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Temporal Analysis of Climate Variability and Vegetation Change from 2000 to 2017 in Bonny LGA, Rivers State, Nigeria

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Abstract—The study examined the temporal analysis of climate dynamics and vegetation change Bonny LGA in Rivers State, Nigeria. MODIS imagery to assess the vegetation health through NDVI and point grid pattern of meteorological data for total precipitation (TP), air temperature (AT), and soil temperature (ST) of 2000, 2003, 2006, 2009, 2015 and 2017 were used for the study. Descriptive and inferential statistics were used for data analysis. Findings showed that vegetation health was highest in 2006 (0.4262±0.17) and least in 2017 (0.2544±0.24). Also, vegetation health decreased with increasing time. Similarly, AT was highest in 2017 (26.2145±4.60 °C) and lowest in 2000 (25.9685±5.13 °C) while ST was highest in 2000 (30.0045±1.20 °C) and the least was observed in 2017 (26.8976±0.12 °C). TP was highest in 2000 (2144.486±24.53 mm) and the lowest was recorded in 2003 (1882.503±21.49 mm). The AT, TP, and ST were higher in the southern part of Bonny LGA. NDVI correlated significantly with AT ($r=0.2085$; $p<0.05$); ST ($r= 0.2867$; $p<0.05$) and TP ($r=0.2952$; $p<0.05$). The study concluded that climate parameters have influence on vegetation stability and richness. It is recommended among others that monitoring factors that affect vegetation health in a changing climate environment is highly essential .

Index Terms— Bonny LGA, Climate change, Meteorology, NDVI, Pearson Correlation, Nigeria, Vegetation Health

1 Introduction

Throughout the 21st century, there has been an increased variation in regards to the climate in Nigeria viz., rainfall, temperature, storms, and sea levels. Climate variability refers to a phenomenon that can be connected to human activities which impact the climate system and cause variations that ultimately lead to global warming. Inadequate adaptive countermeasures to combat these shifts may be the chief cause of uncontrollable ravishment in some areas of the country [1]. The role of vegetation in the functioning and servicing of ecological systems is intricate and paramount. Notwithstanding, there has been a consistent downturn in global vegetal cover as a result of human activities [2]. An escalation in activities such as combustion of fossil fuels, wood, and solid waste, as well as the rearing of livestock and decomposition of organic waste in solid waste landfill has resulted to emission of GHGs and in turn Global warming [3].

Vegetation plays several critical roles in the biosphere. These include its role in climate change mitigation, regularizing extreme temperatures and its effect on soil erosion and flood [4,5]. A number of resources such as food, fiber, timber, wood-based fuel, and firewood are obtained from vegetation [6,7]. Fashae et al [8] reported that land use is the major cause of vegetation change. Growth and vigor of the vegetation cover are controlled by factors such as climate, soil, and topography. However, other factors viz., soil type and nature of soil also contribute greatly to the state or health of vegetation. Notwithstanding, climatic factors prove to exert more influence than other factors.

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Plant activities are facilitated by moisture, and this needed moisture is made available by climatic factors (rainfall and surface temperature) [9]. There is the need to continuously monitor vegetation changes over time for proper management of ecosystems, biodiversity, and adaptation to climatic changes. Changes in vegetation dynamics are monitored by field surveys and remote sensing technology. Although field surveys provide accurate information and changes in vegetation, they are time-consuming and limited in extent. The remote sensing technology was developed to monitor changes in land use, land cover which is occurring in large areas especially in remote and inaccessible regions characteristics of the tropical environment

Remote sensing technology is now widely used because they provide high spatial and temporal resolution and are inexpensive [10]. Vegetation productivity can be obtained by using remote sensing due to its low cost and non-destructive nature and rapidity when compared to ground field survey methods [11]. Vegetation is evaluated using vegetation indices based on the spectral characteristics of the vegetation in the near-infrared and red spectral characteristics or at the red edge. Vegetation indices have proven to be useful in obtaining information about vegetation. The spatial and temporal variations in vegetation structure are monitored and analyzed by using vegetation indices. Yengoh et al [12] identified normalized difference vegetation index (NDVI) as the most suitable index for land productivity assessments.

NDVI maps the presence of vegetation on a pixel and also provides the condition of the vegetation within the pixel and thus, its use is widespread for being efficient in the removal of disturbance of topographic effects and atmospheric elements [5]. NDVI gives an indication of the varying density of vegetation, is suitable for large vegetated areas where analysis is carried out without recourse to ground truth data and can be used to detect the change in canopy cover or vegetation biomass [5,11, 12,]. NDVI is used in detecting the health and vigour in vegetation as well as for estimates of green biomass [13].

It is evident, from researches, that vegetation plays a pivotal role in global changes considering their involvement in water and carbon energy cycle on land [14]. How the change in vegetal cover influence climate system is seen in the surface albedo, aerodynamic resistance and regional evapotranspiration [15]. Hence, current global change research on environmental changes take significant interest in vegetal cover change researches [16]. Healthy vegetation is usually denoted by very high vegetation index while a low vegetation index denotes deteriorating, diseased, damaged leaves, water-stressed vegetation and non-vegetation cover [17]. The NDVI values have been used in agriculture to estimate crop yield, point out stress in plants and to mark distinctive patterns of growth across landscapes [18,19]. Application of NDVI for vegetation health and other phonological attributes of plants have been demonstrated. Seelan et al. [20], Shanahan et al. [21] and Shanahan et al. [22] showed that the NDVI is a suitable index to evaluate the nitrogen status, the chlorophyll content, the green leaf biomass, as well as the grain yield of a plant. Furthermore, many studies have shown that the fraction of absorbed radiation for photosynthesis, leaf area index, area of vegetal cover, as well as green biomass, are linked to NDVI [23,24]. Thus, NDVI is predicted to be an essential tool to support the management of a field.

Monitoring the health of vegetation is paramount in comprehending the impact climate and environmental factors have on vegetation as well as its productivity. Pal and Mandal [25] observed a decline in vegetation health as a result of dust generated from stone mining and crushing in Dwarka river basin of Jharkhand and West Bengal in India. Although, there have been several studies on vegetation change in Nigeria [8,26]; the negative implication of mining on the vegetal cover in South Nigeria [11,26,27]. There is a dearth of works of literature on how variation in climatic conditions affects viability of flora, most especially in Nigeria. This study, therefore, seeks to assess the influence of climate parameters on the vegetation health of Bonny LGA from 2000 to 2017.

Materials and Methods

The study area was Bonny LGA, Rivers State, Nigeria. Bonny Island is an island found in the Rivers State of Nigeria. It is domiciled 25km from the state's capital city, Port Harcourt. It is located on latitudes between 6o 45′ 00′′N and 6o 47′ 15′′N; and longitudes 4o 41′ 32′′E and 4o 43′ 30′′E (Figure 1). It has an elevation of 6.19m. Bonny LGA is surrounded west, north, east and south by Degema LGA, Okrika and Ogu Bolo LGA, Andoni LGA and the Atlantic Ocean respectively. Bonny LGA is situated in the sub-equatorial region. It has an average yearly temperature of 28°C with 25°C and 31°C as the least hot and hottest in a month. The annual range of temperature is 3.8oC. It enjoys monsoon climate with high rainfall of about 2500 mm annually and relative humidity of about 85%. The moist southeast air blows over the region between February and November resulting to rains, while the northeast trade wind blows over the region in the months of November through February which ushers in the dry season [28]. The study area is endowed with high forest and mangrove. Rainforest tree species include Mahogany, Militia excelsa, and Triplochiton scleroxylon. The mangrove swamp forests included Rhizophora sp. and Nypa fruticans. The topography of the area is flat terrain with very gentle slopes with an elevation less than 15m above mean sea level. The soil of Bonny LGA is predominantly sandy and also endowed with sandy beach-ridges which cause alternating lower and higher lands. The ecological zone of Bonny area is saltwater swamp and the major occupation in Andoni LGA was fishing and farming.

Acquisition of Data

Secondary data were for the most part utilized for the study which involved the satellite symbolism of Moderate Resolution Imaging Spectroradiometer (MODIS) Terra and Aqua Normalized Difference Vegetation Index (NDVI) of 16 Day L3 Global 250m goals downloaded from https://earthexplorer.usgs.gov. This is used to measure vegetation health. The study considered the NDVI imageries of 2000, 2003, 2006, 2009, 2012, 2015 and 2017. Similarly, the point grid pattern of meteorological data was obtained for total precipitation, air temperature, soil moisture and soil temperature at an interval of three years from 2000 to 2015 (i.e. 2000, 2003, 2006, 2009, 2015 and 2017). 1-km GSD of point pattern the climate data were primarily produced by NOAA and IPCC and were obtained from Community Climate System Model which is available from https://gisclimatechange.ucar.edu/gis-data. The data were used because previous studies revealed the vitality and capability of CLM4.0 simulation in capturing features of variations of the climate parameters in space and time. [4]. This model reproduces vitality, dampness, and energy fluxes among land and environment, the hydrologic cycle at the land surface, and soil temperature [29,30,31]. Climate models from the CCSM4 are created on a Gaussian grid, where every grid point can be distinctively gotten by unidimensional latitude and longitude assortments (in other words they are orthogonal coordinates). The spacing for both longitudes and latitudes in the CCSM4 model output were 1.25º and 0.942408376963o respectively. Hence, a rough estimate of the spatial resolution of global climate predictions is 105 km. as a result of the crooked grid in the CCSM model, this portal distributes data in a point shapefile set-up, where each point represents a centroid of a corresponding CCSM grid cell. A shapefile of irregular rectangular polygons of the original model output is also available.

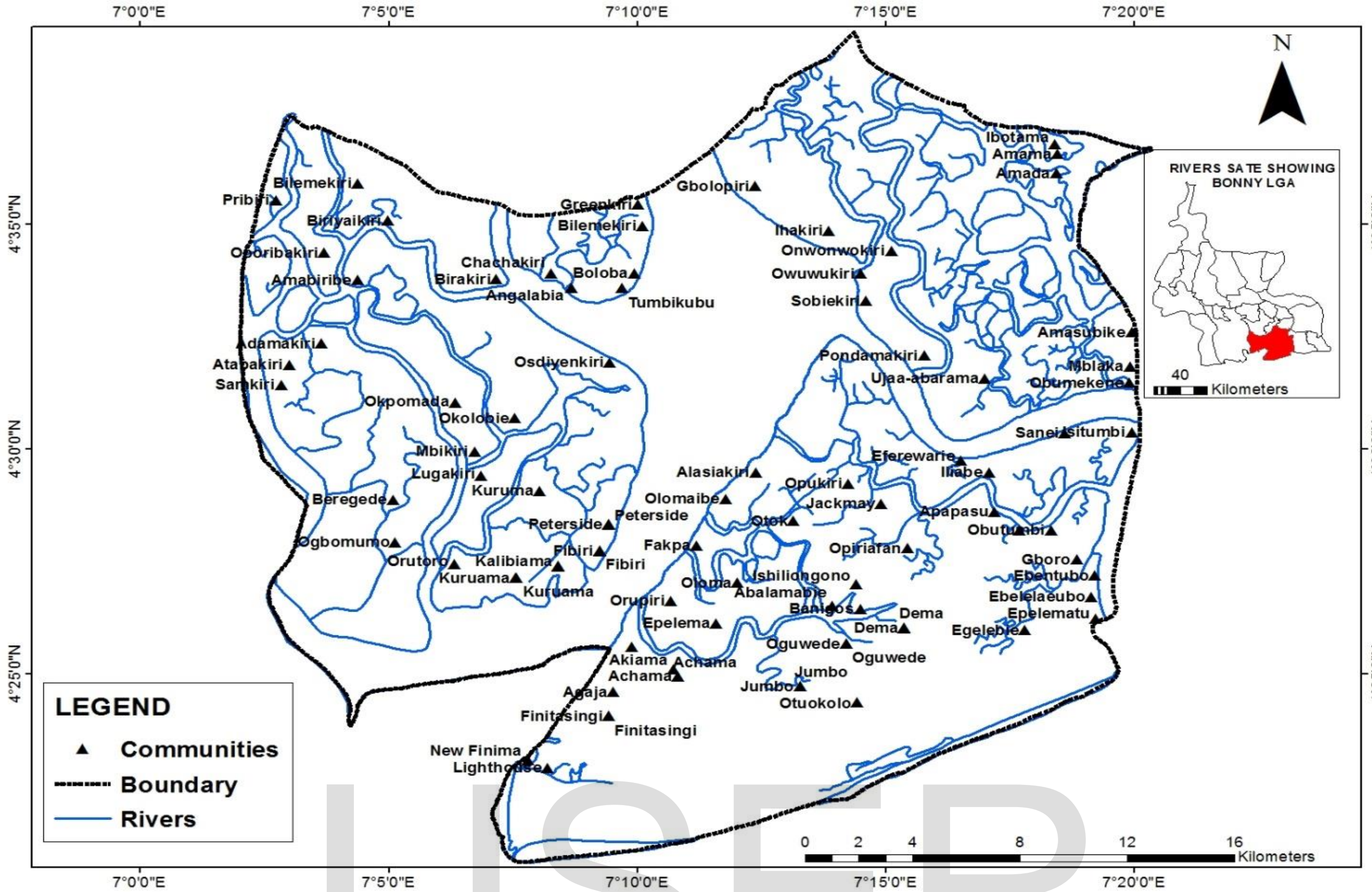

Figure 1: Bonny LGA showing communities
Source: Rivers State State Ministry of Land, Housing, Survey and Urban Development, 2018

Image Geo-processing for Vegetation Change
A number of indices as regard vegetal cover have been obtained based on the integration of red and near-infrared values of remotely sensed data numerically. Mapping vegetal cover and the health of flora make use of near-infrared (NIR) and red bands (TM4/TM3) ratio. High ratio connotes a healthy vegetation, low ratio represents unhealthy or yellow vegetation or non-vegetated landscape. It is a generally utilized approach for vegetation analysis. In NDVI relating cell values in the two bands are first subtracted, and then the result "normalized" by dividing the sum of two brightness values. NDVI is calculated using:
NDVI = (Near-infrared – Red)/(Near-infrared + Red) ………………….. (Equ. 1)
Thus, NDVI characterizes canopy growth or vigor and its use for vegetation index is common for this purpose as wells as its ability to show the amount of green cover and vegetal biomass [32]. It is a non-linear function that changes between -1 and +1 and is not defined when both Pred and Pnir are zero [33]. Pred and Pnir represent reflectance in red and near-infrared bands of the satellite imageries respectively [34].
The boundary shapefile of the study area was used to clip the NDVI images of different years and zonal statistics were used to extract data from the images both as tables and graduated maps. The zonal statistics showed the minimum, maximum, mean and standard deviation. The mean values of NDVI were made use of for further analysis. The original mean NDVI values were multiplied by 0.0001 as a multiplication factor to scale the original NDVI value to range from -1 to +1 (Land Processes Distributed Active Archive Center (LP DAAC), 2014).

Extraction of Precipitation, Air Temperature, Soil Temperature and Soil moisture
The point data of each of the climate parameters were clipped to the shapefile of the boundary of Nigeria and interpolation was done using Inverse Distance Weight (IDW) to generate values of air temperature, soil temperature and precipitation data for the unsampled places. The shapefile of the study area (Bonny LGA) was used to delineate the raster format of each of the climate data. Zonal statistics were used to extract the mean values of total precipitation, air temperature and soil temperature which was used for further statistical analysis.
To generate the relationships among vegetation health, air

temperature, soil temperature, and total precipitation, 18 point data were generated randomly throughout the entire study area. The coordinates of the point shapefiles were computed and these were overlaid on the imageries of vegetation health, air temperature, soil temperature, and total rainfall. The value of each point data in relation to vegetation health, air temperature, soil temperature, and precipitation was generated through the Extract values to point module from Extraction Tool. These values were used to compute the correlation occurring among the climate and vegetation parameters in the study area.

The study made use of descriptive statistics and inferential statistics for data analysis. Significant variations in the vegetation health, air temperature, precipitation and soil temperature in Bonny LGA from 2000 to 2017 was tested using analysis of variance while the relationship among the vegetation health, air temperature, precipitation, and soil temperature, in Bonny LGA, was tested using Pearson's' correlation statistics. Pearson's correlation measures how related the different variables are. Results were depicted in tables and graphs.

3 Results and Discussions

The analysis in Table 1 presents the NDVI, air temperature, total precipitation and soil temperature of Bonny LGA from 2000 to 2017. Also, Figures 2 and 3; 4 and 5; 6 and 7; 8 and 9 display the maps showing the NDVI, air temperature, total precipitation, and soil temperature respectively in Bonny LGA in 2000 and 2017. The vegetation health was highest in 2006 (0.4262±0.17) and least in 2017 (0.2544±0.24). The NDVI has no regular pattern from 2000 until 2015 when it started reducing in value. This shows that vegetation health in a more recent time has reduced. This is also displayed in the trend analysis shown in Figure 10. The air temperature was highest in 2017 (26.2145±4.60 oC) and the lowest was recorded in 2000 (25.9685±5.13 oC). The analysis of air temperature increased with increasing time in Bonny LGA as it is shown in Table 1 and Figure 11. The air temperature in terms of space was higher in the southern part of Bonny LGA (Figure 4 and Figure 5). This can be attributed to the reduction of vegetation as a result of residential and general human activities that are always happening in that part.

Furthermore, the analysis total precipitation of Bonny LGA from 2000 to 2017 shows that their total precipitation had no pattern but the highest was recorded in 2000 (2144.486±24.53 mm) and the lowest was recorded in 2003 (1882.503±21.49 mm). Spatially, more total precipitation was recorded in the southern part of Bonny LGA (Figure 6 and Figure 7). This may be attributed to the concept of Southwest laden wind arising from the Atlantic Ocean and dropping much of its moisture as it goes northward. Thus, proximity to the Atlantic Ocean might have affected the total precipitation of Bonny LGA. The trend analysis of total precipitation shows its relative increase from 2000 to 2017 (Figure 12).

However, the soil temperature was highest in 2000 (30.0045±1.20 oC) and the least was observed in 2017 (26.8976±0.12 oC). There was no regular pattern of soil temperature temporally but it was observed that soil temperature after dropping in 2003, it continued to increase from 2006 till 2015. Just like air temperature, generally, the soil temperature was higher in the southern part of Bonny LGA than the northern part (Figure 9 and Figure 10). The trend analysis shows a decreasing pattern of soil temperature from 2000 to 2017 (Figure 13).

Table 1. NDVI , Air Temperature, Precipitation and Soil Temperature Analysis from 2000 to 2017

Year	NDVI	Air Temperature (oC)	Total Precipitation (mm)	Soil Temperature (oC)
	Mean±SD	Mean±SD	Mean±SD	Mean±SD
2000	0.3871±0.24	25.9685±5.13	2144.486±24.53	30.0045±1.20
2003	0.3680±0.18	26.0152±5.44	1882.503±21.49	29.9827±1.22
2006	0.4262±0.17	26.1516±4.72	2005.411±29.49	29.9889±1.11
2009	0.3638±0.20	26.1069±5.51	2089.361±17.47	29.9891±1.23
2012	0.3721±0.21	26.1377±5.29	2101.290±24.45	29.9947±1.21
2015	0.3182±0.17	26.1528±5.46	2040.107±25.47	29.9960±1.23
2017	0.2544±0.24	26.2145±4.60	2056.534±25.65	26.8976±0.12

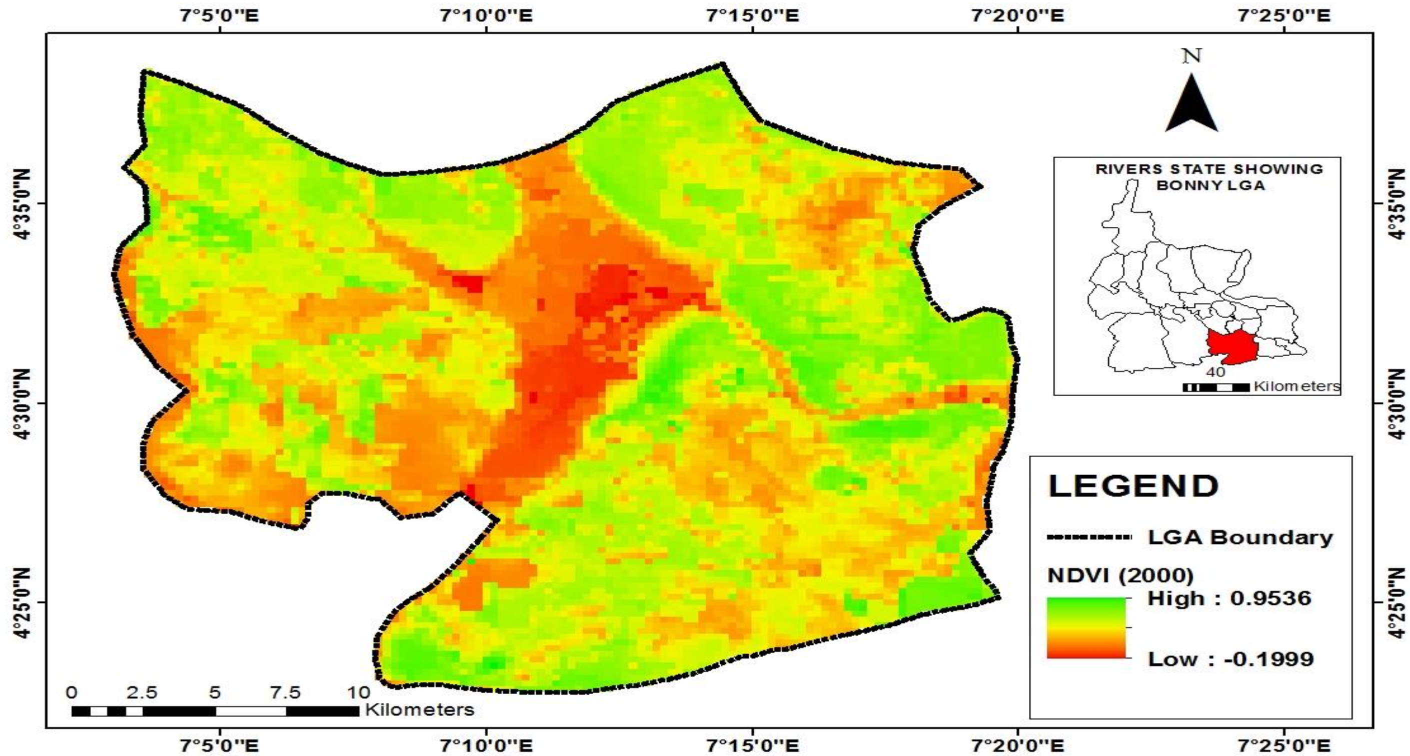

Figure 2. NDVI of Bonny LGA in 2000

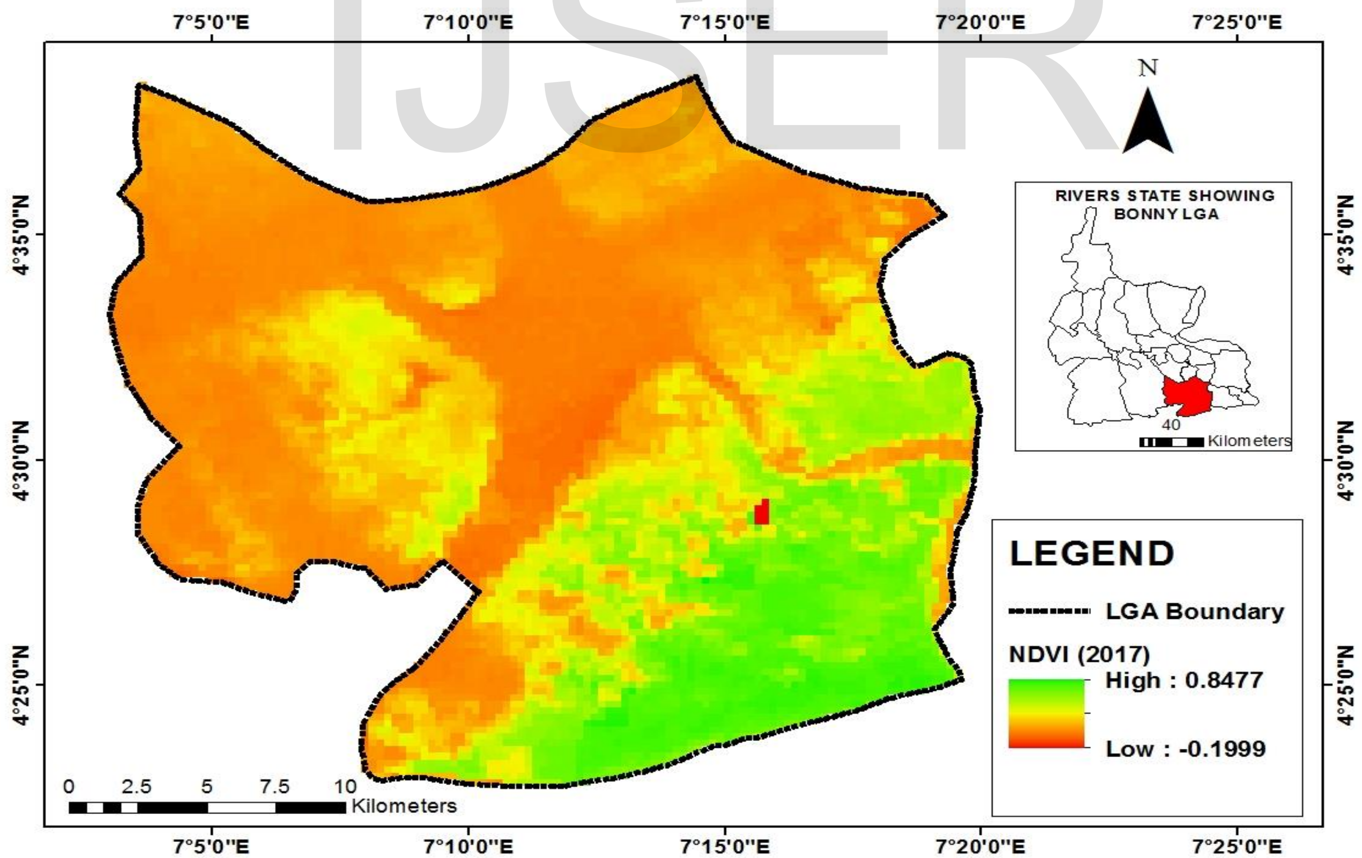

Figure 3. NDVI of Bonny LGA in 2017

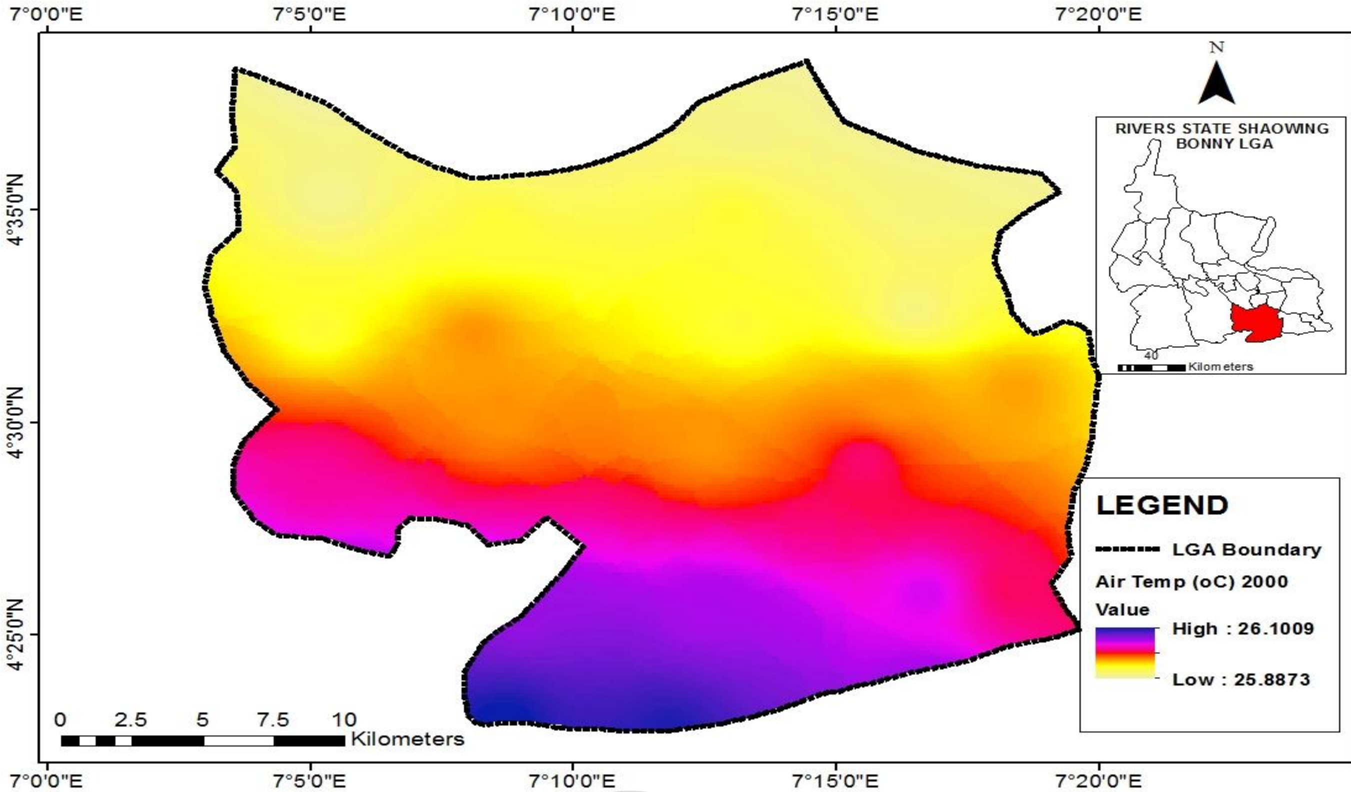

Figure 4. Air Temperature of Bonny LGA in 2000

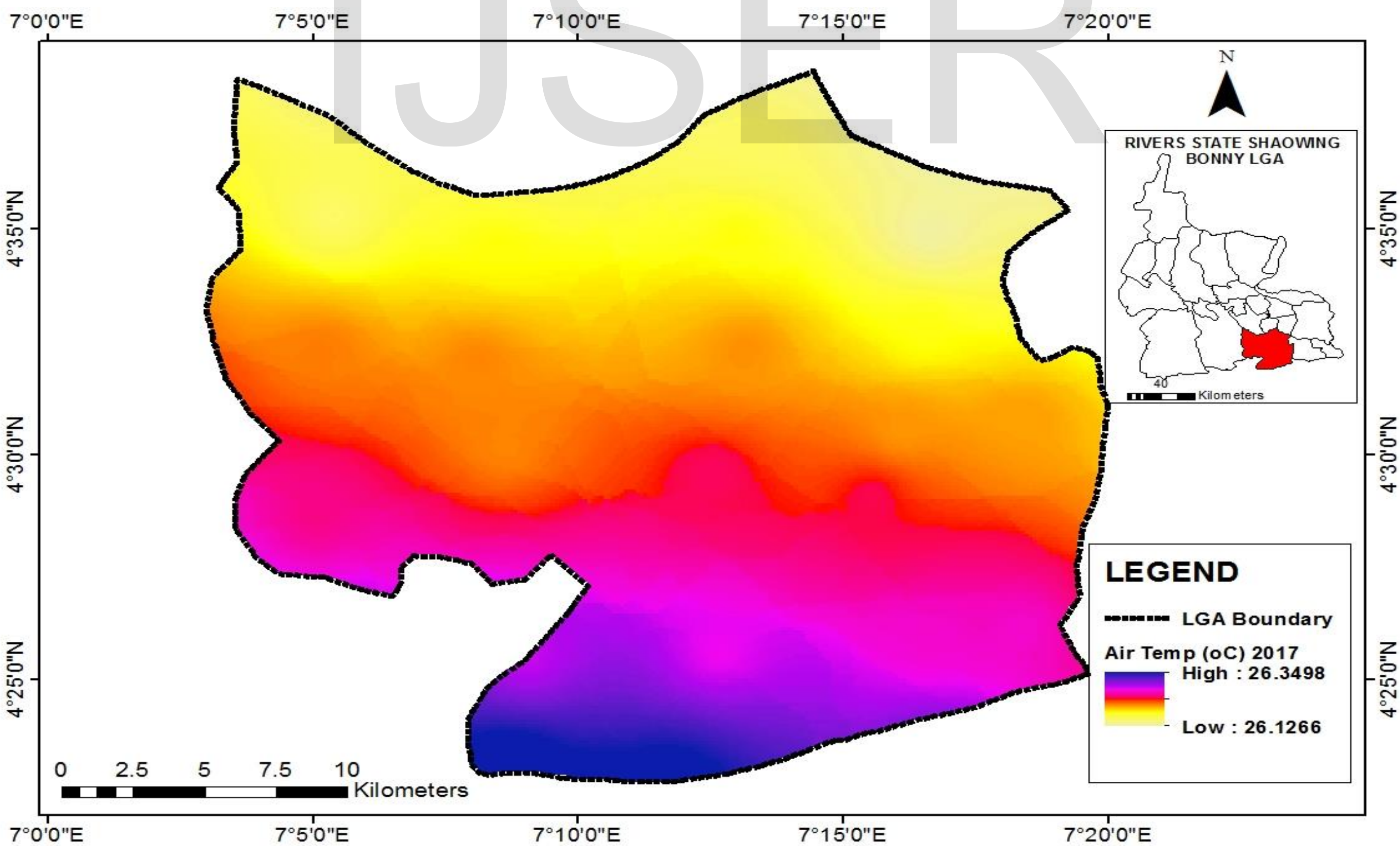

Figure 5. Air Temperature of Bonny LGA in 2017

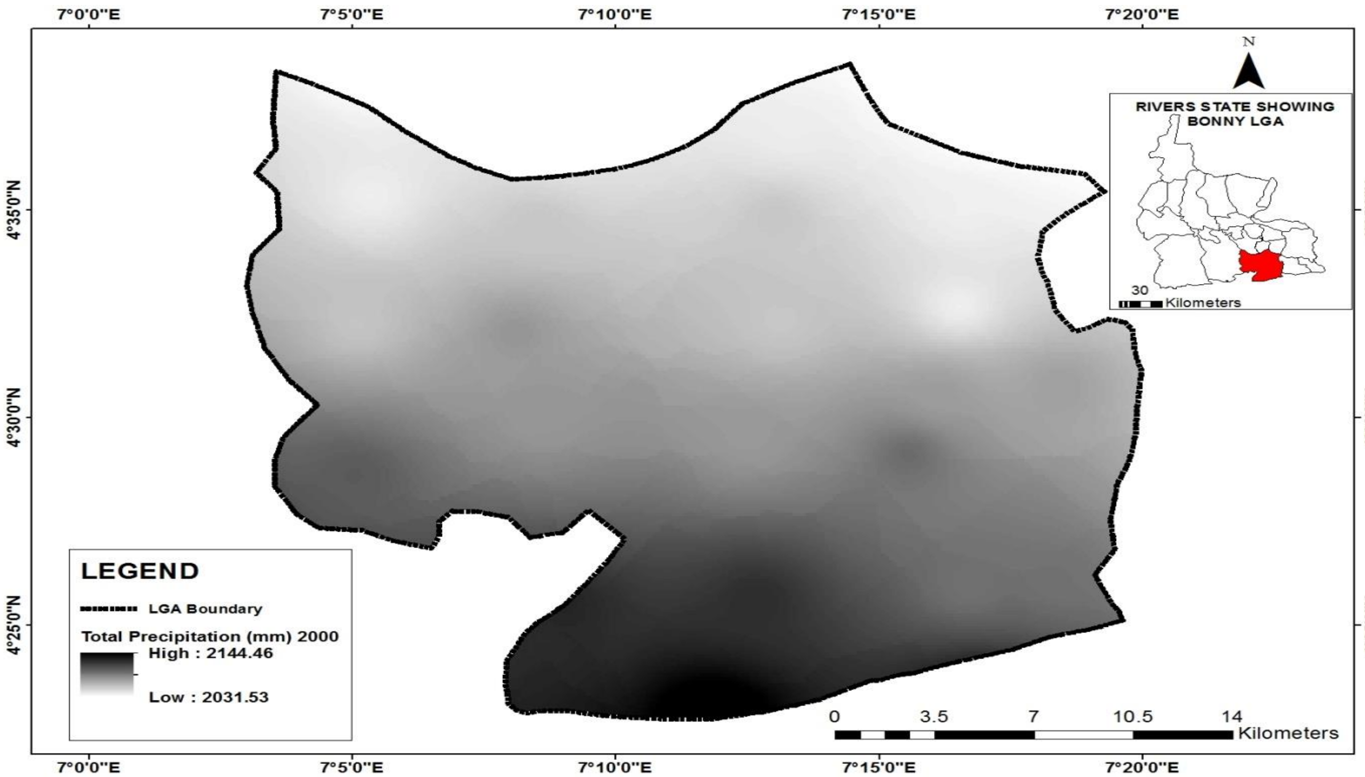

Figure 6. Total Precipitation of Bonny LGA in 2000

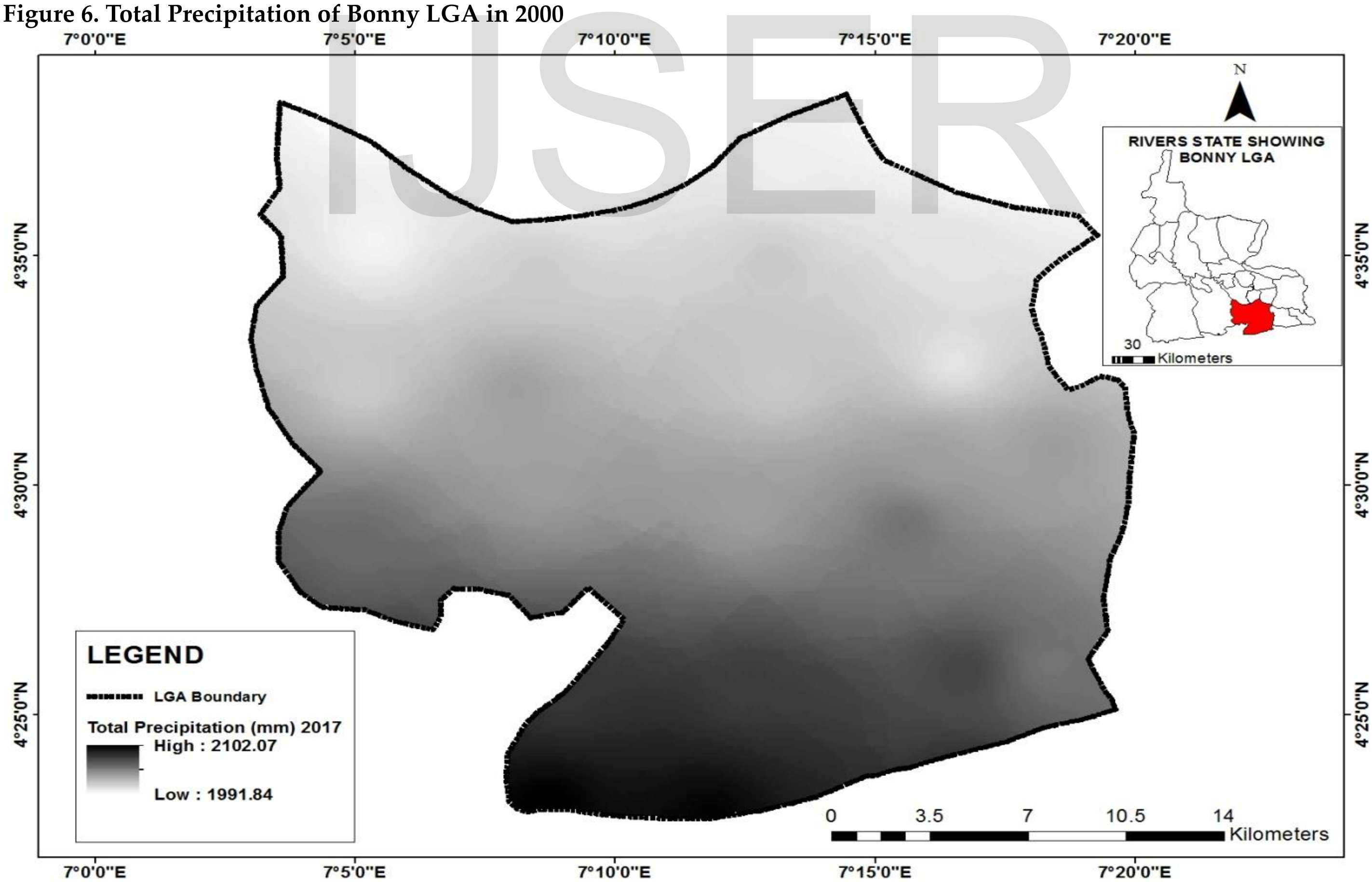

Figure 7. Total Precipitation of Bonny LGA in 2017

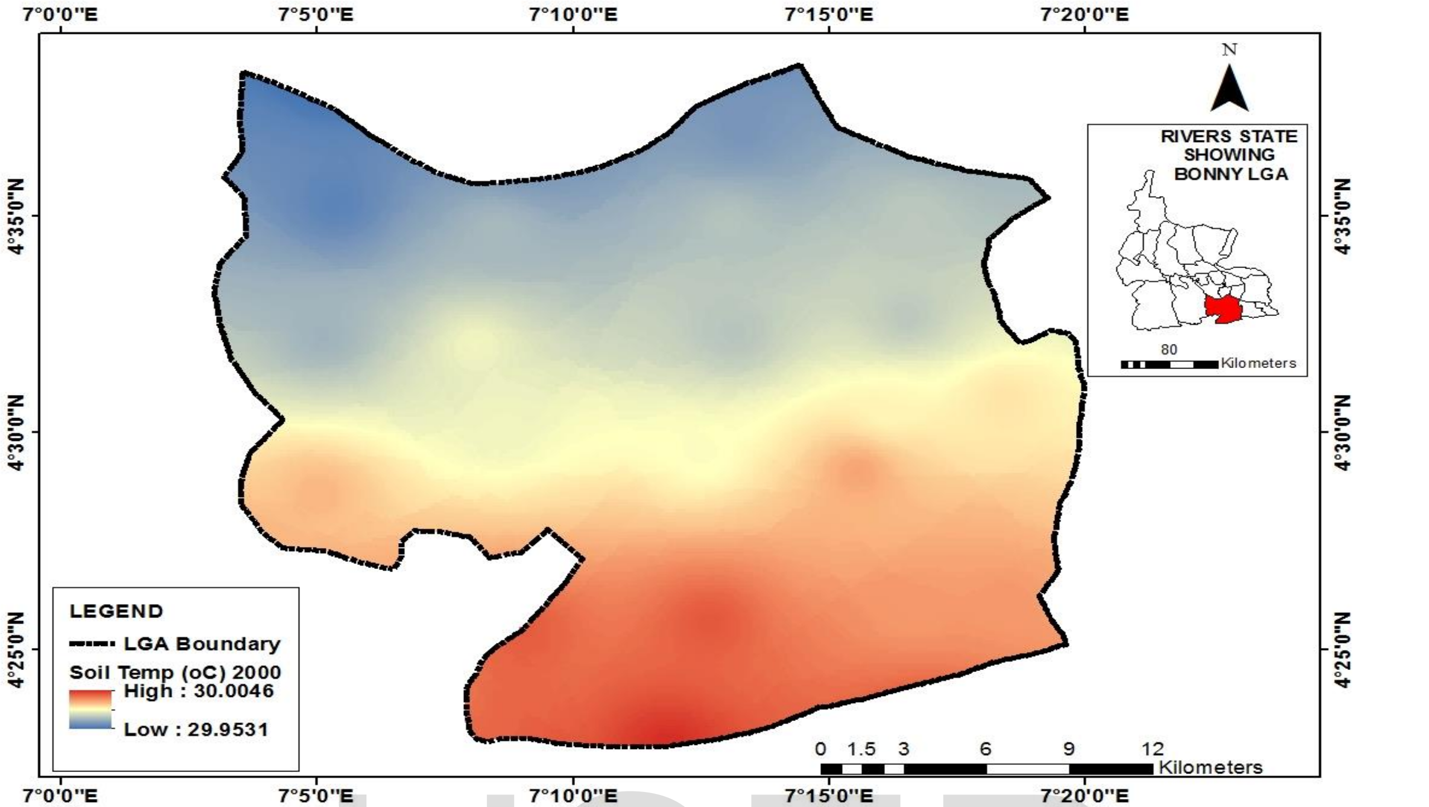

Figure 8. Soil Temperature of Bonny LGA in 2000

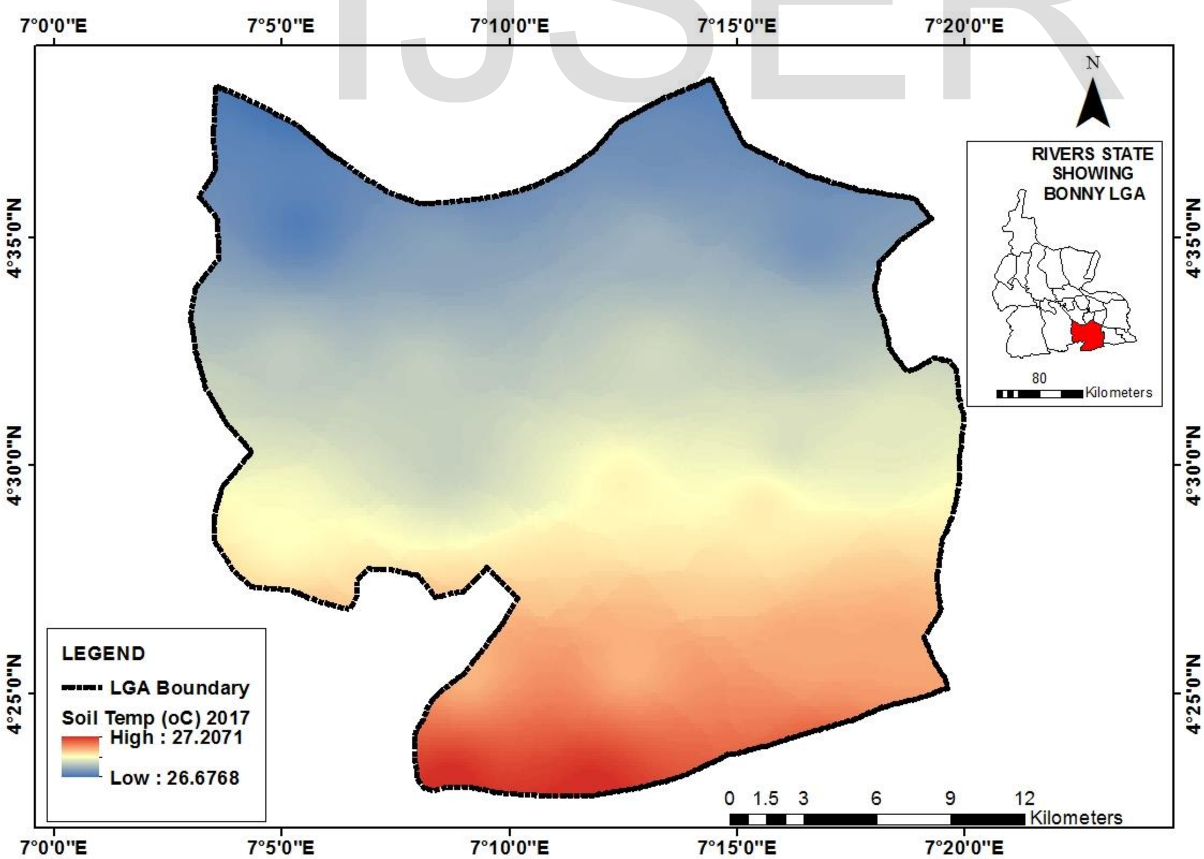

Figure 9. Soil Temperature of Bonny LGA in 2017

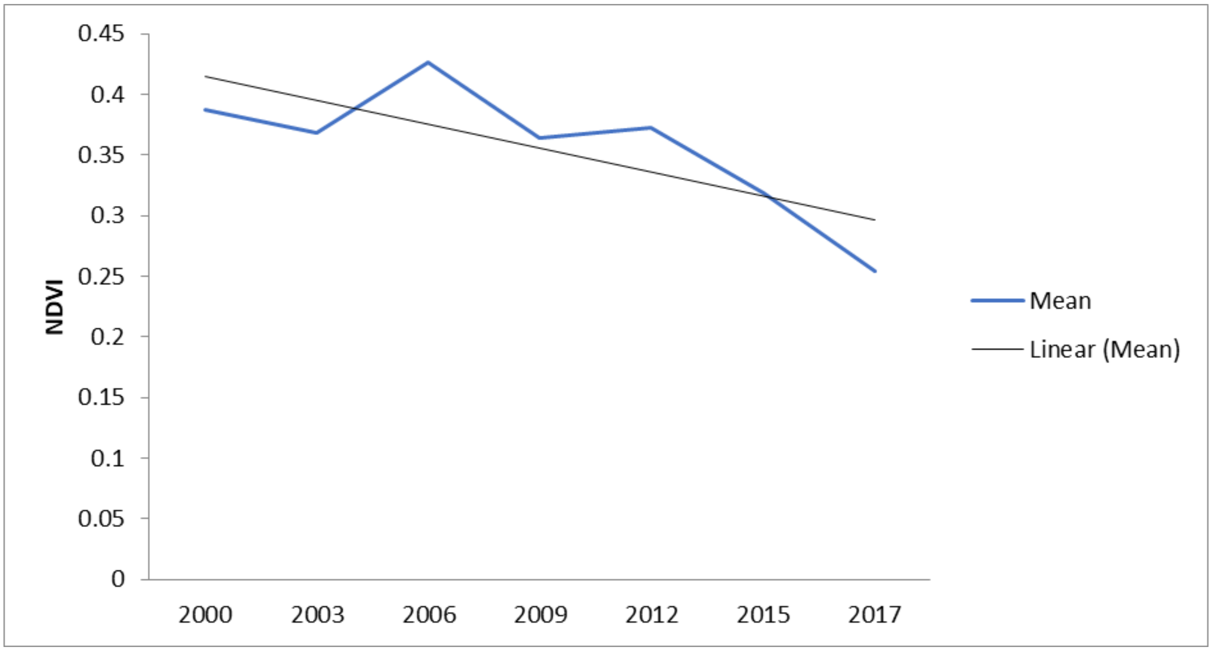

Figure 10: Vegetation Health (NDVI) and Linear Trending Analysis from 2000 to 2017

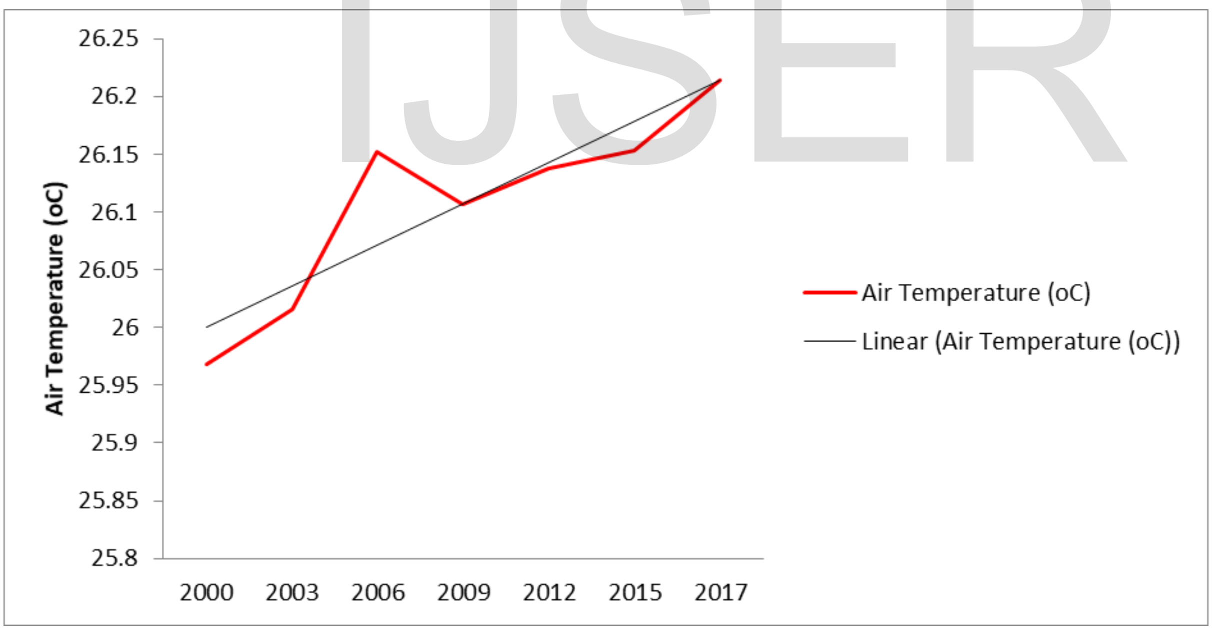

Figure 11: Air Temperature and Linear Trending Analysis from 2000 to 2017

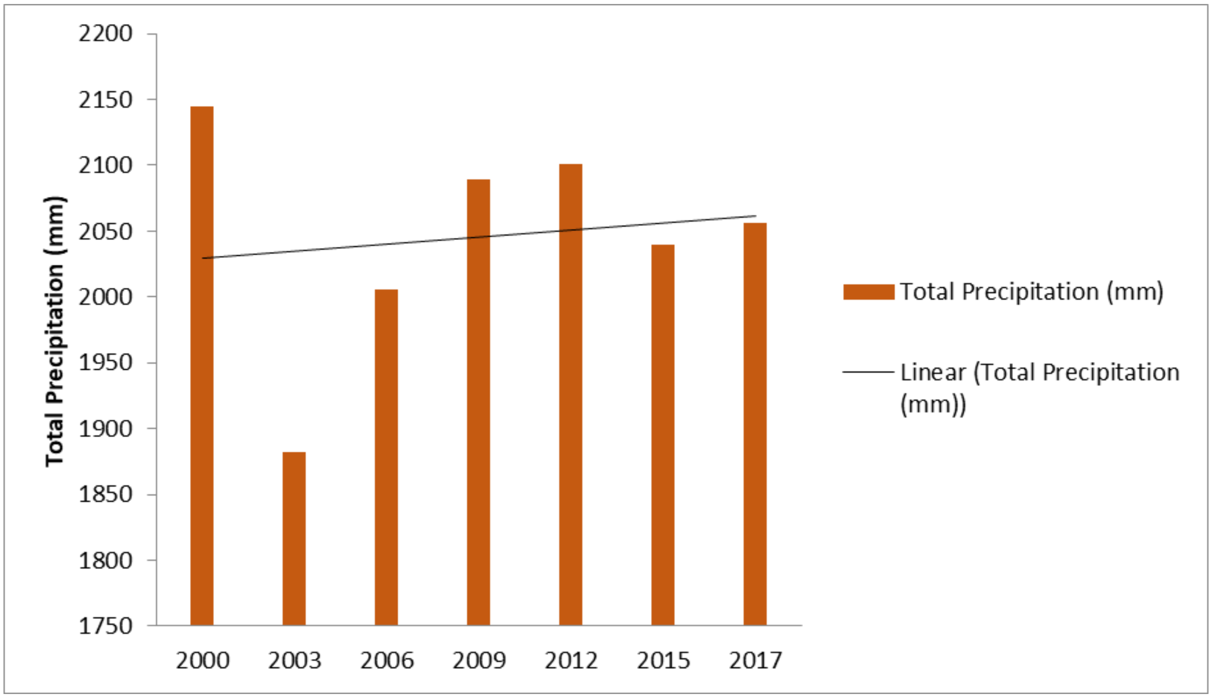

Figure 12: Total Precipitation and Linear Trending Analysis from 2000 to 2017

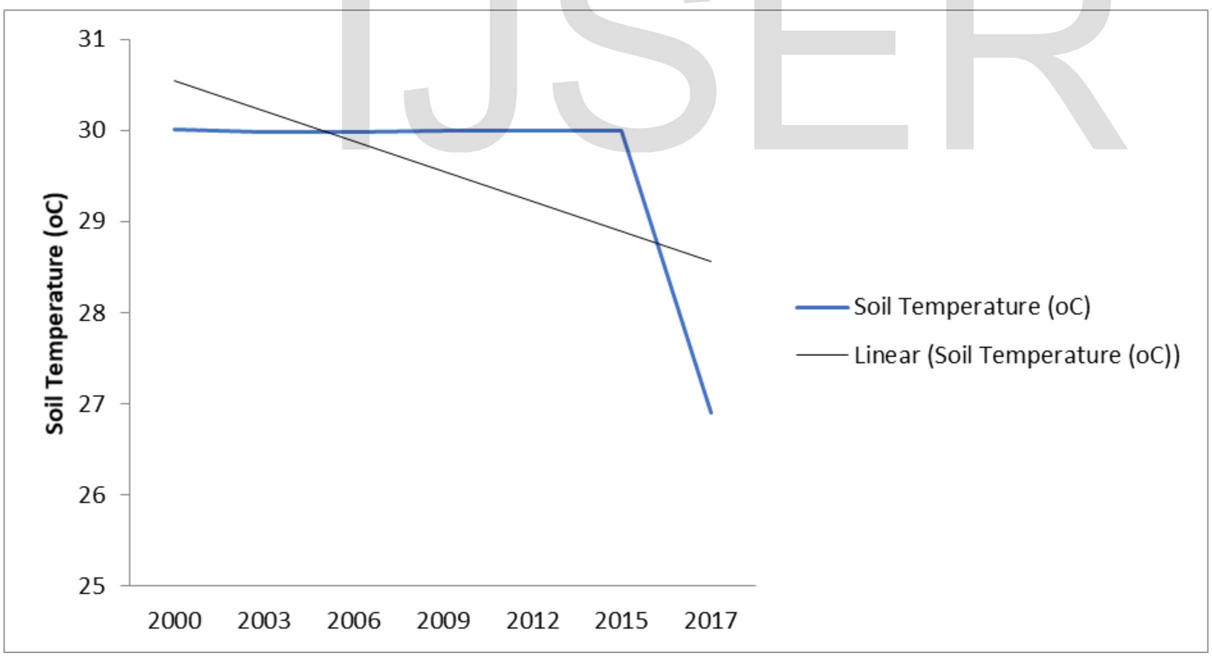

Figure 13: Total Precipitation and Linear Trending Analysis from 2000 to 2017

The relationship among the vegetation health, air temperature, precipitation, soil temperature and soil moisture in Rivers State

It is shown in Table 2 that NDVI had a remarkable and negative relationship with air temperature (r=0.2085; p<0.05) and a positively relationship with total precipitation (r=0.2952; p<0.05) and soil temperature (r= 0.2867; p<0.05). A further statistical inquiry affirmed a significant cum negative interrelationship with total precipitation (r=-0.3115; p<0.05) and soil temperature (r = -0.9274, p<0.05). with regards to soil temperature, it bore a remarkable relationship with total precipitation (r= 0.6338; p<0.05).

Table 2. Correlation Analysis among NDVI and Climate Parameters

	NDVI	*Air Temperature*	*Total Precipitation*	*Soil Temperature*
NDVI	1			
Air Temperature	-0.2085*	1		
Total Precipitation	0.295241*	-0.31159*	1	
Soil Temperature	0.286739*	-0.92742*	0.633802*	1

*Correlation is significant at the 0.05 level (2-tailed).

Discussion of Findings

The total precipitation did not follow any regular pattern and this is similar to the study of Ayanlade [35] that believed that there were rainfall anomalies in recent times, though the rainfall is more reliable especially in the rainforest zone of Nigeria in which part of Bonny LGA is inclusive. However, after the increase of vegetation health in 2006, the vegetation index continued to decline till 2017. This could be linked to some developments that might have taken place within this period which might have attracted some people to come and dwell in these areas. Ade and Afolabi [10] reported that nations' sustainable development is influenced by dynamics in its population, and pressure would be mounted on the environment when there is an upturn in population. Ade and Afolabi [10] further asserted that increasing population spontaneously leads to consistent alterations of humans and land-use practices thereby resulting to changes in structures [10]. In order to corroborate this, it was reported by the study of Fashae et al [8] that increased rate of land uptake for developmental purpose in the country, as well as other human factors and practices exacerbate the issue of loss of vegetal cover. The reduction of vegetation health in the entire Bonny LGA in recent years has a number of environmental implications viz., soil erosion, loss of soil nutrient, damage to biodiversity and environmental degradations. This also corroborates the results observed in air temperature and soil temperature which were higher in the southern part of Bonny LGA. More so, the increase in the air temperature and soil temperature in the southern part can still be linked to various oil exploration technologies being practiced in the study area. Fabiyi [28] noted that the evidence of the negative impact human practices have on the environment is seen as loss of biodiversity, deforestation, desertification, environmental degradation, reduced vegetal qualities and loss of soil nutrient.

Conclusion and Recommendations

The study shows that the status of vegetation health in Bonny LGA has been influenced by climate dynamics. However, air temperature, precipitation, and soil temperature have also influenced the behaviour of vegetation health. The study recommends that the vegetation richness should be improved to retain its ecosystem services of both rainforest and mangrove ecosystems. Also, studies on the influence of other climate parameters like relative humidity and solar radiation on vegetation greening should be carried out; and extended to other LGAs in Rivers State and entire Niger Delta region.

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