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The Impact of Climatic Change on Nigerian Landcover During the El-Nino Southern Oscillations (ENSO), Event of 1997 to 1998

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Abstract: Seventytwo dekadal NDVI dataset derived from Advanced Very High Resolution Radiometer-Normalised Difference Vegetation Index (AVHRR-NDVI) on board the National Oceanic Atmospheric Administration-National Aeronautics Space Administration (NOAA-NASA) meteorological satellites were recomposed into a 24 time-series monthly Maximum Value Composite (MVC) images covering the El-Nino Southern Oscillations (ENSO) event of 1997 to 1998 and analysed within a Geographical Information System (GIS) environment using Principal Component Analysis (PCA) with the standardised principal components and supplemented with coefficient of variation derived images. The purpose is to assess the impact of such event on landcover across Nigeria and in particular, vegetation patterns across the country. Results from this analysis produced 24 standardised principal component imageries with another corresponding 24 individual loading scores presented in graphs. Others include inter-seasonal coefficient of variation change images for 1997 and 1998 as well as an annual mean NDVI image of the total 24 time-series dataset; temporal profiles of sites observed with distinct changes and a coefficient of variation graph through the monthly time-series were presented. The resultant component one image shows an overall 96.5% of the variation in the total time-series dataset while the succeeding imageries illustrated change elements in the order of the component loadings (which are weighted). In comparison with the mean imagery of the total 24 time-series dataset, the first component image showed a considerable similarity indicating a typical characteristic of landcover (particularly vegetation NDVI) pattern over the whole country during the 1997 to 1998 ENSO event with positive and negative anomalies in certain locations across some states but more distinct in locations around the Kainji and Lake Chad basins, Niger delta area, Bayelsa, Lagos, Taraba, Plateau, Jigawa, Katsina, Sokoto, Zamfara Adamawa, Yobe and Borno states. Thus, results from this study highlighted specific locations across the country with anomalies of climatic impact as a result of the 1997 to 1998 ENSO event.

Key words: Environment, climatic impact, ENSO, AVHRR-NDVI, NOAA, sea surface temperature, PCA

INTRODUCTION

In the scientific context, global climatic anomalies linked to the El-Nino Southern Oscillations (ENSO) are a major topic of scientific investigation (Anyamba and Eastman, 1996). However, by the end of the 19th century most meteorologists held firmly that climate was stable overall about the same in one century as in the last. That still left room for cycles within the overall stability. However, confusion persisted in the early decades of the 20th century as researchers continued to gather evidence for solar variation and climate cycles as well as reason for their impacts on the general environment. By the end of this century a small community of scientists was also pursuing the question of how solar variability might relate to short-term weather cycles as well as long-term climate changes. Attempts to correlate weather patterns with the sunspot cycle were stymied, however by inaccurate and unstandardised weather data and by a lack of good statistical techniques for analysing such data. Besides, it was hard to say just which of many aspects of weather were worth looking into and how it affects the landcover.

The 1970s also brought controversial claims that the planet's climate system could go through purely self-sustaining oscillations, driven by feedbacks between ocean temperatures and wind patterns. Such oscillations

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in relation to the solar patterns cycled quasi-regularly on timescales ranging from a few years to several decades now being referred to as El-Nino Southern Oscillations (ENSO) occurring in the surface waters of the tropical Pacific Ocean (Anyamba, 1994) and it affects the entire globe (Singh *et al*., 2002). In the past decades, there has been a series of record-breaking extreme weather events the hottest years on record according to Dawson and Spannagle (2009) are 1998 and 2005. Accordingly, this caused an intense El-Nino event in 1997 to 1998 with a series of floods followed by extended droughts and powerful tropical storms. All these are as a result of the changing climate (Kogan and Wei, 2000; IPCC, 2007).

Climatic changes both in themselves (sea surface temperatures) and in response to the land cover such as vegetation can be detected and monitored in order to detect their impacts on the general environment (Reed *et al*., 1994). Studies that used time-series global Advanced Very High Resolution Radiometer-Normalised Difference Vegetation Index (AVHRR-NDVI) dataset (Townshend and Justic, 1986; Ehrlich and Lambin, 1996; Anyamba and Eastman, 1996) demonstrates that there is a connection between changing patterns of sea surface temperature and patterns of plant growth across the surface of the earth. Sea surface anomalies like the ENSO therefore, exert a profound influence on rainfall patterns around the globe. Rainfall and temperature variations on the other hand are also reflected in variations in plant growth generally (Rasmussen, 1998a, b; Anyamba *et al*., 2001). The Normalised Difference Vegetation Index (NDVI) is a measure derived by dividing the difference in the infrared and red reflectance measurements by their sums (Sellers, 1989). Thus from the AVHRR sensors, NDVI is derived as: Channel 2-Channel 1/Channel 2+Channel 1.

Long-term changes in the NDVI data have been evaluated in several studies but results have not been conclusive due to differences in the tools used data processing techniques as well as the length and time of the analysed time-series. NDVI however is a land surface parameter which plays an important role in ecology (Diallo *et al*., 1991; Richards and Poccard, 1998). It is also said to be sensitive in the circulation process between land surface and atmosphere (Lambin and Ehrlich, 1995; Ehrlich and Lambin, 1996; Milich and Weiss, 2000; Shaghude *et al*., 2003).

Other studies have also indicated that NDVI is closely related to some biophysical parameters such as photosynthetically active radiation, leaf area index, biomass of vegetation, etc. (Lambin and Ehrlich, 1995; Eklundh, 1998; Zhan *et al*., 2004).

The impacts of this ENSO as predicted and ascertained thus gave various organisations an early warning opportunity to prepare for extreme weather events and their intensities so that such impacts can be mitigated.

The ENSO event of 1997 to 1998 in particular was reported to be one of the most extreme and severe in the 20th century both in terms of Sea Surface Temperature (SST) departure patterns and the associated magnitude of the climatic anomalies worldwide (Anyamba *et al*., 2001). For example, this event was said to have the strongest SST anomaly (>2.0°C) because it affected most parts of the world during that period. By some measures, it was the strongest on record with major climatic impacts felt round the world (McPhaden, 1999; NASA, 2012).

Other studies covering certain parts of Nigeria (Ezemonye and Emeribe, 2011; Maina and Maina, 2012; Olowa and Olowa, 2012; Usman *et al*., 2011; Yelwa and Eniolorunda, 2012) suggested highly vulnerability to impact of climatic change ranging from exposure to desertification in the form of accumulated soil-erosion to increased loss of soil fertility to reduction in ecosystem production and to flooding thereby threatening all forms of life.

With the global view and repetitive coverage provided by meteorological satellites, remotely sensed data are vital to the monitoring and understanding of such ENSO events and impacts particularly as it affects vegetation and the general environment. The purpose of this study therefore is to utilise meteorological satellite data from AVHRR covering Nigeria during the 1997 to 1998 ENSO period and analyse it within a Geographical Information System (GIS) environment in order to assess the impact of the ENSO event on land cover across Nigeria. The rationale is that when such datasets are taken over long time intervals (months or years) and analysed or compared can help understand how land cover changed over time. Furthermore, satellite data can be used to detect land cover change from one growing season to the next from year to year or from decade to decade (Townshend and Justice, 1986). The utilization of such dataset has shown that it assisted in understanding the impact of mankind generally on the natural biological cycles and the mapping areas of habitats for disease vectors (Smith *et al*., 1997; Yelwa, 2004, 2008).

MATERIALS AND METHODS

In this study, dekadal NDVI dataset from the NOAA-14 satellite which was acquired between 1995 to 2000 were utilised. A total of 72 dekadal NDVI dataset covering Nigeria during the El-Nino Southern Oscillations (ENSO) event of 1997 to 1998 was sourced from the Pathfinder-Land (PAL) dataset. The compositing technique by Holben (1986) to further reduced noise in the dataset was adopted. This reduced the dataset from seventy two dekadal images to 24 time-series monthly Maximum Value Composite (MVCs) images and was analysed within a Geographical Information System (GIS) environment using Principal Component Analysis (PCA) with the standardised principal components (Eastman and Fulk, 1993). In order to enhance the results derived from the PCA, inter-seasonal coefficient of variation change images for 1997 and 1998 as well an annual mean NDVI image of the total 24 time-series dataset were derived indicating percentage coefficient of variation through the time-series. Others include temporal profiles and graphs of selected areas which exhibited positive or negative anomalies during the 1997 to 1998 ENSO period. These were also derived and compared. The purpose is to assess the impact of the ENSO event on the general environment across Nigeria.

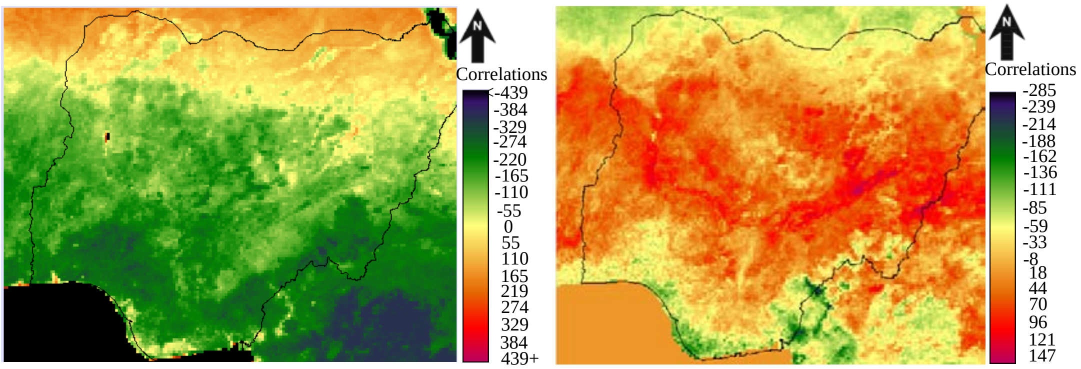
RESULTS AND DISCUSSION

Because the time-series NDVI dataset was subjected to PCA employing the standardised principal components, 24 component images with their corresponding loading 24 scores (weighing) showing their correlations with each input NDVI image were derived. The percent variance explained was also calculated for all the components utilised in this analysis, loading graphs were automatically created for all the 24 components. However, because of ease in interpretation and presentation only four component images and their corresponding loading scores (graphs) are used in this study. Others supporting results includes temporal graphs and profiles of selected sites exhibiting negative and positive anomalies during the 1997 to 1998 ENSO period.

An examination of the results from the four component images in Fig. 1 and the loading graphs in Fig. 2 for the dekadal time-series covering the 1997 to 1998 ENSO event across Nigeria shows clearly that the landcover across the country was affected during this period. Component 1 image for example, explains 96.5% of the variation in 24 NDVI-MVCs. By implication, it shows a typical representation of the vegetation NDVI across the country during this period regardless of the season although, with a distinctive positive anomaly except in the extreme Northern part of the country which shows slight

Component one

Component two



Component three

Component four

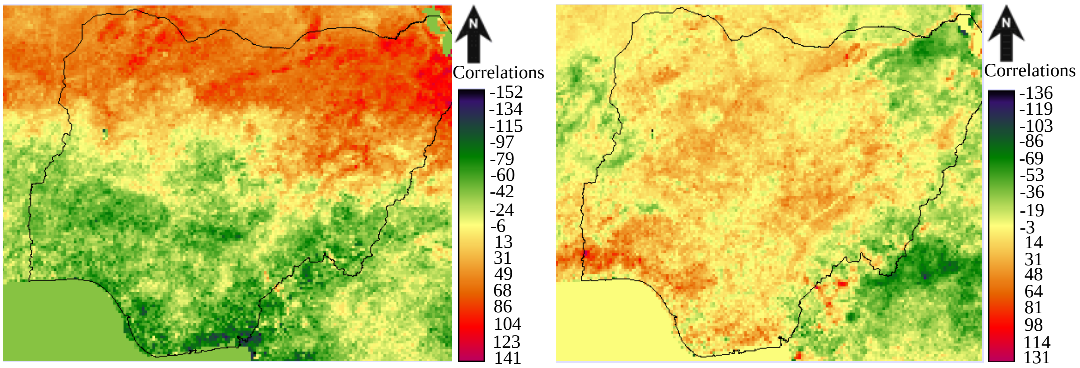


Fig. 1: The first four components images derived from time-series analysis from PCA using standardised principal components

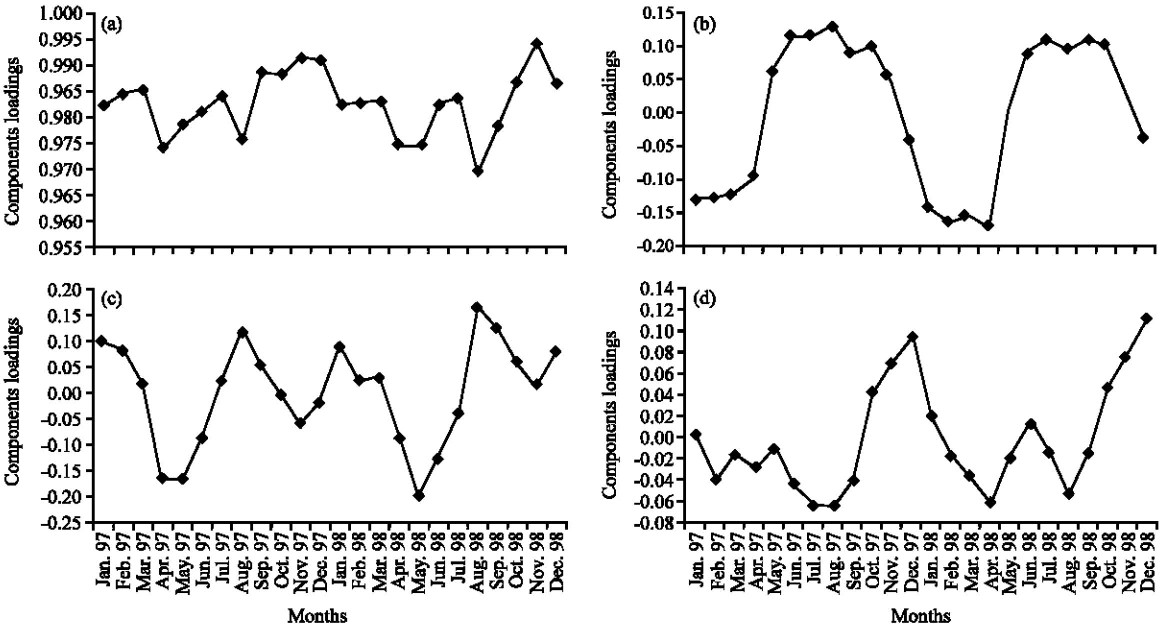


Fig. 2: Graphs showing components loadings of time-series analysis from PCA using standardised principal components; a) Graph of component 1 loading; b) Graph of component 2 loading; c) Graph of component 3 loading; d) Graph of component 4 loading

or no changes. Pockets of positive anomalies can however be sighted around Lagos State, the Kainji Lake area and the extreme Niger Delta region with a very low positive correlation (0.97) with the time-series NDVI dataset and the component loading scores in August 1998. With regards to the spatial patterns of component 2, 3 and 4 images, these demonstrated gradual decrease in total percentage variation of changes in the general landcover pointing to the fact that certain vegetation pattern and changes that are not apparent but are most likely changes that have been shrouded by the typical vegetation NDVI in the input dataset used for the PCA analysis. All the correlations as shown by the graph of component 1 loadings are very high (above 0.97 except for August 1998). With regards to the correlations between the NDVI dataset and the component images as the loading graphs have shown in Fig. 2. It is very likely that their spatial pattern exhibited seasonal precipitation trends bearing in mind that NDVI correlates strongly with vegetation phenology. For example while the graph of component 2 loadings shows significant positive anomaly in NDVI between June to October 1997 and same period in 1998 for most areas across the country, the coastal areas on the other hand showed negative correlations particularly between the months of January to April 1997 and for the same months in 1998. The research conducted using Fourier analysis by both Andres *et al*. (1994) and Olsson and Eklundh (1994) confirmed that seasonal and sub-seasonal signals of vegetation can be detected from NDVI data and consequently climatic variability related to the ENSO. Accordingly, the spatial pattern of components 3 and the graph of its loading scores corresponds to the views of Udosen (2012) regarding the movement of the Intercontinental Convergence Zone (ITCZ) from the South to the North of the country. However, high positive anomalies are exhibited in the North-West to North-East direction of the country in both August 1997 and 1998 while the negative anomalies can be seen prevailing from the South-West to South-East direction during the month of May 1998. An examination of the graph of component 3 shows depressed peaks in April and May 1997 as well as in May 1998. The coefficient of variation of graph in Fig. 3a indicated lower variations from April through June for both 1997 and 1998. The spatial pattern on component 4 image on the other hand exhibits positive NDVI anomaly pattern around Western part of the country and negative anomaly located around the Kainji and Lake Chad basins, particularly along the major rivers. The timing of this negative NDVI anomaly pattern exhibited around the water bodies in the country corresponds precisely to the period when the ENSO was highest in 1997 with a 28-29°C water filling the equatorial region (McPhaden, 1999). However, there was a high negative correlation with component 4 image in August 1998 suggesting that certain areas in the country must have experienced either flood or drought. For example, the study by Udosen (2012) showed that one of the driest years in Akwa-Ibom was in 1997 (an area in the tropical rain forest where high rainfall is expected). This clearly relates to the impact of this ENSO event in Nigeria (Table 1 and 2).

A comparison between the Mean NDVI Image derived from the time-series dataset (Fig. 3a) and the Component 1 image in Fig. 1 showed similarities but significant differences can be observed around the river basins, the Niger delta and the extreme Northern part of the country (covering parts of Sokoto, Kebbi, Adamawa, Katsina, Kano, Jigawa, Bauchi, Gombe, Zamfara, Yobe and Borno states). Figure 1b and c shows inter-seasonal coefficient of variation (%) images for 1997 and 1998 indicating different variability across the country with the highest (19.23%) in 1997 and (16.95%) in 1998, respectively. However, Fig. 3d shows that the lowest inter-seasonal coefficient of variation in the time-series

Table 1: Percentage variation of the total time-series dataset for the component images

Component image (%)	Comp-1	Comp-2	Comp-3	Comp-4
Variation of the total dataset	96.52457	1.152011	0.957005	0.237894

Table 2: Loading scores (weight) of the 24 monthly NDVI dataset used as input in the PCA analysis

	Component loadings			
Months	Comp-1	Comp-2	Comp-3	Comp-4
Jan. 1997	0.982092	-0.129030	0.099086	0.002758
Jan. 1998	0.982075	-0.141500	0.087033	0.020184
Feb. 1997	0.984364	-0.124860	0.080783	-0.036270
Feb. 1998	0.982578	-0.163020	0.021350	-0.014430
Mar. 1997	0.985032	-0.120610	0.016185	-0.013840
Mar. 1998	0.982922	-0.156140	0.029198	-0.034110
Apr. 1997	0.973761	-0.098000	-0.168090	-0.024830
Apr. 1998	0.974450	-0.170170	-0.084710	-0.059170
May 1997	0.978320	0.065437	-0.169180	-0.008460
May 1998	0.974186	0.001766	-0.200520	-0.016590
Jun. 1997	0.980970	0.112875	-0.089720	-0.040860
Jun. 1998	0.982237	0.089588	-0.129600	0.014043
Jul. 1997	0.983912	0.113230	0.021766	-0.059950
Jul. 1998	0.983623	0.108174	-0.040830	-0.012860
Aug. 1997	0.975238	0.128823	0.118683	-0.060600
Aug.1998	0.969054	0.094617	0.163761	-0.051650
Sept. 1997	0.988431	0.088259	0.053783	-0.036770
Sept. 1998	0.978244	0.105096	0.123009	-0.011670
Oct. 1997	0.988113	0.099648	-0.002860	0.042660
Oct. 1998	0.987039	0.100904	0.058421	0.047465
Nov. 1997	0.991228	0.046148	-0.061700	0.068178
Nov. 1998	0.993797	0.027777	0.011912	0.075508
Dec. 1997	0.990927	-0.042570	-0.018680	0.094256
Dec. 1998	0.986226	-0.037070	0.079362	0.112137

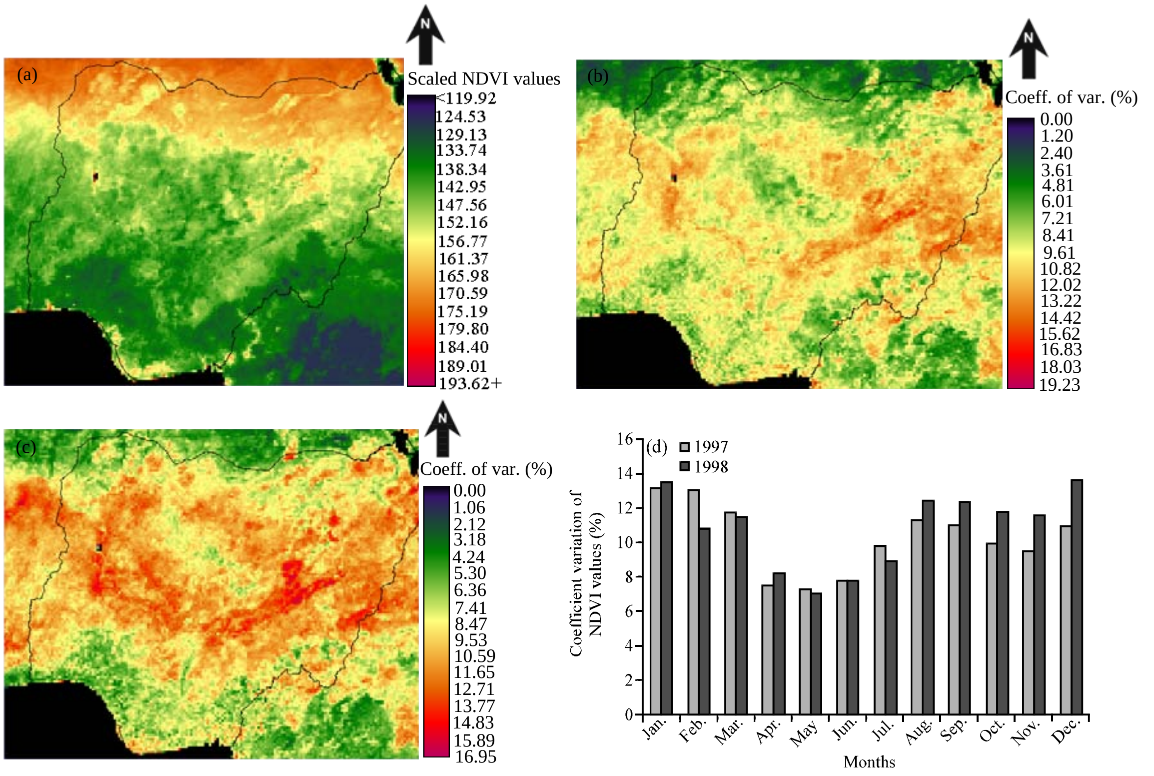


Fig. 3: a) The mean image derived from the 24MVCs images used in the analysis of the time-series dataset; b) the 1997 inter-seasonal coefficient of variation image while; c) 1998 inter-seasonal coefficient of variation image while; d) the graph the representing the coefficient of variation (%) of the monthly MVCs used in the time-series dataset

are found between April and July with the lowest variabilityin the month of May 1998 (7.04%). This lowest inter-seasonal variability is found to coincide with the negative correlation (lowest peak) of the graph of component 3 loadings (-0.2). On the other hand, the highest inter-seasonal variability is found to be in August 1998 (13.66%) which coincides with the positive correlation (highest peak) of this component loadings (0.16). This suggest that while the Northern part of the country was experiencing positive impact of the ENSO due to the high positive NDVI anomaly, the Southern part of the country on the other hand was experiencing negative impact of the ENSO during the 1997 to 1998 event. In Fig. 4 temporal profiles of the distinct anomaly sites were presented including their variability (%) across the time-series.

The study conducted by Linthicum *et al.* (1999) for example indicated that certain vector diseases such as animal trypanasomiasis and malaria can be linked to anomalies in time-series NDVI due to very high or low rainfall. Accordingly, climatic change has always been a major determinant of human health. Thus, the prevailing climate during any period determines the range of temperatures that individuals experience, their exposure to different types of diseases and the incidence of extreme weather events such as storms, floods and droughts. These factors determine the extent and type of health risk people face and the coping strategy they adopt to minimise these risks. Generally, temperature can have both direct and indirect impacts on human health. The direct impacts can arise mainly from extremes of heat and cold which can cause illness and sometimes death. The indirect effects can arise from changes in the incidence and distributions of vector-borne diseases; the occurrence of photochemical smog and forest fires; changes in the reproduction patterns of rodents an pests, crop failure and a greater incidence of food contamination among others. A study conducted by Aliyu *et al.* (2000) for example indicated that in 1997 there was an outbreak of Contagious Bovine Pleuroneumonia (CBPP) diseases with a serious outbreak and high mortality in cattle in the northern states of Nigeria covering Sokoto, Zamfara, Bauchi, Borno and Adamawa States. This corresponds to the period the different fluctuations in the temporal profiles of negative and positive NDVI anomaly sites shown on Fig. 4a and b during the 1997 to 1998 ENSO period and may likely be as a result of the impact of climatic change. Accordingly, the coefficient of variation graphs of the various distinct sites of negative and positive NDVI anomaly during the 1997 to 1998 ENSO period shown in Fig. 4c can attest that such variabilities can be linked to the impact of climatic changes because in Nigeria, the outbreaks of most animal related diseases are reported to have occurred in areas dominated by savanna, montane and rain forest vegetation zones as well as water courses, ponds, reservoirs and lakes (Kalu, 1995, 1996; Anene *et al.*, 1991). This also suggest that such outbreaks must have occurred due to the changing pattern of rainfall which is significantly related to vegetation (Anyamba and Eastman, 1996).

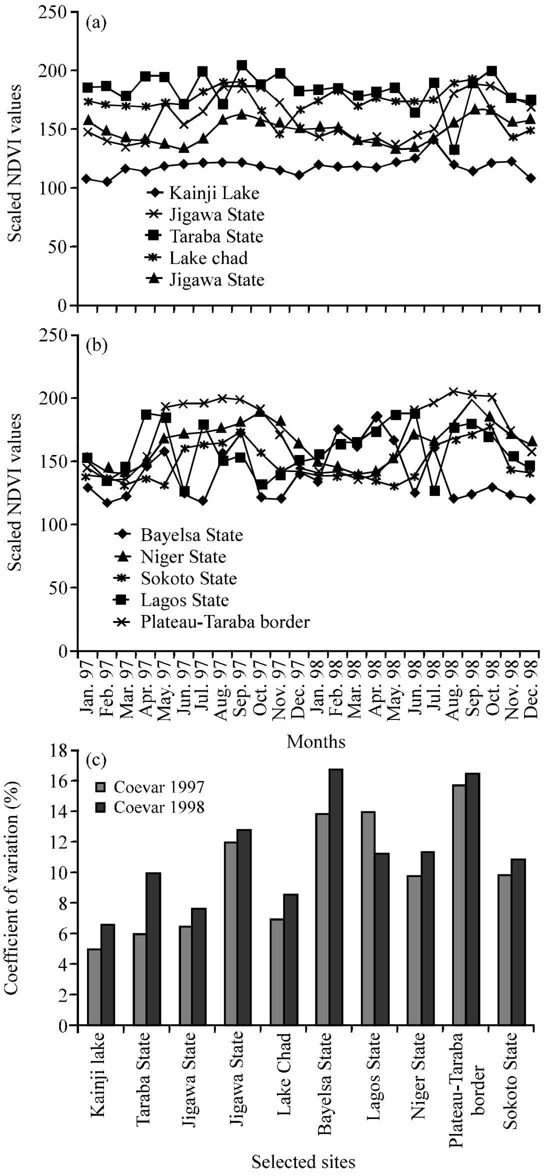


Fig. 4: a) Temporal profiles of selected sites from Kainji Lake, Taraba State, Jigawa State and Lake Chad; b) temporal profiles of selected sites from Bayelsa State, Niger State, Sokoto State, Lagos State and Plateau/Taraba State; c) 1997 and 1998 inter-seasonal coefficient of variation graphs of the selected sites in a and b

From the temporal profiles and graphs in Fig. 4c for the sites in Lagos and Bayelsa States it can be agued that coastal zones are particularly susceptible to climate change as they are subject to several different and often reinforcing physical and biological climate-related impacts. This include sea level rise, high risks of exposure to extreme events (such as intense storms, storm surges and flooding), salt contamination of fresh-water resources and climate-related changes to marine and terrestrial ecosystems. On the other hand, humans are also vulnerable to coastal zone changes as one-quarter of the world's population resides within 100 km distance and 100 m elevation of the coastline with significant increase in the number of people living in coastal regions expected over the next half century (Small and Nicholls, 2003). Furthermore, one particular concern regarding the impact of climatic change on coastal mangroves is that they perform an important biological function and provide important fish breeding grounds, erosion control and protection from storms.

Human activity including conversion of mangrove systems to shrimp farms and clearance for ports and urban development has already had significant impact on mangrove forests as can be observed nowadays on the coastal areas of Nigeria. As mangroves are very susceptible to changing sea levels, water temperatures and sedimentation patterns, climatic change is expected to adversely affect them. Furthermore, the increases in atmospheric concentrations of greenhouse gases and the global warming associated with such increases can affect marine ecosystems through alterations in ocean chemistry increases in water temperatures changes in ocean currents modifications to nutrient circulation patterns.

As wide range of marine species depend on coral reefs for their existence any reduction in health and vitality of reef systems will likely have major impacts on marine biodiversity. Many coastal and Island communities particularly in Nigeria, depend on coral reefs for fishing; tourism, biodiversity or beauty could therefore represent a major cost of climatic change to these communities (Dawson and Spannagle, 2009). As was clearly shown by McPhaden (1999) the 1997 to 1998 ENSO was by some measures the strongest on record with major climatic impacts felt around the world. Accordingly, changes in water temperatures have also affected the productivity of both fauna and floral populations and in some areas, there have been significant declines in the abundance of certain species across the country (Jimoh *et al*., 2012; Labaris, 2012).

CONCLUSION

In this era of climatic change debates, this study demonstrated that time-series NDVI data derived from AVHRR on board the NOAA-NASA Meteorological Satellites with its repetitive coverage across the globe is very vital for monitoring the impacts of ENSO on the general environment either on a local, national, regional or global scale using appropriate technique.

As clearly seen from the results of this study across Nigeria, there were serious impacts on its land cover on various aspects of the environment. However, measures can be adopted as suggested by Vos *et al*. (2010) so as to enhance the adaptive capacity to cope with climatic change in most of the affected areas across the country namely, to create and have a link in habitat networks so that species will be able to colonise habitats that become suitable as compensation for the loss of habitat at the contracting side of its range to increase the carrying capacity of protected areas in the country by either enlarging the size of these areas or by improving habitat quality.

Furthermore, projects that will reduce both loss of natural habitat and deforestation so as to promote biodiversity, soil and water conservation can be implemented in a socially and economically sustainable manner. For example, the Jatropha plant is a very good species that can be planted around farms and forest reserves so as to safeguard/prevent animals from going into these areas to destroy crops and other rare plant species. Forestation and bioenergy plantation in states like Sokoto, Kebbi, Katsina, Zamfara, Yobe, Borno, Gombe and Taraba can be introduced/established in order to restore degraded land and manage water runoff as well as retain soil carbon so as to benefit rural economies. On the other hand by increasing the carrying capacity of major protected areas across the country more space will be provided for larger populations thus reducing populations of specie extinctions to better accommodate natural landscape forming processes such as sedimentation, marshland development as in the riverine areas, meandering of rivers and freshwater-salt water gradients and this will hopefully increase the spatial heterogeneity of species in order to cope with increased weather variability as large scale correlated, population fluctuations will be avoided. This is because in heterogeneous habitats, some parts may allow positive growth rate in very dry years and other parts may be optimised during wet years. Thus, although, this study utilised a coarse spatial resolution 8 km NDVI dataset from AVHRR to examine the impact of the 1997 to 1998 ENSO event on Nigerian land cover highlighting hot spots (of both negative and positive anomalies) it is hoped that if a 1 km resolution dataset from SOPT satellite is utilised in the future to examine the impact of the ENSO event of 2005 across the country, a more glaring result is likely to emerge.

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