Evaluation of the Relationship between Land Use/Land Cover Dynamics and Land Surface Temperature across the Niger Delta Region of Nigeria

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Abstract

The Niger delta region of Nigeria being the sole oil producing region of the nation has witness increase anthropogenic activities over the last three decades. These activities have had serious impact on the natural Land use/land cover and it is believed that this has in turn affected the Land Surface Temperature (LST) dynamics. Hence, this research seeks to investigate the relationship between Land use/Land cover(LULC) change and Land Surface Temperature (LST). Landsat 5(TM), 7 (ETM+) and 8 (OLI) images of 1986, 2002 and 2016 were used for the land use/land cover classification and the thermal bands of the corresponding Landsat was used to obtain the Land surface temperature. The three dataset of images were classified into seven LULC classes using supervised maximum likelihood algorithm and the LST maps for the corresponding years (1986, 2002 & 2016) of Landsat were also generated. ArcGIS was then used to evaluate the relationship between Land use/land cover and land surface temperature (LST). The result indicated that LST changes followed the pattern of LULC changes overtime and the Heat Intensity appears to be at the peak in the high density settlement areas and low at the vegetated areas. The analysis revealed an increase of LST by 1.78 ^{0}C during the 30years period considered at the rate of 0.059^{0}C/year in high density built up due to increase in settlement growth. The study concluded that a change in Land Use Land cover has an impact on the land surface temperature in the Niger delta region of Nigeria.

Keywords: *Land use/Land cover change, Land Surface Temperature, Relationship between LULC & LST; Niger Delta Region;*

I. INTRODUCTION

There have been so much changes across the eco-environment of Niger Delta Region of Nigeria since the discovery of oil in commercial quantity. Increase anthropogenic activities aiming at exploring and exploiting the natural resources in the region has given rise to alteration of the natural Land use/land cover and it is believed that this has in turn affected the Land Surface Temperature (LST) dynamics. Since the 1970s, satellite remotely sensed data has been offering considerable advantages in monitoring environmental changes, especially for detecting Land use/land cover changes and retrieving land surface temperature (LST). Also, availability of these remotely sensed data on a time series bases makes investigation of environmental phenomenon such as Land use/land cover, land surface temperature (LST) etc. achievable. Orhan et al., (2014), opined that remote sensing is extremely useful for understanding the Spatio-temporal land cover change in relation to the basic physical properties in terms of the surface radiance and emissivity data. Weng, (2001), Lilly et al. (2009), Jiang and Tian (2010), Falahatkar et al., (2011), Zhi-qiang and Zhou, (2011), Omran (2012), Srivanit et al. (2012), Xian and Crane (2015) etc. in their studies, all corroborated that land use/cover change can alter Land surface temperature significantly. Thus investigating the relationship between LULC change and LST for a region like Niger Delta that has experience serious eco-environment alteration is pertinent. Hence the aim of this study is to evaluate the relationship between Land use/land cover and land surface temperature (LST) from 1986-2016 using Remote sensing and Geographic Information System Technique.

II. MATERIAL AND METHOD

A. Study Area

The Niger Delta Region (shown in Figure 1) lies in the southern part of Nigeria where the River Niger divides into numerous tributaries ending at the edge of the Atlantic Ocean. It is bordered to the south by the Atlantic Ocean and to the east by Cameroon. It lies between longitude 4º 30’ - 9º 50’E and Latitude 4º 10’ - 8º 0’N. The temperature in the region is between

24°C to 32°C throughout the year, rainfall ranges from 3000- 4500mm. The region has two seasons: dry season (starting around December- February) and the rainy season (starting around July- September) [Nwilo & Badejo, 2006]. The region covers nine southern states namely: Cross River, Akwa Ibom, Abia, Imo, River, Bayelsa, Delta, Edo and Ondo state with more than 40 ethnic groups and has about 250 different dialects (NDRDMP, 2004). The region is the sole oil producing basin since the discovery of oil in commercial quantity in 1965. The region is asserted to be the main source of export earnings to Nigeria. Records has it that oil and gas earnings from the region funds 85% of the Nation's yearly budget; and contribute about 95% of Gross Domestic Product (GDP) (Dokubo 2004; NDRDMP, 2004; Ebegbulem et al., 2013; Ringim 2016). A United Nations' report indicates that there are more than 7,000kilometres of pipelines, 5,284 oil wells, 275 flow stations, 10 Gas plants, and 10 Export Terminals operated by more than 13 oil companies (UN Report, 2006).

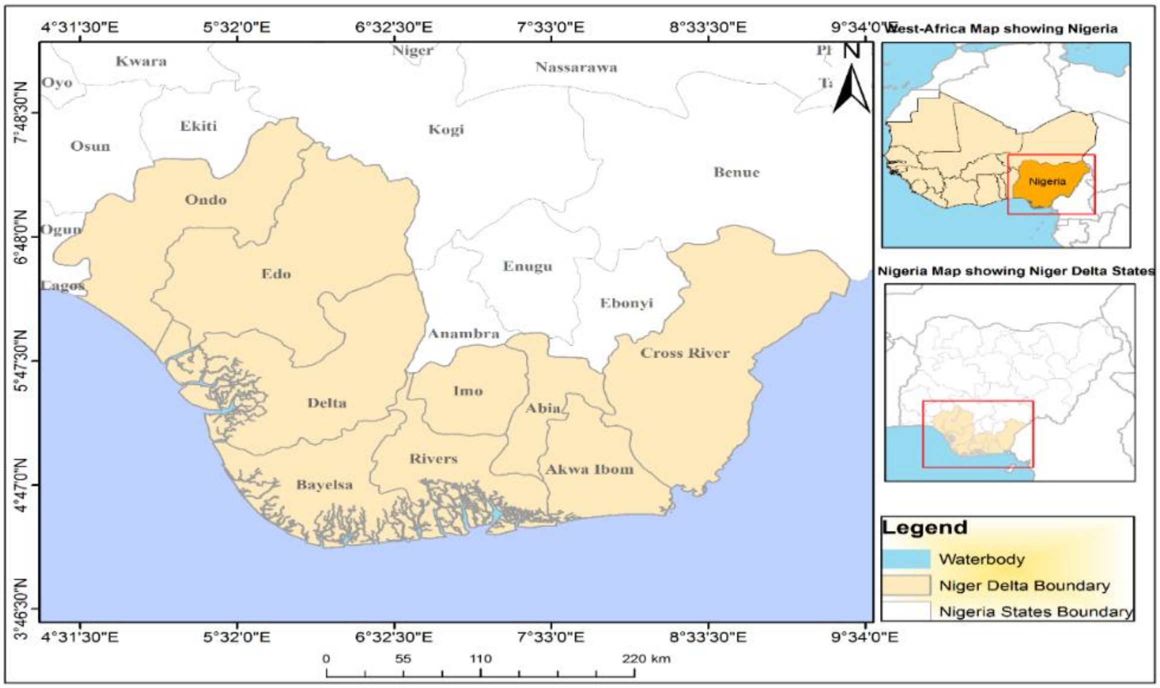

Figure 1: Study Area in Relation to West Africa and Nigeria

B. Data

Landsat 5(TM), Landsat 7 (ETM+) and Landsat 8 (OLI) images (multispectral and Thermal Infrared band) of 1986, 2002 and 2016 were used. The eleven Landsat scenes (path 187/row 55, 56 & 57; path 188/row 55, 56 & 57; path 189/row 55, 56 & 57; and path 190/row 55 & 56) that covers the entire study area were obtained from the United State Geological Surveys (USGS) and NASA Earth Observatory website. These datasets were all acquired in the dry season in order to minimize seasonality variations.

Table 1. Imageries Attributes.

Acquisition Year	Sensor	Spatial Resolution	Path/Row	Landsat	Number of Bands	Radiometric Resolution
2016	OLI-TIRS	30 m	187-190/55-57	Landsat 8	11	16 bits
2002	ETM	30 m	187-190/55-57	Landsat 7	8	8 bits
1986	TM	30 m	187-190/55-57	Landsat 5	7	8 bits

OLI-TIRS: Operational Land Imager-Thermal Infrared Sensor; ETM: Enhance Thematic Mapper; TM: Thematic Mapper

1) Image Processing and Data Preparation

For the eleven Landsat scenes of images to be use together for spatial and temporal analysis of LULC change studies, image processing was carefully carried using ERDAS IMAGINE and ENVI software.

2) Atmospheric and Radiometric Correction

For a successful operation of atmospheric and radiometric correction, ATCOR for ERDAS IMAGINE was used. ACTOR is an application which can be installed as an extension in ERDAS Imagine and used for atmospheric and radiometric correction. There are two ATCOR models available, one for satellite imagery, the other one for airborne imagery. The application uses various sensor-specific parameters describing the geometry and radiometry of the target image to implement atmospheric correction. The required input data are usually recorded by the earth observing satellite vendor as a metadata file. Hence, for this study, the metadata information was extracted and used to build calibration parameter in excel and then imported to ATCOR in ERDAS IMAGINE to implement atmospheric correction of each scene of Landsat 5-TM, Landsat 7 ETM+, Landsat 8-OLI images respectively. The steps are as follows:

I. Extraction of metadata information from landsat5_TM, landsat7_TM+, and landsat8_OLI(...MTL.txt)

II. Generation of calibration file [landsat5_ TM _template.cal, landsat7_ ETM+_template.cal, landsat8_oli_template.cal] which is a template that only need to be updated to the actual values for c0 and c1. That is the respective values of Gain (multiplicative value [c1]) and Bias (additive value [c0]) available and extracted from the Meta data (...MTL.txt) as RADIANCE values.

From the min/max radiance for each band, Lmax, Lmin , the radiometric offset c0 and slope or gain c1 for ATCOR's ".cal" file are calculated as :

$$c0=0,1*Lmin \quad \ldots(1)$$

$$c1=0,1*Lmax-Lmin255 \quad \ldots(2)$$

The factor 0.1 converts from radiance unit [W(m2* s-1* μ-1)] into the ATCOR for ERDAS IMAGINE radiance unit [mW/(m2 * sr1* μm1)].

III. The generated calibration file along with the sun elevation angle (as at the time the image was acquired) was then used to implement atmospheric correction in the ATCOR module in ERDAS IMAGINE environment for each scene of Landsat 5-TM, Landsat 7 ETM+, Landsat 8-OLI images respectively.

3) Geometric Correction and Final Data Preparation

Geometric correction aimed at rectifying image coordinates to existing ground coordinates. All the Landsat images being a level IG fully processed product implied that the image was geometrically standardized. Nevertheless, as a check, the ground point coordinates spread across the study area were charted on the images using ENVI software and they corresponded without significant difference. Furthermore, Landsat 5-TM and Landsat 7 ETM+ images were co-registered to Landsat 8-OLI being the most recent image. This final geometric operation ensured that Landsat 5-TM, Landsat 7 ETM+, Landsat 8-OLI images were all rectify together. Finally, subseting and integration was done to generate/extract the spatial extent of the study area from eleven scene of Landsat images.

C. Development of Image Classification Scheme and Land Use/Land Cover classification

Since Image classification is the process of assigning pixels of continuous raster image to pre-defined land cover classes, there was need for development of classification scheme. Hence, before the image were classified, field reconnaissance was carried out to identify and developed land use/land cover classes. The land use/land cover classes identified and used for the study were as shown in Table 2.

Table2: LULC Classes and Description

LULC Class Name	Description
Waterbody	All the water bodies, ocean, rivers, stream, lagoons, creeks, etc
High density Built up	City centers, commercial/industrial areas, high density residential settlements.
Low Density built up/Exposed Surface	All low density settlements and bare/exposed surfaces within built up area.
Forest	Primary Evergreen forested areas and forest reserves.
Sand Deposit	Sand bars and sediment deposit without any vegetation.
Vegetation	Lightly forested areas, cultivated lands and farmlands mixed with light forestation.
Mangrove	Mangrove, swamps/wetlands.

Also, reasonable number of ground control points belonging to corresponding land use land cover classes were acquired in the field across the study area. In this study image classification was done by performing supervised maximum likelihood classification in ERDAS IMAGINE and further LULC analysis was done in IDRISI and ArcGIS software. Accuracy assessment was also carried out using ground control points acquired during field ground truth along with historical map information of the study area.

D. Development of Models using ArcGIS 10.1 for Land Surface Temperature Retrieval

Land Surface Temperature (LST) for each pixel was computed from thermal bands of 1986-Landsat 5 TM; 2002-Landsat 7 ETM^+ and 2016-Landsat 8 OLI. The LST computation includes several steps including Converting digital numbers (DN) to spectral radiance (L), Converting spectral radiance to Kelvin temperature (TB °K), Correcting Emissivity and Conversion of Kelvin temperature to Celsius. Using equation 3, 4, 5 and 6, ArcGIS was used to develop model for efficient calculations of those components.

1) Converting Digital Numbers (DN) to Spectral Radiance (L)

$L = Lmin + (Lmax – Lmin) * (DN/2^n-1)$ …(3)

where: L is the spectral radiance; L_{min} is the spectral radiance that is scaled to QCALMIN; L_{max} is the spectral radiance that is scaled to QCALMAX; QCAL is the DN. A model was built in ArcGIS for it calculation.

2) Converting Spectral Radiance to Kelvin Temperature (T °K)

$T\,°K = K2 / \ln\left(\frac{K1}{L} + 1\right)$ …(4)

where $T^{o}k$ is radiant surface temperature (in Kelvin); K2 is calibration constant 2; K1 is calibration constant 1; and L is the spectral radiance at sensor. Table 1 shows the Sensors Constant Calibration information.

Table 3: Sensors Constant Calibration Information.

	Landsat 5 TM	Landsat 7 ETM^+	Landsat 8 OLI
K1	607.76	666.09	774.89
K2	1260.56	1282.71	1321.8

3) Correcting Emissivity

$T_s°K = T\,°K / (1 + (\lambda * T\,°K / \rho) \ln\varepsilon$ …(5)

Where;

Ts - is the emissivity corrected Land Surface Temperature in degrees Kelvin;

λ is the wavelength (11.5μm);

$\rho = h\times c/ \delta = (1.438\times10^{-2}$ m K $= 1.438 \times 10^{-8}$ μmk);

ε is emissivity (0.92);

h - is Planck's constant=6.626×10^{-34} J/s;

c - is Velocity of light=2.998×10^{8} m/s and

δ - is Boltzman's constant=1.38×10^{-23}J/k

4) Conversion of Kelvin Temperature to LST in Celsius

$LST_C = Ts -273$ … (6)

where LST_C is temperature in degree Celsius and Ts is the emissivity corrected Land Surface Temperature in degrees Kelvin.

III. DATA ANALYSIS AND RESULT DISCUSSION

This section presents and discusses the results of LULC classification, evaluation of LST and the relationship between LULC and LST.

A. LULC Classification Results

The classified LULC distribution maps of the respective years are presented in figures 2, 3 & 4. Also, the magnitude and percentages of LULC are presented in table 3, 4, & 5. All the three classified LULC images of 1986, 2002, and 2016 were subjected to accuracy assessment. The overall classification accuracy was 66.7% for 1986; 70.10% for 2002 and 74.50% for 2016. KAPPA (K^) statistics was 0.60, 0.64 and 0.70 for 1986, 2002 and 2016 respectively. The high density built-up areas had higher percentages of both user' (83%, 86% and 90% respectively) and producer' (71%, 86% and 84% respectively) accuracies followed by low density built-up areas/exposed surfaces.

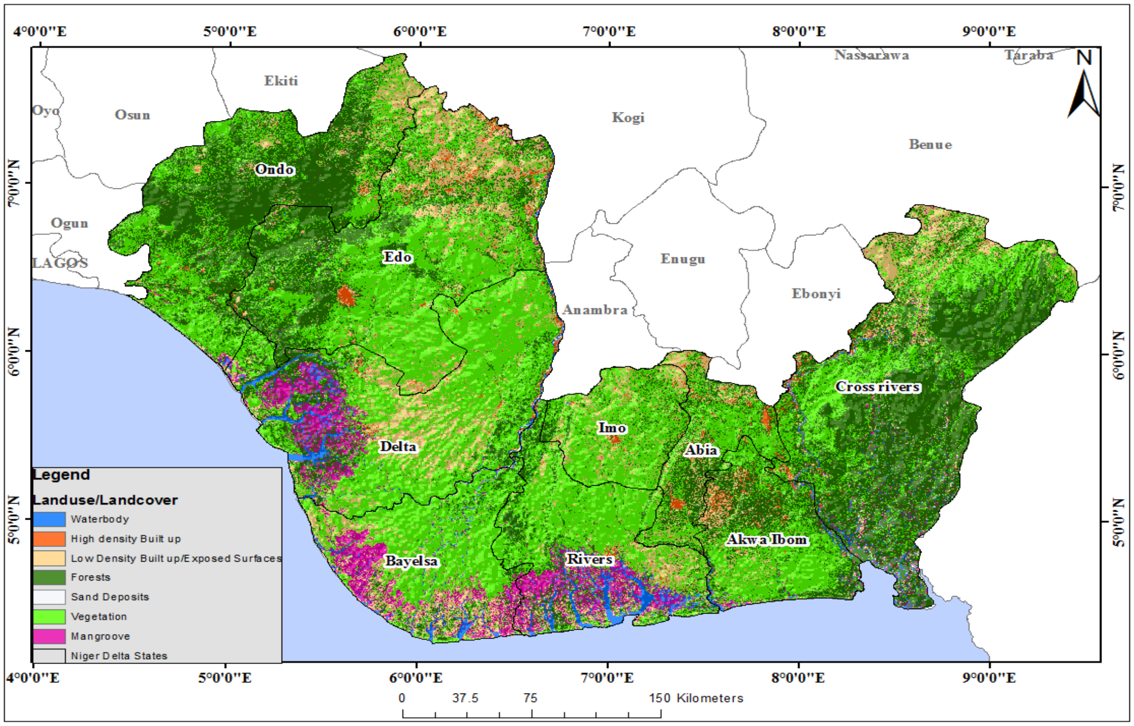

Figure 2: 1986 LULC Map of Niger Delta Region, Nigeria

The map of figure 2 above shows the initial distribution of LULC of in 1986. It could be seen that the study area was a healthy eco-environment as a greater part of it environment was still naturally vegetated environment. A large magnitude of forest could be seen clearly in Ondo, Edo, Akwa Ibom, Cross River and the boundary between Delta, Imo and Rivers states.

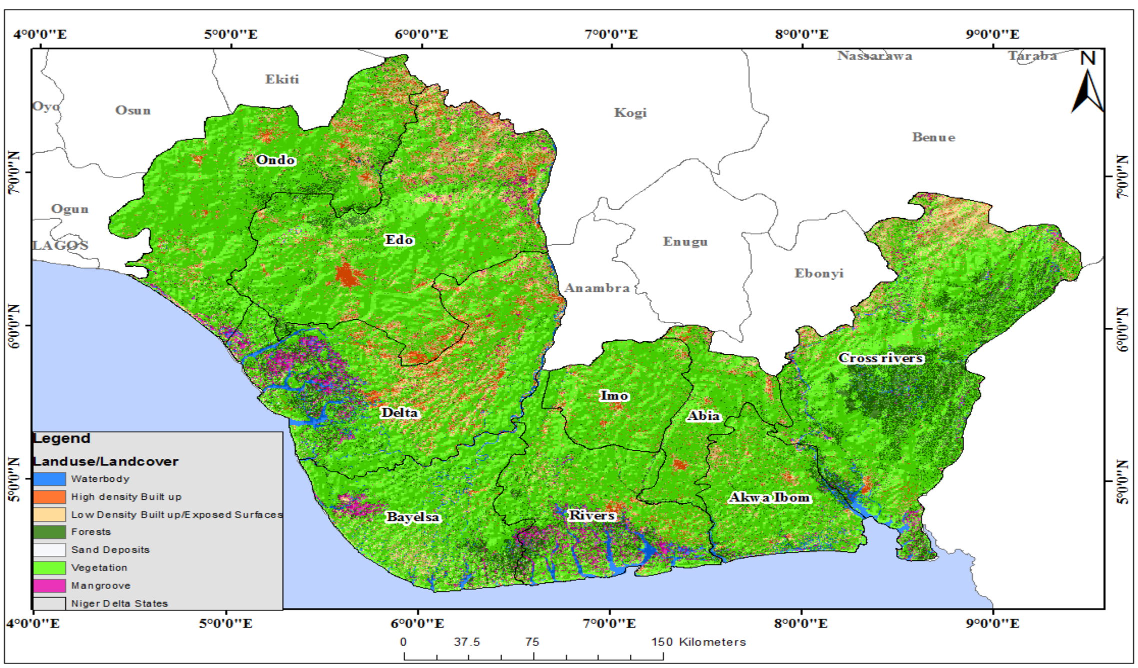

Figure 3: 2002 LULC Map of Niger Delta Region, Nigeria

Comparing the 1986 Land use/Land cover Map of study area shown in figure 2 and the spatial distribution of Land use/Land cover for the year 2002 shown in figure 3, it could be seen clearly that there has been alteration. The spatial extent of high density built up, low density built up/exposed surface, water, sand deposit and vegetation increased whereas, the forested area suffered depletion mostly in Ondo, Edo, Akwa Ibom, Cross River and the boundary between Delta, Imo and Rivers states. The mangrove was depleted mostly in the core oil producing states of Bayelsa, Rivers, Akwa Ibom and Delta States as a result of over two thousand incidents of oil spill that occurred between 1997 and 2002.

The Percentage trend of LULC magnitude for the three years (1986, 2002 and 2016) is as shown in table 4 below.

Table 4: Percentage trend of LULC magnitude

Land use/Land cover	Year 1986 (%)	Year 2002 (%)	Year 2016 (%)
Waterbody	2.41	2.56	4.11
High density Built up	1.31	3.83	4.00
Low Density built up/Exposed Surface	12.91	11.24	24.28
Forest	33.86	9.29	7.00
Sand Deposit	0.22	0.21	0.04
Vegetation	44.68	69.86	50.23
Mangrove	4.62	3.03	10.34

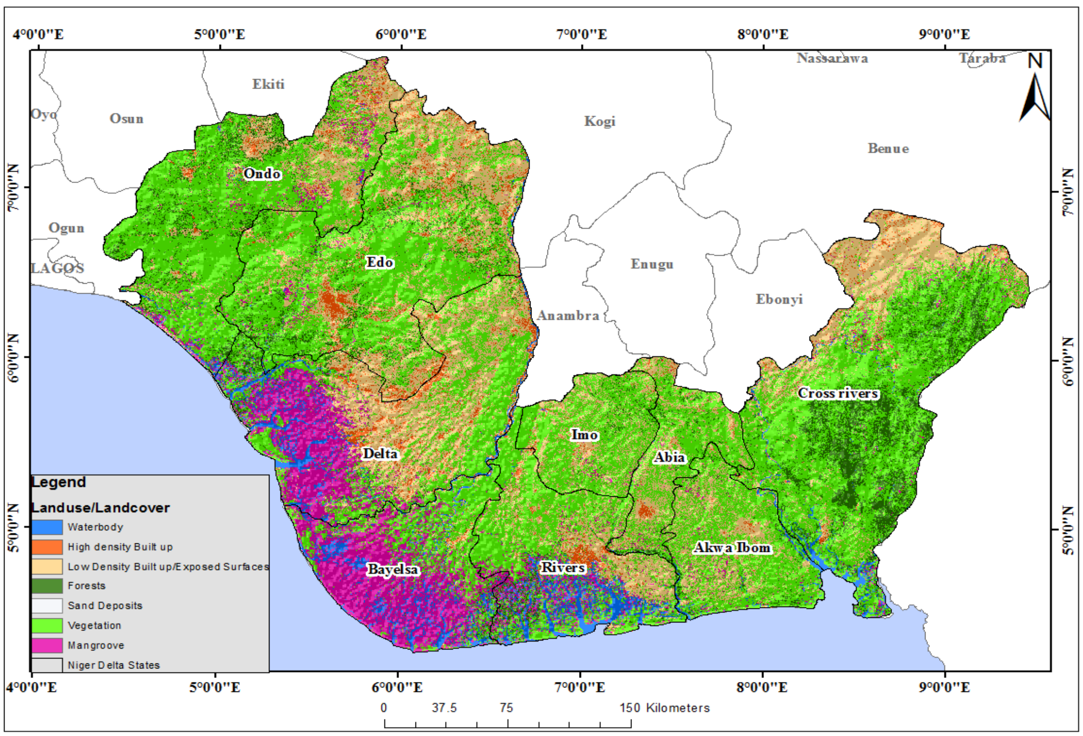

Figure 4: 2016 LULC of Niger Delta Region, Nigeria

In 2016, almost similar trend of increase in 2002 occurred. The map of figure 4 and table 4 shows that high density built up and low density built up/exposed surface continue to increase and depletion of the forest continued in virtually all the states. But vegetation magnitude this time was reduced in all the states as a result of settlements sprawl and mangrove surprisingly was increased in all the coastal states probably due to improved strategy of oil spillage amelioration and amnesty intervention that reduced the incident of pipeline vandalism.

B. Land Surface Temperature Result and Discussion

This section illustrates the spatial distribution of Land Surface Temperature in the year 1986, 2002 and 2016 and also accesses the dynamics across the years.

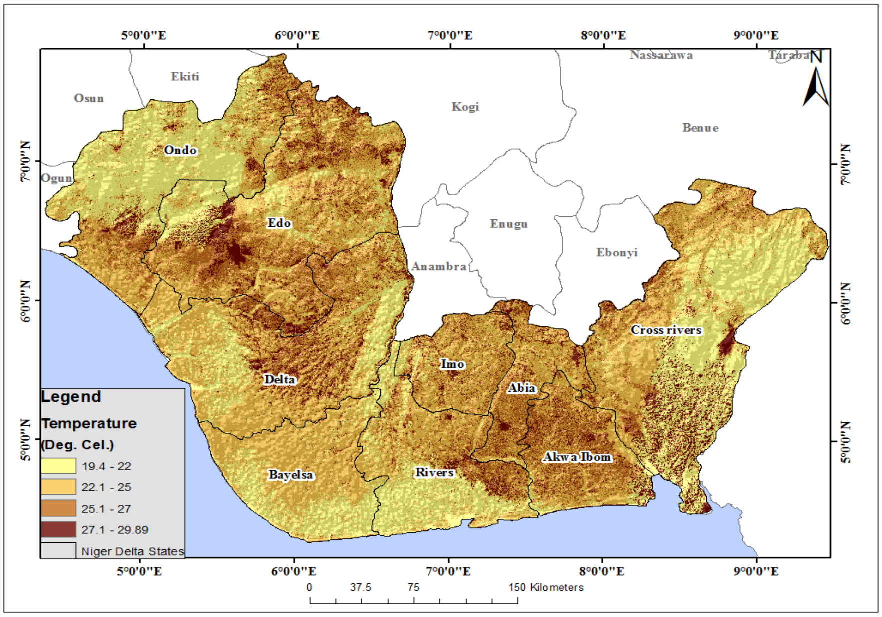

Figure 5: Map showing the spatial Pattern of LST across Niger Delta States in 1986

Figure 5 above shows the spatial distribution of Land Surface Temperature in the year 1986. As at 1986, the lowest Land Surface temperature (LST) was from 19.4 ^{0}C while the highest LST was about 29.89^{0}C distributed across the study area.

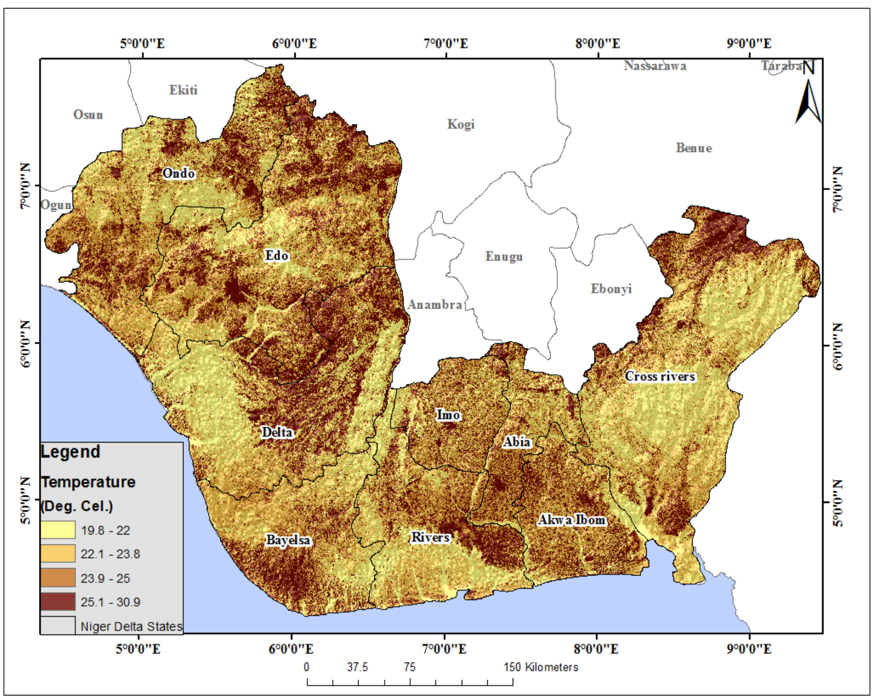

Figure 6: Map showing the spatial Pattern of LST across Niger Delta States in 2002

Year 2002 showed increase in the temperature as compared to the year 1986 with the minimum LST of about 19.8^{0}C while the maximum temperature was about 30.9 ^{0}C.

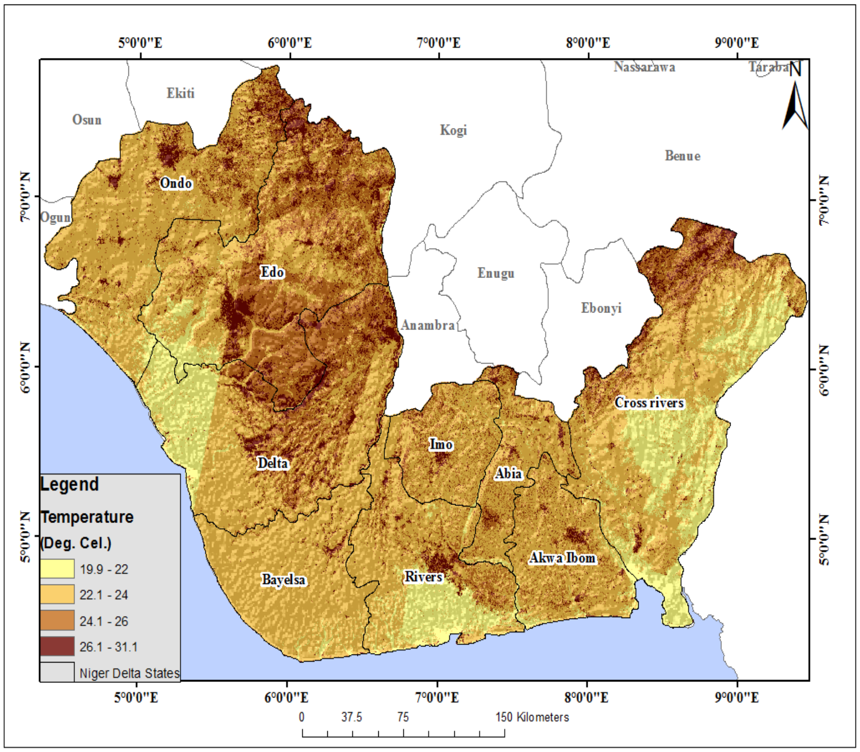

Figure 7: Map Showing the Spatial Pattern of LST Across Niger Delta States in 2016

The Result of LST assessment indicated that LST continued to increase across the 30years period. As at 1986 the lowest LST was 19.4 ^{0}C while the highest LST was 29.89^{0}C but in 2002 it increased to a minimum of 19.8^{0}C while the maximum temperature rose to 30.9 ^{0}C and in 2016 it ranges further increased to lowest of 19.9^{0}C and maximum of 31.1^{0}C.

C. Evaluation of the Relationship/Impact of LULC change and LST Across the Study Area

Relationship between Land use/Land cover (LULC) and Land Surface Temperature (LST) derived from Landsat was examined for 1986, 2002, 2016 and between 1986-2002, 2002-2016 and 1986-2016 using a model created in ArcGIS as illustrated in the methodology. The results are presented in this section.

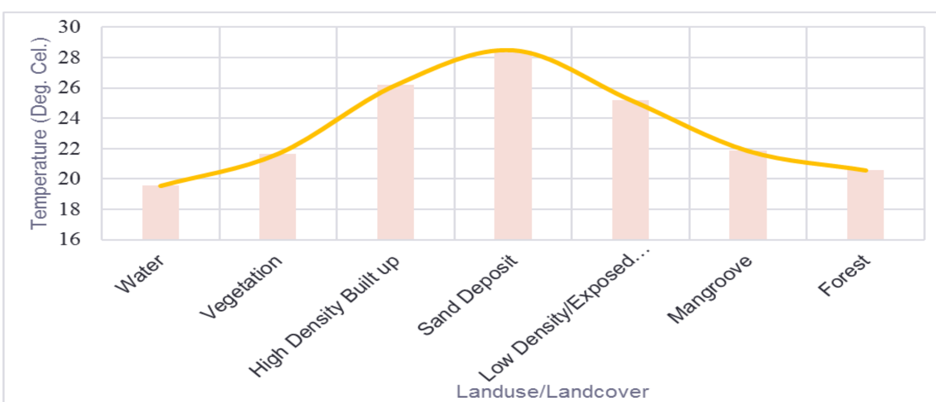

Figure 8: Chart Showing the Relationship Between LST and LULC for Year 1986.

Table 5: Mean LST Values across LULC types for Year 1986

LULC	Mean LST (^{0}C)
Water	19.57
Vegetation	21.68
High Density Built up	26.18
Sand Deposit	28.47
Low Density/Exposed Surface	25.20
Mangrove	21.86
Forest	20.59

Sand deposit, exposed surface and High density built up area showed high LST values of 28.47 ^{0}C and 26.18 ^{0}C while forest and water had a low LST values of 19.57 ^{0}C and 20.59 ^{0}C respectively.

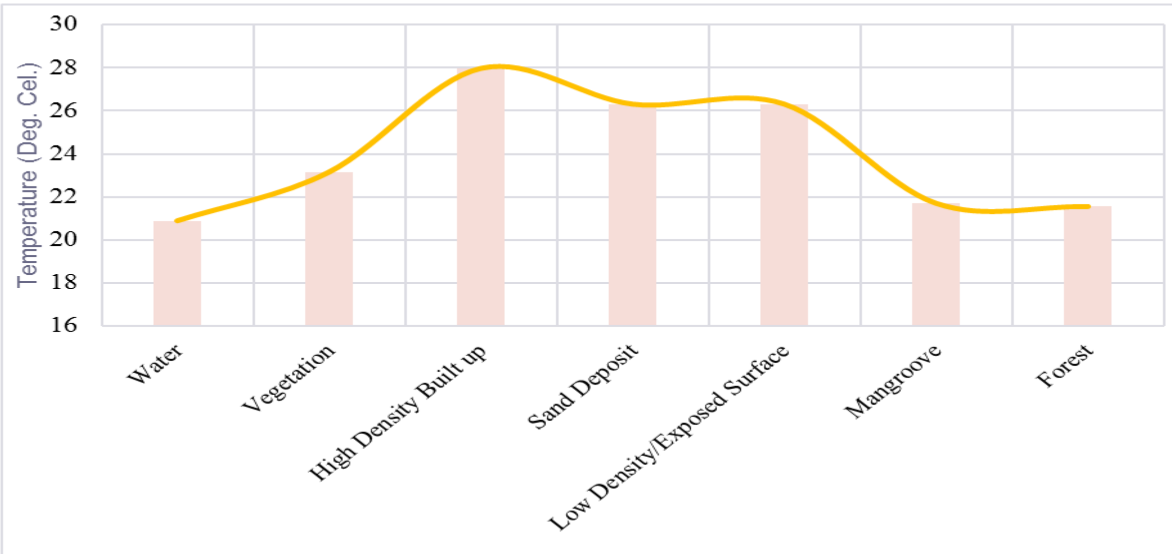

Figure 9: Chart Showing the Relationship Between LST and LULC for year 2002

Table 6: Mean LST Values Across LULC Types for Year 2002

LULC	Mean LST (^{0}C)
Water	20.89
Vegetation	23.15
High Density Built up	27.96
Sand Deposit	26.30
Low Density/Exposed Surface	26.30
Mangrove	21.70
Forest	21.55

Due to Increase in settlement growth in 2002, the high density built up had the highest temperature 27.96 ^{0}C due to the high latent heat capacity, while waterbody, forest, mangrove and vegetation had the low LST values.

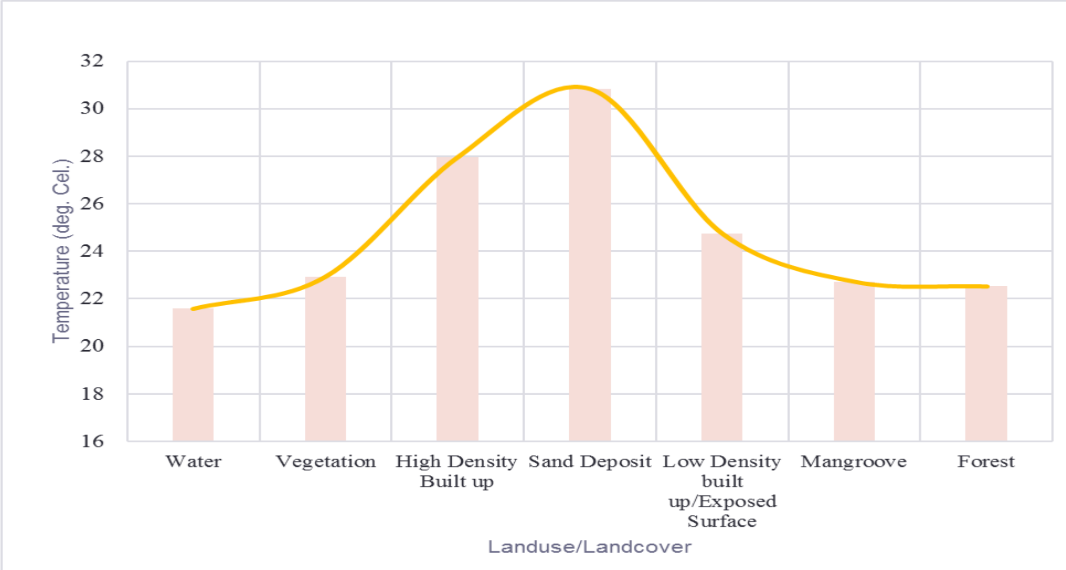

Figure 10: Chart Showing the Relationship Between LST and LULC for Year 2016.

Table 7: Mean LST Values Across LULC Types for Year 2016

LULC	Mean LST(^{0}C)
Water	21.59
Vegetation	22.94
High Density Built up	27.96
Sand Deposit	30.83
Low Density /Exposed Surface	24.75
Mangrove	22.73
Forest	22.53

Year 2016 showed similar trend in temperature across the different LULC types as the previous years with sand deposit having the highest temperature while waterbody, forest, mangrove and vegetation had the low LST values.

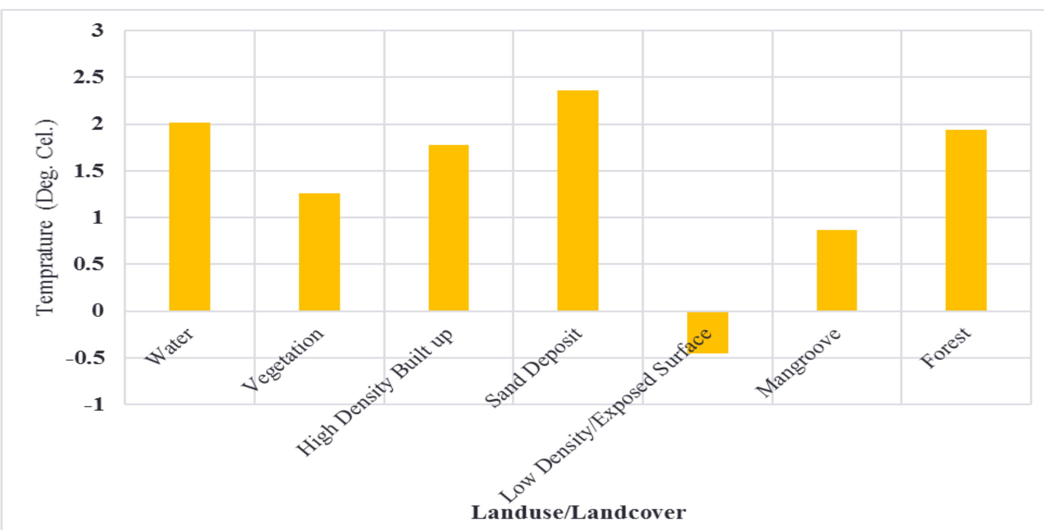

Figure 11: Chart Showing the Difference in LST Values (year 1986 to 2016)

Table 8: Difference in LST value (1986-2016)

LULC	LST Difference(^{0}C)
Water	2.02
Vegetation	1.26
High Density Built up	1.78
Sand Deposit	2.36
Low Density/Exposed Surface	-0.45
Mangrove	0.87
Forest	1.94

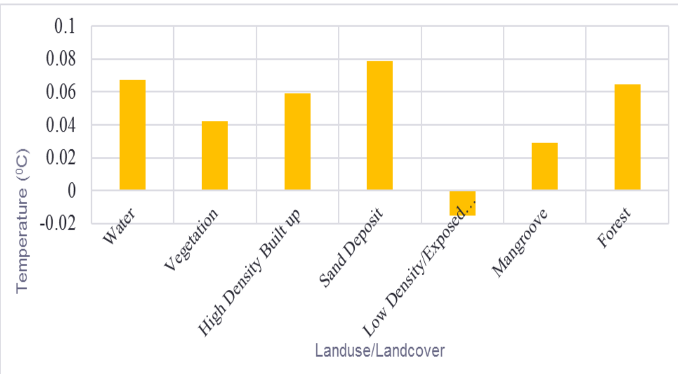

Figure 12: Chart Showing the Rate of LST/LULC (1986-2016).

Exposed surface showed reduction in the temperature which corresponds to the reduction of exposed surface between the year 1986 and 2016. while Sand deposit showed increased temperature by 2.02 ^{0}C.

LULC	Rate (^{0} C/ year)
Water	0.067
Vegetation	0.042
High Density Built up	0.059
Sand Deposit	0.078
Low Density/Exposed Surface	-0.015
Mangrove	0.029
Forest	0.064

Table 9: Rate of Change in LST/LULC (1986-2016)

IV. CONCLUSION

This study has revealed useful information about Land Use/Land cover (LULC) and Land Surface Temperature (LST) changes in the Niger Delta. From 1986 to 2016 all the Land use/land cover classes was considerably altered from its initial state. Also, the result of LST assessment indicated that LST continued to increase across the 30years period. As at 1986 the lowest LST was 19.4 ^{0}C while the highest LST was 29.89^{0}C but in 2002 it increased to a minimum of 19.8^{0}C while the maximum temperature rose to 30.9 ^{0}C and in 2016 it ranges further increased to lowest of 19.9^{0}C and maximum of 31.1^{0}C. On the overall, the minimum LST increased by 0.5^{0}C while the maximum LST increased by 1.21^{0}C. Evaluation of the relationship between LULC change and LST across the study area showed that the spatial and temporal variation of temperature result followed the pattern of LULC changes overtime and heat intensity appears to be at the peak in the high density settlement areas and low at the vegetated areas (forest, mangrove and vegetation). The analysis revealed an increase of LST by 1.78 ^{0}C at the rate of 0.059^{0}C/year in high density built up due to increase in settlement growth. These results therefore has confirmed the assertion that changes in Land Use Land cover has an impact on the climate change in the Niger delta region of Nigeria.

REFERENCES

[1] Dokubo, A. (2004). "Niger Delta People in the Nigerian State". The Argus 3(61):4.

[2] EarthExplorer: http://earthexplorer.usgs.gov

[3] Ebegbulem, J. C. Ekpe, D. and Adejumo, T. O. (2013). Oil Exploration and Poverty in the Niger Delta Region of Nigeria: A Critical Analysis. International Journal of Business and Social Science. 4(3).

[4] Falahatkar, S., Hosseini, S. M. and Soffianian, A. R., (2011) "The relationship between land cover changes and spatial-temporal dynamics of land surface temperature," Indian Journal of Science and Technology. 4(2):76–81.

[5] Jiang, J. and Tian, G. (2010) Analysis of the impact of Land use/Land cover change on Land Surface Temperature with Remote Sensing. International Society for Environmental

Information Sciences 2010 Annual Conference (ISEIS). Procedia Environmental Sciences (2):571–575.

[6] 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.

[7] NDRMP: Niger Delta Regional Master Plan, NDDC, (2004) available at: http://www.nddc.gov.ng/ masterplan.html (last access: 11th August 2015).

[8] Nwilo, P. C., Badejo, O. T. (2006). "Impacts and management of oil spill pollution along the Nigerian coastal areas. Administering Marine Spaces: International Issues, 119.

[9] Omran, F. (2012) Detection of Land use and land surface Temperature change at Different Resolution. Soil and water department faculty of Agriculture suez corner university Ismalia, Egypt. Journal of GIS. 4(3)

[10] Orhan, O., Semih, E. and Filiz, D. C. (2014). Use of Landsat Land Surface Temperature and Vegetation Indices for Monitoring Drought in the Salt Lake Basin Area, Turkey. Hindawi Publishing Corporation. The Scientific World Journal. 2014

[11] Ringim, A. S., Sulaiman, I. M. and Lyakurwa, J. V. (2016). Implementation of Integrated Coastal Zone Management Approach in the Niger Delta, Nigeria: A Review. International Research Journal of Environmental Sciences and Studies. 1(3):(43-55).

[12] Srivanit, M., Hokao, K., Phonekeo, V., (2012) Assessing the Impact of Urbanization on Urban Thermal Environment: A Case Study of Bangkok Metropolitan. International Journal of Applied Science and Technology. 2(7).

[13] United Nations Fact Sheet on Climate Change (2006). "Africa is particularly vulnerable to the expected impacts of global warming. Prepared by the United Nations for UN Climate Change Conference Nairobi 2006, 1-2." Retrieved on 3rd May, 2015 from http://unfccc.int/files/press/backgrounders/application/pdf/factsheet_africa.pdf

[14] USGS Landsat Missions. Assessed online on May 18, 2016 from http://landsat.usgs.gov/tools_faq.php.

[15] Weng Q. A. (2001) remote sensing-GIS evaluation of urban expansion and its impact on surface temperature in the Zhujiang Delta, China. International Journal of Remote Sensing. 22(10):1999-2014.

[16] Xian, G. and Mike, C. (2015). Evaluation of Urbanization Influences on Urban Climate with Remote Sensing and Climate Observations. Accessed online on September 2015 from SAIC/USGS - National Center for Earth Resources Observation and Science, Sioux falls, SD 57198

[17] Zhi-qiang L. and Qi-gang Zhou, (2011) Utility of Landsat Image in the Study of Land Cover and Land Surface Temperature Change. 2011 3rd International Conference on Environmental Science and Information Application Technology (ESIAT 2011). Procedia Environmental Sciences. 10 (2011):1287 – 1292.