FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 4 No. 4, December, 2020, pp 166 – 174
DOI: https://doi.org/10.33003/fjs-2020-0404-450

ASSESSMENT OF URBAN HEAT ISLAND IN KADUNA METROPOLIS BETWEEN 2000 AND 2018

Mande, Kato Hosea And Abashiya, Deborah Osayi

Department of Environmental Management, Faculty of Environmental Science, Kaduna State University, Nigeria
Corresponding author's email: hosea.mande@kasu.edu.ng

ABSTRACT

Urbanization is a major event in human history and there is no doubt the world is urbanizing rapidly and this is resulting in changes in temperature. This research aims is to identify changes in land surface temperature (LST) between 2000 and 2018. The technique used is the Landsat TM. The result of the land cover classification revealed a +15.93% increase in built-up areas, -27.21% decrease in vegetative cover, +11.19% increase in bare land and +0.09 increase in water bodies between 2000 and 2018. NDVI analysis showed a +0.02 and +0.17 increase in the maximum and minimum range and a +2.16 and -7.76 increase and decrease in maximum and minimum temperature respectively for LST. The finding revealed that the repelling of vegetative cover by built-up is an evidence of rapid urbanization taking place in Kaduna metropolis and a major driver of UHI in Kaduna metropolis. Conclusively, there is a correlation between the various land covers of study i.e built-up, vegetative cover, bare land and water body and LST in Kaduna metropolis between 2000 and 2018. Likewise, urban development has a major impact on urban climate particularly in the increase in land surface temperature which in turn contributes to the development of urban heat. This is true because changes in urban land cover tend to alter the spectral signature and emissivity of the urban surface as observed using remote sensing. The researcher suggests further studies should focus on the assessment of UHI under different land cover and micro-climate in Kaduna metropolis.

Keywords: Heat, Imageries, Land cover , Remote-sensing , Temperature,

INTRODUCTION

Urbanization is a major event in human history and there is no doubt the world is urbanizing rapidly at present. According to the United Nation Development Programme (2001), approximately 2% of the earth's land surface is covered by urban regions which contain about half of the human population. Furthermore, a study conducted by Synnefa *et al*. (2008) has it that "although developed areas account for only 5% of earth's total land area, 50% of earth's population now live in areas that can be considered urban". This research was in line with the United Nations Population Fund findings which states that "more than fifty percent of the world's population lives in cities and this ratio projected to increase" (Aslan and Koc-San, 2016). It was projected that by 2030, 60% of the world's population will live in urban areas and increase to approximately 70% by 2050 (Ashley, 2016). Globally urbanization and human activities are known to be the major determinants inducing changes to the physical characteristics of the earth as well as changes in the urban microclimate. In most large cities, urbanization always takes place at the city core and sprawl to its fringes which make the temperature at the heart of the city's central business district (CBD) to be higher than its surroundings or the suburban area. This higher temperature in the city core compared to its surrounding area is been explained by a phenomenon known as "Urban Heat Island" (Adinna *et al*., 2009; Synnefa *et al*. 2008). The concept of Urban Heat Island (UHI) was first investigated and described by Howard in London. In 1815, he conducted the first-ever systematic urban climate study, measuring what is now called the UHI effect based on thermometers in the city of London and the countryside nearby (Ashley, 2016). He stated that "An UHI refers to any area, populated or not which is consistently hotter than the surrounding area'. UHI is also referring to the elevated temperatures in built-up areas compared to rural surroundings. 'UHI Effect on the other hand means the atmospheric temperature rise experienced by any urbanized area (Meenal and Rajashree, 2017). About UHI intensity, it does not only vary between cities but also vary within cities.

Today, the study of UHI has gained wider acceptance due to its importance in urban climate study, urban planning and management. It investigates issues of urban densification, reduction in vegetation and increase in anthropogenic heat which often results into increase in heat-related illnesses and detoriation of living environment (Archisman, 2017) stated that UHI will also increase energy consumption and elevation of ground-level ozone. Similarly, UHI can also induce urban air quality due to heat waves (Archisman, 2017). In the same way, urban local climate can also be affected by UHI (Archisman, 2017). Archisman (2017) found out that heat - related mortality is higher in the city than in suburbs and that a 3°C increase may cause an increase in hospital. It has been identified by researchers and experts that the three major drivers of UHI connote; vegetation (shade and moisture), urban surface (thermal property and land cover) and urban geometry (dimensions and shapes of the building). Hence, why UHI is been attributed to changes in land cover/ use caused by urbanization.

Quite several researches on UHI have been conducted in so many parts of the world, findings from these researches provided a ground to state that land cover change accelerated by human activities brings about an increase in heat-related illnesses and detoriation of living environment; increase energy consumption and elevation of ground-level ozone (Archisman, 2017) and induce urban air quality due to heat waves (Archisman, 2017). In the same way, urban local climate can also be affected (Archisman, 2017). Also, it was found that heat-related mortality is higher in cities than in suburbs and that a 3°C increase may cause an increase in hospital admissions.

In Nigeria for example study conducted by Nwilo *et. al.* (2012) on the "Assessment of Urban Heat Island of Lokoja Town and Surroundings using Landsat ETM Data" revealed that land surface temperature decreases as one migrates from the urban center to its fringe and further stated that within the urban areas surface temperature may also vary due to differences in land cover/ uses. A similar study was also conducted by Zaharaddeen *et al*. (2016) on "Estimation of Land Surface Temperature of Kaduna Metropolis, Nigeria Using Landsat Images" with the aim to estimate the land surface temperature of Kaduna metropolis. They suggested at the end of their work that future research work within the metropolis should focus on "variation of land surface temperature under different land covers" which according to Giannaros and Melas, (2012) is central to explaining the spatio-temporal characteristics of urban LST. This statement made by and Melas, (2012) was ascertained in the research conducted by Lilly and Monsingh, (2009); Aslan and Koc-San, (2016); Magaji, (2017); Igun and Williams, (2018); Nguyen, (2018) were independently their findings showed variation in LST under different land covers in different study areas. Interestingly, little or no study on such has been conducted in Kaduna metropolis despite its importance and hence why this research seeks to bridge a gap in the field of knowledge by investigating UHI under different land covers within Kaduna metropolis between 2000 and 2018.

MATERIALS AND METHODS

Study Area

Kaduna state is one out of the 36 states in Nigeria and has Kaduna metropolis as the state capital. Kaduna metropolis is located between Latitudes 10° 20' N and 10°37'N of the Equator and Longitudes 7° 22' E and 7°31'E of the Greenwich meridian (Fig 1). The metropolis cuts across Kaduna North, Kaduna South, as well as parts of Igabi and Chukun Local Government Areas of Kaduna State (Fig 1). The metropolis, unlike other Nigerian cities, has no defined central traditional institution but its function as the capital of the Northern region makes most of the prominent northern traditional rulers have their houses in the metropolis. The metropolis is drained mainly by River Kaduna which tends to divide the city into two unequal parts.

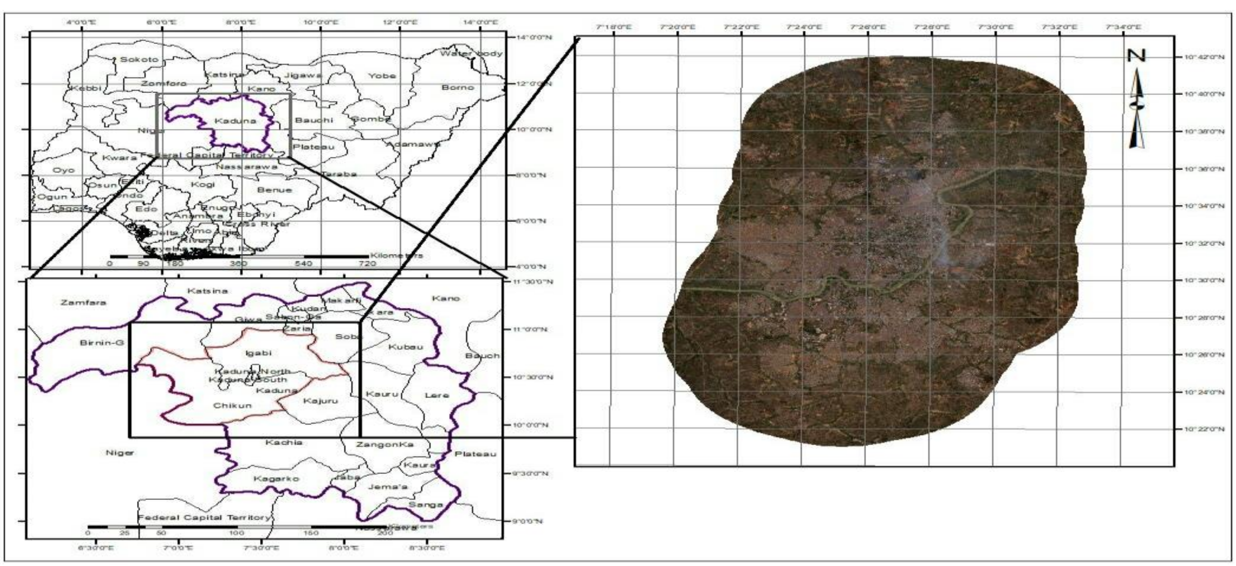

Fig. 1 Map of Kaduna Metropolis
Source: Author, 2018

METHOD

Data Collection

All data used in this research were obtained from secondary sources. Landsat data over the year 2000 – 2018 were downloaded from the US Geological Survey National Center for Earth Resources Observation and Science via the GLOVIS data portal (http://glovis.usgs.gov/). The site was used to retrieve remotely sensed imageries for the year 2000 and 2018 and the Landsat imageries were found suitable and downloaded for this analysis as it was used by Decheng *et al., (*2018) which shown that almost 53% of researchers have used either one or multiple Landsat imageries in their UHI studies because it is the:

i. Longest running uninterrupted Earth observation program". (Decheng *et al.,* 2018)
ii. Secondly, researchers, as a result of a policy change in 2008, can freely obtain Landsat images.
iii. Lastly, Landsat series 5, 7, and 8 capture the Earth's surface in a 16-day repeat cycle with swath coverage of 185 km - 185 km.

The detailed images downloaded and used for the analysis are summarized in Table 1.

Table 1: Details Imageries used in the Analysis of UHI in Kaduna metropolis

DATA	SENSOR	BAND	PATH AND ROWS	RESOLUTION	DATE
Landsat 7	**ETM**	**7**	**189 – 52**	**30m**	**28 – APR – 2000**
Landsat 7	**ETM**	**7**	**189 – 53**	**30m**	**14 - MA – 2000**
Landsat 8	**ETM+**	**7**	**189 – 52**	**30m**	**28 – APR – 2000**
Landsat 8	**ETM +**	**7**	**189 – 53**	**30m**	**14 - MA – 2000**

Source: Extracted from Metadata (2018)

Tools for analysis

The following software were used in analyzing the imageries in this study. Including; ArcMap version 10.3.1 and Google Earth.

DATA PROCESSING

The images downloaded underwent two forms of processing, namely; pre-processing and processing.

PRE-PROCESSING

Satellite imageries downloaded were not just of the study area carved out and therefore had to undergo pre-processing before the processing proper. The pre-processing included the following;

i. **Clip:** here path 189 and row 52 and 53 of each of the years i.e 2000 and 2018 were overlaid to have a single image acting as a whole.
ii. **Mosaic:** this was achieved by overlaying the administrative map of the study area over the downloaded satellite imageries, subsequently the imageries were resized using Arcmap version 10.3.1
iii. **Extract:** the study area was extracted by masking for analysis

PROCESSING

Processing of the extracted images included the following;

Land Cover / Use Classification

The Anderson land cover/ land use classification scheme of 1976 was adopted and modified in other to obtain the desired land covers of study. The images underwent an unsupervised classification where the maximum likelihood classification was adopted from Igun and William (2016). The maximum likelihood classification was adopted because it has a weighting which helps minimize errors that may arise due to misclassification in the classification process. The modified land cover/ land use classification used is shown in table 2.

Table 2: Land Cover Type and Description Use in the Study of UHI in Kaduna Metropolis between 2000 and 2018

Land Cover Type	Description
Built-up areas	Residential, commercial, public, industrial, infrastructure, recreational and other urban ass
Bare land	Exposed soil, landfill site, open surfaces, and barren land

Vegetative cover	All land areas covered by non-agricultural vegetation including natural and man-made fc riparian vegetation
Waterbody	Including all surface water sources

Source: Modified from Magaji, (2017).

Determination of Normalized Difference Vegetation Index (NDVI)

The NDVI was computed for 2000 and 2018 using band 5, 4 and 3. It was computed using the formular:

$$NDVI = NIR - RED / NIR + RED \text{………….} \quad \text{(Eq. 1)}$$

Where,
NIR represents near-infrared
RED represents red reflectance

Retrieval of Land surface temperature (LST) from images brightness

Land Surface Temperature (LST) was retrieved using a single window algorithm:

$$LST = TB / 1 + (\lambda + TB/ \rho) \ln \varepsilon \quad \text{----------- (Eq. 2)}$$

Where,

λ represents the wavelength of the emitted radiance which is equal to 11.5μm.
ρ represents h.c/σ,
σ represents Stefan Boltzmann's constant which is equal to 5.67 x 10-8 Wm-2 K -4,
h represents Plank's constant (6.626 x 10 -34 J S)
c represents velocity of light (2.998 x 108 m/sec) and
ε represents spectral emissivity.

All the procedures above (for estimating land surface temperature) were computed using the map algebra function in Spatial Analyst in ArcGIS 10.3.1 software.

DATA ANALYSIS

All satellite imageries are in raster format and to convert pixels occupied by each land cover of study into polygons the count values were converted into area count. Changes in land covers between 2000 and 2018 were calculated in hectares and percentages.

Testing of hypothesis

To test the research hypothesis and inferential statistical technique was used, specifically the student t-test. Student t-test measures the discrepancy between two variables measured parametrically. The hypothesis was tested at a 95% significant level. To either accept or reject the hypothesis the calculated value for the analysis was compared with the student t table value which is often referred to as the critical value. The null hypothesis was to be accepted if the calculated value is less than the critical value and rejected when otherwise. To avoid committing any form of error when accepting or rejecting either of the hypotheses the decision rule was employed.

Decision Rule

Two types of errors can be committed in the testing hypothesis. These are type I or type II error. The type I error is said to have been committed when we accepted the hypothesis that is false and rejects the hypothesis that is true. On the other hand, we commit a type II error when we fail to reject the false hypothesis and accept that which is true. Type I error is denoted by α (alpha) known as α error, also called the level of significance of test; and Type II error is denoted by β (beta) known as β error.

RESULTS AND DISCUSSION

Land Cover

The imageries of Kaduna metropolis for the year 2000 and 2018 were analyzed using the maximum likelihood classification and presented in figure 2 and table 3. The result revealed an increase of +15.93% in the built-up, -27.21% decrease in vegetation,

+11.19% increase in bare land and +0.09% increase in water bodies between 2000 and 2018 respectively. These findings were in line with Khaled *et al.*, (2015); Meenal and Rajashree, (2017); Igun and Williams (2018) who stated that land cover changes overtime majorly due to population increase and urbanization taking place globally and plays a significant role in SUHI of any area considered urban. The research finding was at variance with none of the findings of other literature viewed at the course of this research work.

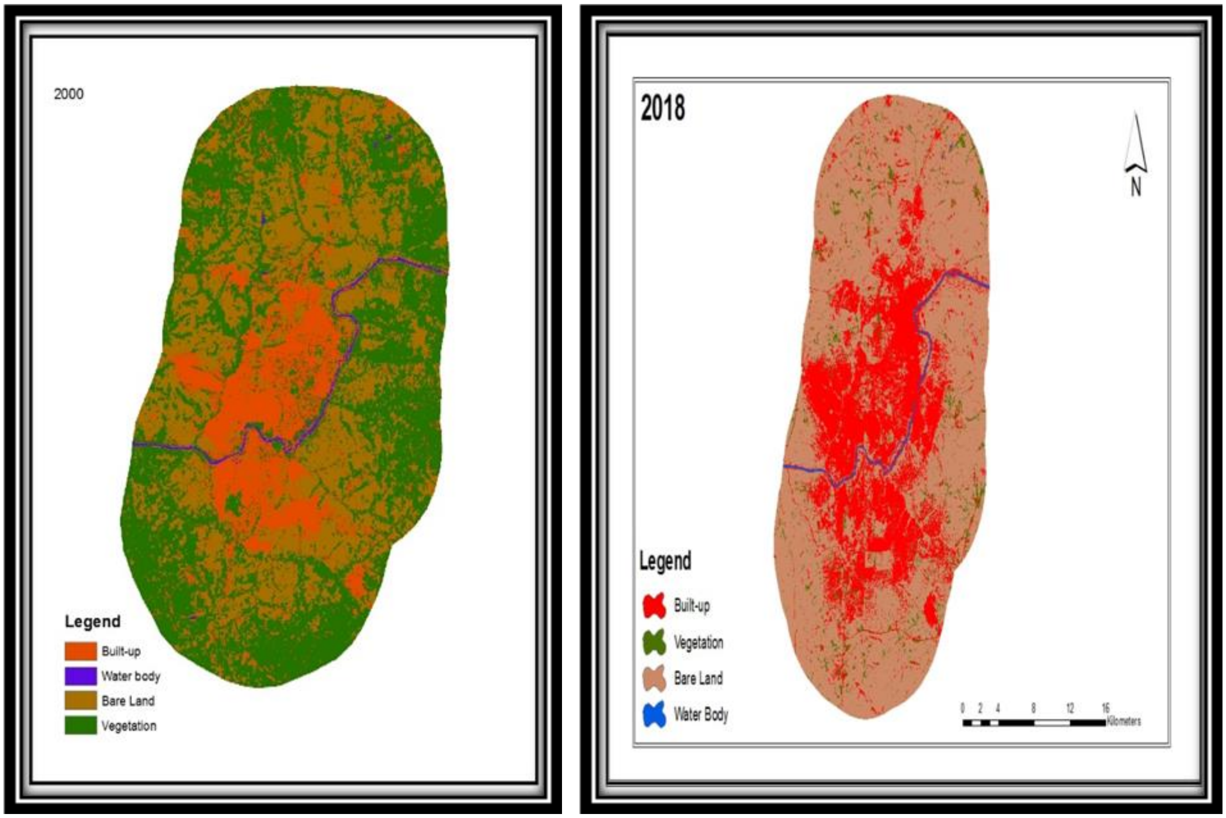

Figure 2: Land Cover clasification of 2000 and 2018 imageries of Kaduna metropolis.
Source: Author, 2018

Table 3: Extent of change in built-up, vegetative cover, bare land and water body respectively in Kaduna metropolis between 2000 and 2018

Year	2000		2018		Difference
Land Cover	Ha	%	Ha	%	%
Built-up	1O,723.55	12.72	20724.93	28.65	+ 15.93
Vegetation cover	22,522.58	30.69	2,523.42	3.48	- 27.21
Bare land	34,417.76	56.08	48,693.78	67.27	+ 11.19
Water body	4717.09	0.51	438.86	0.60	+ 0.09
Total	**72,380.99**	**100**	**72,380.99**	**100**	

Normalized Difference Vegetation Index (NDVI)

The development of NDVI from satellite imageries brightness value is based on the differential absorption, reflectance and transmittance of energy by vegetation in the red and near-infrared portion of the electromagnetic spectrum 9 (Yashim, 2018). According to Yashim, (2018) Vis shows better sensitivity than individual spectral bands for vegetation detection. The NDVI result for the years 2000 and 2018 in Kaduna metropolis was displayed in fig 3, the result showed an increase in NDVI of +0.02 and +0.17 increase in the maximum and minimum range respectively. This finding indicates a decrease in vegetation between the years of study and hence an expected increase in urban heat within the metropolis. The result displayed in Fig 3 shows an increase in Urban Heat Island between 2000 to 2018 and hence in agreement with the NDVI findings displayed in Fig 3.

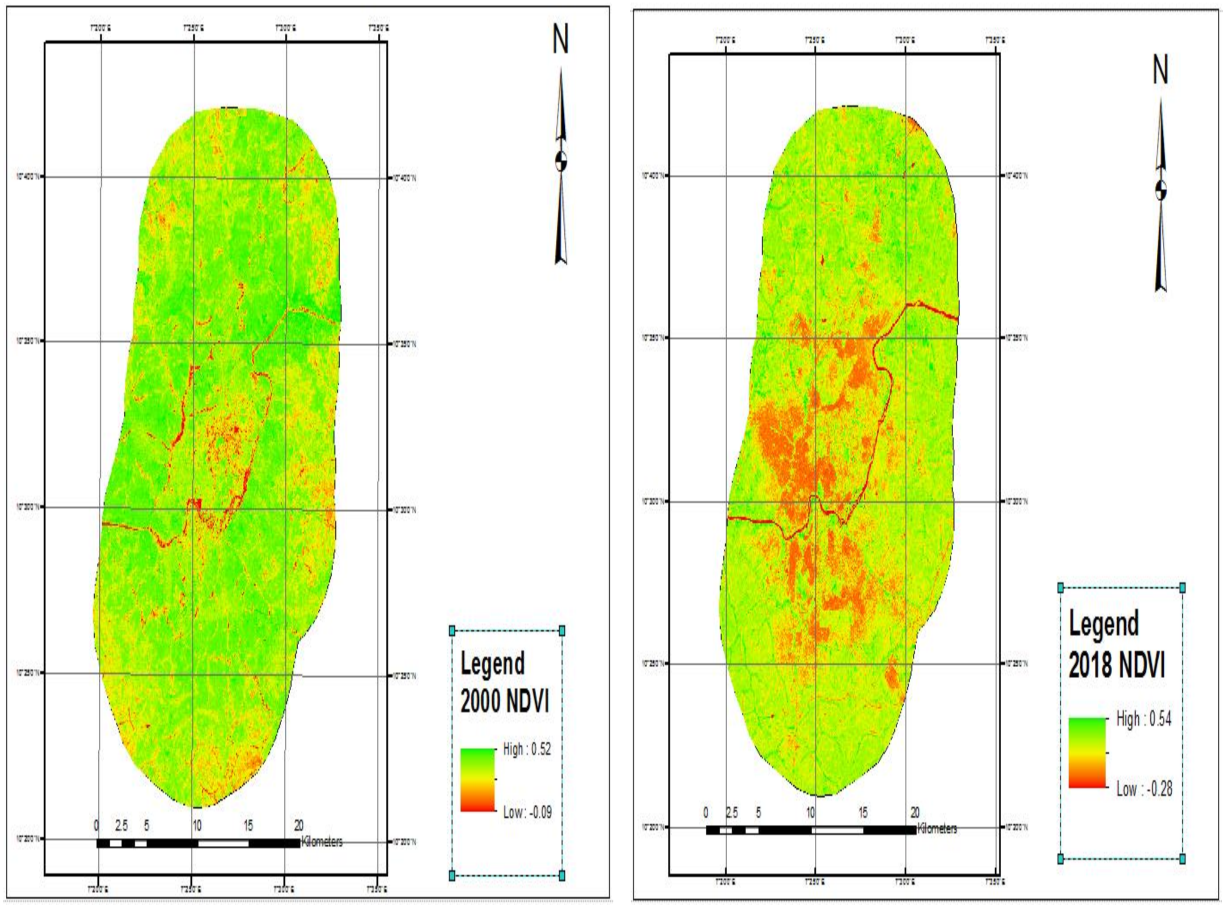

Figure 3: **Normalized Difference Vegetation Index (NDVI)** of 2000 and 2018 imageries of Kaduna metropolis

Source: Author, 2018

Land Surface Temperature

The result from the LST retrieved in Kaduna metropolis as displayed in Fig 4 shows a 2.16ºC increase and a -7.72ºC decrease in maximum and minimum temperature between 2000 and 2018 respectively. These changes in minimum and maximum temperature are also said to have occurred within the Kaduna metropolis due to the drastic reduction in vegetative cover and increase in the built-up areas. The research findings on LST was in line with the statement "SUHI is more at the heart of the city and reduces as one move outward" (Ifatimehin, 2007) and in line with the research findings of (Aslan and Koc-San, 2016; Khaled, *et al.* 2015; Zaharadeen *et al.* 2016; Dechang, *et al.*

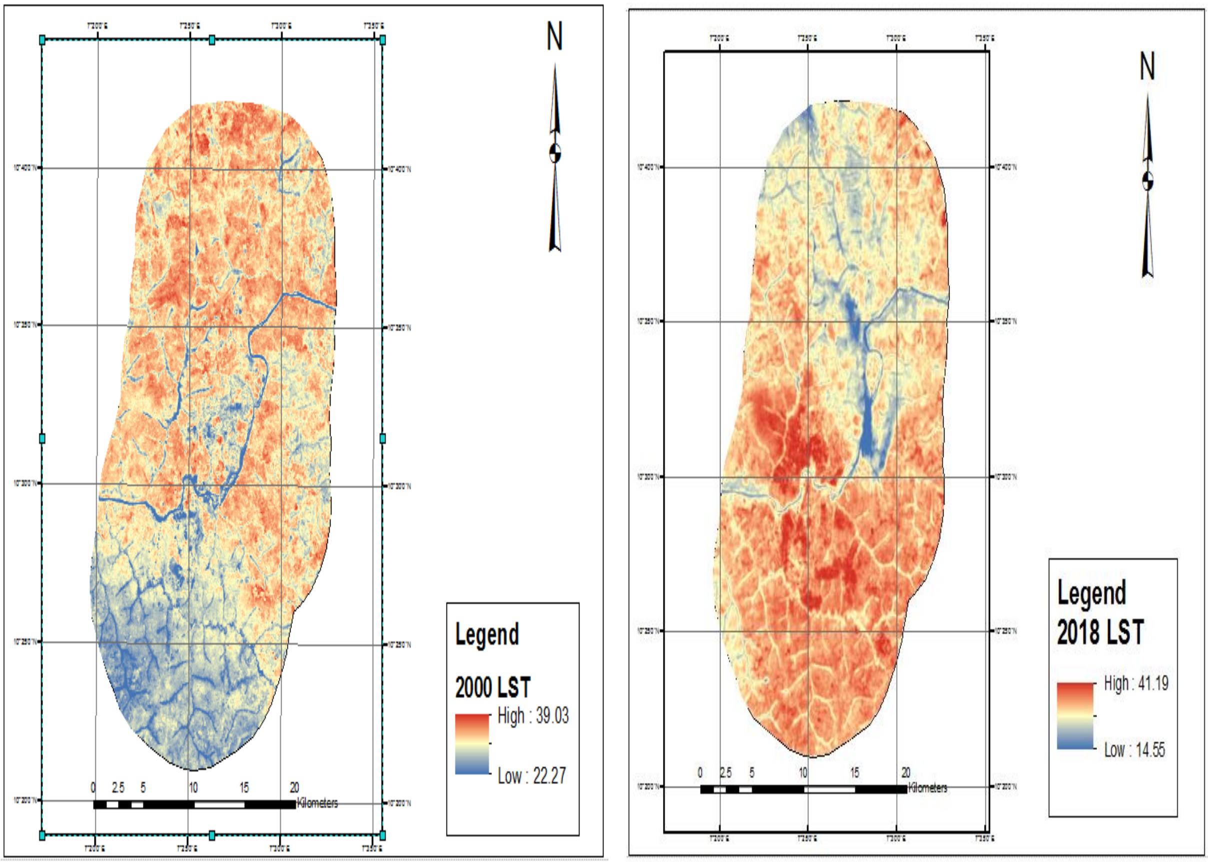

Figure 4: **Land Surface Temperature (LST)** of 2000 and 2018 imageries of Kaduna metropolis
Source: Author, 2018

Land Surface Temperature (LST) response to changes in land cover

The third and which is the last objective of the research finding was achieved using descriptive statistics specifically using a histogram. The histogram was used to show the LST of Kaduna metropolis in 2000 and 2018 (Fig 5) and also the variation that existed between the years. Although the result of the analysis revealed a variation of +2.16ºC and -7.72ºC in maximum and minimum temperature between 2000 and 2018 respectively in the Kaduna metropolis (table 4) and the variation was found not to be significant as related to the study by Qiquqn and Jiayi (2017) and Ifatimehin, (2007). This significance of the variation was determined using descriptive statistics, specifically using the student T test. The student T test was used because it shows the discrepancy between two variables measured parametrically.

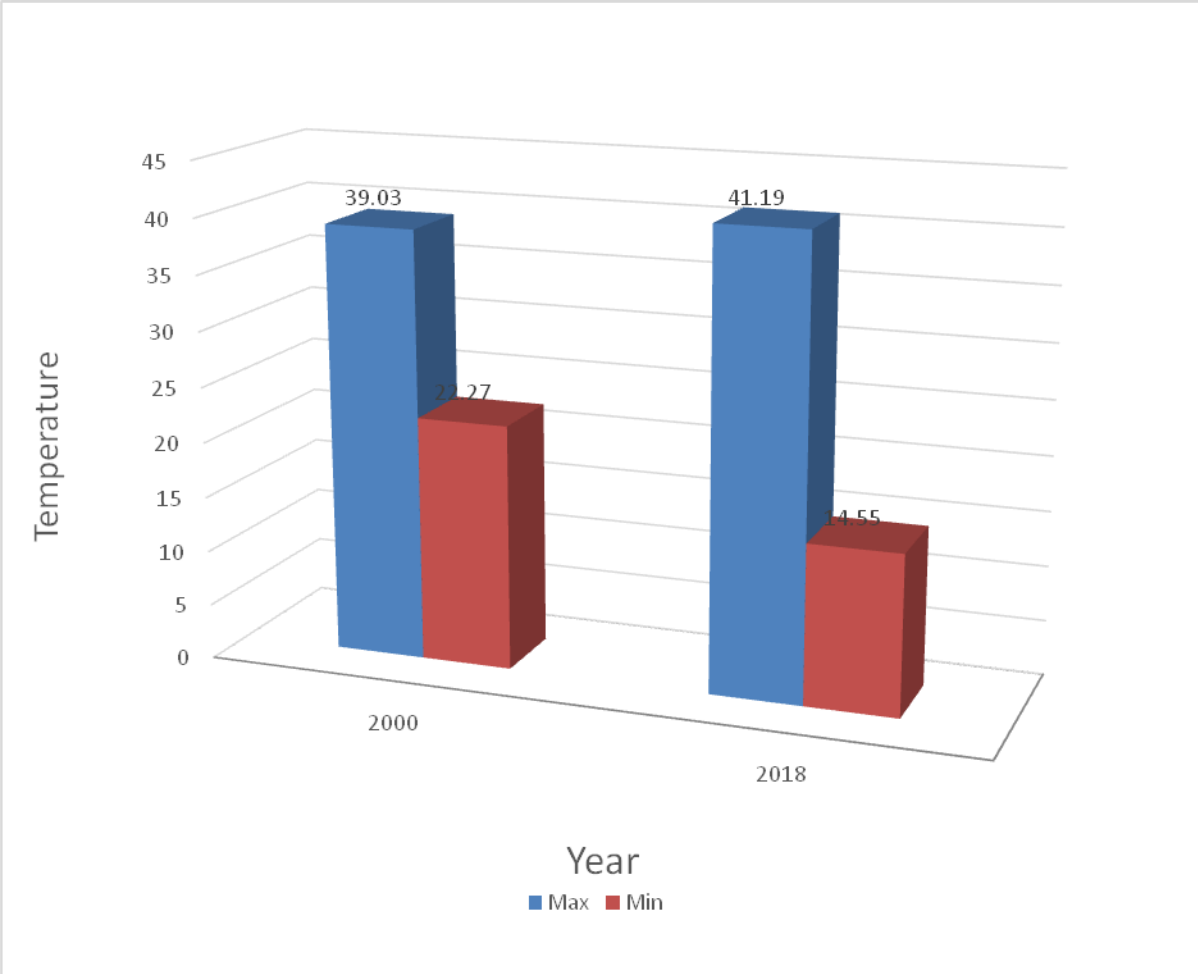

Figure 5: Changes in Land Surface Temperature between 2000 and 2018 in Kaduna metropolis.

Source: Author, 2018

Table 4: LST in Kaduna metropolis from 2000 – 2018

T°C	2000	2018	Difference
High	**39.03**	**41.19**	**+2.16**
Low	**22.27**	**14.55**	**- 7.72**

CONCLUSION

Conclusively, undertaking this research provided the correlation that has existed between the various land covers of study i.e built-up, vegetative cover, bare land and water body and LST in Kaduna metropolis between 2000 and 2018. The study also revealed that urban development has a major impact on urban climate particularly in the increase in land surface temperature which in turn contributes to the development of urban heat. This is true because changes in urban land cover tend to alter the spectral signature and emissivity of the urban surface as observed using remote sensing. These changes observed in this research were in agreement with the research findings of (Khaled *et la.* 2015; Zaharaddeen *et al.* 2016; Meenal and Rajashree, 2017).

References

Adinna, E. N.1., Enete, I. C., and Arch. Tony, O. (2009). "Assessment of urban heat island and possible Adaptations in Enugu urban using Landsat-ETM". Journal of Geography and Regional Planning Vol. 2(2), pp. 030-036, February, 2009Available online at http://www.academicjournals.org/JGRP ISSN 2070-1845.

Archisman, B., Sunny K., Praveen K., and Parth P. S. (2017). "Characteristics of Surface UrbanHeat Island (SUHI) over the Gangetic Plain of Bihar, India". Centre for Environmental Sciences, Central University of South Bihar, Bihar, India. Asia-Pac. J. Atmos. Sci., 54(2), 205-214, 2018. ISSN 1976-7633 / ISSN 1976-7951. DOI:10.1007/s13143-018-0004-4.

Ashley, M. (2016). "Assessing The Urban Heat Island of a Small Urban Area in Central Pennsylvania Along The Susquehanna River". Department of Geography and Earth Science and the Graduate Council, Shippensburg University. Shippensburg, Pennsylvania.

Aslan, N. and Koc-San, D. (2016). "Analysis of Relationship between Urban Heat Island Effect and Land cover/ Use type using Landsat 7ETM+ and Landsat 8 Oli Images". Doi: 0.5194/isprs-archives-XLI-BB-821-2016.

Decheng, Z., Jingfeng, X., Stefania, B., Christian, B., Kaveh, D., Yuyu, Z., Steve, F., Rui, Y., Zhi, Q. and José, A. S. (2018). "Satellite Remote Sensing of Surface Urban Heat Islands: Progress, Challenges, and Perspectives". doi:10.3390/rs11010048 www.mdpi.com/journal/remotesensing.

Giannaros, T. and Melas, D. (2012). "Study of the urban heat island in a coastal Mediterranean city: The case study of Thessaloniki, Greece". Atmospheric Research 118: 103-120.

Ifatimehin, O. O. (2007). "An assessment of Urban Heat Island of Lokoja town and surroundings using Landsat ETM data". FUTY Journal of the Environment, Vol. 2, No. 1, 2007 100. School of Environmental Sciences, Federal University of Technology, Yola – Nigeria. ISSN 1597-882.

Igun,1.E., and Williams, M. (2018). "Impact of Urban Land Cover Change on Land Surface Temperature". Global J. Environ. Sci. Manage. Vol 4(1): 47-58, Winter 2018 DOI: 10.22034/gjesm.2018.04.01.005.

Khaled, A., Adeline, N., Ahmed, D., Mahmoud, A., Sayed, A. and Fathi, A. (2015). "Assessment of Urban Heat Island Using Remotely Sensed Imagery over Greater Cairo, Egypt". Advances in Remote Sensing, 2015, 4, 35-47 Published Online March 2015 in SciRes. http://www.scirp.org/journal/ars.http://dx.doi.org/10.4236/ars.2015.41004."Land Surface Temperature". (Copernicus GLOBAL Land Service). https://land.copernicus.eu

Lilly, R. A and Monsingh, D. D. (2009). "Analysis of Land Surface Temperature and Land Use / Land Cover Types Using Remote Sensing Imagery - A Case in Chennai City, India". The seventh International Conference on Urban Climate, 29 June - 3 July 2009, Yokohama, Japan.Sathyabama University, Chennai, India, Anna University, Chennai, India.

Magaji, R. (2017). "Analysis of Land use and Land cover change in Gonin-Gora Area of Kaduna Metropolis Between 1986 and 2016". Department of Environmental Management, Kaduna State University, Kafanchan Campus.

Meenal, S. and Rajashree, K. (2017). "Assessment of Urban Heat Island through Remote Sensing in Nagpur Urban Area Using Landsat 7 ETM+ Satellite Images". World Academy of Science, Engineering and Technology International Journal of Urban and Civil Engineering Vol: 11, No:7, 2017.

Nguyen, T. H., Yuei-An, L., Kim-Anh, N., Ram, C. S., Duy-Phien, T., Chia-Ling, L. and Dao, D. C. (2018). "Assessing the Effects of Land-Use Types in Surface Urban Heat Islands for Developing Comfortable Living in Hanoi City". Received: 23 October 2018; Accepted: 4 December 2018; Published: 6 December 2018.

Nwilo, P. C., Olayinka, D. N., Obiefuna, J., Atagbaza, A. O. and Adzandeh, A. E. (2012). "Determination of Land Surface Temperature (LST) and Potential Urban Heat Island Effect in Parts of Lagos State using Satellite Imageries". FUTY Journal of the Environment, Vol. 7, No. 1, July 2012 19 © School of Environmental Sciences, ModibboAdama University of Technology, Yola – Nigeria. ISSN: 1597-8826. http://dx.doi.org/10.4314/fje.v7i1.2.

Qiquan, Y., Xin H. and Jiayi, L., (2017). "Assessing the relationship between surface urban heat islands and landscape patterns across climatic zones in China". www.nature.com/scientificreports..

Synnefa, A., Dandou, A., Santamouris, M., Tombrou, M. and Soulakellis, N. (2008). "On the use of cool materials as a heat island mitigation strategy". Journal of Applied Meteorology and Climatology, 47(11), 2846-2856. UNDP internal document: UNDP (2001), in mimeo, pp.6-7 Yashim, G. (2018). "Assessment of land use and land cover change on tree species diversity in kafanchan and environs". Department of Environmental Management, Kaduna State University.

Zaharaddeen, I., Ibrahim I. B. and Zachariah, A. (2016). "Estimation of Land Surface Temperature of Kaduna Metropolis, Nigeria Using Landsat Images". Science World Journal Vol 11 (No 3) 2016. www.scienceworldjournal.org. ISSN 1597-6343.