ASSESSMENT OF THE EFFECTIVENESS OF THE VEGETATION CONDITION INDEX (VCI) AS AN INDICATOR FOR MONITORING DROUGHT CONDITION ACROSS THE NIGER DELTA REGION OF NIGERIA USING AVHRR/MODIS NDVI

Aniekan Eyoh
Faculty of Environmental Studies, University of Uyo, Uyo, **NIGERIA**
aniekaneyoh@uniuyo.edu.ng

Francis Okeke
Faculty of Environmental Studies, University of Nigeria, Enugu, **NIGERIA**
francisokeke@unn.edu.ng

Akwaowo Ekpa
Faculty of Environmental Studies, University of Uyo, Uyo, **NIGERIA**
akwaowoekpa@uniuyo.edu.ng

ABSTRACT

This study assesses the effectiveness of the vegetation condition index (VCI) as an indicator for monitoring drought condition across the Niger Delta region of Nigeria. The vegetation condition index (VCI), which is derived from remote-sensing data was used to evaluate drought conditions across the States in the Niger Delta region of Nigeria from 1983 to 2016. Inter-annual, monthly and mean VCI values for each state of the study area was determine through a model created in ArcGIS software. The results of inter-annual analysis of VCI revealed that all through the years, there was no water stress in the study area except for the year 1994 which had low drought condition. Similarly, monthly temporal variation revealed that the entire study area had no water stress condition from January to December. Nevertheless, lower drought condition was recorded in February and August while October recorded the highest across the 33years period. Also, the mean VCI values of each of the State within the study area showed that Ondo, Akwa Ibom, Bayelsa, Cross River and Rivers States were the healthiest States while Abia, and Imo were the lowliest in terms of drought condition. From the study results, the derivation of inter-annual, monthly and mean VCI values offers robust information on agricultural fertility window and trend that can be utilize for agricultural planning scheme within the region.

INTRODUCTION

The vegetation condition index (VCI), which is derived from remote-sensing data, has been widely used for drought monitoring. Globally, satellite-based vegetation indices such as normalized difference vegetation index (NDVI)-based vegetation condition index (VCI) have been extensively used by various researchers in detecting and monitoring of agricultural drought (Liu and Kogan 2002; Singh et al. 2003; Quiring et al. 2010; Domenikiotis et al. 2014; Kuri et al. 2014; Shen et al. 2014).

In this study, the vegetation condition index (VCI), was used for monitoring water stress condition across the states of Niger Delta region of Nigeria to ascertain the vegetation health history of the region from 1981 to 2016. Vegetation Condition Index (VCI) normalizes NDVI and separates the long-term ecological signal from the short-term climate signal and in this sense it proves to be a better indicator for monitoring water stress condition as compared to NDVI (Kogan, 1995; 2002; Kuri et al. 2014). Kogan (1995) reported that Satellite-based drought indices such as the normalized difference vegetation index (NDVI)-based vegetation condition index (VCI) have been widely used for detecting the onset of agricultural drought and measuring the intensity, duration, and impact of it. Domenikiotis et al. (2004) used NOAA/AVHRR derived Vegetation Condition Index (VCI) to assess early cotton yield in Greece. Also Liu and Kogan. (2002) also used NOAA/AVHRR derived Vegetation

Condition Index (VCI) to assess Brazilian soybean production. They all concluded that remote sensing derived information can be used to monitor crop yield conditions. Rahim (2005), used AVHRR sensor data to estimate drought. From the analysis of NDVI and VCI examined, the results indicate a high correlation between the index and VCI amount in the synoptic station of rainfall. Bhuiyan and Kogan (2006) used NOAA-AVHRR satellite NDVI data to generate VCI, TCI and VHI in the Aravalli region of India to investigate drought. The results obtained was compared with ground based statistical indicators such as SWI and SPI and there were significant correlations of ground based data and remote sensing data. Similarly, Bhuiyan (2008) also successfully used NOAA-AVHRR satellite NDVI data to generate VCI, TCI and VHI to estimate the droughts for Thar Desert northwestern India and East Pakistan between 1984 and 2003.

Zhang et al (2009) in their study in in Huanghuai region of China successfully used NOAA-AVHRR satellite NDVI data along with meteorological data for the years 1981 to 2008 to investigate drought. They concluded that there were significant correlations of meteorological data with that of remote sensing data.

Moghadam et al. (2014) in their study, reported the efficiency of agricultural drought indicators like VCI for estimating vegetation conditions. They used data of satellite images from Terra MODIS sensor from 2000 to 2011 of Sharghi Azerbaijan Province. Their results indicated that VCI of year 2001, 2008, 2000 and 2009 have the most rates of drought, while years 2010 and 2003 had been minimal. Their results showed that agricultural drought assessment through Remote Sensing VCI would be an excellent model in areas where weather stations are sporadic, and in places where there is no model that can be used to estimate drought.

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 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.

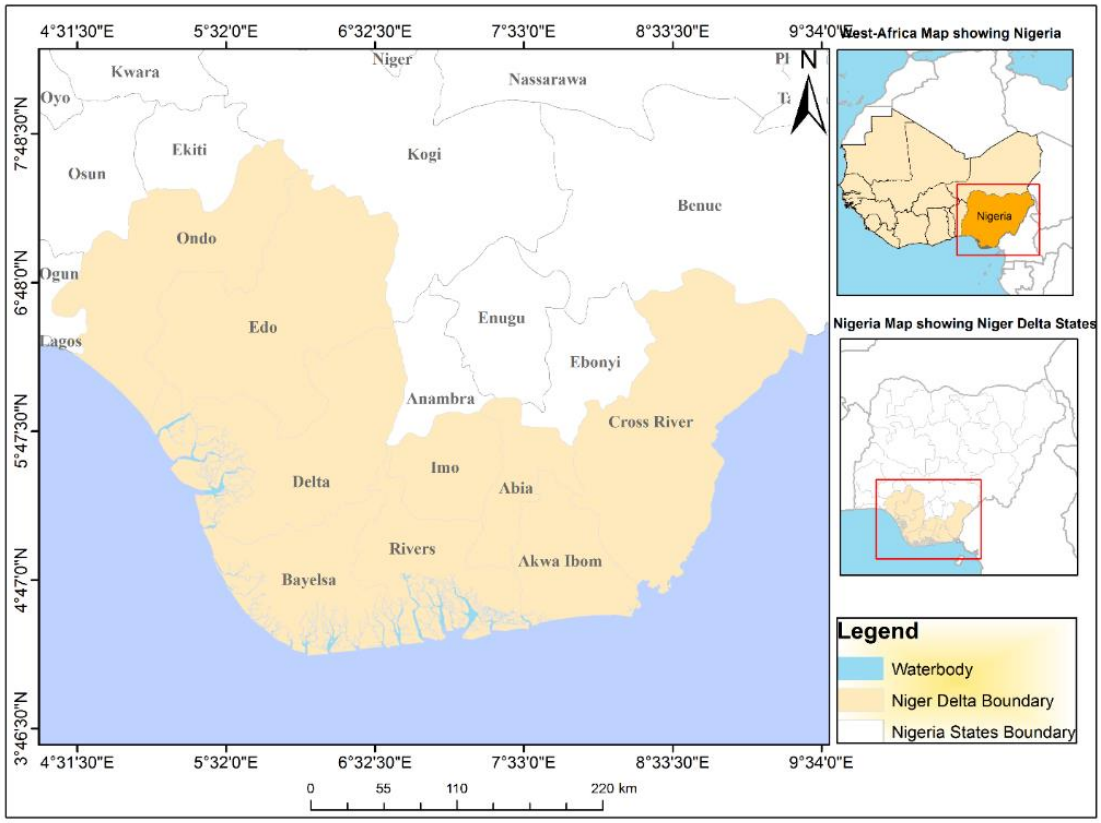

Figure I: Study Area in relation to West Africa and Nigeria

DATA

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

Assessment of Vegetation Condition Index (VCI)

From the Literature review, Vegetation Condition Index (VCI) prove to be a better indicator for monitoring water stress condition (drought). According to. Liu and Kogan 2002, VCI is express as given in equation (1) below.

$$VCI = (NDVI_i - NDVI_{min}) / (NDVI_{max} - NDVI_{min}) * 100\% \ldots (1)$$

Where;

$NDVI_{max}$ and $NDVI_{min}$ represent maximum and minimum NDVI of each pixel calculated for each month and i represents the index of current month.

VCI value is measured in percentage ranging from 1 to 100. The range between 50% and 100% indicates no drought (normal condition of vegetation) whereas the values ranging from 50% to 35% indicate low drought condition and below 35% indicates severe drought condition (Kogan, 1995; Liu and Kogan 2002; Reza et al. 2009; Domenikiotis et al. 2014; Kuri et al. 2014;).

The model for VCI evaluation was created in ArcGIS software using equation 1. The model is illustrated in figure 2.

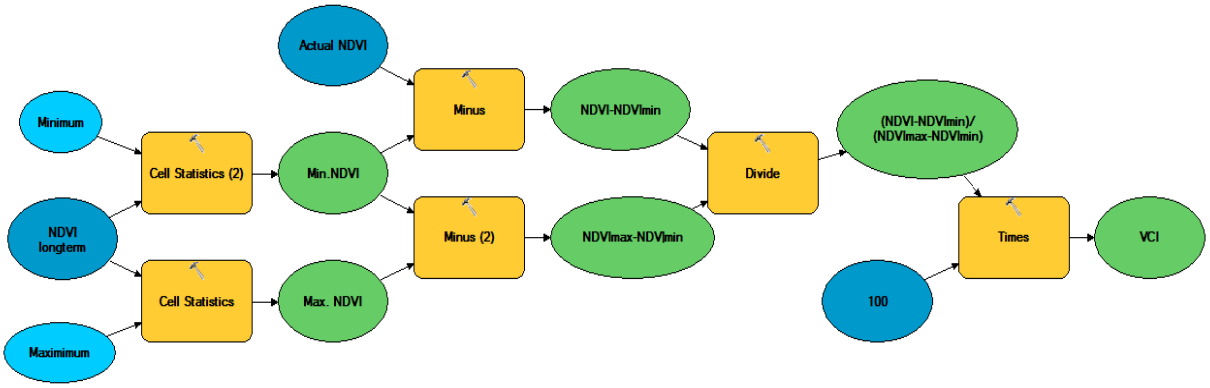

Figure 2: The model for VCI evaluation created in ArcGIS Software

RESULTS AND DISCUSSION

Using the model created in ArcGIS shown in figure 2, evaluation of the temporal trend of VCI; inter-annually, monthly and determination of mean VCI values for each state of the study area was carried out.

Figure 3 below shows the Inter-annual temporal variation of VCI across the Niger Delta Region 1983- 2016 and it revealed that all through the years, there was no water stress in the study area except for the year 1994 which had low drought condition. The year 1999 recorded the highest VCI value.

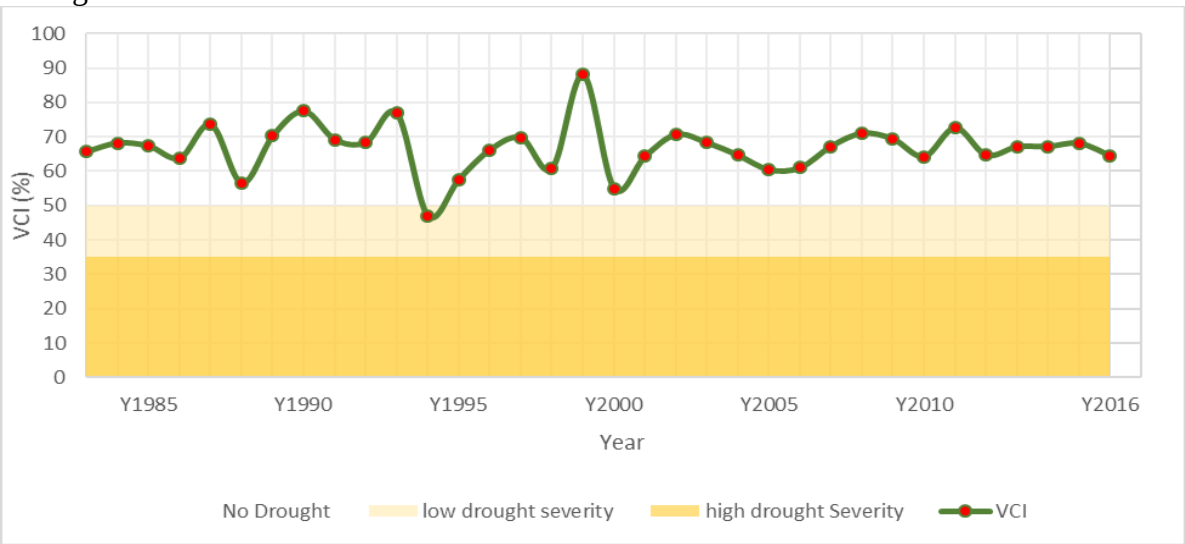

Figure 3: Inter-annual temporal variation of VCI across the Niger Delta Region 1983- 2016

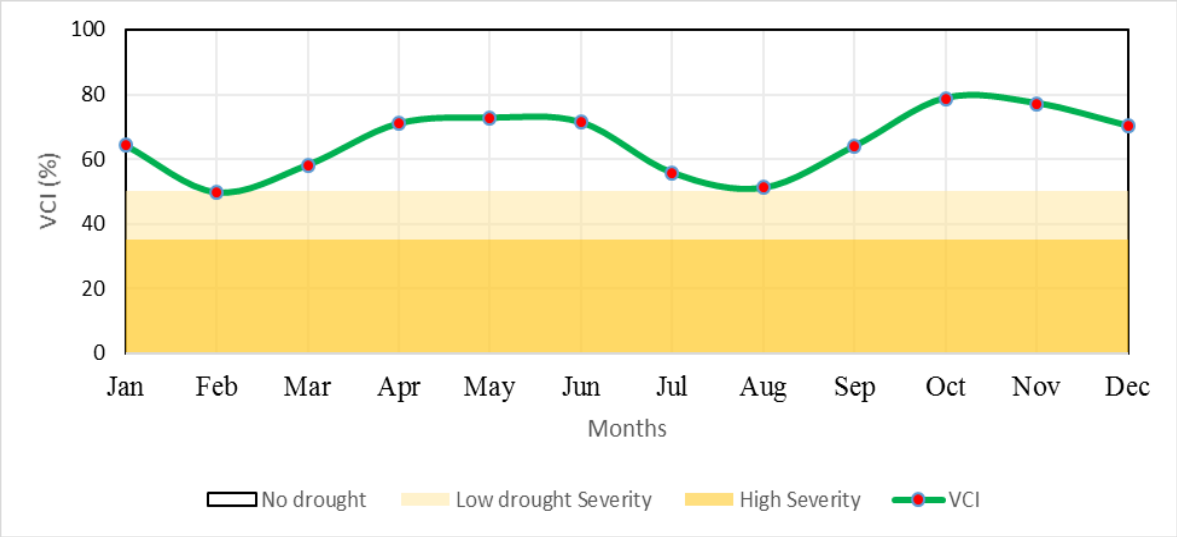

Figure 4: Monthly temporal variation of VCI across the Niger Delta Region 1983- 2016

Figure 4 above and Table 1 below shows the Monthly temporal variation of VCI across the Niger Delta Region 1983- 2016 and it revealed that the entire study area had no water stress condition from January to December. Nevertheless, lower drought condition was recorded in February and August while October recorded the highest across the 33years period.

Table 1: Monthly variation of VCI across Niger Delta Region between 1983- 2016

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
VCI	64.22	49.79	58.17	70.94	72.68	71.31	55.82	51.18	63.98	78.80	77.21	70.28

Table 2: Mean VCI Values per states of Niger Delta Region between 1983- 2016

States	VCI (%)
Abia	50.28
Akwa Ibom	75.23
Bayelsa	71.41
Cross River	67.98
Delta	66.36
Edo	64.36
Imo	51.61
Ondo	83.52
Rivers	67.79

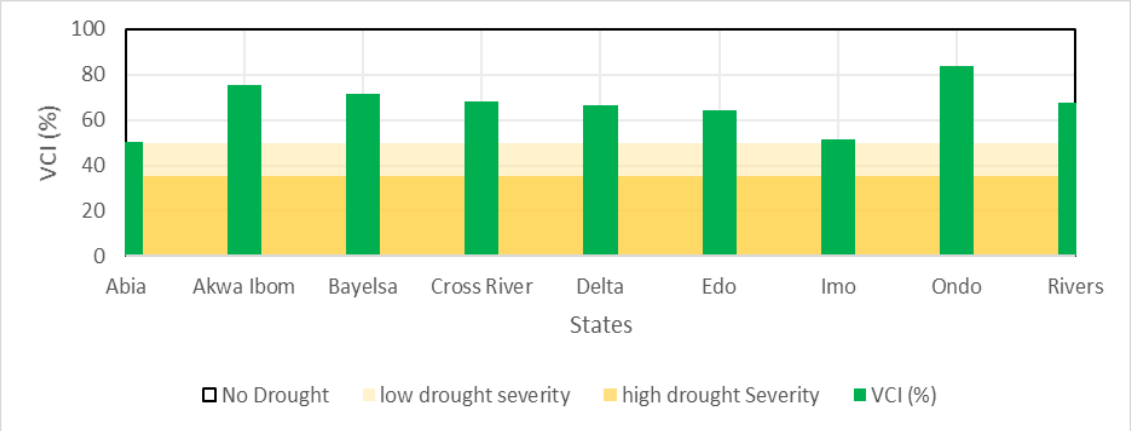

Figure 5: Mean VCI Values per states across the Niger Delta Region between 1983- 2016.

The results in figure 5 and table 2 showed Mean VCI Values per states across the Niger Delta Region between 1983- 2016 depicting vegetation drought condition. The VCI values between 50% and 100% indicates no drought (normal condition with no water stress) whereas the values ranging from 50% to 35% indicate low drought condition and below 35% indicates severe drought condition. From the mean VCI values of each of the State within the study area: Abia; 50.28%, Akwa Ibom; 75.23%, Bayelsa; 71.41%, Cross River; 67.98%, Delta; 66.36%, Edo; 64.36%, Imo;51.61%, Ondo; 83.52% and Rivers; 67.79%, Ondo, Akwa Ibom, Bayelsa, Cross River and Rivers States were the healthiest States while Abia, and Imo were the poorest in terms of drought condition.

CONCLUSION

This study has successfully demonstrated the usefulness of satellite-based vegetation indices such as normalized difference vegetation index (NDVI)-based vegetation condition index (VCI) for monitoring water stress condition of the study area. Although the study revealed that the entire study area had no water stress condition from January to December, the results from the derivation of monthly and inter-annual temporal trend and mean VCI values for each states in the Niger Delta region offers robust information on agricultural fertility window and trend that can be utilize for agricultural planning scheme as the region has a vast majority of rural dwellers whose livelihood depends on agriculture.

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