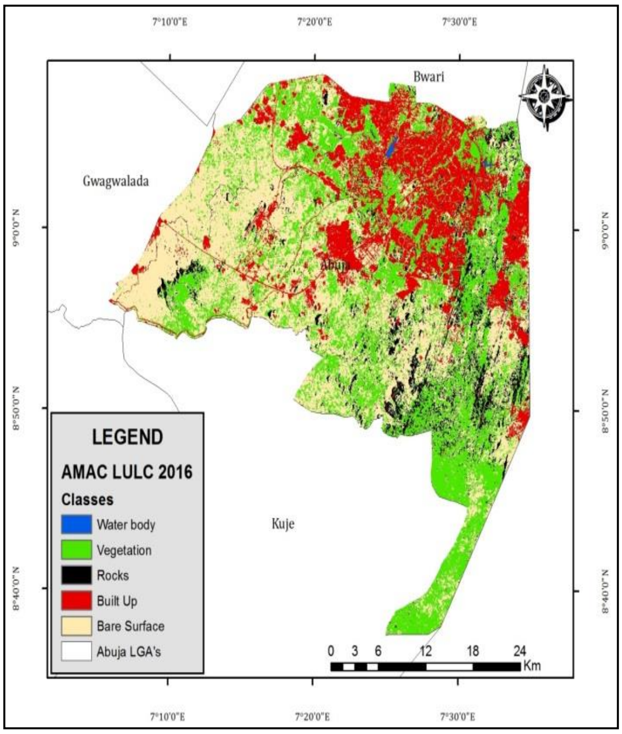

Fig. 4: AMAC land use/land cover 2016

ISSN No:-2456-2165

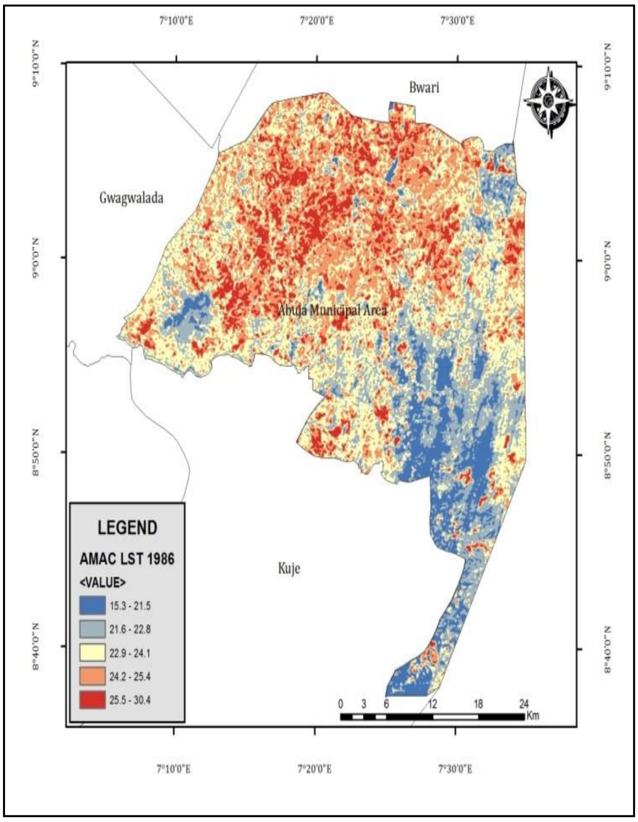

Fig. 5: AMAC Surface Temperatures 1986

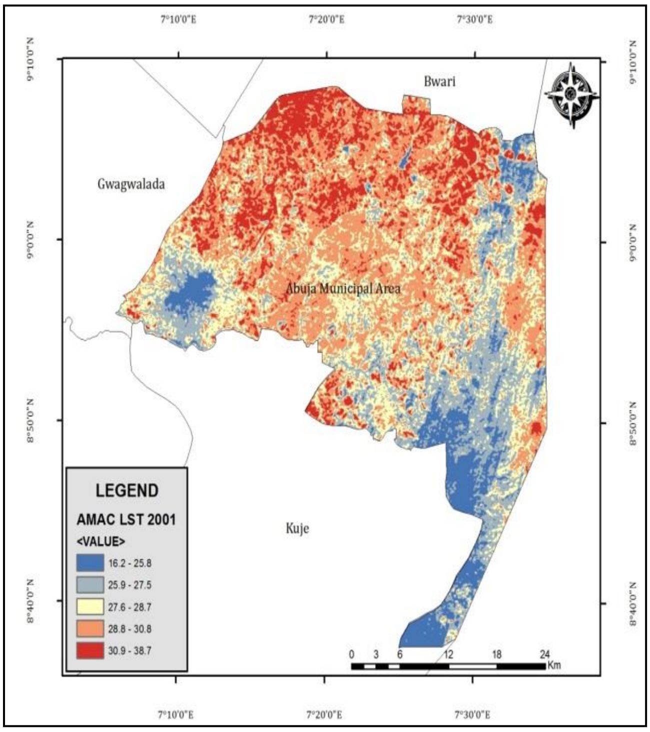

Fig. 6: AMAC Surface Temperature 2001

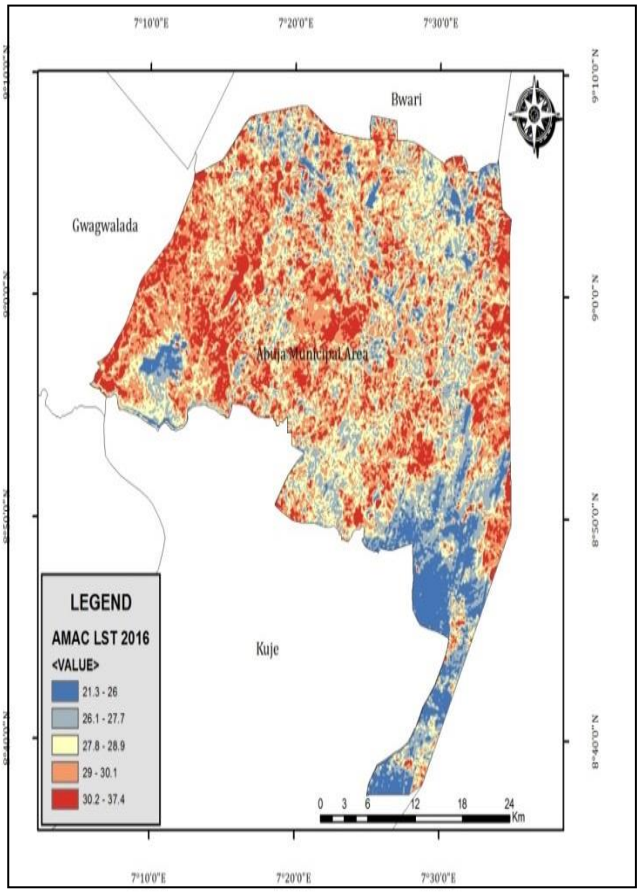

Fig. 7: AMAC Surface Temperature 2016

B. DISCUSSION

The results of this analysis shows that land use land cover changes were significant during the period of study from 1986 to 2016. There is significant increase of built-up area. On the other hand, the vegetation and rock out crop decrease sharply. Water-body covers about 0.22 km2 of the total land area of the study area, which is about 15.34%. Whereas, built-up has about 60.99% spatial extent and covers about 59.8 square kilometers (km2) in the total land area of AMAC. Rock outcrop and bare surface contributed minimally to both spatial extent and total land use of the Abuja. Vegetation cover has a spatial extent of about 0.22 percent and covers about 1.59 square kilometer of the total land use of the Abuja. In the years under review, 2001 to 2016, vegetation and water body contributes little to the land use both in spatial extent and total land mass. The built up experienced the increased of about 183.14 square kilometer of the total land mass of Abuja, which is due to high population growth and urbanization. Rock outcrop also contributes little to both spatial extent and total land use of the Abuja, and there is 82.46% increase in bare surface andthe spatial extent of 13.59 percent.

Surface Temperature and-Land Use and Land-Cover Impact 4.3.

The relationship between land-use land-cover and land surface temperature for this period of investigation showed a significant rise in temperature from 15.3 0C to 38.7 0C. In 1986 Figure 5, the temperature ranged between 15.3 to 30.4 0C (degrees Celsius). In 2001, temperatures ranged between

ISSN No:-2456-2165

16.3 0C to 38.7 0C Figure 6. The degree rise in temperature in Figure 6 from 16.3 0C to 38.7 0C is because of the result of low vegetation cover in this period. The temperature range in the year 2016 in Figure 7 is between 21.3 0C to 37.4 0C. The features with the highest rise in temperature are the built up and bare surface areas having an average temperature of 24.88 0C. This occurs as a result of very low vegetation cover or no vegetation cover at all in these areas, which can help in preventing higher emission of heat. The water body fell within the features, having the least average temperature of about 19.84 Celsius, followed by vegetation of its annual mean temperature of 22.46 Celsius and finally, rocky area having a mean temperature of 24.14Celsius.

The temperature in 2001 had shown a significant increase in degrees Celsius as the maximum temperature ranged from 30.9 0C to 38.7 0C, and then the minimum temperature was between 16.2 0C and 25.8 0C in Figure 5. The built-up areas recorded the highest maximum temperature of 30.22 0C followed by bare surface with a temperature of 29.20 0C. The least temperature was recorded for water body and vegetation cover with their emitting temperature of 25.67 0C and 27.70 0C respectively. The rock outcrop falls within the region with a moderate temperature range (27.6 0C to 28.7 0C) because of vegetation and mean temperature is 28.58 0C.

The Land Surface temperature of year 2016 recorded a maximum temperature of (30.200C and 37.40C), and also minimum temperature of (21.3 0C and 26 0C) as shown in Figure 7. Built-up is highest land use/land cover contributed surface temperature of the environment, while vegetation contributes least to the surface temperature of the study area. The results of the analysis revealed that there were few changes in temperature between 2001 and 2016.The features having the maximum temperature are built up and bare surface areas with their mean temperatures of 29.23 0C and 29.27 0C respectively. Rocky areas are characterized by a moderate temperature range, similar to that of 2001, but with a mean temperature of 27.93 0C. The temperature of vegetation and water bodies is the lowest, with mean temperatures of 27.440C and 22.720C, respectively.

Table 3 represents an error matrix for classified Enhance thematic mapper image of 1986. This table compared the results of classified images of 1986 with referenced high resolution imagery and was used to assess the degree to which they correspond to individual classes. It could be observed that the user's accuracy for five classes ranged between 90 to 98% with an average accuracy of 93.8%. Similarly, the producer's accuracy for four classes also ranged between 83 to 100% with an average of 94%. Classification accuracy for 2001 was estimated 89.4%. Table 4 provides results of classification accuracy for the 2001 classified image of Abuja state using an error matrix/confusion matrix. This compares the result of actual classification alongside the referenced data to assess the degree to which they correspond. The user accuracy for the land use/land cover ranged between 78 to 100% with an average of 90.6% while the producer's accuracy ranged between 73 to 100% with an average of 89.4%. The overall accuracy assessment of this classification was estimated to be 89.4%.

Table 5 shows the result of the Operational Land Imager image for 2016 of the study area using an error matrix: The matrix compared the result of the actual image classification with the ground truth reference information and assessed the degree to which they correspond. In this assessment, the user's accuracy which occurred due to commission error was computed for individual land use types in the classification image. The user's accuracy ranges from 78% to 100% with an average of 91% while the producer's accuracy ranges from 67% to 98% with an average of 89.4%. Overall classification accuracy for the 2014 Landsat OLI image was 89.4%.

Class	Water body	Built up	Rock outcrop	Bare surface	Vegetation	Row Total	User Accuracy
Water body	37	0	0	0	0	37	93%
Built up	0	46	0	1	0	47	92%
Rock outcrop	3	0	43	1	0	47	90%
Bare surface	0	3	5	44	1	53	96%
Vegetation	0	1	0	0	49	50	98%
Total	40	50	48	46	50	235	
Producer Accuracy	100%	98%	91%	83%	98%		Total Accuracy=93%

Table 3: Provides the result of classification accuracy assessment of thematic image of 1986

Class	Water body	Built up	Rock outcrop	Bare surface	Vegetation	Row Total	User Accuracy
Water body	39	0	0	0	0	39	100%
Built up	1	35	1	0	0	37	95%
Rock outcrop	9	0	46	0	0	55	84%
Bare surface	0	12	1	49	0	60	78%
Vegetation	0	1	0	1	46	48	96%
Total	49	48	48	48	46	239	
Producer Accuracy	80%	73%	96%	98%	100%		Total Accuracy=94%

Table 4: Provides the result of classification accuracy assessment of thematic image of 2001

Class	Water body	Built up	Rock outcrop	Bare surface	Vegetation	Row Total	User Accuracy
Water body	47	0	0	0	0	47	100%
Built up	3	48	2	1	0	54	89%
Rock outcrop	0	0	33	0	0	33	100%
Bare surface	0	1	4	45	1	51	88%
Vegetation	0	0	10	4	49	63	78%
Total	50	49	49	50	50	248	
Producer Accuracy	94%	98%	67%	90%	98%		Total Accuracy=89.4%

Table 5: Provides the result of classification accuracy assessment of operational land imager of 2016

VI. CONCLUSION

According to analysis and findings, it can be concluded that built-up and bare surfaces are part of land use and land cover features that contributed more heat energy to the environment of the study area than other features, most likely as a result of absorbing little heat energy from the sun and reflecting high thermal energy to the environment. The built up and bare surface, which contributed maximally to the overall surface temperature, may be due to human involvement in the use of fossil fuel in the area. Water bodies and vegetation are the least contributors to thermal energy in the study area, emitting little heat energy of the surrounding is due to their ability to retain heat for longer time before releasing to the surrounding. In contrast, despite the global warming effect of rising temperature of surface, there are some little benefits of rising surface temperature. For example commercial farmers may also use maps of land surface temperature to assess water requirements for their crops during the summer, when they are prone to heat stress.

However, between the years 2001 to 2016, vegetation and water body contributed little to the land-use both in spatial extent and land area. The builtup experiences increased of 183.14 km^2 of the land area of Abuja, which is due to a high rate of population growth and urbanization. The built-up experiences increased to about 183.14 km^2 of the total land mass of the study area, which is due to the high rate of population growth, commercialization and urbanization.

Due to human inducement such as road construction, building construction, mining activities, and deforestation, vegetation and rock outcrop have experienced a high decrease in total land use and contribute little temperature rise both in spatial extent and land use of the Abuja. Bare surface has increase to 82.46% with a spatial extent of about 13.59% in Abuja because of provision of car park, vegetation clearance and tarred road. The relationship between land use and land cover and land surface temperature for the period of investigation shows a significant rise in temperature from 15 ^{0}C to 39.7 ^{0}C (degrees Celsius). The features with the highest rise in temperature are the built up and bare surface areas having an average temperature of 24.9 ^{0}C. This occurs as a result of very low vegetation cover or no vegetation cover at all in these areas, which can help in preventing higher emission of thermal energy in the study area.

ACKNOWLEDGMENT

The authors acknowledge the moral support of Environmental and Climate change Division in the Department of Strategic Space Applications, National Space Research and Development Agency (NASRDA) Abuja.

REFERENCES

[1.] Artis, D.A., and Carnahan, W.H.,Survey of emissivity variability in thermography of urban areas. United States: N. p., 1982. Web.Doi: 10.1016/0034-4257(82)90043-8.
[2.] Baleynaud (1999). Observing air quality over the city of Nantes by means ofLandsat thermal infrared data International Journal of Remote Sensing, Taylor & Francis, 1999, 20 (5), pp.947-959
[3.] Balogun, (2001). The geology of the area is underlain by basement complex rocks. The annual rainfall is highest within the FCC and its environs which is about 1,631.7 mm. The annual mean temperature ranges between 25.8 and 30.2°C (Balogun, 2001).
[4.] Hegerl G C, Zwiers F W, Braconnot P, Gillett N P, Luo Y, Orsini J A M, Nicholls N, Penner J E and Stott P A 2007 Climate Change 2007.
[5.] Islam MS, Islam KS (2013) Application of thermal infrared remote sensing to explore the relationship between land use-land cover changes and urban heat Island effect: a case study of Khulna City. J Bangladesh Inst Plan 6:49–60
[6.] Landsat Project Science Office, 2001 Landsat 7 Science Data User's Handbook (Goddard Space Flight Center) Available online at: http://Landsathandbook.gsfc.nasa.gov/ handbook/handbook_htmls/chapter11/chapter11.html (accessed 15 September 2010).
[7.] Ma, Y., Kuang, Y., and Ningsheng, H., 2010.Coupling urbanization analysis for studying urban hermal environment and its interplay with biophysical parameters based on TM/ETM+ imagery. International Journal of Applied Earth Observation and Geoinformation, 12, 110-118.
[8.] Marland G, Pielke RAS, Apps M, Avissar R, Betts RA, Davis KJ, Frumhoff PC, Jackson ST, Joyce LA, Kauppi P, Katzenberger J, MacDicken KG, Neilson RP, Niles JO, NiyogiDDS, Norby RJ, Pena N, Sampson N, Xue Y (2003) The climatic impacts of land surface change and carbon management, and the implications for climate-change mitigation policy. Clim Policy 3:149–157

[9.] NASA, 2010. The Enhanced Thematic Mapper Plus. Available online at: http://Landsat .gsfc.nasa.gov/about/etm+.html (accessed 15 December 2010).
[10.] Oke, T. R. 1978: Boundary layer climates. London: Methuen. xxi+372 pp. £5.75 paper. Published by METHUEN YOUNG BOOKS (1978)
[11.] [10] Reducing Urban Heat Islands (2008): Compendium of Strategies (October 2008) describes the causes and impacts of summertime urban heat islands and promotes strategies for lowering temperatures in U.S. communities.
[12.] Srivastava PK, Majumdar TJ, Bhattacharya AK (2010) Study of land surface temperature and spectral emissivity using multi-sensor satellite data. J Earth SystSci 11:67–74
[13.] Stathopoulou, M. and Cartalis, C. 2007. Daytime urban heat islands from Landsat ETM+ and Corine land cover data: An application to major cities in Greece. Solar Energy. 2007, Vol. 81, pp. 358 -368
[14.] Wald, L., and J. M. Baleynaud, (1999). Observing air quality over the city of Nantes by means of Landsat thermal infrared data, *International Journal of Remote Sensing*,20(5):947-959
[15.] Fatile J.O. (2013). Climate Change and Public Service deliver in Nigeria. Journal of Business and Social Science.7(1) 101 -102.
[16.] Ayoade. J. O. (2012). Introduction to Building and Urban Climatology.Agho—AreoPublishers Ibadan.
[17.] Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report: Climate Change (2007). Working Group II: Impacts. Adaption and Vulnerahilil>htlp ://www.ipcc.chipublications_and datalar4/wg2 'en'c h9s9-5- I .html.