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Assessment of Land Surface Temperature across the Niger Delta Region of Nigeria from 1986-2016 using Thermal Infrared Dataset of Landsat Imageries

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Abstract: The Niger Delta region of Nigeria has been the sole oil producing basin since the discovery of oil in commercial quantity in 1965. Gas flaring, oil pipeline vandalism and anthropogenic activities has caused severe eco-environmental changes in the region. This alteration has caused unquantifiable changes to land surface temperature in the region hence, the need to investigate it. The aim of this research was therefore to investigate the historical Land Surface Temperature (LST) dynamics of the entire Niger Delta region of Nigeria from 1986 to 2016 using Thermal Infrared Dataset of Landsat Imageries. Landsat 5(TM), Landsat 7 (ETM+) and Landsat 8 (OLI) images of 1986, 2002 and 2016 were downloaded from NASA Earth Observatory website and used for this research. Image processing was carried using ERDAS IMAGINE and ENVI software. ArcGIS software were used to build model for LST estimation. The results showed that as at 1986 the minimum LST was 19.4 ^{0}C while the maximum LST was 29.89^{0}C but in 2002 it increased to 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, LST increased by 1.21^{0}C across the study area. This result therefore has confirmed the assertion of climate change in the region.

Keywords: Land Surface Temperature; Landsat TM, ETM$^+$, OLI; Niger Delta Region.

I. INTRODUCTION

Land surface temperature (LST) has a significant role in the land surface characters on local and global scale. Global warming has drawn attention of researchers worldwide because the global mean surface temperature has recorded an increase since the late 19th century. Weng, (2009), opined that Land surface temperature (LST) is the main factor determining surface radiation and energy exchange controlling the distribution of heat between the surface and atmosphere. Guillevic, (et al. 2012) articulates that Land Surface Temperature (LST) is a key variable that helps govern radiative, latent and sensible heat fluxes at the interface of Land surface. Sun, et al. (2011) opined that Land surface temperature (LST), governs the urban thermal environment. Hence, investigation and comprehension of historical LST dynamics and its relation to changes of anthropogenic origin is necessary for environmental sustainability. LST retrieval from thermal infrared band data of remote sensors has become one of the major approaches to obtain information about LST spatio- temporal distribution (Gallo et. al. 1999; Owen et. al. 1998). Land surface temperature (LST) has been a key factor in physical processing of land surface at a regional and global scale, and it generalizes the results of the interaction between land surface and atmosphere, exchange of matter and energy (Wan and Dozier, 1996). Also, for ideal of sustainable development, LST change, must be is regarded as an important criterion upon which the evaluation of environmental quality is based (Janssen, 1996). From the forgoing, evaluation of LST changes over a period at regional level, like the Niger delta that has undergone severe eco-environmental change is imperative for information on climate change in the region.

II. MATERIAL AND METHODS

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).

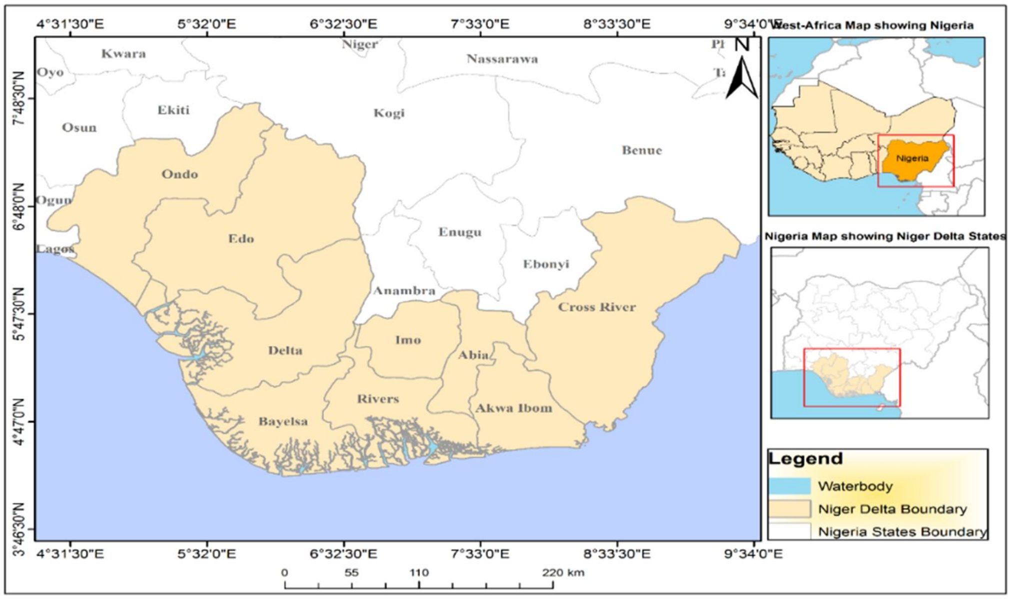

Fig. 1: Study Area in relation to West Africa and Nigeria

B. Data Preparation

Landsat 5(TM), Landsat 7 (ETM+) and Landsat 8 (OLI) images of 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. 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. Radiometric correction was carried out followed by image to image geometric correction. The geometric correction was done by correcting Landsat 5-TM and Landsat 7 ETM+ images using the corrected image of Landsat 8-OLI that was already geometrically registered using ground control points. Thereafter, mosaicking, subseting and integration was done to generate/extract the spatial extent of the study area from eleven scene of Landsat images.

C. 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 1, 2, 3 and 4, ArcGIS was used to develop model for efficient calculations of those components.

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

$$L = Lmin + (Lmax – Lmin) * (DN/2^n-1) \qquad \ldots(1)$$

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. The model build in ArcGIS for it calculation is given below in figure 2

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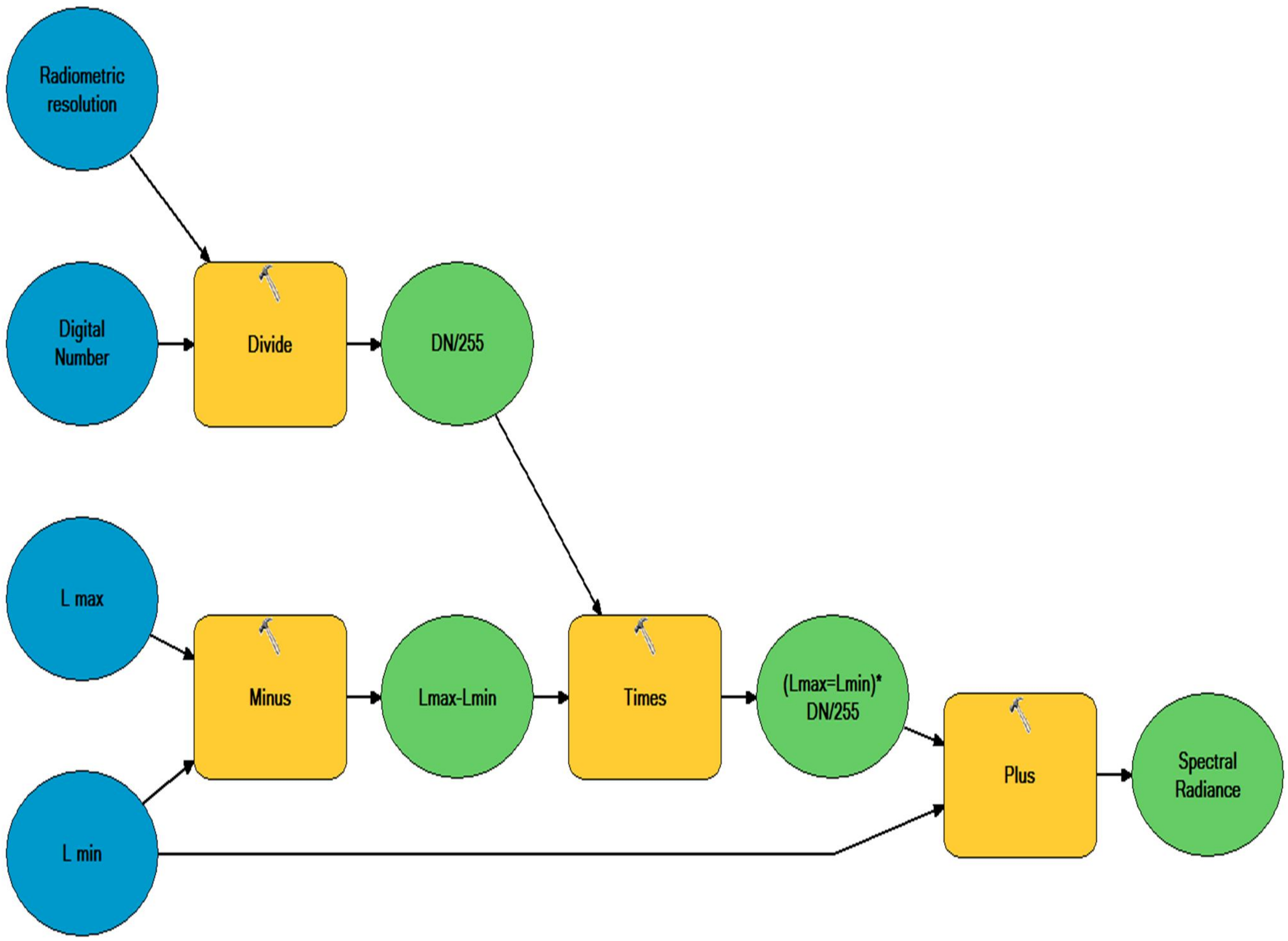

Fig. 2: Model for Converting DN of Thermal Band to Spectral Radiance

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

$$T\,°K = K2 / \ln\left(\frac{K1}{L} + 1\right) \quad \ldots(2)$$

where T°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 1: 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

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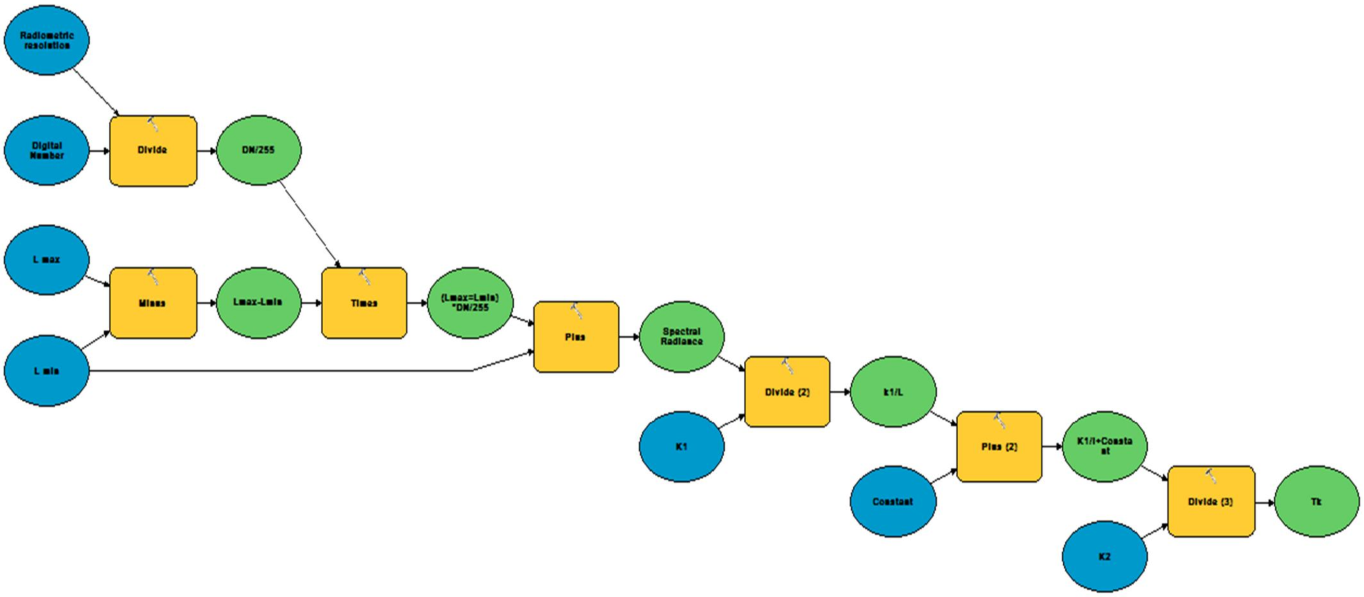

Fig. 3: Model for Converting Spectral Radiance to Surface Temperature.

3) Correcting Emissivity:

$$T_s°K = T\,°K / (1 + (\lambda * T\,°K / \rho) \ln \varepsilon \quad \ldots(3)$$

Where;

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

λ is the wavelength (11.5µm);

$\rho = h \times c / \delta = (1.438 \times 10^{-2}$ m K = 1.438×10^{-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

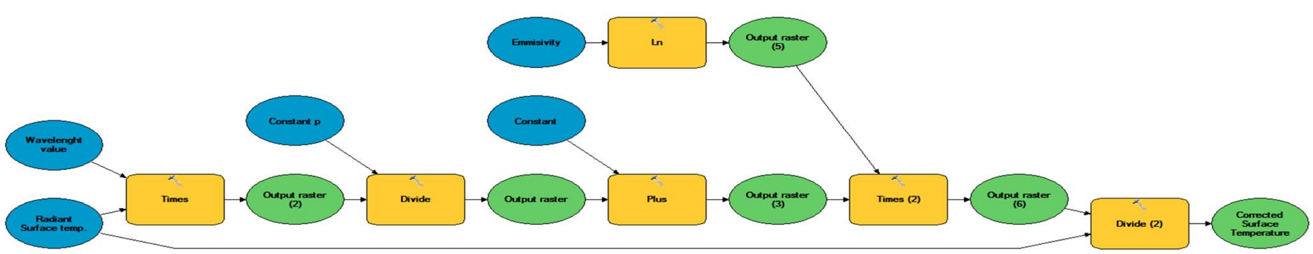

Fig. 4: Model for Correcting Emissivity

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4) Conversion of Kelvin Temperature to LST in Celsius:

$$LST_C = Ts - 273 \quad \dots (4.4)$$

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

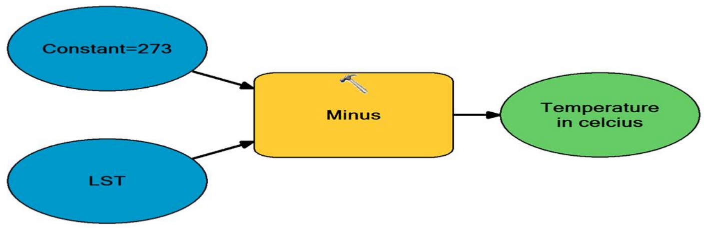

Fig. 5: Model for Converting Temperature from Kelvin to Celsius

III. RESULT AND DISCUSION

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 6 below 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.

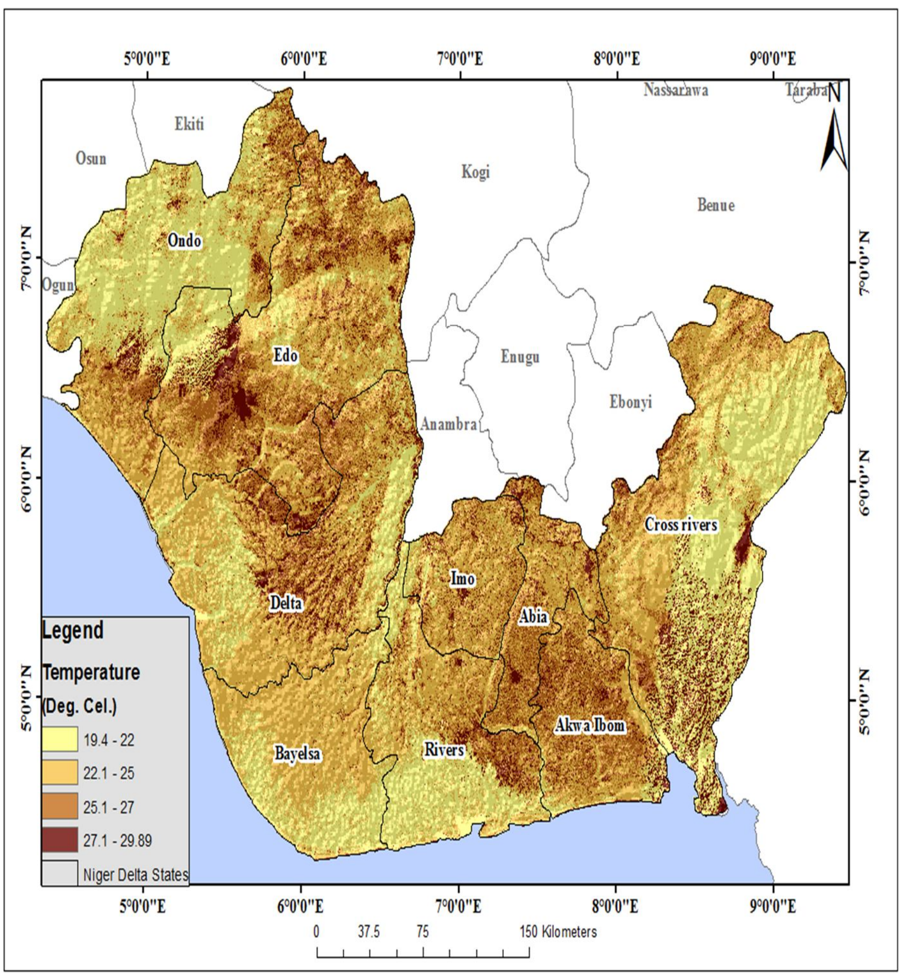

Fig. 6: Map showing the spatial Pattern of LST across Niger Delta States in Year 1986

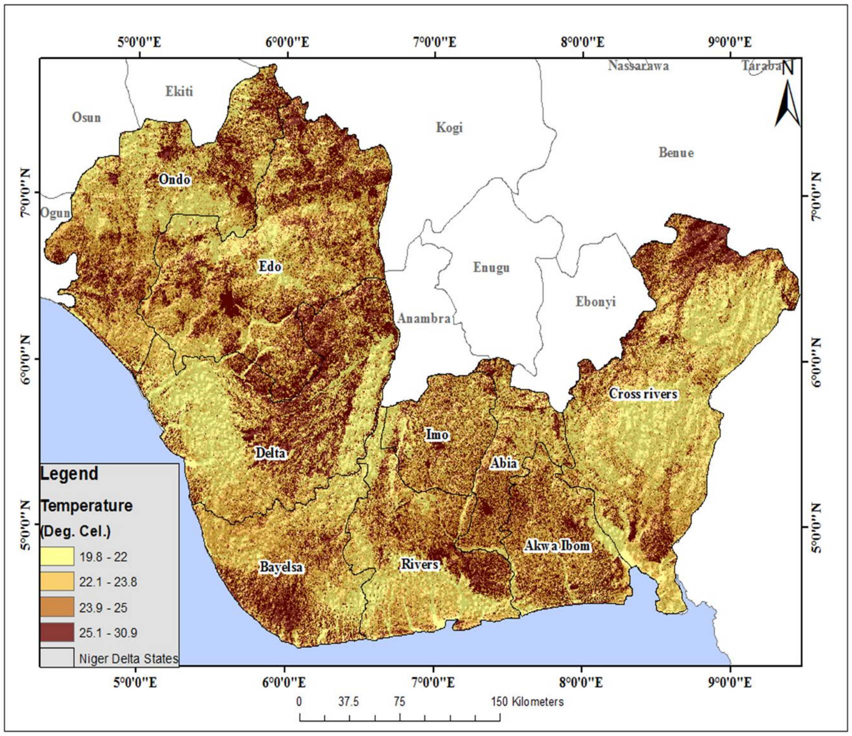

Fig. 7: Map showing the spatial Pattern of LST across Niger Delta States in Year 2002

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

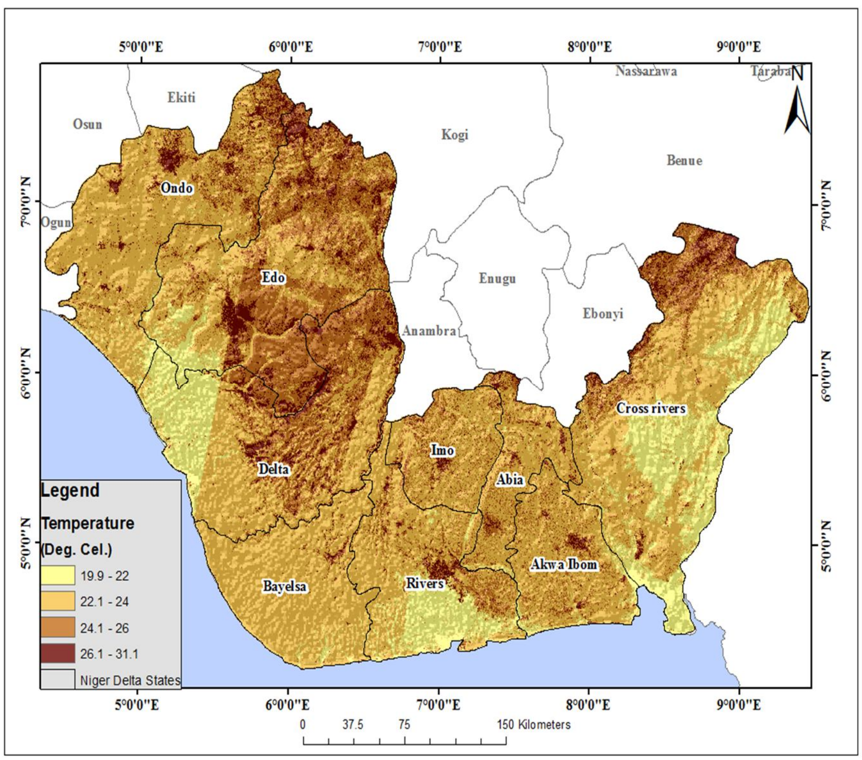

Fig. 8: Map showing the spatial Pattern of LST across Niger Delta States in Year 2016

IV. CONCLUSION

The Result of LST assessment indicated that Land Surface Temperature (LST) continued to increase across the 30years period. As at 1986 the lowest Land Surface Temperature (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. This result has revealed useful information about Land Surface Temperature (LST) in the Niger Delta. On the overall, the minimum LST increased by 0.5^{0}C while the maximum LST increased by 1.21^{0}C. This result therefore has confirmed the assertion of climate change in the region as a result of Gas flaring, oil pipeline vandalism and anthropogenic activities which has cause a severe eco-environmental changes in the region.

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