Cropped Area Mapping of Nigeria Using Time-Series NDVI Data: A Case Study of Southeastern Nigeria

F.I. Okeke, N.K. Ndukwe and A.C. Oturu*

Abstract

Reliable mapping and estimation of cropped area are essential for the design of operational food security programmes. Satellite interpretation of cropped area has proven to be an effective alternative to costly field surveys. This study made use of Time-series MODIS-NDVI data, which has sufficient spatial, spectral and temporal resolutions to detect unique multi-temporal signatures for crops to distinguish cropped areas from non-croplands. MODIS-NDVI data with a spatial resolution of 250m was collected in 16-day composites for 23 days spanning the entire cropping season in each year from the year 2000 to 2005. The MODIS-NDVI tiles for Nigeria were mosaicked; the data was then reprojected to the World Geodetic System 1984. The images were stacked into a Time-series NDVI composites; the southeastern geopolitical region was masked from the Time-series NDVI composites, to be used as model for the country. Through spectral profiling, it was possible to distinguish crops' phenological behaviour in the region, based on the crop calendar. A decision-tree algorithm was developed using the threshold values which produced the highest classification accuracy for distinguishing cropped areas from other land uses. The result was a map of Southeastern Nigeria indicating croplands and non-croplands, which compared favourably with PCU's field reports.

Keywords: *NDVI-Normalized Difference Vegetation Index; MODIS Moderate Resolution Imaging Spectroradiometer; DOY-Day of Year; Cropped Area; Nigeria; Southeast Nigeria; PCU-Project Coordinating Unit*

1.0 Introduction

Accurate and up-to-date reports of regional and national crop conditions, production estimates as well as areal extents are often difficult to obtain in Nigeria due to the fact that a very large proportion of the agricultural sector, reportedly 80%, is involved in traditional farming techniques and the methods of production

* Department of Geoinformatics and Surveying, University of Nigeria, Enugu Campus

estimation are archaic and rudimentary at best. Oftentimes, results are not obtained until the end of the season at which point it becomes irrelevant.

With the aid of remote sensing technology, it has become possible to determine the condition of crops and to provide several indices which can be used in mapping cropped areas and monitoring crop yield. These indices include the normalized difference vegetation index (NDVI), vegetation condition index (VCI) and temperature condition index (TCI). NDVI, soil moisture, surface temperature and rainfall are valuable sources of information for the estimation and prediction of crop conditions as well as yield (Prasad et al, 2005).

Cropped Area Mapping as a form of land use/land cover classification methodology has become an invaluable tool in crop yield estimation modelling for food security. The landscape is generally made up of a conglomeration of local and interacting ecosystems, which may include forests, cropland, shrubland, open grassland and built-up areas (DeFries, et al., 1998); it is therefore noteworthy that besides the cropland information, the other land uses are completely irrelevant in the development of a crop yield estimation model and, if present, have the tendency to skew the yield estimates in either direction.

From the literature, the major method of cropped area mapping/estimation in Nigeria is the Cropped Area and Yield Survey (CAYS), which was adopted in 1991 from the rested Field Records for Agronomic Data and Yields Survey (FRADYS). The CAYS method makes use of a scenario whereby an enumerator obtains the cropped area using traditional survey methods like the prismatic compass, measuring tapes, ranging poles, pegs, measured ropes and weighing scales. All farms cultivated by a selected farming household are duly used by the enumerator. For each farm, the enumerator measures the dimensions for area calculation and lays a 0.01 hectare triangular subplot from which estimates are made and extrapolated for the whole farming households in the zone or state (Ingawa, 2004). However, this method is extremely cumbersome, time-consuming and expensive; more often than not, information about cropped area is acquired when the need is no longer expedient.

It is for this cause that researchers have sought to make use of biophysical characteristics about vegetation as a tool in estimating cropped areas, prime of which is the Normalized Difference Vegetation Index (NDVI). The NDVI's spatial, spectral and temporal properties have been used over the years in order to carry out crop identification in remotely sensed data (Byeungwoo & Landgrebe, 1992; Wharton, 1982).

The Normalized Difference Vegetation Index (NDVI) was introduced by Rouse (1974) in order to produce a spectral Vegetation Index (VI) that separates green vegetation from its background soil brightness using Landsat MSS digital data. It is expressed as the difference between the near infrared and red bands normalized by the sum of those bands, i.e.:

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

The NDVI is the most commonly used vegetation index, because of its ability to minimize topographic effects while producing a linear measurement scale. Divisions by zero errors are also significantly reduced. Furthermore, the measurement scale has the advantageous property of ranging from -1 to +1 with 0 representing the approximate value of no vegetation. Thus negative values represent non-vegetated surfaces making interpretation very easy.

NDVI has been used in a multi-temporal approach to image classification in order to capture the seasonal variability of the vegetation. Kouchoukos *et al.*, 1997, used NDVI in vegetation cover analysis using a one-year 1 km AVHRR (Advanced Very High Resolution Radiometer) data composite in ten-day periods stacks so that each pixel was characterized by 36 NDVI values. The k-means clustering algorithm was used to assign each pixel to one of the thirteen classes having similar seasonal cycles of vegetation cover. The resulting distribution of vegetation classes was complex and patterns of land use and land cover were better differentiated by the shape of the annual cycle, especially in areas where there were multiple cropping cycles.

The study of temporal NDVI data has been found to produce improved results for mapping cropped area, crop yield prediction as well as applications in crop condition monitoring. Time series NDVI data would form a potentially powerful monitoring tool to assess regional variations in the general conditions of specific crop types and identify localized areas of vegetation stress (Wardlow et. al, 2007). Huete et al. (2002) evaluated the time-series NDVI data products over several biome types (e.g., forest, grassland, and shrubland) and found that the multi-temporal signatures (or profiles) of the NDVI well represented the phenology of each biome.

2.0 Area and Scope of Study

The study was restricted to the southeastern geopolitical zone of the country, which is made up of five (5) states - Abia, Anambra, Ebonyi, Enugu and Imo - with a combined area of 29,352 square km (Fig. 1). Southeast Nigeria has a climate that permits the cultivation of a variety of crops in a pattern that emerged in earlier centuries in response to local conditions. As in other West African states, this region enjoys the heaviest rainfall, where the forests and savannas benefit from abundant precipitation and relatively short dry seasons. The staples are root crops, including cassava, yams, taro (cocoyam), and sweet potatoes.

Smallholder farmers, who use simple production techniques and bush-fallow cultivation and cultivate areas of one-half to two hectares each, contribute two-thirds of farm production. In most areas, some non-cash crops are grown, such as sorghum, yams, cassava, cowpeas, millet, corn, cocoyams, sweet potatoes, and rice. The rainfall in this region has a significant effect on agricultural activity, as excess rain leads to high runoff, soil erosion, nutrient losses through leaching and water logging. Too little rainfall limits agricultural activities to 2 or 3 months without supplementary irrigation.

The scope of this research covered the entirety of southeast Nigerian states' land area. It involved the mapping of the entire cropped area of southeast Nigeria. The

term 'crop' in this research refers to all agricultural crops as defined by the Project Coordinating Unit (PCU) of the Federal Ministry of Agriculture and Water Resources. The Moderate Resolution Imaging Spectroradiometer (MODIS) NDVI dataset was used to mask the cropped area (croplands) for southeast Nigeria for the years 2000 2005. It was chosen because of its satisfactory blend of spatial, spectral and temporal resolution, which makes it adequate for studying crop behaviour over large areas. The underlying scope for the research is to proffer a method for estimating cropped area, which can be repeated over time with reasonable levels of accuracy.

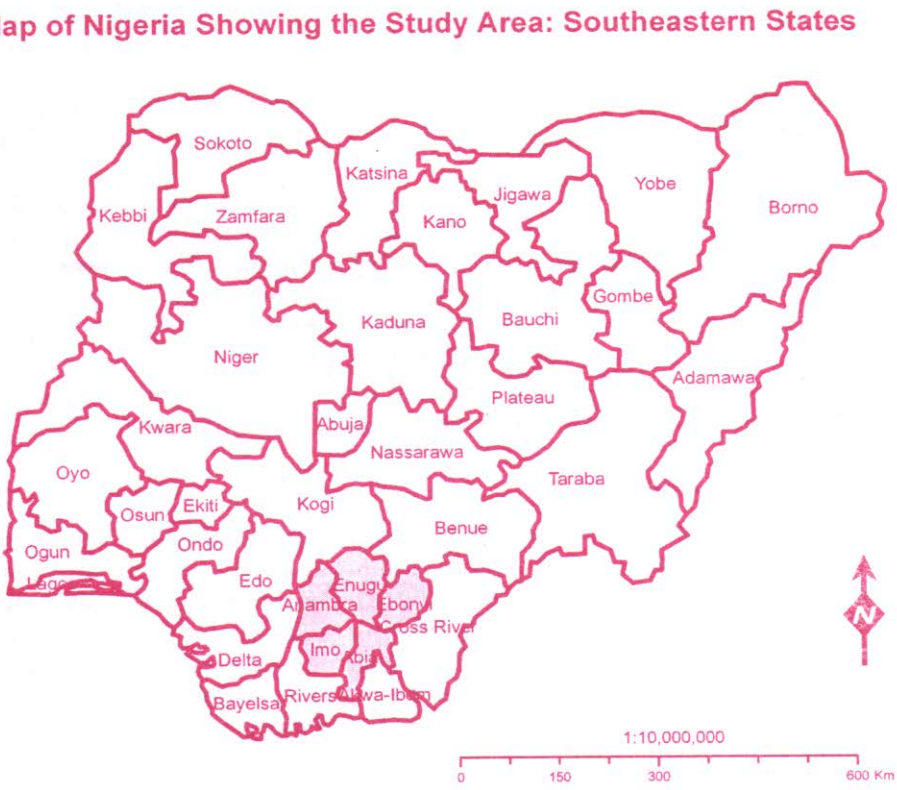

Fig. 1: Map of Nigeria Indicating the Study Area

3.0 Materials and Methods

3.1 Hardcopy Political Map of Nigeria (Digital Image)

A hardcopy political map of Nigeria was acquired from the National Space Research and Development Agency (NASRDA) and was vectorized using ArcGIS 9.2; a Geographic Information System (GIS) software. The map was also used to distinguish the southeastern states from the rest of the country and a mask was produced by converting the vector map of the southeast into a Boolean image, using the same ArcGIS 9.2 software.