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A Remote-Sensing Based Assessment of Seasonal Variation in Vegetation Quality and Productivity in Nimbia Forest

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Abstract
Agriculture plays a vital role in the growth and sustainability of developing countries, such as those in sub-saharan Africa. Therefore, there is need to monitor and assess the changes taking place on vegetation quality and productivity. Conventional ground survey method has proved to be highly tedious, laborious and grossly limited especially when large and densely forested regions are concerned. This paper presents a remote sensing based approach as a real time technology to determine the effect and extent of water loss caused by seasons on vegetation quality in Nimbia forest, Kaduna State. ENVI 4.7, ArcGIS 10.0 and Global Mapper Softwares were used and a discrepancy of about 45% in quality of vegetation has been observed between seasons in the region under study.
Keywords: Remote Sensing, Normalized Difference Vegetative Index, ENVI, ArcGIS.

1.0 Introduction
Vegetation quality monitoring by conventional census or ground survey method could be a very tedious task in large and densely forested regions. In such scenario, remote sensing offers a readily easier and timely method for yield evaluation. With the advances in electronic and information technologies, various sensing systems have been developed. Accurate information concerning the spatial variability within fields is very important for precision agricultural activities. However, this variability is affected by a variety of factors, including crop yield, soil properties and nutrients, crop canopy volume and biomass and water content. These factors can be measured using diverse types of sensors and instruments such as field-based electronic sensors, spectro-radiometers, machine vision, airborne multispectral and hyperspectral remote sensing, satellite imagery, thermal imaging, RFID, and machine olfaction system, among others (Lee et al, 2010).

Remote sensing data are capable of capturing changes in plant phenology (growth) throughout the growing season, whether relating to changes in chlorophyll content or structural changes (Md. Rahman et al, 1985). Spectral vegetation index measurement derived from remotely sensed observations shows great promise as a means to improve knowledge of vegetation pattern (Goward et al, 1985). Vegetation indices are algorithms aimed at simplifying data from multiple reflectance bands to a single value correlating to physical vegetation parameters (such as biomass, productivity, leaf area index, or percent vegetation ground cover). These vegetation indices are based on the well-documented unique spectral characteristics of healthy green vegetation over the visible to infrared wavelengths.

Remotely sensed images have proved optimal for monitoring environmental effects on crop yield and productivity in several geographic locations with the comparison of its output with conventional techniques yielding allowable discrepancies (Francesco 2000; Jones et al 2008). This paper presents the use of remotely sensed data for assessing seasonal variation in vegetation quality and productivity at Nimbia Forest.

2.0 Theoretical Background into NDVI Analysis
Green plants strongly absorb visible light (400 – 700nm) for photosynthesis and accessory plant pigment thereby resulting in very low transmittance and reflectance of light within the visible portion of the electromagnetic spectrum (Chappelle *et al.*, 1992). On the contrary, reflectance and transmittance are both usually high in the near-infrared regions (NIR, 700 to 1300 nm) because there is very little absorbance by subcellular particles or pigments and also because there is considerable scattering at mesophyll cell wall interfaces (Gausman, 1974; Gausman,1977; Slaton et al., 2001). This sharp dissimilarity in reflectance properties between visible and NIR wavelengths underpins a majority of remote approaches for monitoring and managing crop and natural vegetation communities (Knipling, 1970; Bauer, 1975).

This reflectance/transmittance relationship between these two bands is mathematically represented as equation 1:

$$NDVI = \frac{NIR-RED}{NIR+RED} \quad (1)$$

Vegetation indices (VIs) provide a very simple yet elegant method for extracting the green plant quantity signal from complex canopy spectra. Often computed as differences, ratios, or linear combinations of reflected light in visible and NIR wavebands (Jackson, 1983), Vegetative Index exploit the basic differences between soil and plant spectra described above. Indices such as the ratio vegetation index ($RVI = \frac{NIR}{RED}$) and normalized difference vegetation index, perform exceptionally well when management goals require a quantitative means for tracking green biomass or leaf area index through the season or for detecting uneven patterns of growth within a field (Wiegand *et al.*, 1991).

Vegetation indices have served as the basis for many applications of remote sensing to crop management because they are well correlated with green biomass and leaf area index of crop canopies of particular interest from energy balance, modeling, and crop management perspectives. Vegetation indices have also been shown to provide robust estimates of the fractional amount of net radiation going into soil heat flux (Kustas *et al.*, 1993), as well as the fraction of absorbed photo synthetically active radiation (fAPAR) captured by the canopy for potential use in photosynthesis(Pinter *et al.* 1994).

3.0 Study Area:
Laying along Jos - Abuja road, Nimbia Forest Reserve is a forest located near Gimi, a town in Kaduna state, Nigeria at 32 P 448791.37 m E 1050149.72 m N (latitude 9°29'59.45"N longitude 8°32'0.41"E).

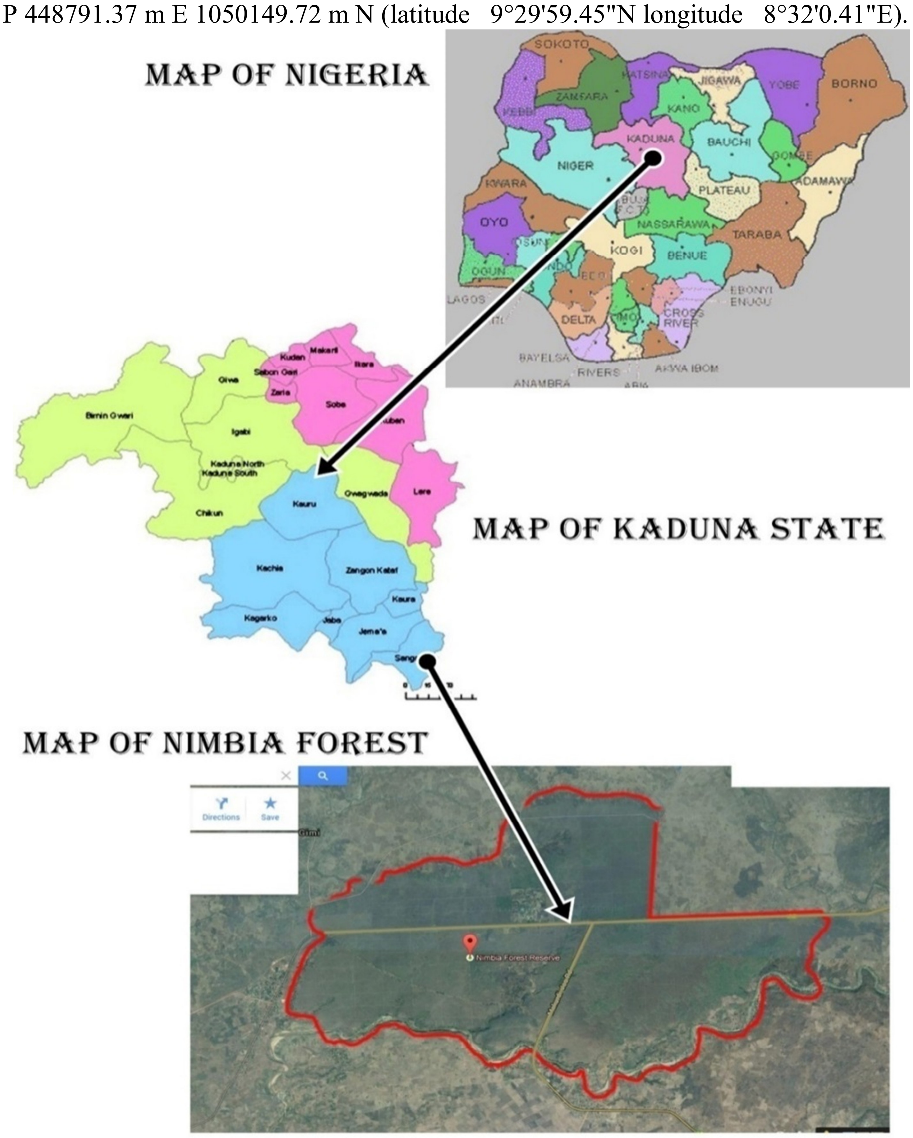


Figure1: Study Area.

4.0 Data Used
Landsat 7 ETM+ images of Nimbia forest of 2013 - Bands 1, 2, 3 and 4 (blue, green, red and near infrared respectively).

To allow for comparison of seasonal productivity level, images of two different dates of the same year were downloaded (i.e January which is predominantly dry season and July which is wet season).

5.0 Methodology

The raw image bands were first combined (layer stacked) using ENVI to create a false colour composite of the study area for both seasons in-order to identify vegetated regions prior to the analysis. NDVI analysis was then performed on bands 3 and 4 using both ENVI and ArcGIS software and the NDVI values computed. The result was exported into Global Mapper where the NDVI values were then extracted with the spatial co-ordinates of the point. These resulted in a 3 by N matrix of points (Eastings, Northings and NDVI). This Matrix was then plotted in ArcGIS to generate a "Vector-layered TIN" that presented a better visual perception the variation in values at both seasons. A flow of the methodology is described in figure 2

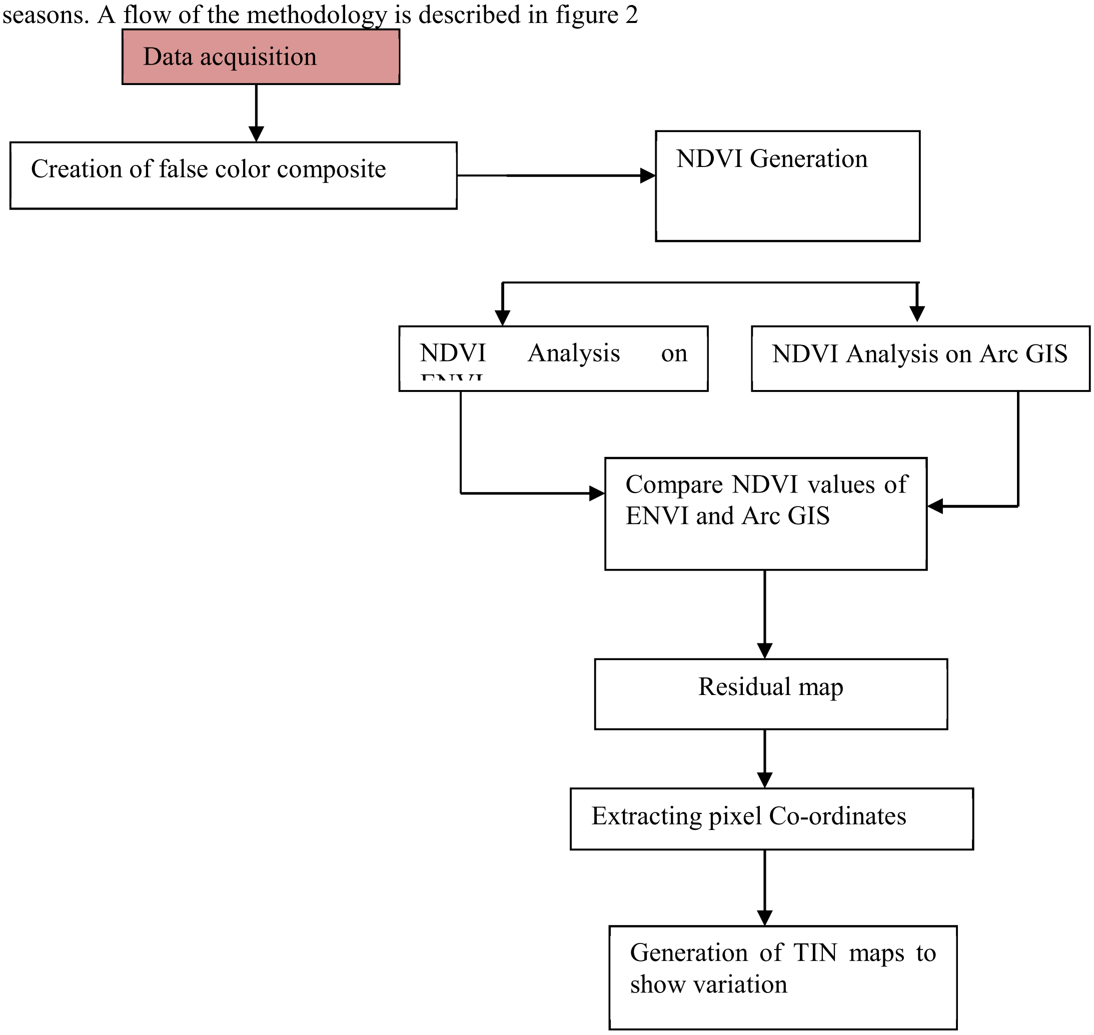
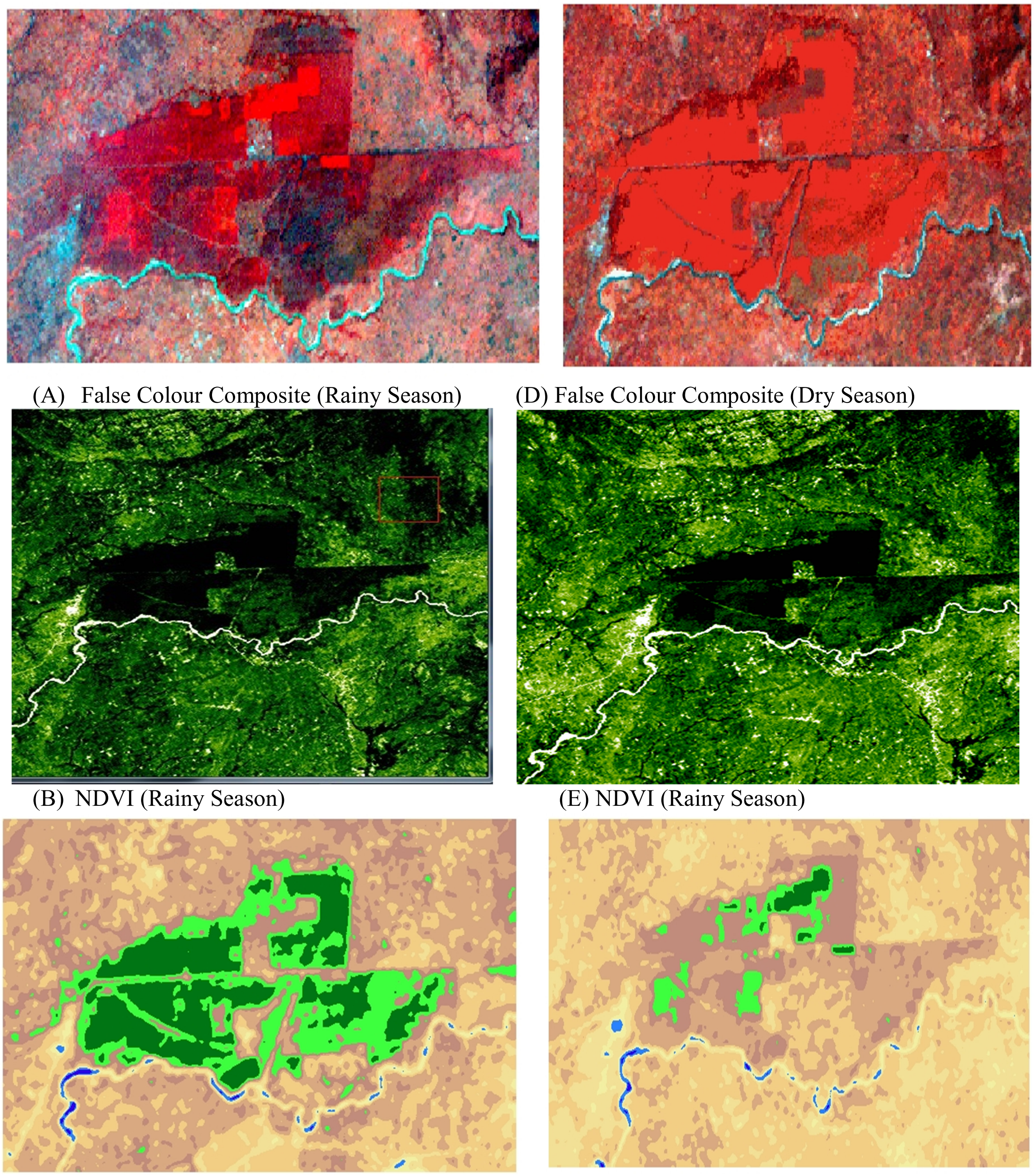


Figure 2: Description of Process

6.0 Results

The results include:

(a) False Colour Composite Map of the study area for both seasons
(b) NDVI Map of the study area for both seasons
(c) Interpolated Vector Layered TIN of the spatial Variation of NDVI across the study area.



(A) False Colour Composite (Rainy Season) (D) False Colour Composite (Dry Season)

(B) NDVI (Rainy Season) (E) NDVI (Rainy Season)

(C) TIN (Rainy Season) (F) TIN (Dry Season)

Figure 3: Maps of Rainy and Dry Season

7.0 Discussion of Results

From the results shown in Figure 3 (A – F) there is a great gap both in the volume of water body and the resulting crop expanse within the study area in both seasons. Figures 3 (A and D) show a decline in the stream volume in the dry season as compared to the rainy season. Besides, traces of sedimentation due to wind erosion are also visible in the stream body as seen in Figure 3(D).

This reduction in water body volume thus show significant impact in the vegetation level and subsequently vegetation quality of the dry season compared to the rainy season as seen in Figures 3 (C – F).

Previous study on NDVI analysis of crops have shown that negative NDVI values (values approaching zero) correspond to water, those between -0.1 and 0.1 represent barren areas of rock, sand, or snow, low-positive values represent shrub and grassland while high values indicate temperate and tropical rainforests (values approaching 1). These indices were therefore used to make inferences as to the percentage coverage of dense and sparse vegetation within the study area.

Shown in the Table 1 and Figure 4 is a summary of the statistics of the quality and volume of the vegetation and other land use classes in the study area in the various seasons:

Table 1: Percentage of vegetation volume and quality.

CROPS	PERCENTAGE (Dry Season)	PERCENTAGE (Rainy Season)
Dense vegetation	14.91%	52.2 %
Sparse vegetation	13.01%	20.9%
Unhealthy	53.93%	11.03%
Water	0.85%	1.42%
Rocks and bare ground	17.30%	14.45%

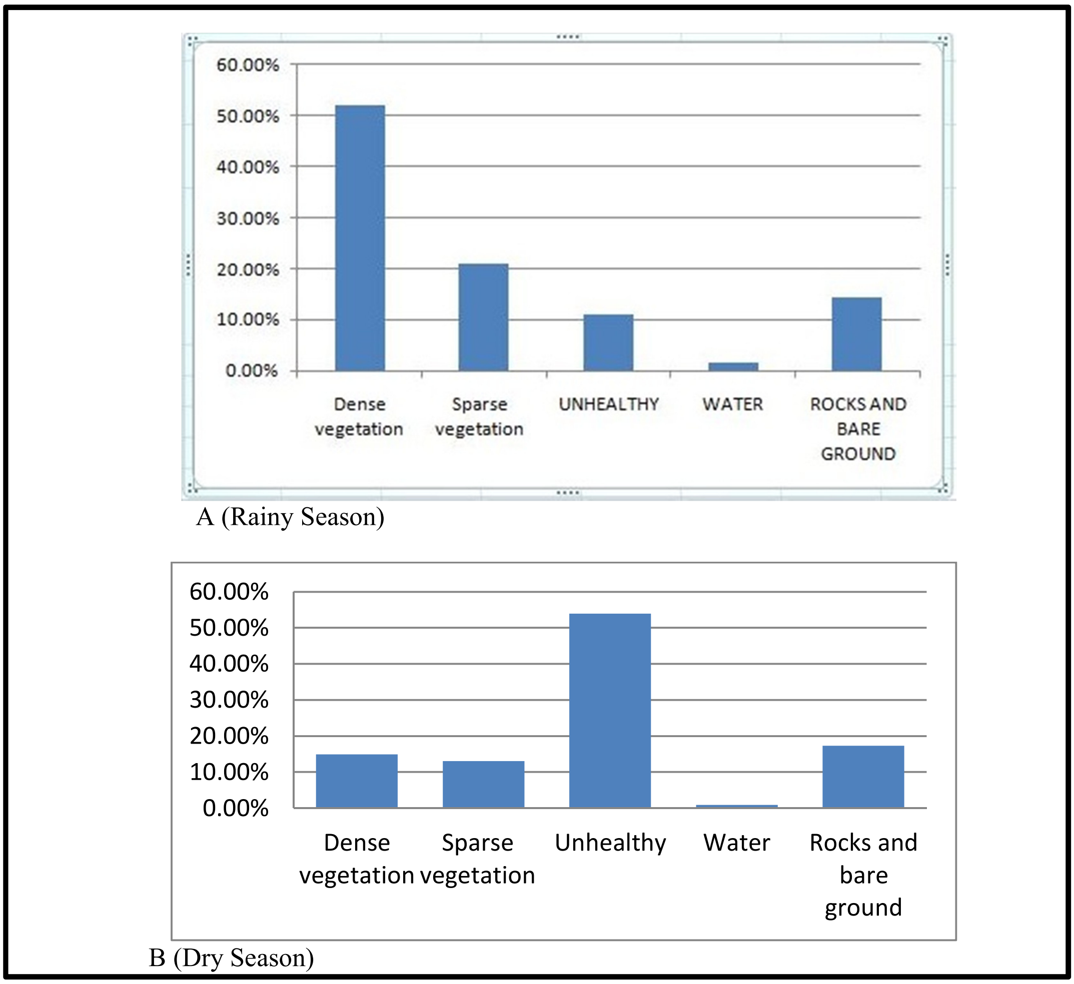


Figure 4: (A & B): Chart showing Crop volume and Quality within the Study area for Rainy and Dry Season in Percentage

8.0 Conclusion

Attempt has been made in the course of this research to scientifically examine and evaluate the seasonal variation in the quality of vegetation and crop productivity of Nimbia Forest using remote sensing approach. The research's findings showed that greater percentage of unhealthy crops was recorded in the dry season while the season also presents the lowest percentage of dense and sparse vegetation. This approach agreed with the general expectation or consensus which suggests that reduction is expected in the productivity and healthiness of vegetation during dry seasons due to the less or reduced availability of water which implies that remote sensing approach could be a dependable and effective alternative for crop monitoring.

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