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Analysis of Land Surface Temperature and Land use/Land cover types in OkigweImo State Nigeria using Remote sensing and GISTechnology.

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This study analyses the changes which occur in the city of Okigwe in Imo State and identify the land surface temperature variations among the land cover types by utilizing geospatial techniques. The aim of the study is to determine the changes in the land cover and consequently evaluate the changes in the land surface temperature for three different study epochs. Three Landsat imageries were utilized to include Landsat 5 TM, which was obtained in December 1986, Landsat 7 ETM +, obtained in December 2000 and Landsat 8 OLI/TIRS, which was obtained in December 2018. Land Use/Land Cover categories for the study were obtained through the use of supervised classification techniques and the land surface temperature was obtained by computing the brightness temperature from the satellite sensor. The results of the study show that there was a huge increase in urban area (including barren land), which is the major factor for the changes in land surface temperature. Thus, Remote Sensing and Geographic Information System techniques are effective approaches for monitoring and analyzing urban growth pattern and evaluating their impact on land surface temperature.

Keywords: *Land surface Temperature, Landsat Imageries, Land Use, Land Cover, NDVI*

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I. Introduction

Land surface temperature (LST) play a vital role in a wide variety of scientific studies, which include ecology, hydrology and global change studies. It entails energy fluctuations and interactions between the earth's surface and the atmosphere [1]. LST has an effect on the environment and atmosphere, since it is involved in the process of rising land radiation and heat flux exchanges in the atmosphere[1]. Thus, LST is a key parameter to estimate the surface and atmosphere energy exchanges and for studying local, regional and global environmental change [2]. LST is a source to obtain information about different kinds of land surface, since it plays an important role in the dynamics of land surface processes. Its measurements are becoming popular for modeling climate change (e.g. global warming) as well as greenhouse effect [3]. Land surface temperature (LST) has an implication for urban planning as un – planned urban areas have higher air surface temperature and well – planned urban areas with wide range of green spaces, are more likely to have a lower air surface temperature [4]. LST is associated with the energy balance as well as the procedure of evapotranspiration. It differs from the land surface air temperature (LSAT), as it is associated with heating and cooling processes of the earth's surface. Mapping Land surface temperature (LST) by utilizing remotely sensed thermal infrared (TIR) data to represent the skin temperature of the earth's surface, is useful in analyzing and characterizing landscape thermal behavior modeling surface energy balance [5],[6], quantifying evapotranspiration, which is useful for water management [7]and understanding the interactions between human activities and environmental changes. Understanding of landscape thermal behaviour has displayed its profound implications in many disciplines such as Ecology[8], Urban Planning [9], Hydrological cycles and Environmental pollution [10]. Exploration of landscape thermal characteristics is usually dependent on the surface temperature parameters derived from the remotely sensed infrared information. Several studies have expounded that LST has a direct link to the land surface characteristics [11] and in contrast, LULC change is related to the urban growth, thus the study of the relationship between LST and LULC is fundamental to explore the impact of urban growth on Land surface temperature. Researchers such as[12],[13],[14] and [15] utilized remote sensing, by using Landsat images to generate land use and surface temperature maps so as to monitor land use changes for commercial purposes, business centres, government offices, residential areas and public amenities and which replaces green spaces, forest and un – used lands. The study of the relationship between LST and LULC changeshelp the researchers to understand the cause, spatial – temporal distribution, consequences and possible measures to mitigate the urban heat island (UHI) effect.

The Role of Remote Sensing in Land Surface Temperature Retrieval and Application

Remote Sensing (RS) technology based temperature estimation is important in revealing Land surface temperature (LST) using radiance. The technology has also been utilized in identifying vegetation cover, air pollution and several other surface characteristics [16],[17]. Space borne thermal remote sensing techniques have been developed and successfully applied to map UHI in various urban areas [18],[19]. Remote Sensing can provide continuous data over a surface, but the images can only be captured at discrete times. It has proven to offer great advantages over the use of the traditional methods. Traditional methods have been developed to compute and obtain urban air temperature, especially from mounted temperature sensors or observation stations based on land [20]. The traditional method is very expensive for mapping large areas. It would require the construction of meteorological stations in large numbers, which is not really feasible. Retrieval of urban climate with traditional methods is cumbersome; but remote sensing techniques can obtain data and generate accurate analysis within a short space of time. Inaccessible regions make it unfeasible to employ traditional micro – meteorological techniques to study forest canopy thermal budgets. However, remote sensing, in such locations can serve as an excellent source of information [21]. Land surface temperature (LST) is a vital climate component which allows detection of the amount of sunlight energy reflection, and which is connected with surface energy balance, with the atmospheric integrated thermal state within the boundary layer of the earth[22]. Being an important parameter in land surface processes, LST promotes climate change and is applicable in monitoring sensible and latent heat flux exchanges within the atmosphere [23]. These surface heat dynamics promote local convection in the atmosphere and produce alterations in air temperature, cloudiness, surface winds and precipitation [24]. According to [25]it was regarded as a primary variable to correctly represent the budget of surface energy. The temperature of the earth's surface, which can be accessed from LST, may be useful in assessing the surface energy balance, monitor vegetation water stress, detect land surface disturbances and monitor conditions that are suitable for insect – vector disease proliferation [26]. The temperature of the earth varies with different types of land cover, which aid in classifying land use in an area. It has also been used in the study of changes over time in the land use/land cover of an area. Satellite sensors which capture thermal data include: AVHRR, MODIS and ASTER. Others such as Quick bird – 2, IKONOS – 2 and Spot 4 and 5, despite their high spatial and temporal resolutions, do not have thermal bands and thus cannot provide data to map LST. Landsat image has been used successfully in classifying land cover and is popularly used in monitoring and detecting environmental changes [27].

The Study Area

The study area "Okigwe Local Government" is one, out of the 27 Local Government Areas found in Imo State. It is found between latitudes 5^0 56'24"N to 5^0 42'19"N and longitudes $7^0$12'58"E to $7^0$24'02"E (see figure 1). Okigwe Local Government is bounded to the North by Orumba South LGA of Anambra State and Umu-Nneochi LGA of Abia State, to the East by Isuikwato LGA of Abia State and to the South by Umuahia North LGA of Abia State, Ihitte/Uboma and Ehime Mbano LGAs both of Imo State while Onuimo and Ideato-North L.G.As both of Imo State forms the border to the west. The study area is sub - divided by the Port Harcourt – Enugu – Maiduguri rail line and the Port Harcourt – Enugu Expressway. Okigwe L.G.A has numerous tourist and historical attraction sites. It also has a number of secondary schools to include Federal Government College, Agbobu community secondary school, Community secondary school among others [28].The study area is mainly drained by Imo Rivers and its tributaries. The drainage pattern is mainly that of dendritic, and is characterized by slightly undulating topography, which shows that the area is somewhat hilly and about 70 m above the sea level. Like most towns in Nigeria, the study area often experiences two distinct climatic seasons; namely the dry season, which starts from October and ends in March and the wet season which starts from April and ends in September with annual rainfall varying from 1500mm to 2200mm. Within the dry season, a period of dry, dusty and cold known as "Harmattan" often occurs from December to February annually. The climate of the study area is tropical with a mean maximum monthly temperature of about 37ºC with an annual temperature between 23.5-32ºC which creates an annual relative humidity of 75%. Within the study area, the hottest months are between January and March [29].

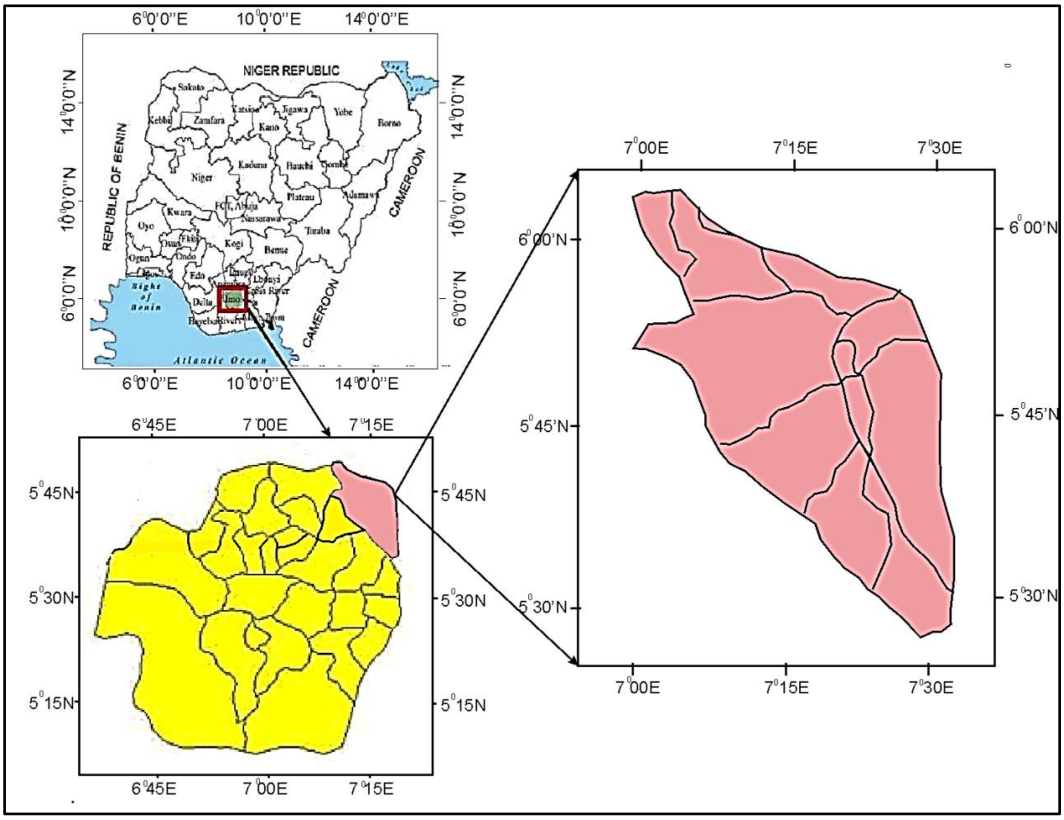

Figure 1: Location and extents of the study area (Author, 2018).

II. Material And Methods

Land use/Land cover distribution and change and Land Surface Temperature and change are two main sub – sections utilized in this study. Figure 2 shows the methodology flow diagram of the study.

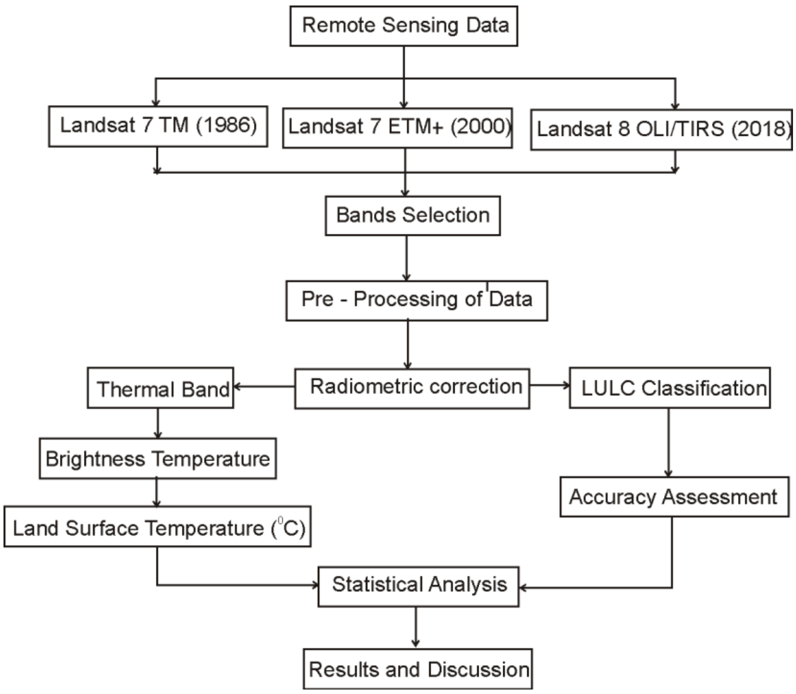

Figure 2: Methodology flow diagram for the study.

Data Used

Both primary and secondary data were adopted in the study to detect how land surface temperature (LST) is affected by the alteration in land use/land cover. The United State Geological Survey (USGS) provides the primary data of three Landsat images with spatial resolution of 30m. The first(1) Landsat TM – 5 is dated 19th December 1986; the second(2) Landsat ETM + is dated 17th December 2000; and the third(3) image of Landsat OLI/TIRS is dated 27th December 2018 (see table 1). Secondary data utilized for the study include relevant literatures, journal papers, online materials, and base map of Okigwe etc.

Table 1: Data type and sources

S/N	Date of acquisition	Path/row, scanner	Spatial resolution (m)	source
1	19 – Dec – 1986	188/56	30	USGS
2	17 – Dec – 2000	188/56	30	USGS
3	27 – Dec – 2018	188/56	30	USGS

Image Classification and Accuracy Assessment

To detect changes in the land use for this study at different epochs, LULC classification change detection techniques was used. ERDAS imagine software was used for the pixel-based classification for LULC changes for 1986, 2000 and 2018. Background, Built up areas, Water bodies, Bare land and Vegetation are the five selected LULC types. This study designated 40 training samples of 40 pixels for each land cover class. Supervised classification was performed using maximum likelihood classifier, and this involves identifying pixels possessing the same spectral features. Beside the field checked LULC maps, a field survey was also used as reference data.

Table 2: Classification Scheme adopted for the study*(Source: Modified from Anderson, 1967).*

Code	Land Use Categories	Description
1	Built – Up	This includes Land used for residential and transportation/ communication purposes (i.e. settlements and roads, high residential area, industry and administrative block).
2	Bare Land	This includes exposed soils, lands devoid of vegetal cover.
3	Vegetation	This includes Land covered with natural forest and natural vegetation that is predominantly grasses, shrubs and grass-like plants.
4	Water bodies	This includes areas covered by body of water e.g. dam, lake and rivers.
5	Farming	This includes areas that is spatially cultivated e.g. farmland, irrigation areas etc.

Land Surface Temperature Retrieval

Estimating the land surface temperature, comprises of various procedure and steps which have been describe by NASA.

Radiometric Calibrations

In terms of atmospheric correction, the digital numbers (DN) of the Landsat image were converted to normalized atmospheric reflectance using the equations below. The calibration parameters can be retrieved from the image head files and the NASA website.

$$L_{\lambda} = \text{GAIN x DN x BIAS} \quad (1)$$

Where;

Lλ is the normalized atmospheric reflectance at a particular wavelength.

Conversion to At Sensor Spectral Radiance (Qcal - to - Lλ)

The digital number (DN) of thermal infrared band is converted to spectral radiance (Lλ) using the equation produced by the Landsat user's hand book.

$$L_{\lambda} = \frac{LMAX - LMIN}{QCALMAX - QCALMIN}(QCALMAX - QCALMIN) \quad (2)$$

Where

LMAX	=	the spectral radiance that is scaled to QCALMAX in W/(m2 * sr * μm)
LMIN	=	the spectral radiance that is scaled to QCALMIN in W/(m2 * sr * μm)
QCALMAX	=	the maximum quantized calibrated pixel value (corresponding to LMAX) in DN = 255
QCALMIN	=	the minimum quantized calibrated pixel value (corresponding to LMIN) in DN = 1

Conversion to At - sensor Brightness Temperature ($L\lambda$ – to - T)

The thermal band data (Band 6 on ETM+ and band 10 and 11 on OLI) can be converted from at - sensor spectral radiance to effective at - sensor brightness temperature. The conversion formula from the at - sensor's spectral radiance to at- sensor brightness temperature is

$$L_{\lambda}= \frac{K2}{\text{In}\left(\frac{K1}{L\lambda}+1\right)} \qquad (3)$$

Where**;**

T = Top of Atmosphere Brightness Temperature, in Kelvin.

$L\lambda$ = Spectral radiance (Watts/(m2 * sr * µm))

K1 = Thermal conversion constant for the band (K1_CONSTANT_BAND_n from the metadata)

K^1 = Thermal conversion constant for the band (K2_CONSTANT_BAND_n from the metadata)

Temperatures were converted from degree Kelvin into degree Celsius by subtracting 272.15 from the result, which is the conversion rate of kelvin to Celsius.

Estimation of Land Surface Temperature (LST)

The final Land Surface Temperature (LST) is estimated using single window by the following equation

$$L_{\lambda}= \frac{TB}{1 + (\lambda + TB/\rho)\,\text{In}\ e} \qquad (4)$$

Where;

λ is the wavelength of the emitted radiance which is equal to 11.5µm. ρ h.c/σ, σ Stefan Boltzmann's constant which is equal to $5.67 \times 10^{-8} Wm^{-2} K^{-4}$, h Plank's constant ($6.626 \times 10^{-34}$ J Sec), c = velocity oflight (2.998×10^{8} m/sec) and ε is the spectral emissivity. In this study spectral emissivity is determined using the following equation

$$e = 0.004Pv + 0.986 \quad (5)$$

Where ;

Pv = proportion of vegetation and its computed from NDVI as follow

$$Pv= \left(\frac{NDVI – NDVIMIN}{NDVIMIN – NDVIMIN}\right)^{2} \quad (6)$$

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

III. Results

Land Use and Land Cover Distribution

The relative distribution of land use/land cover classes of the study area in 1986, 2000 and 2018 is represented in table 3. The land uses/land covers identified by this study were of five categories: which include: background, build up area, bare land, vegetation and water body.

Data Presentation (Tables, Histograms and Pie – Charts)

For this study, the results of the analysis are presented in statistical tables and histograms.

Table 3: Land-use/Land-cover proportion: 1986/2000

LULC of the study	Area in 1986 (km^2)	Area in 2000 (km^2)	Differences (change) between 1986 and 2000
Background	43.55	43.55	+0.00
Built – up	13.55	25.34	11.79
Bare Land	11.77	8.54	- 3.23
Vegetation	25.65	19.21	- 6.44
Water bodies	4.96	2.84	- 2.12

Table 4: Land-use/Land-cover proportion: 2000/2018

LULC of the study	Area in 2000 (km^2)	Area in 2018 (km^2)	Differences (change) between 2000 and 2018
Background	43.55	43.55	+0.00
Built – up	25.34	32.16	+6.82
Bare Land	8.54	9.12	+0.58
Vegetation	19.21	11.54	-7.67
Water bodies	2.84	3.11	+0.27

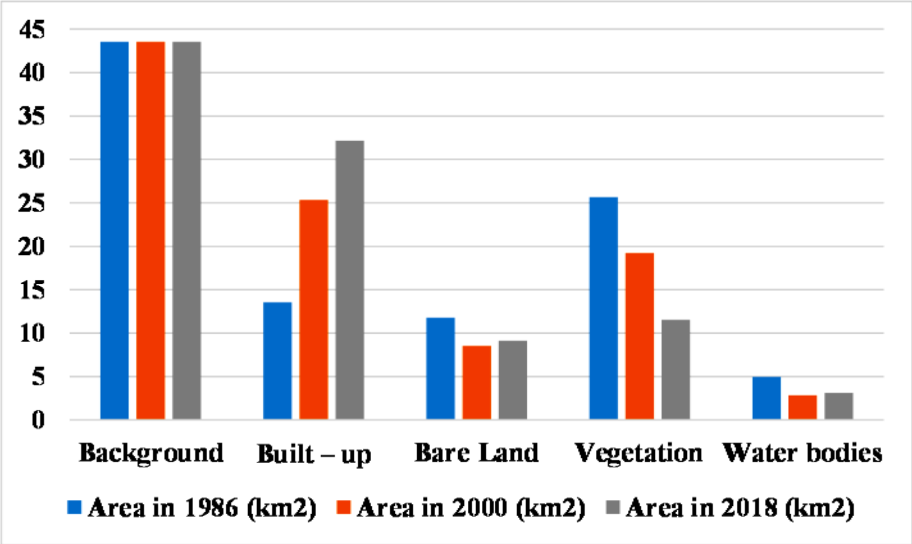

Figure 3: Bar – chart showing LULC changes for the study years (1986, 2000 and 2018)

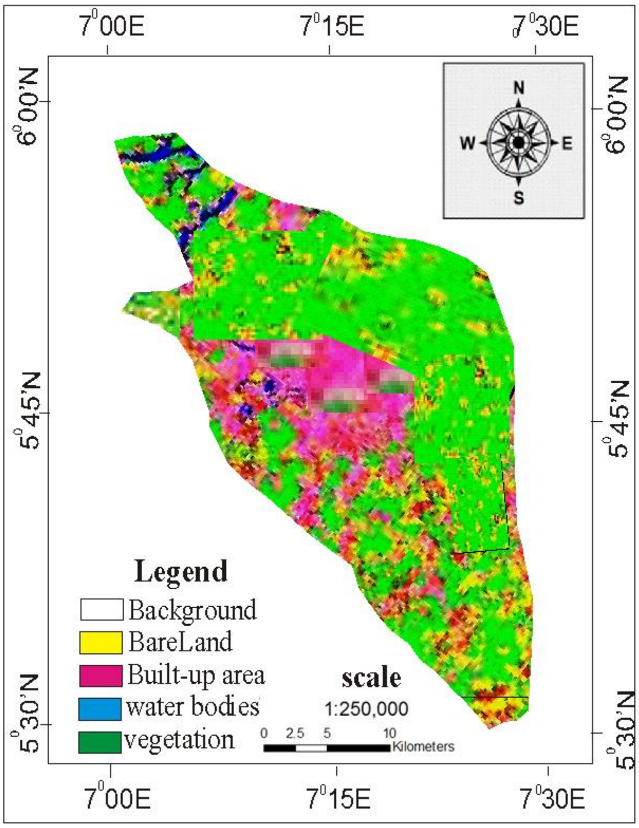

Figure 4: Land Use/Land Cover Change (LULC) Map for 1986

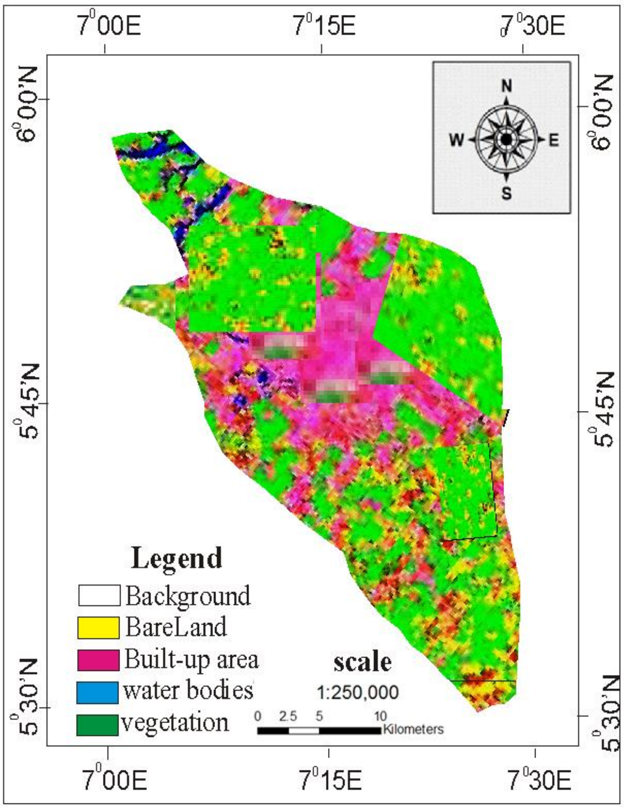

Figure 5: Land Use/Land Cover Change (LULC) Map for 2000

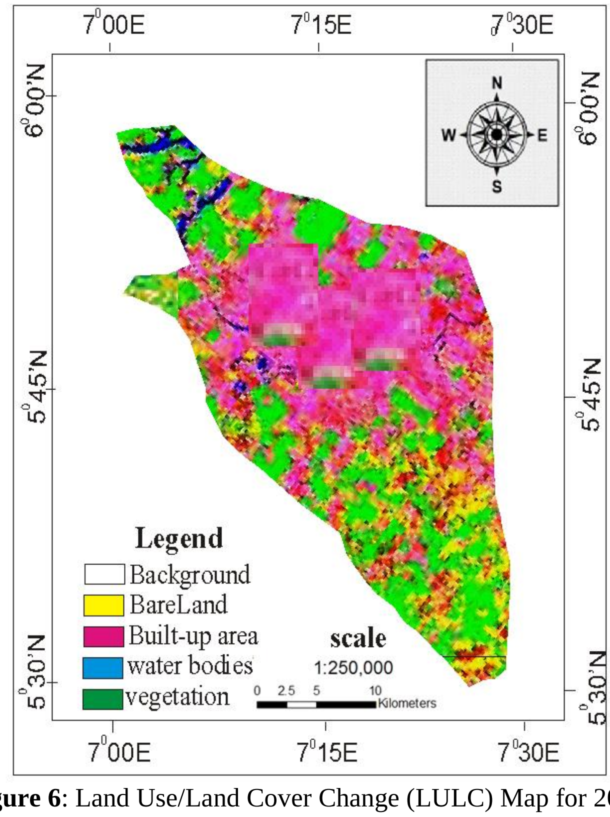

Figure 6: Land Use/Land Cover Change (LULC) Map for 2018

Detail Discussion of the Result of LULC Classification

Background: This category of LULC class was a constant with a value of 43.55 km^2 throughout the study period highlighting the same administrative area.

Built-Up Areas: There was a positive change in the built-up areas within the study. From the analysis of this study, the built-up areas was 13.55km^2in 1986 and increased to 25.34 km^2in 2000 with a positive difference of +11.79 and 32.16% in 2018 respectively. This shows an increase in population and infrastructure development in the study area.

Bare Land: This category of LULC class recorded both positive and negative change over the year under study. Bare surface proportion recorded11.77km^2in 1986, 8.54 km^2 in 2000 and 9.12 km^2 in 2018. This can be attributed to activities, such as over grazing, indiscriminate bush burning and fire wood extraction.

Vegetation: Vegetation LULC witness a steady decline from 1986 to 2018. In 1986, it was 25.65km^2 and in 2000, it was 19.21 km^2. In year 2018, it further decline to 11.54km^2. This maybeattributed to increase in the built – up area as well as the use of land for farming purpose to feed the ever increase population.

Water bodies: Like Bare land, this category of LULC class also recorded both positive and negative change over the year under study. In 1986, water bodies LULC shows 4.96 km^2, 2.84km^2in 2000 and 3.11 km^2 in 2018.. This may be due sand deposit, land reclamation and other developmental activities along the coast.

Land Surface Temperature

Land Surface Temperature has been established as an indicator of the presence of urban heat in cities and urban areas, and which have been proven in the study.

Land Surface Temperature, 1986

Figure 7 shows the temperature map, which highlight the temperature ranges for the year 1986. The range is somewhat below 18^{0}C to 28^{0}C. This expound that the year 1986 was a relatively cool year with the highest temperature range, put at 28^{0}C, the effect of the green areas dominant at that time is evident. The temperature (26^{0}C to 28^{0}C) indicates the highest temperature for this study, which shows more in the built – up areas while the range (23^{0}C to 25^{0}C) is the next highest and is recorded for bare land. The range (18^{0}C to 23^{0}C) is the lowest temperature record for vegetation land cover

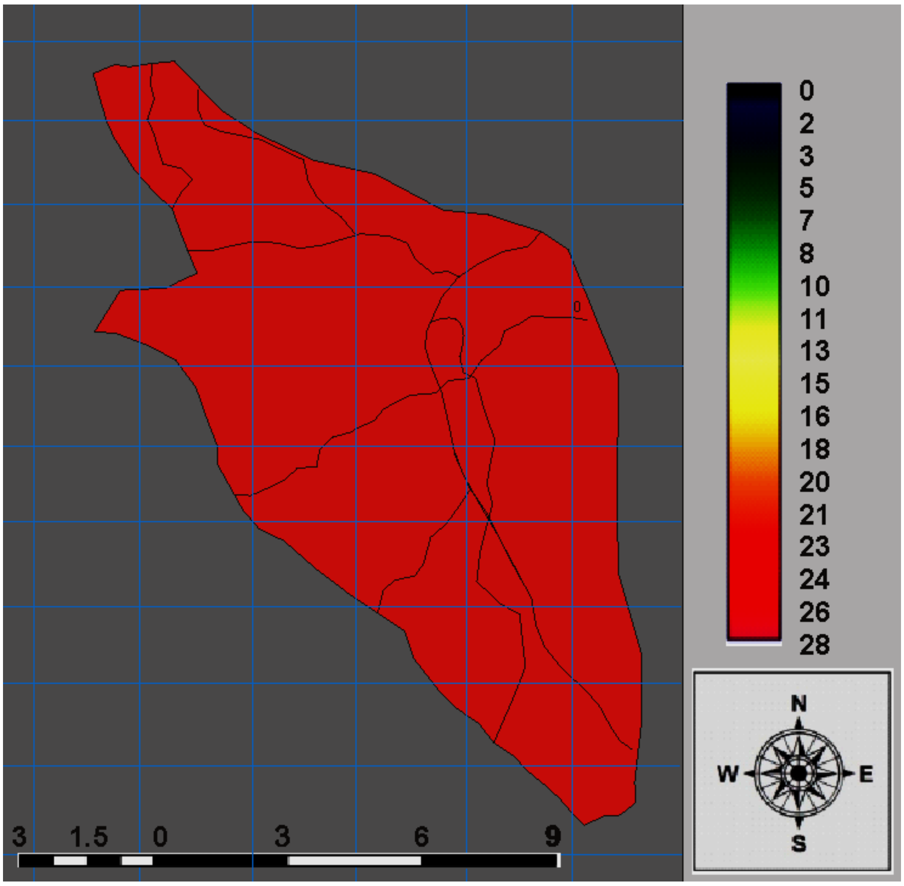

Figure 7: Land Surface Temperature Map, 1986

Land Surface Temperature, 2000

Figure 8 expounds the temperature map, which reflect the temperature ranges for the year 2000. The year 2000 experienced an increase in temperature (0^0C to 52^0C), as compared to the temperature range in the year 1986, which was (0^0C to 28^0C). Thus, the year 2000 was hotter than the year 1986. The built – up areas had a temperature range (48^0C to 50^0C),while bare land recorded a temperature range (45^0C to 47^0C) and vegetation land cover (32^0C to 35^0C).

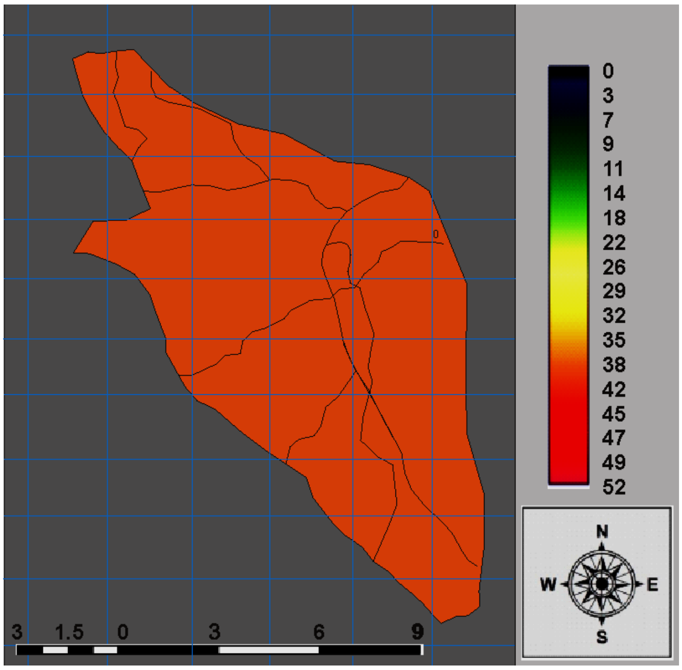

Figure 8: Land Surface Temperature Map, 2000.

Land Surface Temperature, 2018

Figure 9 shows the temperature map, which reflect the temperature ranges for the year 2018. The year 2018 experienced a decrease in temperature (0^0C to 46^0C) as compared to the temperature range for the year 2000, which was (0^0C to 52^0C) and an increase in temperature range (0^0C to 28^0C), as compare to the year 1986. Thus, the year 2018 was cooler than the year 2000 and hotter than the year 1986.

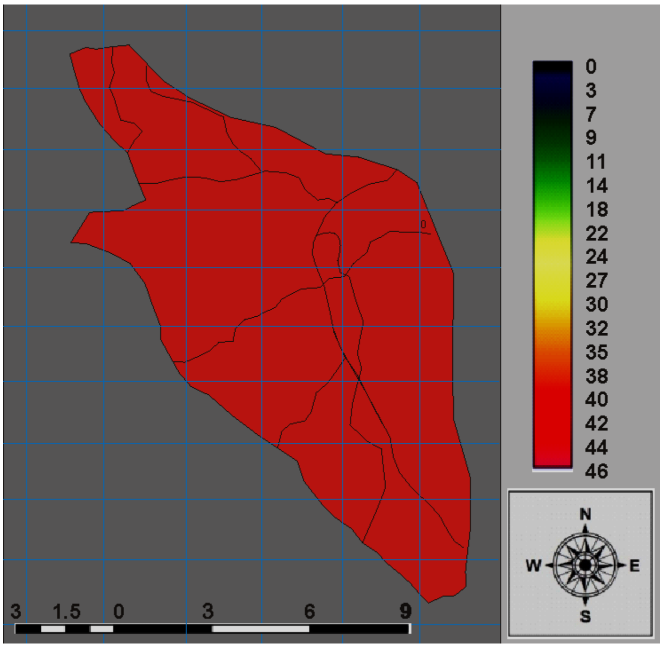

Figure 9: Land Surface Temperature Map, 2018.

Surface Temperature for the LULC of the study

Year 1986/2000

Table 5 clearly illustrate the land use class for 1986 and 2000 respectively and which is produced in terms of surface temperature, as well as the differences between both.

Table 5: Surface Temperature for LULC and their differences 1986/2000

LULC of the study	Average Temperature (^{0}C) for 1986	Average Temperature (^{0}C) for 2000	Differences between 1986 and 2000
Background	0.00	0.00	0.00
Built – up	25.20	43.50	18.30
Bare Land	21.00	35.00	14.00
Vegetation	19.00	34.50	15.50
Water bodies	15.00	26.50	11.50

From table 5, we see that built – up area gives 25.20 reflectance for 1986 and 43.50 for 2000. Bare-land, vegetation and water bodies shows 21.00, 19.00 and 15.00 respectively for 1986 and 35.00, 34.50 and 26.50 for year 2000. These land use/land cover classes recorded increased temperature from 1986 to 2000 (14 years), showing that the temperature in Okigwe is generally higher over a space of 14 years.

Year 2000/2018

Table 6 shows the land use class for 2000 and 2018 respectively in terms of surface temperature. The differences between the LULC of the study areas is also shown.

Table 6: Surface Temperature for LULC and their differences 2000/2018

LULC of the study	Average Temperature (^{0}C) for 2000	Average Temperature (^{0}C) for 2018	Differences between 2000 and 2018
Background	0.00	0.00	0.00
Built – up	43.50	41.00	- 2.50
Bare Land	35.00	33.50	- 1.50
Vegetation	34.50	31.00	- 3.00
Water bodies	26.50	22.80	- 3.70

Observing table 6, we see that built – up area gives 43.50 reflectance for 2000 and 41.00 for 2000, thus producing a difference of - 2.50. Bare land, vegetation and water bodies shows 35.00, 34.50 and 26.50 respectively for year 2000; and 33.50 and 31.00 and 22.80 for year 2018. The analysis show that the land use/land cover classes recorded decreased in temperature from 1986 to 2000, showing that the temperature in Okigwe is generally lower over these space of time.

IV. Conclusion And Recommendations

This study utilized remote sensing technology to monitor how changes in land use and land cover has impacted on the land surface temperature of Okigwe. Landsat 4 TM (1986), Landsat 7 ETM+ (2000) and Landsat 8 OLI/TIRS (2018) data were used to extract LST and LULC, which were then statistically analyzed, to establish any logical relationship between them. The Maximum Likelihood Classification proved to be a very efficient method in classifying the LULC over the FCC. Five LULC classes (background, built-up area, bareland, vegetation and waterbody) were identified. The results indicate that the study area has grown to become a relatively compact urban agglomeration. It recommends that further studies on the urban morphology of the FCC should adopt the local climate zone classification concept, which permit for a more detailed urban typology information extraction for the study.

References

[1]. Alsultan, S., Lim H., Matjafri M. and Abdullah K. (2005): An algorithm for land surface temperature analysis of remote sensing image coverage over Al Qassim, Saudi Arabia. In: From Pharoahs to Geoinformatics FIG working week and GSDI-8 Cairo, Eygpt, April 16 – 21.

[2]. Lo, C. P. and Quattrochi, D. A. (2003): Land – use and Land – cover change urban island phenomenon and health implications: A remote sensing approach: *Photogrammetric Engineering and Remote Sensing*, 69 (9): 1053 – 1063.

[3]. Douset, B. and Goumelon, F. (2003): Satellite multi – sensor data analysis of urban surface temperature and land cover: *Journal of Applied Photogrammetry and Remote Sensing*, 58 (1 – 2): 43 – 54.

[4]. Kumar, K. S., Bhaskar, P. U. and Padmakumari, K. (2012): Estimation of land surface temperature to study urban heat island effect using LANDSAT ETM+ image. *International Journal of Engineering Science and Technology*, 4 (2): 771 – 778.

[5]. Friedl, M. A. (2002): Forward and inverse modeling of land surface energy balance using surface temperature measurement*: Remote Sensing of Environment*: 79 (2 – 3): 344 – 354.

[6]. Renzullo, L. J., Barrett D. J., Marks A. S., Hill, M. J., Guerschman J. P., Mu Q. Z. and Running S. W. (2008): Multi – sensor model – data fusion for estimation of hydrologic and energy flux parameters: *Remote sensing of Environment*: 112 (4): 1306 – 1319.

[7]. Anderson, R. G. *et al* (2011): Biophysical considerations in forestry for climate protection. Front Ecology Environment: (9): pp 174 – 182.
[8]. Luck, M. and Wu, J. (2002): A gradient analysis of the landscape pattern of urbanization in the phoenix metropolitan area of USA. *Landscape Ecology* 17 (4): 327 – 339.
[9]. Svensson, M. K., and Eliasson, I. (2002): Diurnal air temperature in built-up area in relation to Urban planning. *Landscape and planning* 61(2002)37-54.
[10]. Sarrat, C. A., Lemonsu, V., Masson and Guedalia D. (2006): Impact of urban heat island on regional atmosphere pollution: *Atmospheric Environment*, 40: 1743 – 58.
[11]. Quattrochi, D. A. and Luvall, J. C. (1999): Thermal infrared remote sensing for analysis of landscape ecological processes: methods and applications. *Landscape ecology*, 14 (6), 577 – 598.
[12]. Xiao, R., Weng, Q., Quyang Z., Schienke E. W. and Zhang Z. (2008): Land Surface Temperature variation and major factors in Beijing China. *Photogrammetric Engineering and RS.*74 (4), 451 – 461.
[13]. Amirtham, L. and Devadas, M. (2009). Analysis Of Land Surface Temperature And Land Use/Land Cover Types Using Remote Sensing Imagery-A Case In Chennai City, India. *The 7th International Conference On Climate Change, Yokohama Japan,* 29th June -3rd July, 2009.
[14]. Abdullah, H. (2012): The use of Landsat – 5 TM Imagery to detect urban expansion and its impact on Land Surface Temperature in the city of Erbil, Iraqi Kurdistan, Master Thesis Leicester University, Leicester, UK.
[15]. Fu, P., Weng, Q. (2016): Time series analysis of urbanization induced Land Use/Land Cover change and its impact on Land Surface Temperature with Landsat imagery. *Remote Sensing of Environment*, 175, 205 – 214.
[16]. Weng, Q. (2001): A remote sensing – GIS evaluation of urban expansion and its impact of surface temperature in Zhujiang Delta China. *International Journal of Remote Sensing*, 22 (10), 1999 – 2014.
[17]. Zha, Y., Gao, J. and Ni, S. (2003). Use of Normalised Difference built-up index in Automatically, mapping Urban areas from TM Imagery. International Journal Of Remote Sensing 24:583-94.
[18]. Voogt, J. A. and Oke, T. R. (2003): Thermal remote sensing of urban areas: *Remote Sensing of Environment*; 86, 370 – 384.
[19]. Kato, S. and Yamaguchi, Y. (2005). Analysis of urban heat-island effect using ASTER and ETM+ Data: Separation of anthropogenic heat discharge and natural heat radiation from sensible heat flux. *Remote Sensing of Environment*.44-54. 10. 1016.
[20]. Mallick, J., Kant Y. and Bharath, B. (2008): Estimation of Land Surface Temperature over Delhi using Landsat 7 ETM. *J. IndGeophys*Vol 12, No 3, pages 131 – 140, 2008.
[21]. Luvall J., Lieberman D., Hartshon G. and Peralta R (1990): Estimation of tropical forest canopy temperatures, thermal response numbers and evapotranspiration using an aircraft – based thermal sensor. *Photogrammetry Engineering and Remote Sensing* 56 (10): 1393 – 1401.
[22]. Jin, M. and Dickinson, R. (1996): Correcting the orbit drift effect on AVHRR Land Surface skin temperature measurement. *International Journal Remote Sensing,* 24: 4543 – 4558.
[23]. Sun, D. and Rachel, T. (2003): Estimation of Land Surface Temperature from a Geostationary Operational Environmental Satellite. *Journal of Geophysical Research*, 108, 4326 – 4241.
[24]. Aires, F., Prigent C., Rossow W. and Rothstein M. (2001): A new neutral network approach including first – guess for retrival of atmospheric water vapour, cloud liquid water path, surface temperature and emissivity over land from satellite microwave observations. *Journal of Geophysical Review*: 106: 14887 – 14907.
[25]. Prata, A. J., Caselles, V., Coll C., Sobrine, J. and Ottle, C. (1995): Thermal remote sensing of Land Surface Temperature from satellites: Current status and future prospects. *Remote Sensing Reviews*, 12, 175 – 224.
[26]. Pinheiro, M. and Tucker, C. (2006): Development of a daily long term record of NOAA – 14, Land Surface Temperature over Africa: *Remote Sensing of Environment*, vol 103, pp 153 – 164.
[27]. Wang S., Ma Q, Ding H. and Liang H. (2016): Detection of urban expansion and Land Surface Temperature change using multi – temporal Landsat images. Resource Conservation Recycling, pp 10, 1016.
[28]. Wikipedia, the free encyclopaedia (2018).
[29]. Nigeria Meteorological Agency (NIMET,2018).

Okereke, Chukwudi Andy. "Analysis of Land Surface Temperature and Land use/Land cover types in OkigweImo State Nigeria using Remote sensing and GIS Technology." IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT) 13.5(2019): 74-84.