

Inter annual variation of vegetation anomaly over Nigeria using satellite-derived index

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ABSTRACT

Vegetation is a determining factor for agriculture and food security. Therefore, a detailed understanding of vegetation variability and its dynamics is very important as it has to deal with issues such as drought and food security. This paper reports a study of the inter-annual variations of vegetation anomaly over Nigeria using the Normalized Difference Vegetation Index (NDVI) derived from the Advanced Very High Resolution Radiometer (AVHRR) data sets using the visible and near-infrared channel reflectance. The study covers the period between the year 1982 and 2000. The analysis was done for the various vegetation belts of the country with some years of extreme anomalies noted. These anomalies have been linked to extreme El Nino Southern Oscillation (ENSO) events that took place within this period.

Keywords: Climate, Meteorological Satellites, Normalized Difference Vegetation Index (NDVI), Advanced Very High Resolution Radiometer (AVHRR), El Nino Southern Oscillation (ENSO).

INTRODUCTION

Satellites are tools that are primarily used to monitor the weather and climate of the earth. They generate data which are also used to acquire imageries. These meteorological satellites, however, see more than clouds and cloud systems. They acquire images of vegetative cover in diverse resolutions of space and time.

Satellite data processed into Normalized Difference Vegetation Index (NDVI) can be used to explain deficiencies in rainfall and describe meteorological and agricultural drought patterns both temporally and spatially, thus serving as an indicator of regional drought patterns. This remotely sensed NDVI allows continuous and long-term monitoring of information on vegetation, which should hold valid information for investigation into relationship between vegetation and climate.

The Normalized Difference Vegetation Index (NDVI) is generally recognized as a good indicator of terrestrial vegetation productivity. The normalized difference vegetation index (NDVI), which is the normalized reflectance difference between the near infrared (NIR) and visible red bands [1,2] is used extensively in ecosystem monitoring.

The onset of suitable moisture conditions for vegetation causes the emergence and growth of plants. Therefore, the resulting increase in the amount of vegetation and in the photosynthetic activity leads to a consistent increase in the NDVI. When these conditions cease, the resulting moisture stress will reduce biophysical rates (photosynthetic rate and transpiration) which will result in a substantial fall in the NDVI [3].

Vegetation, simply defined, is the plant cover of the earth consisting of assemblages of plants. Together with physiography, it constitutes the most observable element of the landscape. Vegetation expresses and reflects environmental conditions, particularly climate.

Broadly speaking, the national vegetation over a geographical area is essentially a response to the climate in that area. Nigeria's vegetation belts reflect this very close link between vegetation and climate hence, the similarity in the west-to-east zonation of both climate and vegetation. With the south to north progressive decline in total rainfall and length of wet season, vegetation belts are demarcated on west-to-east zonation pattern characterised by transitional zones from one belt to another.

Nigeria consists of various vegetation belts with their specific characteristics in terms of variation of rainfall and vegetation properties. With the growing concern of climate change, the need arises to take a critical look into the anomalies of vegetation in the various belts of the country. This is in part the object of this paper.

MATERIALS AND METHODS

The NDVI data was extracted from the NOAA satellite which has a five – channel radiometer AVHRR with channel 1 in visible and channel 2 in the near infrared spectral bands. The ratio of near infrared to visible is referred to as the Vegetation Index. The Normalized Vegetation Index (NDVI) was computed using the equation below:

$$NDVI = \frac{CH2(NIR) - CH1(VIS)}{CH2(NIR) + CH1(VIS)} \dots\dots\dots (1)$$

where: CH 2 = Channel 2 Reflectance
CH 1 = Channel 1 Reflectance

The CH 1 and CH 2 are values generated from the AVHRR channels 1 and 2 respectively. The data for the period between 1982 and 2000 were retrieved and analyzed.

The raw NDVI values were analysed into decadal values (a period of 10 days). This method is quite efficient as it takes a closer look into the details of the vegetation characteristics for the various zones of Nigeria.

The major vegetation belts in Nigeria are:

- The Sahel Savannah
- The Sudan Savannah
- The Guinea Savannah
- The Tropical Rain Forest and
- The Mangrove Forest

For these regions, various locations were considered and compared so as to know the variation patterns of the anomalies of vegetation in the various zones. The anomalies were as the normalized index value from a distribution characterized by mean and standard deviation which is given as:

$$Z = \frac{X - \mu}{\sigma} \dots\dots\dots (2)$$

where: X is the value of each normalized index

μ is the arithmetic mean of the distribution

σ is the standard deviation of the distribution

For some stations the year 1994 was excluded due to incomplete data.

RESULTS AND DISCUSSION

Figure 1 shows the mean anomalies for the Sahel-Sudan Savannah of Nigeria. The various stations used are located in this region. The trend of anomalies for this zone was quite similar in all the locations considered. There were sharp negative anomalies generally between 1982 and 1988 with the year 1984 having the most negative anomaly with the exception of Kano in which the most conspicuous anomaly was seen in 1985. The year 1994, with a value of about -2, had the strongest departure from the average NDVI value for this region with the year 1999 having the strongest greenness anomaly with a maximum value of about +1.8. The anomalies were tending to be negative for the year 2000 though they were still positive except for Kano which had a strong negative anomaly for this year. Nicholson (1995) further buttressed that the climate of the Sahel is characterized by a marked seasonality with a long dry season and a short humid season in the northern hemispheric summer, which is explained by the position of the region relative to major global and regional circulation features and the seasonal variation of tropical weather patterns. Climatic constraints, i.e. not only scarcity but also variability and unpredictability of rainfall, which increase from south to north, are the most important controlling factors of the Sahelian ecosystem. The vegetation cycle closely responds to the seasonality in rainfall, with virtually all biomass production taking place in the humid summer months. The sharp seasonal contrasts are overlain by considerable fluctuations in rainfall at inter-annual and -decadal time scales, which make the Sahelian region the most dramatic example of climate variability that has been directly measured. [5].

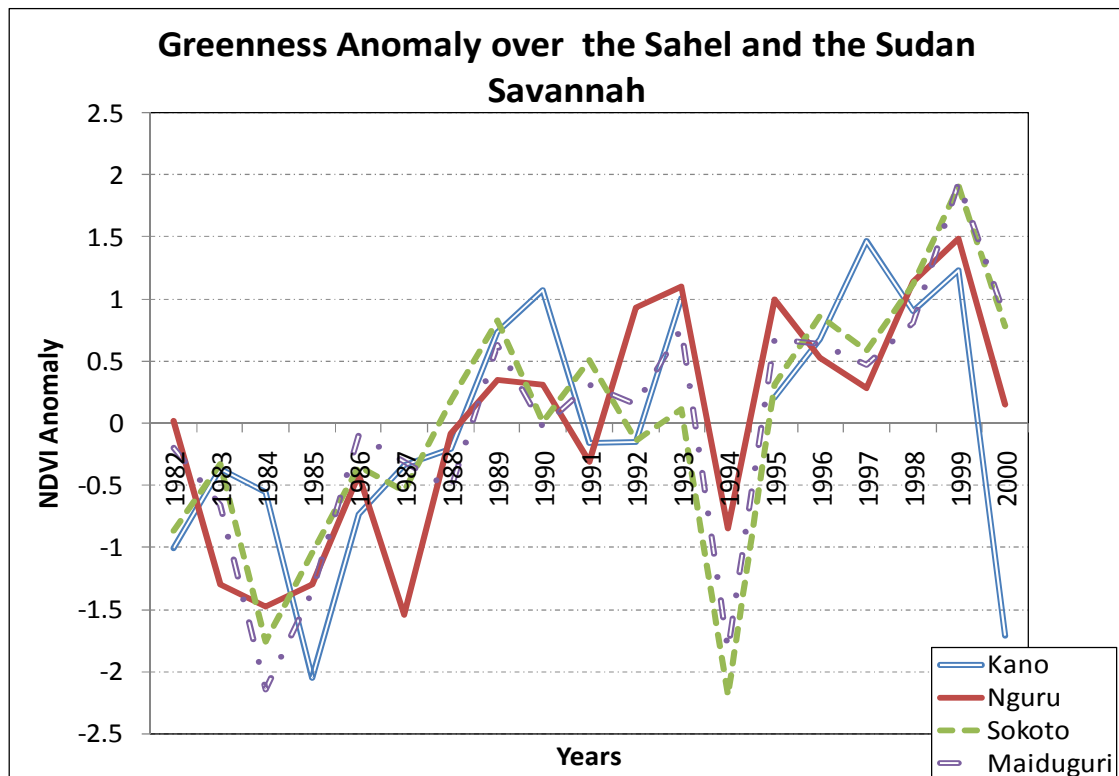


Fig 1: Anomaly of vegetation over the Sahel and Sudan Savannah

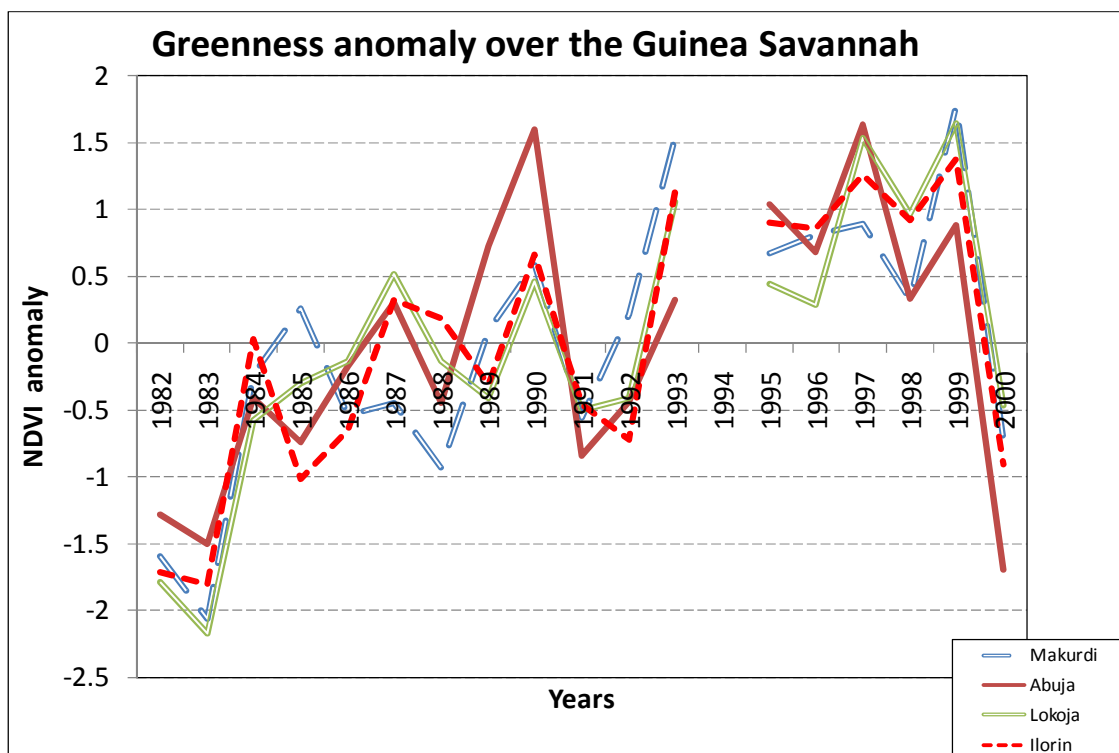


Fig 2: Anomaly of vegetation over the Guinea Savannah

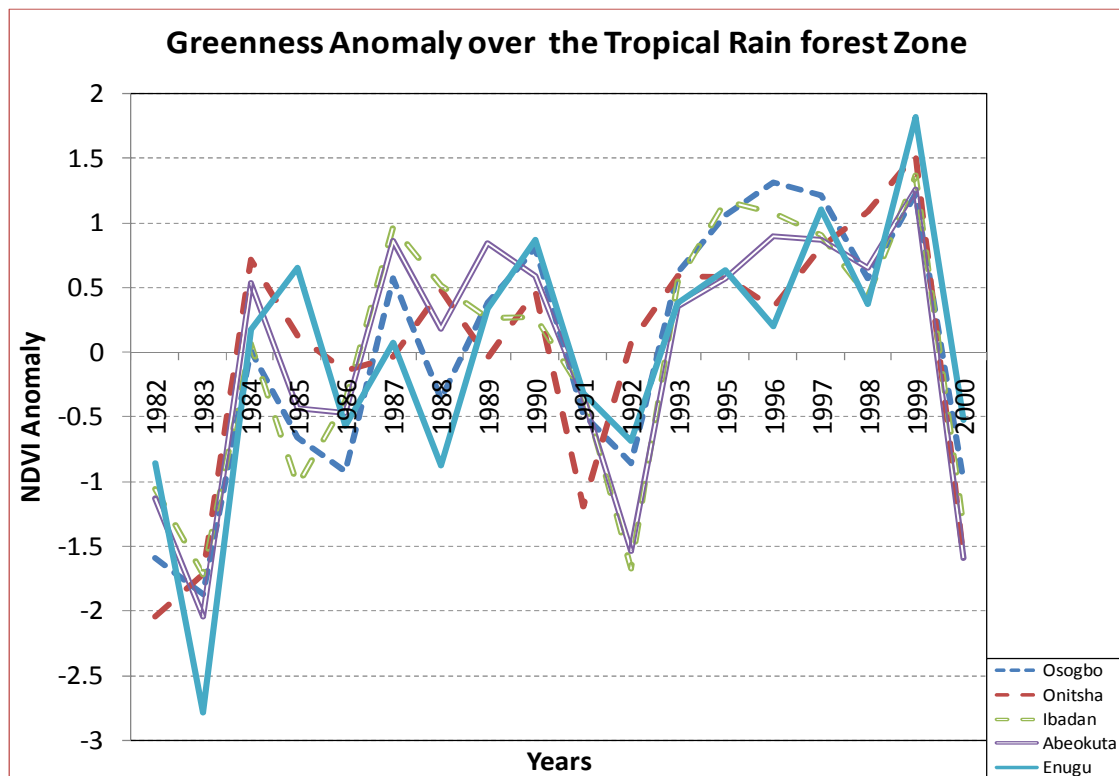


Fig 3: Anomaly of vegetation over the Tropical Rainforest zone

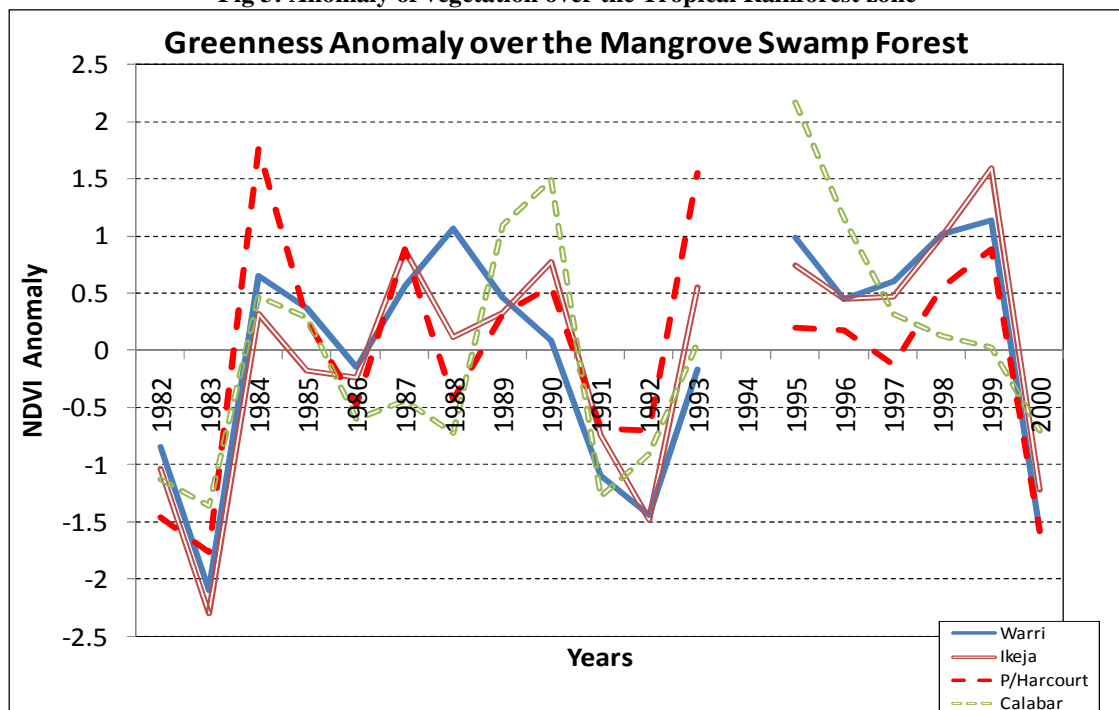


Fig 4: Anomaly of vegetation over the Mangrove Swamp Forest zone

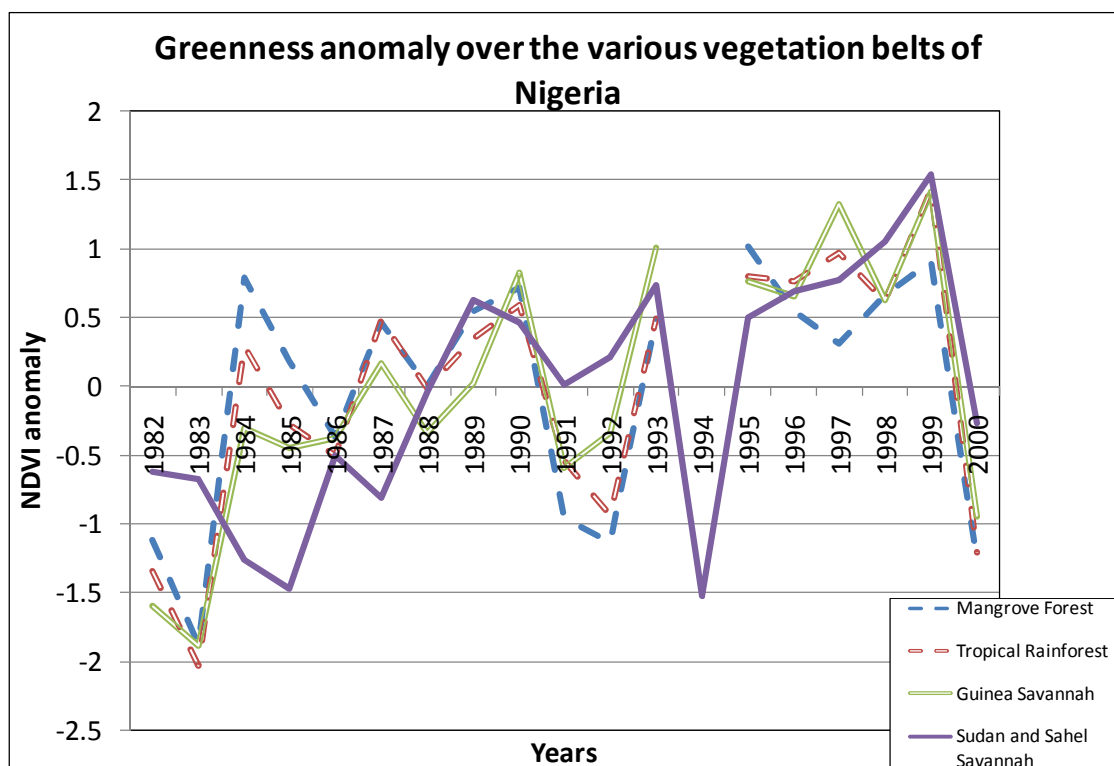


Fig 5: Anomaly of vegetation across the various vegetation belts of Nigeria

In figure 2, it is seen that the Guinea Savannah region had major negative anomalies in 1983 and 2000 with minimal negative anomalies between 1984 and 1989. There was a strong positive anomaly of about +0.5 and a notable one of about +1.5 in Abuja. Other notable years of strong positive anomalies are 1997 and 1999 with values of about +1.5.

The variation of vegetation over the tropical rain forest region was quite similar to that of the Guinea Savannah region (Figure 3) but for the fact that the vegetation variation had a more regular pattern for all the stations under consideration than the other regions discussed above with the series of NDVI anomalies showing the spatial coherence and temporal persistence of drought conditions during the early 80s depicting a prevalence of drought conditions during this period. This vegetation belt also experienced strong negative anomalies in 1983 with a peak value of about -2.8 in Enugu and between years 1991 and 1992 with Abeokuta having an anomaly of -1.5 and positive anomalies thereafter. The strongest positive anomaly was experienced in 1999 and a negative anomaly thereafter in the year 2000.

The variation greenness anomaly over the mangrove swamp forest is shown in figure 4. It also had a similar variation pattern with that of the tropical rain forest zone. This region experienced its strong negative anomaly also in 1983 with a value of about +2.3 and also between the years 1991 and 1992 with a value of about -1.5. It had its peak anomaly value between 1993 and 1995 (though there were missing data values in 1994). Similarly, it also had its notable positive greenness anomaly value in 1999 and a general negative trend of anomaly for all the stations in year 2000.

Figure 5 gives a summary of the variation of anomalies for the various vegetation belts in Nigeria. The Sudan and Sahel Savannah had stronger variations and did not follow the anomaly pattern like that of the other stations. The negative anomalies for the Sudan-Sahel region were in 1984-1985, 1994 and 2000. Other vegetation belts had their negative anomalies in 1983, 1991-1992 and 2000 with values of about -2, -0.8 and -1 respectively. The years 1982-193 and 1991-1992 can be termed as a period of nationwide drought conditions. Nevertheless, the general trend of positive anomaly values were noticed in years 1984, 1990 and 1999 which depicts periods of above normal vegetation conditions.

A growing archive of satellite observations has indeed shown a close coupling between vegetation greenness and rainfall variability (Aweda et al, 2009). Tucker and Nicholson (1999) found the green vegetation boundary of the Sahel to fluctuate by up to 150 km from a wet year to a preceding dry year in response to rainfall. With such great natural fluctuations, the permanence of land degradation in the form of desertification can only be established by monitoring susceptible areas over a time scale of decades. Ecosystem monitoring, in the Sahel and elsewhere, has been facilitated by the progress in remote sensing technology and the availability of data sets at ever finer spatial, temporal and spectral resolutions. Remote sensing presents important advantages to the monitoring of vegetation dynamics and land degradation—such as the synoptic perspective it offers—however, there are limitations to this technology that also have to be taken into account.

As a synergistic tool, remote sensing does not distinguish between different vegetation types and, therefore might hide changes in vegetation cover not associated with changes in overall greenness, such as shifts in vegetation composition. Other limitations arise from the technological and cost-induced trade-offs between different types of resolution, such that simultaneous increases of spatial, spectral and temporal resolutions, all of which can provide more precise information in different aspects of vegetation dynamics, in one system are inhibited [9].

CONCLUSION

Analysis of vegetation anomalies within this 18-year period shows the existence of positive and negative anomalies over the various regions across Nigeria. It has been shown that the Sahel and Sudan had more variability than other regions of the country. This may be due to the fact that the north is more prone to drier conditions than the south and another reason why so much effort have been put in place to study the Sahelian vegetation.

It is also noteworthy that years 1983 and 1987 were drought years coincided with the global droughts widely believed to be the result of El Niño's effect.

Long-term rainfall variability (which accounts for vegetation variability) in Nigeria is accounted for, not by the ITD mechanism alone, rather, other factors such as the tropical easterly jet (TEJ), sea surface temperature anomaly (SSTA), biogeophysical feedback mechanism, and the El Nino Southern Oscillation (ENSO) also enter the picture in addition to anthropogenic factors such as land use, deforestation and so on.

Studies on El-Nino has shown that its effects was prominent in the years 1982-1983 and 1991-1992 (Douglas, 2010) which also coincides with adverse anomalies of greenness. It is therefore apparent that there is a strong connection between ENSO events and the variability of vegetation. Further studies can therefore be carried out for further investigation.

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