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SPATIO-TEMPORAL ASSESSMENT OF VEGETATION HEALTH ACROSS THE NINE STATES OF NIGER DELTA REGION OF NIGERIA USING LANDSAT AND AVHRR/MODIS DATASET

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ABSTRACT: *The Niger Delta region of Nigeria since the oil boom era of 1975 has undergone severe eco-environmental alterations associated with negative changes to the natural ecosystem particularly vegetation. This alteration is believed to cause unidentifiable changes in vegetation health, hence, the need for the spatio-temporal assessment of the vegetation health condition of the entire region. Multi-temporal Landsat remote sensing satellite images of 1986, 2002 & 2016 and AVHRR and MODIS dataset were used to generate the normalized difference vegetation index (NDVI) by creating a model in ArcGIS software. The generated NDVI results from Landsat disclosed that the general health condition of vegetation in 2002 was less than 1986 and 2016 poorer than 2002. Also, the inter-annual temporal analysis of the NDVI result showed that Years 2007 and 2008 recorded the healthiest vegetation condition while 1994 recorded lowest and monthly temporal analysis result indicated that lower vegetation condition was recorded in February and August while October recorded the highest. The mean NDVI values for each state of the study area revealed that the vegetation condition of the core oil producing states of Akwa Ibom, Bayelsa, Rivers, and Delta State were the most stressed as result of heavy alteration of the vegetation due to unwholesome activities of oil exploration/exploiting like gas flaring, oil spillage, pipe line vandalism etc. whereas Ondo, Edo, Abia, Cross River, Abia and Imo state that has not had similar heavy alteration had healthier vegetation condition. This study has proved that the oil and gas exploration and exploitation in the region is really altering the vegetation health condition of the region.*

KEYWORDS: Normalized Difference Vegetation Index (NDVI), Niger Delta, AVHRR/MODIS and LANDSAT.

INTRODUCTION

Since the discovery of oil in Nigeria, the Niger Delta region has been suffering several negative environmental consequences as a result of oil exploration and exploitation. Nwilo and Badejo, (2006) reported that between 1976 and 1996 a total of 4,647 incidents of oil spill resulted in the spill of approximately 2,369,470 barrels of oil into the environment. In addition, between 1997 and 2001, Nigeria also recorded a total number of 2,097 oil spill incidents. Likewise, in 1998, 40,000 barrels of oil from Mobil platform off the Akwa Ibom coast were spill into the environment causing severe damage to the Niger delta environment. Consequently, these oil seepages into the

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ecosystem destroys the mangrove and aquatic lives, contaminates drinking water, leaves fishermen jobless, and results in severe threat to the natural land cover of environment and public health. Attitudinal effects related to these physical problems are accountable for the emergence of militia and pressure groups that are perceived to be individuals crying foul for their selfish interest rather than that of their immediate communities. Kidnap of oil workers, payment of ransom by multinationals, and bombing of government oil facilities are some of the socio-physical events emanating from such sociological change, no thanks to the marginalization of the region during the regime of the military, lax approach of the democratic Government, and unethical operation of the multinational companies.

The above issues and many more anthropogenic activities directed at exploring and exploiting the natural resources in the region, has caused unquantifiable eco-environmental changes to natural land cover, land surface temperature, vegetation health etc.

Remotely sensed data from earth observation satellites provide a significant contribution to vegetation monitoring. Procedures to extract such information from digital imagery are generic and lead to results that are comparable, which is ideal for monitoring purposes at regional, national or supranational scales. Satellite images also make it easier to conduct regular updates, and even allow extracting historic information on land cover to study vegetation health trends. Over the years, NDVI has been successfully used in different studies based on vegetation phenology, vegetation classification and mapping of continental land cover. NDVI is suitable for monitoring and estimating healthy status of vegetation, crop growth conditions and crop yields (Kogan, 1987; Dabrowska-Zielinska et al., 2002; Singh et al., 2003). The basic concept of NDVI is based on the fact that internal mesophyll structure of healthy green leaves reflects Near-Infrared (NIR) radiation whereas the leaf chlorophyll and other pigments absorb a large proportion of the red visible (VIS) radiation. This function of internal leaf structure becomes reversed in case of unhealthy or water stressed vegetation.

Although several researches have studied vegetation health using satellite-based vegetation indices such as NDVI there has hitherto been no study that has evaluated both spatial and temporal dynamics of vegetation health, for the entire environment of the Niger Delta(Covering the entire nine states) using both AVHRR/MODIS and LANDSAT(TM, ETM$^+$ & OLI) data and also deduced monthly and inter-annual temporal trend and minimum, mean and maximum NDVI, values for each states in the Niger Delta region. This study attempts to fill this gap. Hence, evaluating vegetation health of the highly diversified eco-environment like the Niger delta region was very crucial as it was likely to yield information about vegetation health history and its dynamics

MATERIAL AND METHOD

Study Area

The Niger Delta Region (shown in Figure I) 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

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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 and Badejo, 2006; Okonkwo et al., 2015).

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 (9). The region is home to about 39 million people and is abundantly endowed with natural resources such as crude oil. The oil and gas from the region accounting for over 85% of the Nation's gross domestic product (GDP); about 95% of the National budget; and over 80% of the national wealth (Dokubo 2004; NDRDMP, 2004; Ebegbulem et al., 2013). Ironically, the region remains the poorest, due largely to the ecologically unfriendly exploitation of oil and natural resources. These physical misfortunes associated with oil production in the region calls for continuous research such as this on the study area so as to give an insight to the unquantifiable eco-environmental changes in the region.

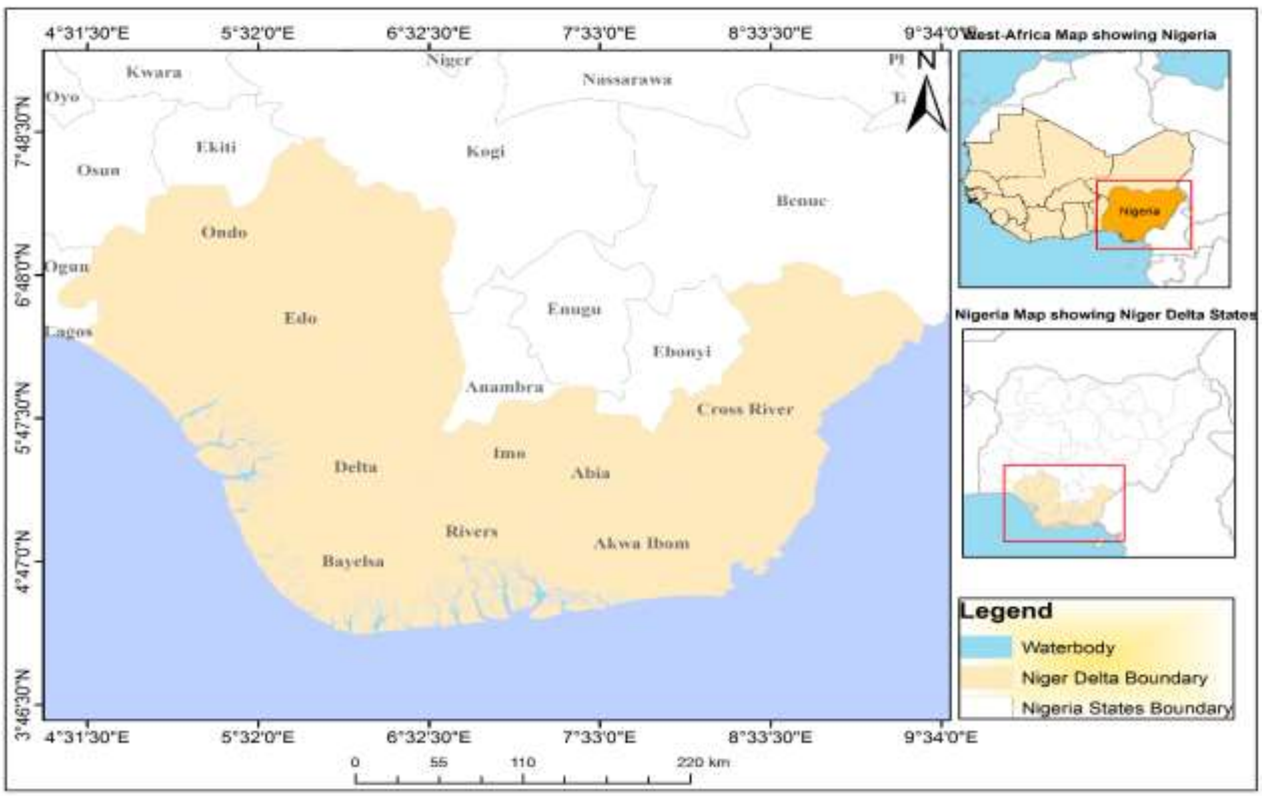

Figure I: Study Area in relation to West Africa and Nigeria.

Data

The primary data used in this study were Remotely Sensed satellite imagery of Landsat, AVHRR and MODIS dataset.

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i. Landsat 5(TM), Landsat 7 (ETM+) and Landsat 8 (OLI) images 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. Landsat dataset was used for evaluation of LULC dynamics, Spatial LST analysis, Vegetation health evaluation and coastline/shoreline evaluations.

Table I. 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

ii. AVHRR NDVI of 1982-2000 and 2001-2016 MODIS NDVI data with spatial resolution of 1.1km and 250 meters respectfully was downloaded from NASA Earth Observatory website. AVHRR and MODIS were used for the temporal evaluation of NDVI and VCI trend across the study area.

Methodology for Evaluation of the Vegetation Health Dynamics Across the Study Area.

The methodology for generation of Normalized Difference Vegetation Index (NDVI) from the Landsat imageries and AVHHR/MODIS NDVI data is as illustrated in the flow diagram in figure 2 below.

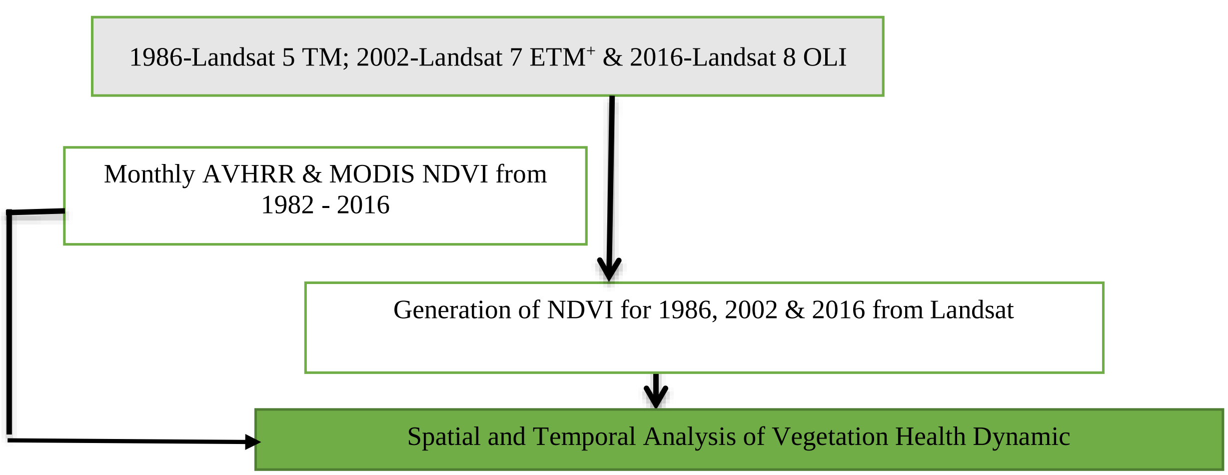

Figure 2: Research methodology flow diagram

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ArcGIS software was used to create models as shown in figure 3, for the spatial and temporal evaluation of NDVI, based on equation 1. The NDVI being a normalized transform of the NIR to Red reflectance ratio, is designed to standardize Vegetation Index values to between −1 and +1 and provides the measures of the amount or health of vegetation within a pixel. Values between -1 -0.3 indicates poor vegetation status; 0.3-0.5 indicates Normal vegetation condition and 0.5-1.0 indicates a healthy condition. It is expressed in equation 1 below;

NDVI = (NIR – Red) / (NIR + Red) … (1)

Where; NIR is the Near Infrared Band and Red is the Red band.

The model for NDVI evaluation was created in ArcGIS 10.2 using equation 1 above. The model is illustrated in figure 3 below.

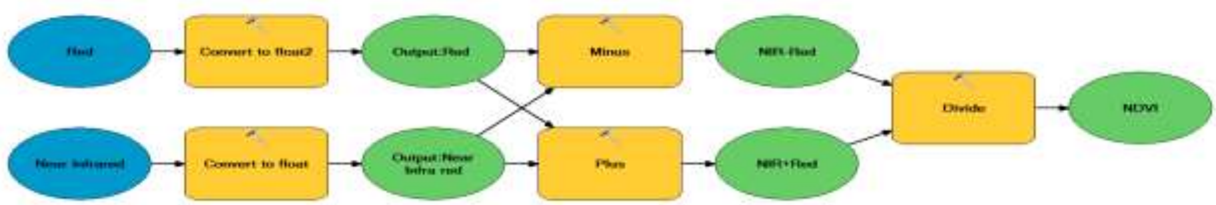

Figure 3: Model for Evaluation of NDVI

RESULTS AND DISCUSSION

Results of Spatial Analysis from Landsat Dataset

Using the model for NDVI evaluation created in ArcGIS 10.2, the spatial distribution analysis of NDVI across Niger Delta Region from Landsat 5(TM), Landsat 7 (ETM+) and Landsat 8 (OLI) images of 1986, 2002 and 2016 were respectively produced. The results are as shown in figure 4, 5 and 6.

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Figure 4: Map showing spatial distribution of 1986 NDVI across Niger Delta Region

Figure 5: Map showing spatial distribution of 2002 NDVI across Niger Delta Region

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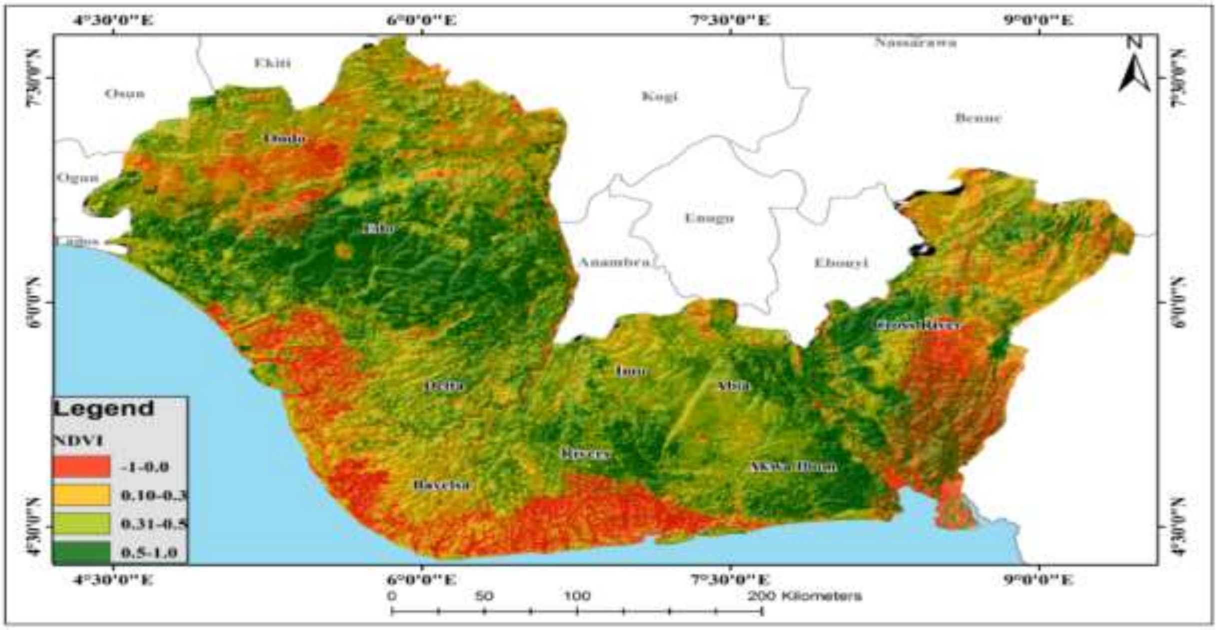

Figure 6: Map showing spatial distribution of 2016 NDVI across Niger Delta Region

The values between

a) -1 - 0 indicated very poor vegetation condition;
b) -1-0.3 indicated poor vegetation condition;
c) 0.31-0.5 indicated normal vegetation condition and
d) 0.5-1.0 indicates a healthy vegetation condition.

These results generally depict a deteriorating trend of health condition of vegetation in the Niger Delta. While there was a sufficient measure of chlorophyll across the region as at 1986, this seriously reduced in spatial spread in 2002 and was worse off in 2016. If this trend continues without intervention, it leaves much to be desired for the region in terms of vegetation status in the next 30years.

The Results of Temporal Analysis of NDVI Assessed from AVHRR (1981-2000) and MODIS (2001-2016)

Figure 7 & 8 illustrate a yearly and monthly trend of vegetation health condition across the Niger delta region from 1981 to 2016.

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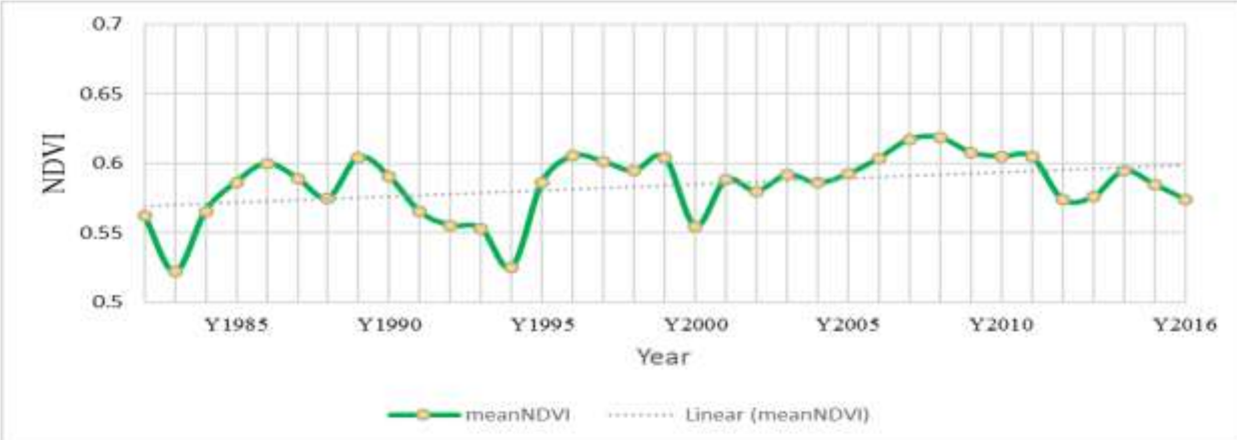

Figure 7: Temporal variation of yearly NDVI across Niger Delta Region from 1982- 2016.

The yearly temporal analysis of the NDVI result assessed from AVHRR (1982-2000) and MODIS (2001-2016) shown in figure 7 illustrate a trend of vegetation health condition across the Niger delta region from 1982 to 2016. Years 2007 and 2008 recorded the healthiest vegetation condition while 1994 recorded lowest. Generally, the vegetation health condition trend has not been smooth as depicted by the trend.

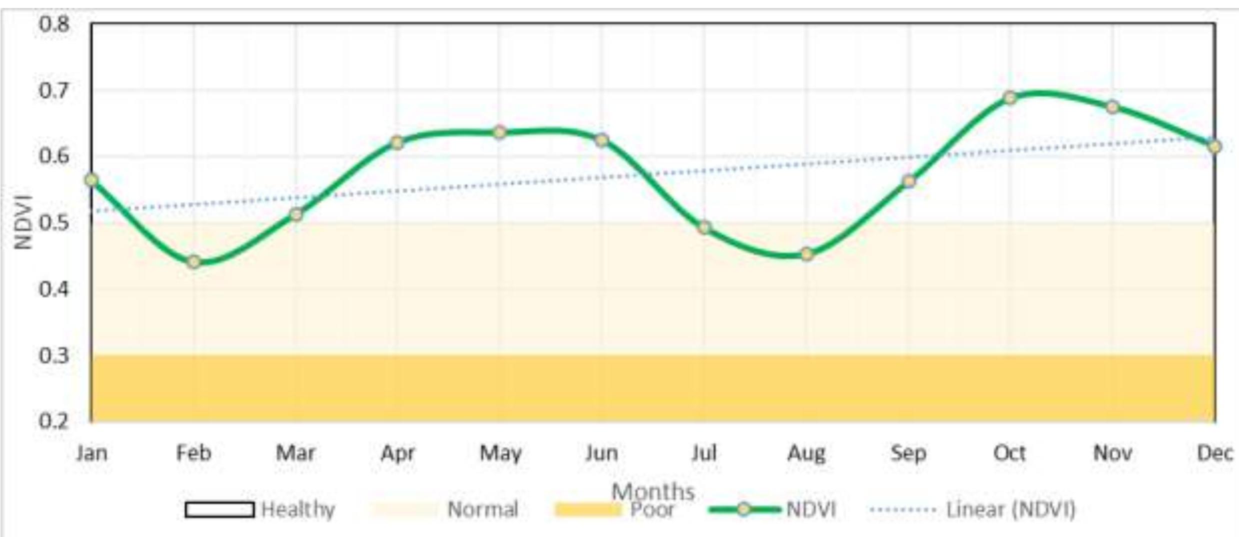

Figure 8: Monthly Temporal variation of NDVI across Niger Delta Region 1982- 2016

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Table 2: Monthly variation of NDVI across Niger Delta Region 1982- 2016

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NDVI	0.56	0.44	0.51	0.62	0.63	0.62	0.49	0.45	0.56	0.68	0.67	0.61

The monthly temporal analysis result in figure 8 and table 2 indicated that lower vegetation condition was recorded in February and August while October recorded the highest across the 34years period.

Also, the results in figure 9, 10, 11 and table 3 illustrate the minimum, maximum, mean and overall vegetation health condition of each state across the Niger Delta Region between 1982- 2016.

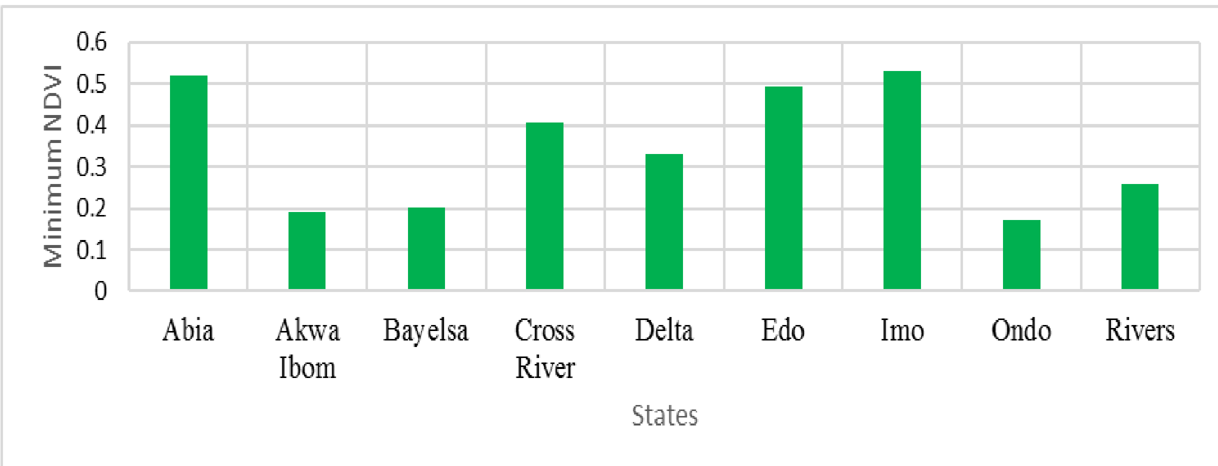

Figure 9: Minimum NDVI values across each state of the Niger Delta Region 1982- 2016

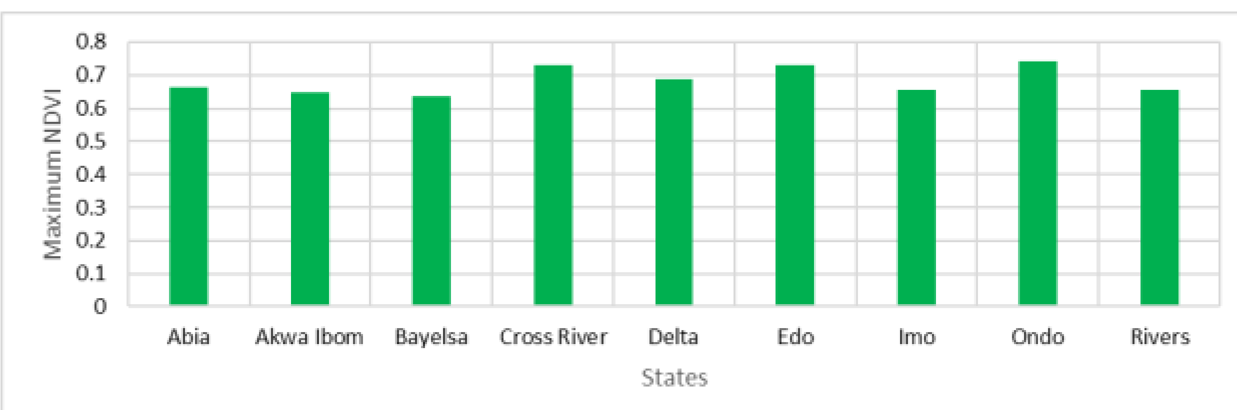

Figure 10: Maximum NDVI values across each state of the Niger Delta Region 1982- 2016

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Table 3: Minimum, Max., & Mean NDVI of each states of Niger Delta Region 1982- 2016

STATES	Min.NDVI	Max.NDVI	MeanNDVI
Abia	0.51	0.66	0.59
Akwa Ibom	0.19	0.64	0.53
Bayelsa	0.20	0.63	0.51
Cross River	0.40	0.73	0.62
Delta	0.33	0.688	0.56
Edo	0.49	0.73	0.64
Imo	0.53	0.65	0.59
Ondo	0.17	0.74	0.64
Rivers	0.25	0.65	0.52

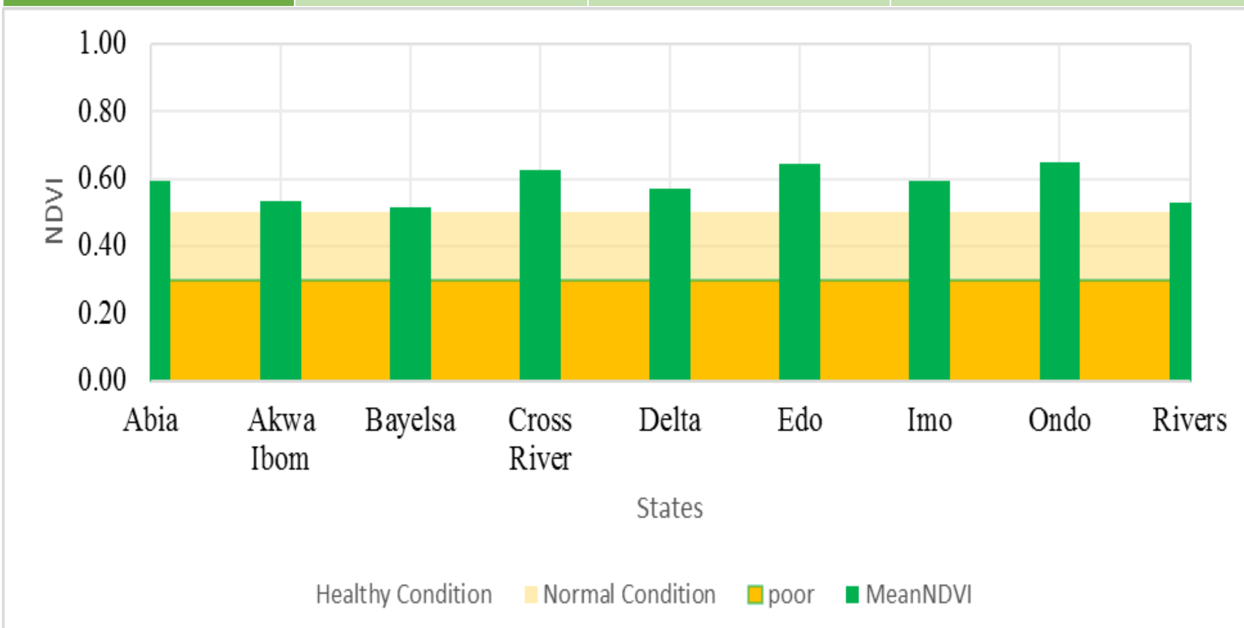

Figure 11: Overview of Vegetation Health across each states of Niger Delta Region 1982- 2016

Low NDVI values in the core oil producing states of Akwa Ibom, Bayelsa, Rivers, Delta and state is likely to be as result of heavy alteration of the vegetation due to unwholesome activities of oil exploration/exploiting like gas flaring, oil spillage, pipe line vandalism etc. whereas Ondo, Edo, Abia, Cross River, Abia and Imo state that has not had similar alteration had healthier vegetation condition. This AVHRR and MODIS NDVI also substantiate the result from Landsat NDVI.

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CONCLUSION

This study has demonstrated that remotely sensed data from earth observation satellites can provide a significant contribution to vegetation health monitoring. The generated NDVI maps of the study showed that the general health condition of vegetation in 2002 was less than 1986 and 2016 poorer than 2002. The mean NDVI values of each of the States within the study area were: Abia; 0.59, Akwa Ibom; 0.53, Bayelsa; 0.51, Cross River; 0.62, Delta; 0.56, Edo; 0.64, Imo; 0.59, Ondo; 0.64 and Rivers; 0.52. The vegetation of the core oil producing states of Akwa Ibom, Bayelsa, Rivers, and Delta State were the most stressed. This low NDVI values in the core oil producing is likely to be as result of heavy alteration of the vegetation due to unwholesome activities of oil exploration/exploiting like gas flaring, oil spillage, pipe line vandalism etc. as Ondo, Edo, Abia, Cross River, Abia and Imo state that has not had similar heavy alteration had healthier vegetation condition. These results is really an eye opener to the devastating effect of oil and gas exploration and exploitation in the region and thus calls for proactive measures from environmental planners to stem the trend.

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