Nigerian Journal of Environmental Sciences and Technology (NIJEST)
www.nijest.com
ISSN (Print): 2616-051X | ISSN (electronic): 2616-0501
Vol 3, No. 2 October 2019, pp 210 – 217

Spatial pattern of Land Surface Temperature over Umuahia North and Bende LGA, Abia State, Nigeria

Uchendu U. I *, Kanu C., Kanu K. C. and Mpamah C. I.
Department of Environmental Management and Toxicology, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria
Corresponding Author: *uchendu.udochukwuka@mouau.edu.ng, udouche@yahoo.com

https://doi.org/10.36263/nijest.2019.02.0138

ABSTRACT

This study evaluated the Spatial pattern of Land Surface Temperature (LST) over Umuahia North (Urban Area) and Bende LGA (Rural Area), Abia State, Southeast Nigeria. LANDSAT Imagery spanning Row 056 and Path 188, with 30m spatial resolution was captured on the 17th of May, 2018. Temperature and relative humidity were measured using a thermometer and multi-purpose Hydro-20 - 100 % model. Eight measurements were taken for each parameter at an interval of 8 hours at an elevation of 1.5m above the ground. Coordinates and elevation of the points were captured using a Garmin Handheld GPS. Data obtained were imported in compatible formats with ArcGIS 10.5 and the values for the un-sampled locations within the study area was determined through the interpolation of the collected data. A subset covering the study area was extracted for bands 1,2,3,4 and 5. Bands 1, 2 and 3 which are visible bands were used in generating a true colour composite image of the study area; the bands 4 and 5 which are not visible bands were used for the NDVI (Normalized Differential Vegetation Index). Result showed that Bende LGA had a vegetal cover of 45,741.26hectares out of a total of 60,152.76 hectares while Umuahia North had 19,689.09 hectares of vegetal cover out of a total of 24,459.75 hectares. Umuahia North had an average daily temperature of 31.309°C while Bende had 27.405°C. The average relative humidity in Bende LGA was 82.37% while Umuahia North was 67.274%. In conclusion, the study showed the existence of heat islands in the urban areas in Umuahia North LGA which was characterized by higher temperature but lower relative humidity. The heat island could be attributed to the gradual loss of vegetation cover and the increase in built-up environments in Umuahia North LGA.

Keywords: Land uses, soil depth, soil physical and chemical properties, watershed

1.0. Introduction

Urban population is increasing and the infrastructural development required often leads to higher building density, resulting in a lack of green spaces (Abdollah, 2012). In comparison with rural areas, urban areas are more prone to the risks of lack of green space. One of the effects of urbanization is the urban heat island effect (UHI) (Kleerekoper *et al.*, 2012). Urban heat island is an urban area whose ambient temperature is higher than the surrounding rural areas due to human activities which increasingly use asphalt and modify land surfaces while decreasing the green spaces and evaporation surfaces (Mobaraki *et. al.*, 2012). Surface temperature is important to urban climates because it regulates the air temperature of the lowest layers of the atmosphere mostly affecting city dwellers (Voogt and Oke, 2003). Increased surface temperature from UHI effects impacts on air quality and environmental conditions. Higher temperature increases ozone production at ground level from volatile organic compounds emitted from the combustion of fossil fuels. Ground level ozone and elevated temperatures are hazardous to public health because it can cause respiratory and cardiovascular problems (Quattrochi and Lo, 2003).

The elevated temperatures within urban environment also have biological impacts. Warmer temperatures in urban areas result in earlier green-up of flowers and trees in the city, a longer growing season and the attraction of birds to warmer habitats (Albers *et al.*, 2015). Changes in the composition of the urban land structure and transforming the naturally vegetated land into the built-up area have been mainly caused by the formation of the UHIs. Similarly, other anthropocentric factors, such as industrial activities, transportation, emission of CO2, and energy consumption, have affected an increase in the magnitude of UHIs in both day and night (Igun, 2017).

In view of the above, earlier studies have identified LST also known as surface urban heat island (SUHI) by assessing measured rural-urban temperature differences (Balogun et al., 2012; Ojeh et al., 2016) in some areas in Nigeria. For instance, Ojeh et al. (2016) investigated urban temperature conditions based on the hourly air temperature difference between City hall (Urban area) and Okoafo (Rural area) in Lagos, Nigeria. The study found that maximum nocturnal LST magnitudes in Lagos can exceed 7°C during the dry season, and during the rainy season, wet soils in the rural environment supersede regional wind speed as the dominant control over LST magnitude. The study of Ojeh et al. (2016) was in agreement with Balogun et al. (2012), which found that nocturnal heat island was more frequent than the day-time heat island over Akure city, Nigeria. More recently, studies have employed remote sensing and GIS techniques to analyze and quantify the effect of Land-use/Land-cover (LULC) change on LST (Ishola. et al., 2016b).

In Umuahia and Bende LGA in Abia State of Nigeria, where this study is focused, land use and land cover patterns have undergone a rapid change due to accelerated expansion over the years. Urban growth has increased tremendously and extreme stress to the environment has occurred (Eniolorunda *et. al.,* 2017). This increasing level of migration may be attributed to favorable socio-economic, agricultural, political and physical factors. Furthermore, environmental changes due to urbanization can have significant effects on local climate. One of the most familiar effects of urbanization is the urban heat island, which is the direct representation of environmental degradation. Increase in population and anthropogenic heat might have also contributed to this phenomenon (Babalola and Akinsanola, 2016). Thus, the aim of the study was to evaluate the Spatial pattern of Land Surface Temperature (LST) over Umuahia North (Urban Area) and Bende LGA (Rural Area), Abia State, Southeast Nigeria.

2.0. Materials and Methods

2.1. The Study Area

This study was carried out in Umuahia North and Bende local government areas in Abia State, South-East Nigeria. This area is located in the lowland rainforest zone of Nigeria which lies between Latitude $05^{0}29'$ to $05^{0}42'$ North and Longitude $07^{0}29'$ to $07^{0}33'$ East. The area has an average rainfall of 2,238 mm per year that is distributed over seven months rainy season period (Nzegbule and Ogbonna, 2008). It has bimodal peaks, the first occurring in the month of June or July and the second occurring in the month of September. Its minimum and maximum temperatures are 23^{0}C and 32^{0}C respectively and a relative humidity of 60-80% (Nzegbule and Ogbonna, 2008). The capital of Abia state is Umuahia which is bounded by Port-Harcourt to its South and Enugu city to its north. Umuahia has a population of 359,230 according to the 2006 Nigerian Population Census.

2.2. Collection of Remotely Sensed Images

Remotely sensed satellite images and field observations provided the datasets that were used to achieve the objectives of the study. Remotely sensed data was obtained from a Landsat data spanning Row 056 and Path 188, with 30m spatial resolution captured on the 17th of May, 2018. The data was obtained from the earth explorer website, which provides a range of satellite images with varying spatial resolution for download. Landsat was chosen because of its suitability for land use/land cover studies. Varying landcover types such as built-up areas/settlements, vegetal cover, water bodies, rocky and bare surfaces can be measured from this satellite image.

2.3. Collection of field Data

Field data collected during the study includes temperature, relative humidity using a thermometer, Multi-purpose Hydro-20 - 100 % model, while location coordinates and elevation were captured using Magnetic Compass and a Garmin handheld GPS.

Data were collected at 6 hours interval at an elevation of 1.5m above the ground. Data obtained for each sampled location were analyzed and then imported in compatible formats with ArcGIS 10.5 and allocated to its location using the longitude and latitudinal values obtained with the GPS. The values for the unsampled locations within the study area was determined through the interpolation of the values obtained from each location.

2.4. Processing of the Remotely Sensed Data

Visible bands 1,2,3 were extracted from the Landsat imagery and a sub map covering Umuahia North and Bende Local Government Areas was created, which is a representation of the study area. This sub scene was extracted from the original dataset covering Row 056 and Path 188. The submap was created using vector layers covering the extent of the two Local Government Areas of Interest. A true colour composite which displays a combination of visible red, green and blue bands to the corresponding red, green and blue channels on the computer display was created for the study area (Figure 1). This results to an image representing what the eye would see naturally i.e. vegetation as green, water as shades of blue, while bare ground and impervious surfaces are shown as shades of light gray and brown. This was chosen over a false color composite as it suits the purpose of the research. Bands 4 and 5 which are not visible bands were used for the Normalized Differential Vegetation Index (NDVI). The NDVI is a standardized vegetation index which is used to generate images showing relative biomass. The chlorophyll absorption in red band and relatively high reflectance of vegetation in near infrared band were used to calculate NDVI. This was used to determine the vigour of vegetation within the study area. Supervised image classification was carried out on the satellite image and samples such as built up areas, settlements, impervious surfaces and vegetation were identified and captured through pixel training and the maximum likelihood classification algorithm.

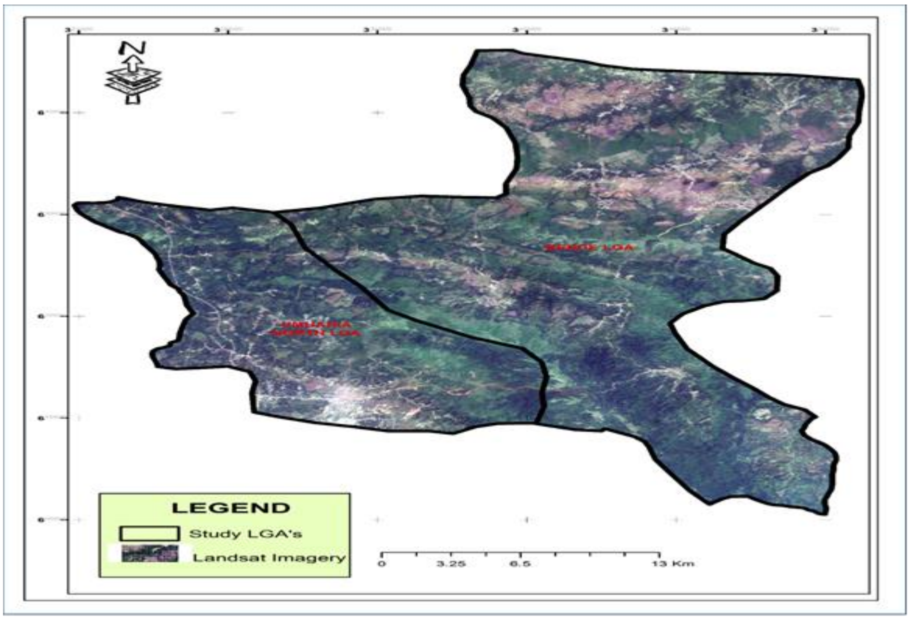

Figure 1: True color composite landsat imagery of the study area

3.0. Results and Discussion

3.1. Temperature

Analysis of the data showed higher temperature in Umuahia North LGA an urban area compared with Bende LGA a rural Area (Table 1). Higher values were recorded in the morning and evening in Umuahia North LGA when compared to Bende LGA. The average daily temperature recorded for Umuahia North LGA was 31.309ºC while that of Bende LGA was 27.405ºC. Variations in temperature observed in the study locations was in line with the study of Roth, (2007) who observed higher temperature in urbanized areas compared with areas that exhibit the rural attributes. This variation in temperature is often due to the difference in vegetal cover, paved surfaces, human population, economic activities, roofing sheets and emission from vehicles and industries. Due to urbanization activities in Umuahia North LGA as compared to Bende LGA, there was higher temperature experienced in the area, this is due to the land use in Umuahia North LGA which is predominantly built-up area and agricultural land.

3.2. Relative Humidity

Lower relative humidity was observed in Umuahia North LGA compared with Bende LGA (Table 1). The average relative humidity values recorded for Bende LGA during the period of study was 82.37% while that of Umuahia North LGA was 67.274%. The higher relative humidity observed in Bende LGA can attributed to the lower temperature in the area, more vegetation and evapotranspiration and fewer population and human activities. There is an inverse relationship between relative humidity and temperature (Mallik et al., 2008). Studies in the past have shown that cold air holds more water vapour than warm air, relative humidity falls when the temperature rises. Whenever the relative humidity value of 100% is attained the air becomes saturated.

Table 1: Weather Parameters at the sampled point in the study area

Location	Time	Temperature (ºC)			Relative Humidity (%)		
		Average	Lowest	Highest	Average	Lowest	Highest
Bende	Morning	29.444	25.67	36.11	80.8	77.9	84.5
Umuahia North		34.85	32.43	38.27	58.394	46.4	63.45
Bende	Evening	25.366	22.56	26.61	83.94	80.3	87.4
Umuahia North		27.768	23.7	29.65	76.154	56.67	83.6
Bende	Daily	27.405	22.56	38.27	82.37	77.9	87.4
Umuahia North		31.309	23.7	38.27	67.274	46.4	83.6

Source: Field Survey, 2018.

3.3. Image Classification, Vegetal Cover, NDVI and Heat Island Occurrence

The image classification analysis (Figures 2 and 3) showed that Bende has more vegetal cover than Umuahia North LGA. The vegetal cover of Bende LGA was 45,741.255 hectares while Umuahia North had 19,689.087 hectares of vegetal cover. The vegetal cover observed in Bende LGA was healthier than the vegetal cover in Umuahia North LGA. Loss of vegetation in urban areas increases heat storage in the ground and buildings which in turn could lead to higher air and surface temperature compared to the surrounding areas (Oke, 1982).

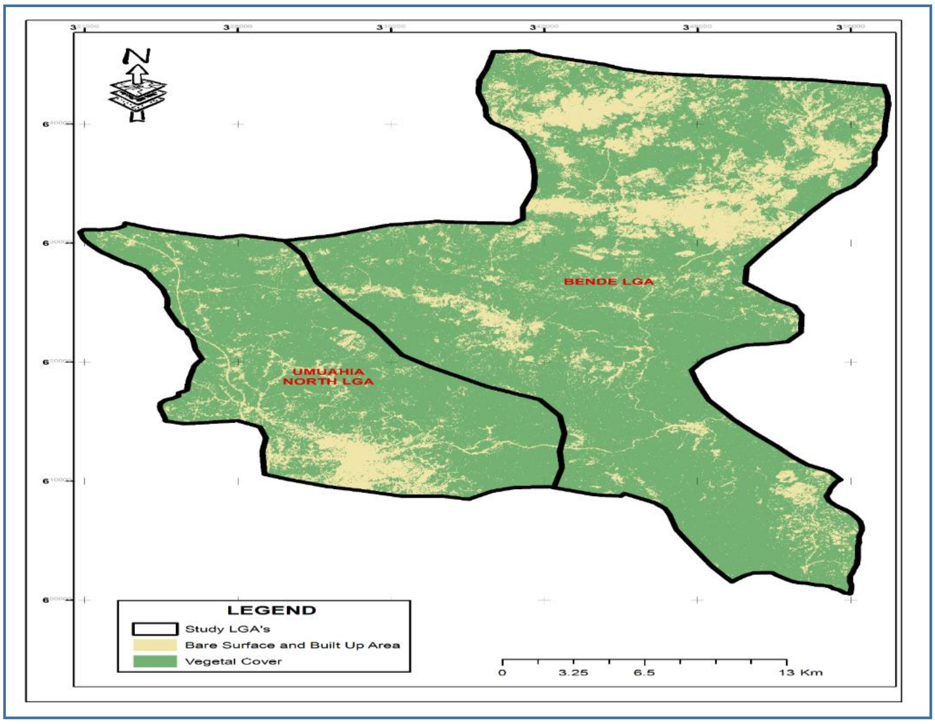

Figure 2: Classified landsat imagery of the study area

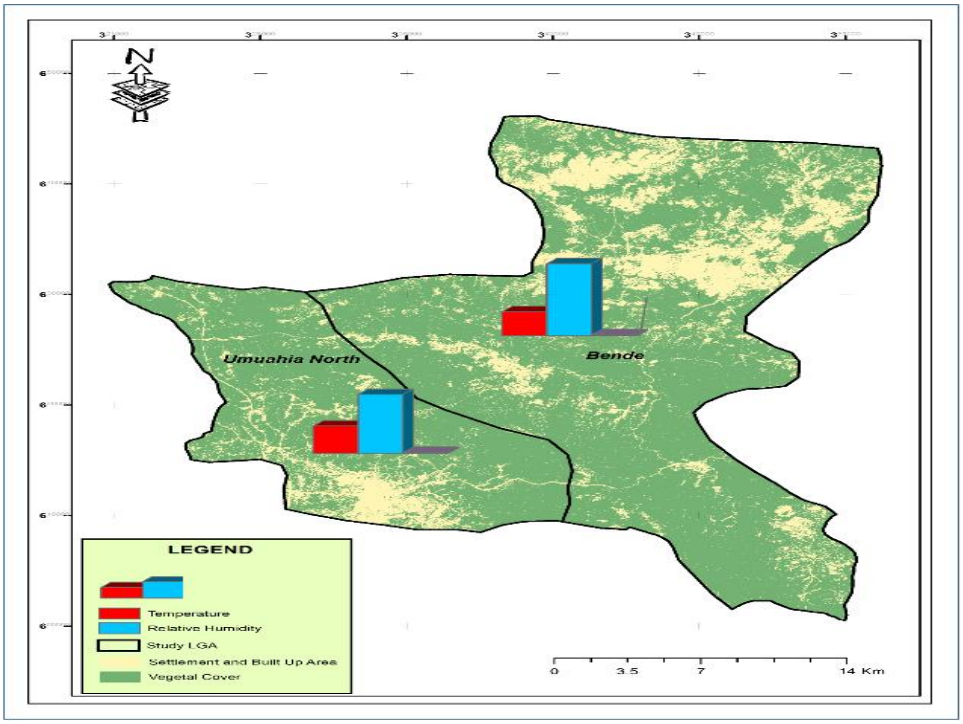

Figure 3: Distribution of observed parameters by LGA

The findings of this study also showed that there is a reversed relationship between vegetation, NDVI and the existence of heat island (Figures 4 – 6), implying that an increase in vegetation abundance would generally reduce surface temperatures, and thus UHI intensity, this is due to the impact of the different properties of Land use Land cover (LULC) (Voogt and Oke, 2003). While the vegetation areas are directly related to lower surface temperatures, responsible for generating the cooling effect in the urban microclimate, concrete built-up areas add to the existing high temperatures. The built-up areas and road and network have influenced the NDVI of Umuahia North LGA. Previous studies have shown negative correlation between temperature and urban vegetation abundance (Weng *et al.*, 2004; Chen *et al.*, 2006; Mallik *et al.*, 2008; Sundara *et al.*, 2012).

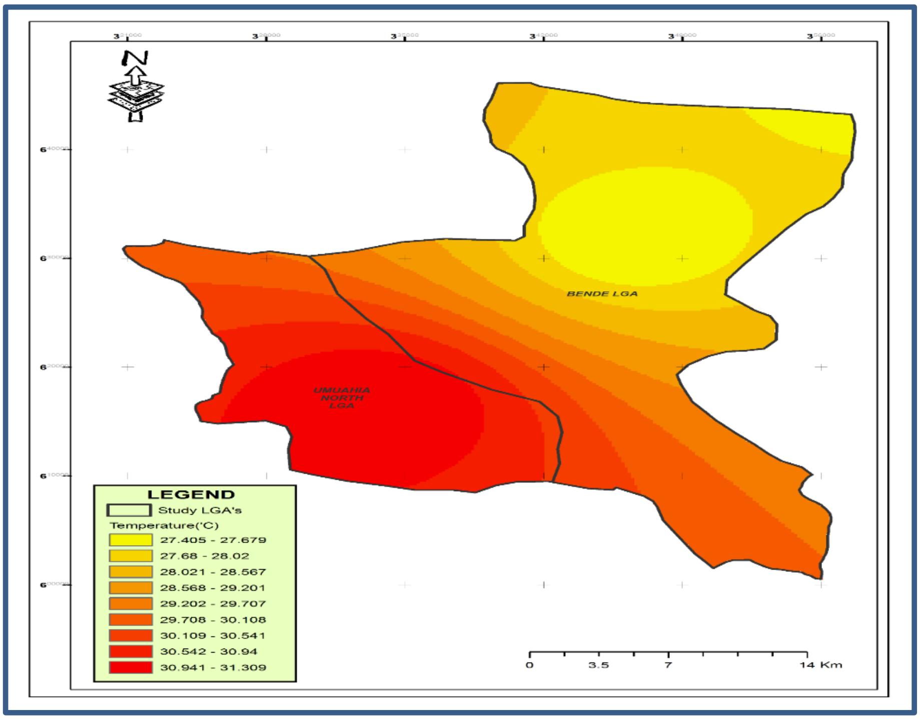

Figure 4: Heat map of the study area by LGA

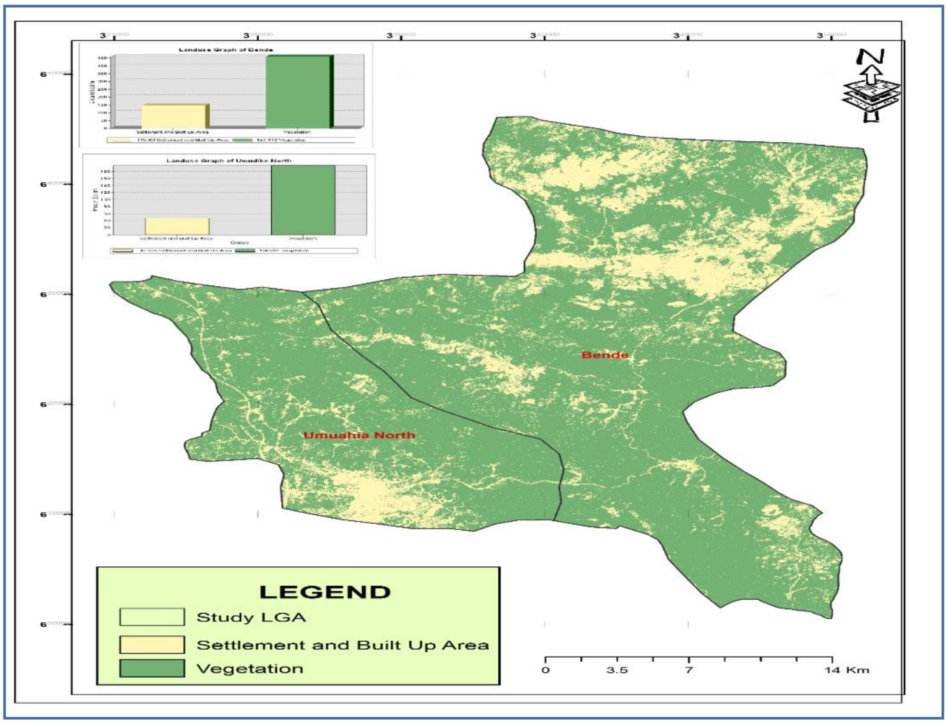

Figure 5: Landuse map of the study area by LGA

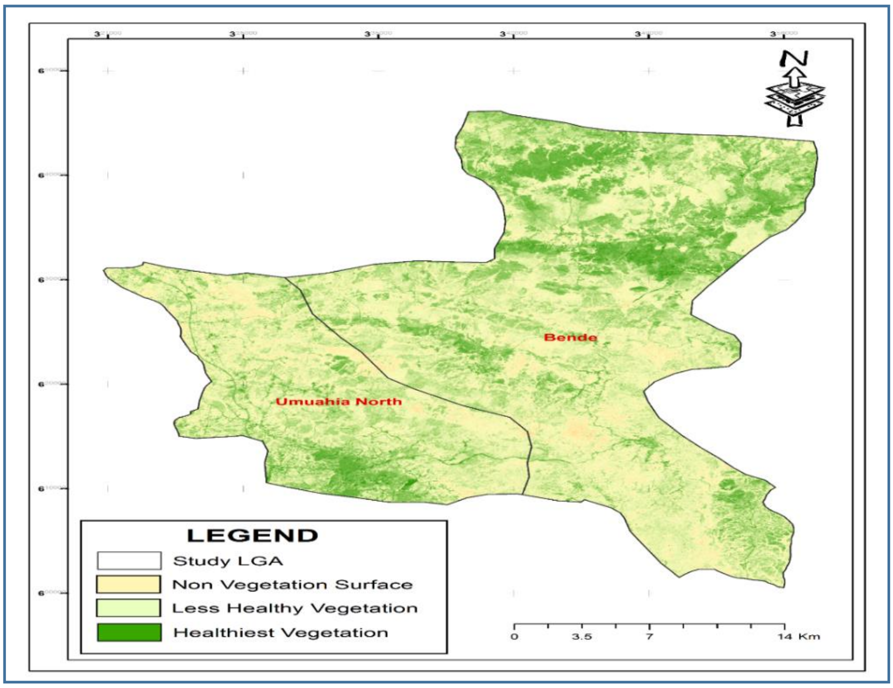

Figure 6: NDVI map of the study area by LGA

4.0. Conclusion

The study showed the existence of SUHI in the urban areas in Umuahia North LGA which was characterized by higher temperature but lower relative humidity compared with the lower temperature and higher relative humidity observed in Bende LGA a rural area. The SUHI could be attributed to the gradual loss of vegetation cover and the increase in the built-up environments in Umuahia North LGA. This study recommends that Landuse planning should be instituted and implemented in Umuahia and its environs. This is to ensure that rural landuse is sustainable. This effort should involve the Abia State Ministry of Environment, Urban Development Board and relevant bodies of the Local Government Areas. Urbanisation is a process that cannot be halted hence, urban managers and planners should embark on re-designing cities in such a way that a lot of parks, gardens, orchards, and open spaces will be accommodated into the city physical plans. These provisions will allow for the free flow and passage of air as well as provision of shades that will contribute to city cooling.

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Cite this article as:

Uchendu U. I., Kanu C., Kanu K. C. and Mpamah C. I. 2019. Spatial pattern of Land Surface Temperature over Umuahia North and Bende LGA, Abia State, Nigeria. *Nigerian Journal of Environmental Sciences and Technology*, 3(2), pp. 210-217. https://doi.org/10.36263/nijest.2019.02.0138