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Analysis of Trends in Vegetation Avhrr-Ndvi Data Across Sokoto State 1982 – 1986 Using Remote Sensing and GIS

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ABSTRACT: The current situation in vegetation productivity across Nigeria and indeed in Sokoto State is being affected by climatic change and other unfavourable environmental conditions. Time-series Remotely Sensed data within Geographic Information System (GIS) environment can be utilized to timely monitor the trajectory in vegetation productivity and dynamics in environmentally unstable areas across the state. In this study, dekadal Normalised Difference Vegetation Index (NDVI) data derived from the National Oceanic Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) Pathfinder (PAL) dataset was utilised in monitoring trends in vegetation NDVI productivity for 5-year growing seasons (July, August and September) within seven selected sites of irrigated and rain-fed croplands across Sokoto State from 1982 to 1986. Ground truthing was conducted using Global positional System (GPS) and digital camera to establish typical status of the individual selected sites and evaluated with the IDRISI-ANDES GIS software. Profiles of the monitored sites were plotted using Excel Spreadsheet. Results have shown that shelter belts within the study area have high variability in vegetation NDVI productivity in all the growing season months compared to the irrigated and rain-fed cropland sites. Although studies have shown that NDVI from AVHRR has strong correlations with rainfall and net primary productivity particularly in the arid and semi arid areas, the month of July 1985, August 1985 and September 1984 had shown very low vegetation NDVI productivity in all the sites monitored compared to the productivity of the preceding months. This is likely to be connected to the El-nino Southern Oscillations (ENSO) warm phase (changes in sea surface temperature) which other studies have shown that it affected the world primary net production (NPP).
Keywords: Vegetation, Changes, Remote Sensing and GIS

INTRODUCTION

The current situation in vegetation productivity across Nigeria and indeed in Sokoto State is being affected by the ongoing climatic change and other anthropogenic factors. For several years, many investigations have been carried out on the land surface utilising data from the National Oceanic Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) Pathfinder (PAL) dataset particularly to monitor vegetation (Tucker *et al,* 1984, *et al,* 1985, Quarmby *et al,* 1993, Nicholson *et al,* 1994, Leblon *et al*, 2001, Pouliot *et al,* 2009). Changes in landcover surface however, are driven by causes such as natural changes in climatic conditions, geomorphological and ecological processes like soil erosion and vegetation successions, human induced changes of vegetation cover and landscapes like deforestation and land degradation as well as inter-annual climatic variability (El-nino Southern Oscillations (ENSO) warm phase which refers to the sea surface temperature anomaly) which in turn affects world net primary production (Ochi, *et al,* 2000) and particularly the arid and semi-arid areas like Sokoto State. These changes have not only different processes but have also different effects on biodiversity and therefore require frequent monitoring for effective agricultural productivity and sustainability. The NOAA-AVHRR instrument has five detectors/sensors which are sensitive to the wavelengths of light ranging from 0.55-0.70 and 0.73 -1.0 µm, the

NDVI from AVHRR is calculated from the visible and near infrared light reflected by vegetation as:

NDVI = (NIR-VIS) / (NIR + VIS)

This is because healthy vegetation absorbs most of the visible light that hits it, and reflects the large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light and less near-infrared light. As mentioned earlier, time-series NDVI data from the Pathfinder Land (PAL) data set was provided by the Earth Observing System Data and Information System (EOSDIS). This data has been radiometrically and atmospherically rectified using standardadised algorithms (James and Kalluri, (1994) and have been used for different studies related to changes in vegetation productivity as well as crop yield estimation influenced by climatic and other environmental changes (eg. Schneider *et al,* 1985, Quarmby *et al,* 1993, Richards and Poccard, 1998, Schmidt and Gitelson 2000, Ochi *et al,* 2000, Maselli and Chiesi, 2006, Pouliot *et al,* 2009). This paper utilise the Normalised Difference Vegetation Index (NDVI) data derived for the NOAA-AVHRR in monitoring trends in vegetation NDVI productivity within selected sites across Sokoto State from 1982 to 1986.

METHODOLOGY

The area under study covered selected sites within Sokoto State which are located across the state. However the AVHRR-NDVI satellite data covers the area falling between longitudes 4° 00' E to 6° 30'E and latitudes 12° 00'N to 14° 00' N which enclosed the southern parts of Niger Republic, parts of Katsina, Zamfara and Kebbi states in Nigeria. To assess trends in Vegetation NDVI productivity across the state, a total of seven sites were selected. Two irrigation sites one close to the Nigeria-Niger border (Kalmalo) and one close to Sokoto town (Kwalkwalawa), one shelter belt and four rain-fed croplands were selected. The climate of the study area in general is tropical continental which is dominated by two air-masses (tropical maritime and tropical continental). The former is moist and blows from the Atlantic ocean and predominates particularly during the rainy season, while the later is dry and blows from the Sahara desert and thus, characterized by the prevalence of harmattan which is dry, cold and dusty and sometimes foggy. Mean annual rainfall ranges between 400mm in the northern part of this study area to about 1400mm in the southern part of the study area. Highest temperatures are experienced between the months of March and April while rainy season falls between April and October (Mamman, 2003). Because the study area partly falls within the Sudan and Sahel savannah where plant productivity are highly variable due to environmental conditions, this study choose to utilize the 8 km spatial resolution NDVI data from AVHRR so as to determine if such coarse spatial resolution data can successfully be useful in monitoring the trajectory in vegetation productivity and dynamics. Furthermore, the choise of NDVI from AVHRR is to be able to establish the normal growing condition for vegetation biomass for any given time of the year in this area since time-series NDVI can be averaged to determine whether the productivity in a given area is typical of the site or the plant growth is inherent. In order to monitor and assess trends in vegetation NDVI productivity across the study area, time series dekadal NDVI data for 5-year growing season (July, August and September of 1982 to 1986) covering the whole of Nigeria was initially acquired from the PAL Dataset Archive in Hierrachical Data Format (HDF), unzipped into Band Interleave-by-Line (BIL) image files, saved as Lotus Spreadsheet files and imported into Microsoft EXCEL (in ASCII format). The dekadal data for the growing season were re-composited into maximum value composites (MVCs) Holben, (1986) for each growing season months (ie. July August and September) so as to reduce the noise in the data set because the NDVI PAL dataset has legacy of noise. These were subsequently imported into IDRISI-ANDES Raster based Geographical Information Systems (GIS) Software as raster images in Latitude/Longitude grid. All these image data were originally produced in the Goode's Interrupted Homolosine equal-area projection. The study area covering Sokoto state was windowed from the original dekadal dataset covering the whole country so as to be make it easy to monitor the trend vegetation productivity in the selected study areas. Seven sample sites were randomly selected within Sokoto State and their positions (Latitude, Longitude and altitude above mean sea level) were each determined using a Global positional System (GPS), sample pictures of the status of the sites was also captured using a digital camera during ground truthing and each site was digitized and rasterised. Using the Collection Editor, a time series file of the growing season months was created. The Overlay module of the Idrisi GIS software was further utilized so as to monitor and create profiles for each site on each satellite imagery covering the time-series dataset. The information was imported into Microsoft EXCEL where Univariate statistics were calculated and graphs of the profiles plotted.

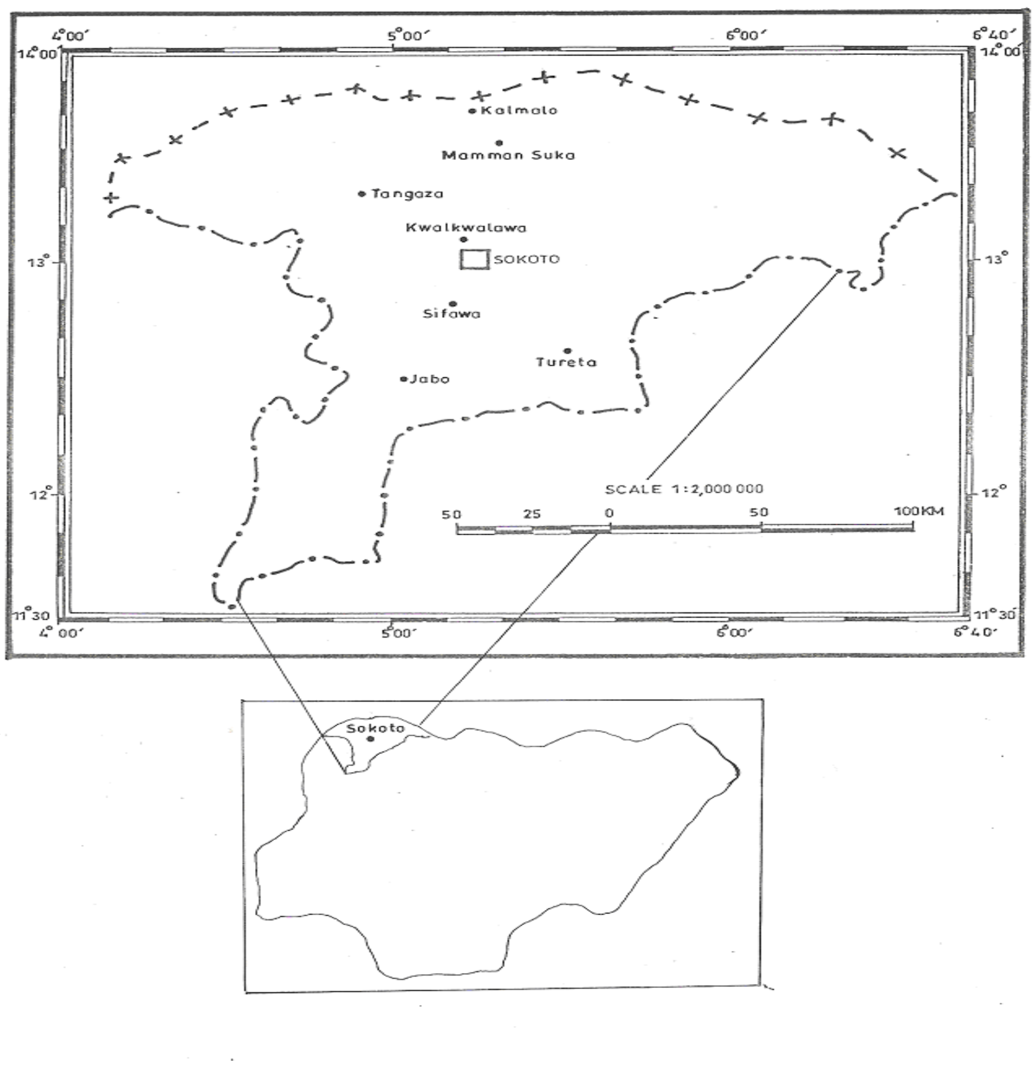

Figure 1. The Study Area showing the Selected Site within Sokoto State

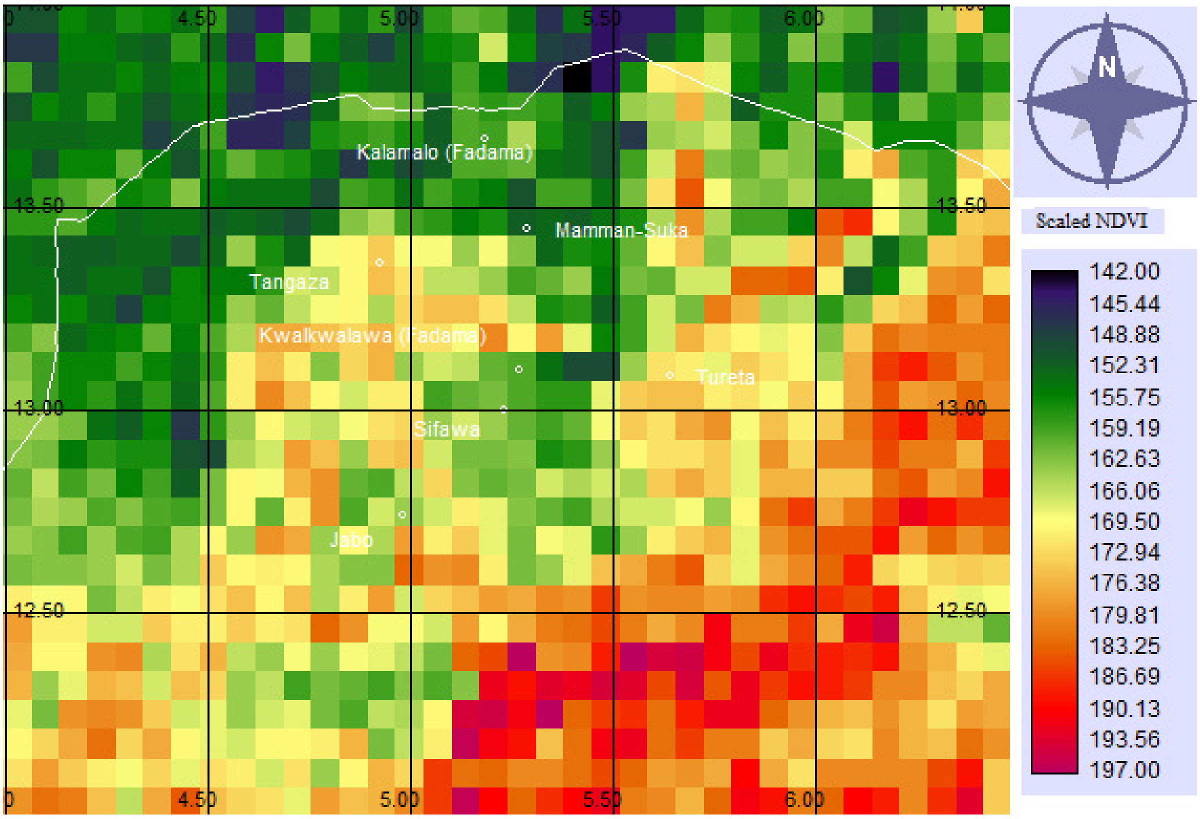

Figure 2. Sample of the 8-km AVHRR-NDVI Imagery covering Sokoto State showing the Selected Sites

Table 1. Univariate Statistics of the AVHRR-NDVI Data covering the Selected sites

Selected Sites	Min	Max	Mean	STDev	CoeffVar	Elevation (M)
Kalamalo (Fadama)	137	169	153.8	10.09385	6.562968	255
Tangaza	145	179	165.7333	10.93139	6.595769	244
Mamman Suka	140	182	155.4667	12.33385	7.933436	268
Kwalkwalawa (Fadama)	141	176	158.6	10.92049	6.885556	229
Sifawa	144	171	159.6667	9.216962	5.772627	215
Tureta	146	181	166.6667	10.23765	6.142591	272
Jabo	149	177	164.2	7.532785	4.587567	291

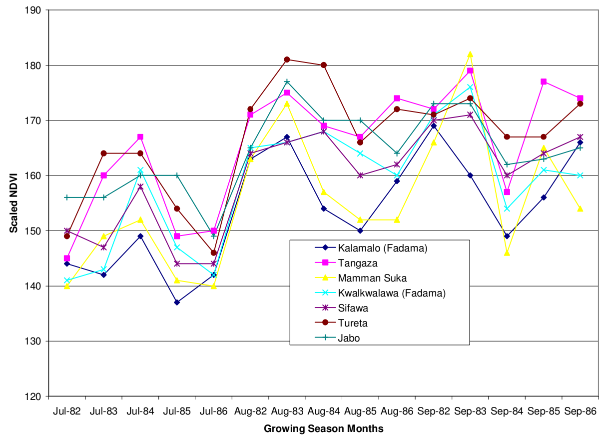

Figure 3. Trend in Vegetation NDVI Time-Series of the growing seasons 1982 to 1986 for the Selected Sites

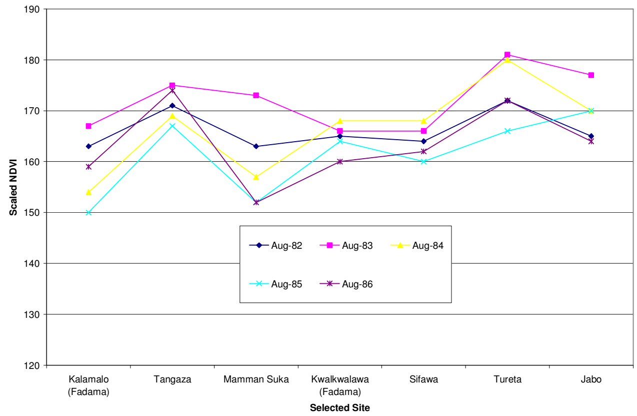

Figure 5. Trend in Vegetation NDVI for the August months of the Time-Series of 1982 to 1986 for the Selected Sites

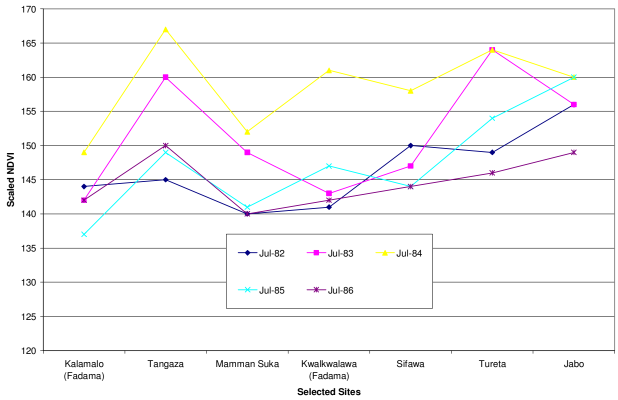

Figure 4. Trend in Vegetation NDVI for the July months of the Time-Series 1982 to 1986 for the Selected Sites

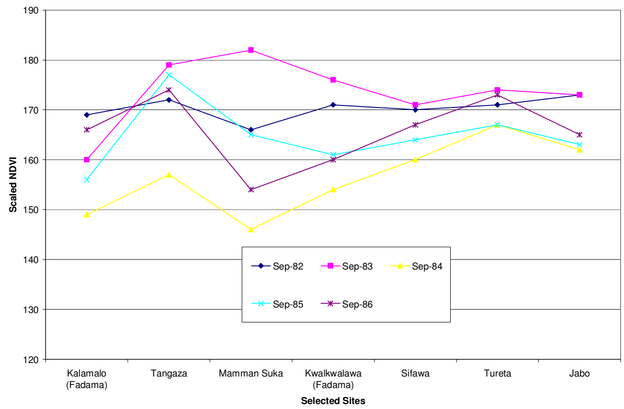

Figure 6. Trend in Vegetation NDVI for the September months of the Time-Series 1982 to 1986 for the Selected Sites

RESULTS AND DISCUSSION

Table 1 shows the summary of univariate statistics of the selected sites and graphs showing trends in the vegetation time- series of the growing seasons(Figures 1 to 6) as well as pictures of the physical status of sampled selected sites as at the last week of the month of May (not shown). The potential of satellite remote sensing and GIS is clearly demonstrated in this study where time-series NDVI data from AVHRR is shown to be very useful for timely monitoring and to a large extent crop yield forecasting in the arid and semi-arid areas like Sokoto State where environmental conditions is very variable. In Table 1 the univariate statistics of the monitored sites shows the variability in vegetation NDVI productivity. Although studies have shown that NDVI from AHVRR has strong correlations with rainfall and net primary productivity, particularly in the semi arid regions however, the study located at the shelter belts areas located at Mamman Suka village has shown otherwise because it has the highest Coefficent of variation of 7.93%. This is followed by the irrigated sites in the lowland fadama in Kwalkwala near Sokoto township and Kalamalo (6.89% and 6.56% respectively). The rain-fed cropland sites around Sifawa and Tureta have lower coefficient of variation in vegetation NDVI productivity (5.77% and 6.14% respectively) with the site located around Jabo town having the least coefficient of variation (4.59%). The extent and location of the three sites located at Mamman-Suka village, Tangaza and Kalamalo corresponds closely to the zone of large inter-annual variation in the seasonal rainfall as shown in the study conducted by Nicholson *et al,* (1994). These sites also correspond to the inter annual variation in the geographical location of the inter-tropical convergence zone (ITCZ) as reported by Justice et al, (1991). The satellite imagery in Figure 2 though very coarse in terms of spatial resolution is indicative of the typical vegetation NDVI productivity within the study area. However, in Figure 3 the time-series growing season profile of the whole selected sites is presented. There is a general down-shift trend in vegetation productivity and probably crop yield in all the sites as shown in the profile in July 1985, August 1984 and September 1984. This clearly reflects the effect of sea surface temperature anomalies (El-nino) during these growing season months in the study area where the world Net Primary Production (NPP) was also shown to be affected (Ochi *et al*, 2000). In Figures 4, 5 and 6 the profiles show some agreements with the summary statistics presented in Table 1 where despite the fact that studies have shown that NDVI from AHVRR has strong correlations with rainfall and net primary productivity (Malo and Nicholson, 1990; Maselli et al, 1992 and Nicholson et al, 2000) sites monitored within the study area that are located in the shelter belts experienced highest vegetation variability in vegetation NDVI productivity followed by the irrigated lowland fadama sites. The rain-fed cropland sites on the other hand have least variability in vegetation NDVI productivity.

Conclusion: The potential of remote sensing data analysed within a GIS environment and particularly that of the AVHRR-NDVI from the Pathfinder (PAL) dataset supplemented with ground truthing can provide the means of timely monitoring of vegetation productivity and to a certain degree crop yield forecasting where precipitation data is not readily available. The results from this study using such data can be used as indicator of plant productivity in areas where plants are highly variable due to climatic and other environmental influences. Furthermore, though such data has a very coarse spatial resolution, the MVCs NDVI data for growing season months of July, August September proved to be very useful for analysis of trends in vegetation productivity, and to a certain degree, yield forecasting in semi-arid and arid areas such as Sokoto State within a GIS environment.

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