Applicability of MODIS-NDVI dataset for assessment of changes in Vegetation across Benue State, Nigeria

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Abstract: *The purpose of this study is to test the possibility of using MODIS-NDVI satellite dataset of an area of less than 50,000 square kilometers at 250m spatial resolution to see if the changing pattern of vegetation across Benue state in Nigeria between 2000 and 2011 can successfully be identified. The analysis derived annual mean (end points) NDVI datasets between two consecutive years and a quasi 10-year change imageries using the Idrisi GIS and remote sensing software. Although a simple image differencing technique was utilised, the study identified that though on such low spatial resolution the spatio-temporal change in vegetation can still be ascertained broadly. Furthermore, the findings indicated that the amount of change in vegetation NDVI and the trend in Benue State has different patterns when two successive end-years are compared. However, there is about 36.4 percent decreased in vegetation NDVI between 2000 and 2011 which may be due to anthprogenic activities across the state and the annual flooding experienced between these dates. To determine a more comprehensive result on the trend and changes in vegetation MODIS-NDVI particularly in hot spots locations within the study area, a high spatial resolution satellite dataset will be required.*

Keywords: *Vegetation, MODIS-NDVI, spatio-temporal, flooding, urbanization, change*

1. Introduction

Monitoring land-cover change locations and distributions is critical for identifying correlations between policy choices, regulatory measures, and land related activities. Overall, land-cover is susceptible to a variety of natural and man-made processes of change [1].

Satellite-based remote sensor data has been frequently used to give a cost-effective technique of developing land cover and vegetation changes over broad geographic areas. These data are widely used to construct landscape-based metrics, evaluate landscape condition, and track status and changes across time [1]. Furthermore, multi Spectral Remote Sensing images are very useful for gaining a deeper comprehension of the earth [2].

The normalized difference vegetation index, often known as NDVI, was established for the purpose of measuring or computing vegetation productivity using satellite data's reflective bands [3 - 4]. This NDVI is a tool that is frequently used to identify changes in land use and land cover, particularly changes in the amount of vegetation and its pattern [5, 6, 7]. The spatial resolution of remote sensing data has increased from kilometers to centimeters, and its spectral resolution has decreased from a broad band range to a narrow band, making it feasible to operate at the micro level. Images captured by satellite are necessary for the NDVI calculation to be performed by the GIS software to determine if the vegetation is in good condition or otherwise. The NDVI method was used to determine the rate of vegetation destruction [7]. It is also a strong index for evaluating data about vegetation from satellite images, which may be done using those images derived from such index. The ability to compare several satellite images from multiple dates for either the same or different plots on different scenes is a key step in the application of satellite data and GIS tools to monitor change [8]. Changes in plant coverage or species composition for example are commonly linked to global warming or soil erosion, which affects vegetation in a slow and continuous manner [9]. Finding out what's causing changes in ecosystem functioning and the underlying reasons therefore, requires reliable detection of land cover changes. Remote sensing tools can detect all of the aforementioned changes in terrestrial ecosystems [10]. The availability of the time-series vegetation index datasets from the MODIS (Modern Resolution Imaging Spectoradiometer) data nowadays allow for the medium-scale vegetation trend and change analysis possible [11, 12, 13].

2. The Study Area

The study area is centred on Benue State located in Nigeria's middle belt, within the lower Benue basin. It is geographically located between longitude 7° 30' to 9° 50'E and between latitude 6° 20' and 8° 20'N (Figure 1). Over 75% of the state's population work as farmers. The state is a wooded savanna region which got its name from Benue river that cuts across the entire middle belt region. It is bounded on the south by Cross River, Ebonyi, and Enugu states, on the west by Kogi state, on the north by Nassawara state, and on the northeast by Taraba state. The state has a land area of

34,059 square kilometers and a population of about 4,253,641 based on 2006 national census. Just like most parts of the country, Benue State has two different seasons, the Wet season and the Dry season [14]. Benue State experiences both dry and rainy season during the year, its climate is characterised by tropical sub-humid, according to Koppens classification. The dry season in this study area starts from November to March, and between the Month of March and April, the temperature becomes very high; the rainy season lasts for seven months (April and October) with annual rainfall in the range of between 100 to 200mm ; with an annual temperature range is between 21 and 37 degrees Celsius [15]. However, the south-eastern part of the state next to the Obudu-Cameroun mountain range has a climate comparable to that of Plateau State.

The state has one of the longest river systems in the country, which could support a fishing industry, dry-season farming, and an inland water highway while the southern part of the states' vegetation is made up of woody species that supply timber and served as habitat for the endangered wildlife in the area which can be developed as a forest and wildlife reserve. Within the study area and surrounding parts the suspected changes in vegetation generally is mainly attributed to the flooding, deforestation for timber supply and other farming activities to support the growing population.

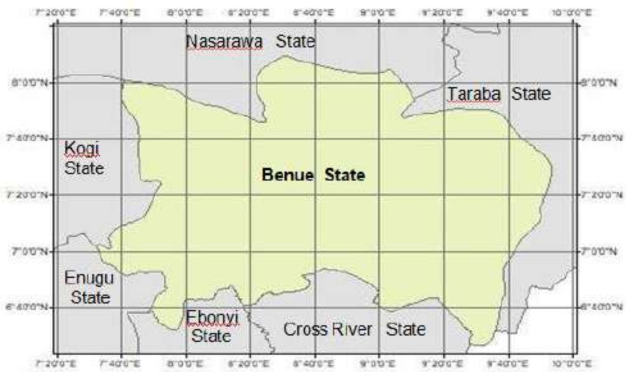
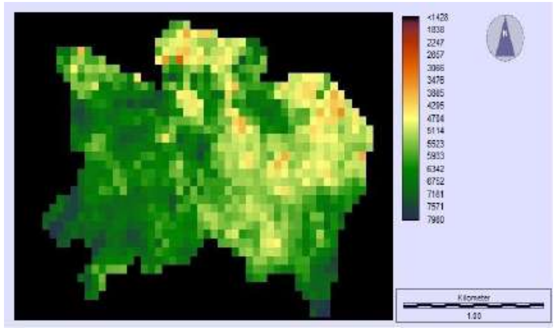


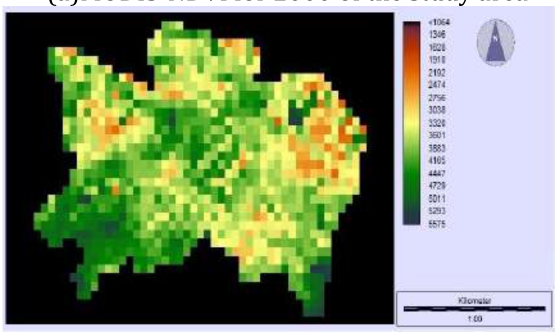
Figure 1. Location of the study area centred on Benue State, Nigeria

3. Data and Methods

A total of tree hundred and ninety six (396) MODIS-NDVI dataset (imageries) centred on Benue state but covering few areas from adjoining states in Nigeria for the period from 2000 to 2011 (in dekadal images from Jan 1-10 through to Dec 1-31) were used as input and analysed using a simple image differencing technique within a Geographical Information Systems environment. Initially each of the 36 imageries for each year were recomposed into a single mean image representing each year thereby deriving 12 monthly imageries for each year. These were further recomposed into yearly imageries giving a total of 11 imageries representing each year from 2000 to 2011. Samples of the mean MODIS-NDVI for 2000 and 2011 for the study area are shown in Figure 2.



(a)MODIS-NDVI for 2000 of the study area



(b)MODIS-NDVI for 2011 of the study area

Figure 2. Samples of MODIS-NDVI the study area.

To provide an overview of vegetation biomass change covering short and long time spans, and further reduce the influence of climatic extremes and possible cloud contamination in the imagery, the mean NDVI of the end years of each comparison (the quasi time period) was calculated [16], and the eleven annual mean NDVI end-year composite images were categorised into two sets based on the annual mean and the quasi ten-year time periods, as summarised in Table 1 and classified in Figure 3.

Table 1. Composition of residual datasets for the annual Mean NDVI end-years and the quasi ten-year periods.

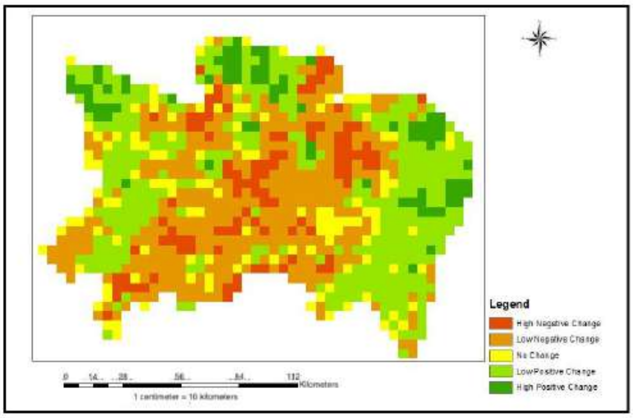
Annual Mean Images (End Point years)	Quasi Ten-Year period
2000/2001	2000–2011
2001/2002	
2002/2003	
2003/2004	
2004/2005	
2005/2006	
2006/2007	
2007/2008	
2008/2009	
2009/2010	
2010/2011	

4. Results and Discussion

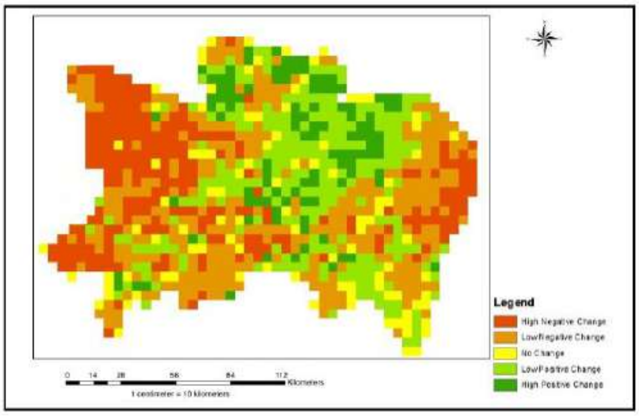
4.1 The annual mean NDVI end-year images and quasi ten-year time periods

This experimental study utilized MODIS-NDVI imageries of an area of less than 50,000 square kilometers. The main purpose of this experiment is to test if at 250 meter spatial resolution this imagery can be used to identify the changing pattern of vegetation across Benue state in Nigeria between 2000 and 2011. This resulted into deriving two major residual imageries for the mean and quasi ten-year time periods. From this analysis it is very clear that from the base year imagery (2000/2001) (Figure 2a) through the successive years in the time-series imageries that the study area had undergone both positive and negative changes in vegetation for most of the 23 local government areas of the state though more prominent positive changes can be seen in (Figure 3). However, there are more vegetative surfaces in the northwest and south west part of the study area as can be seen in parts of Guma, Logo and Okponkwu Local government areas. On the other hand, negative changes in vegetation productivity can be seen in Gboko Local Governments with prominence in the 2005/2006 imagery across the study area on (Figure 3).

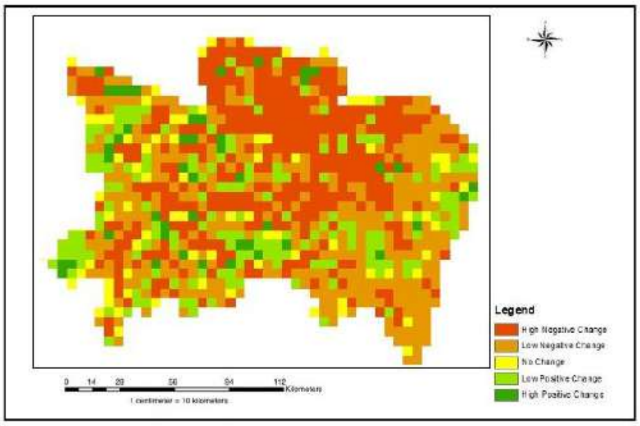
Each of the successive NDVI change imageries across the time-series seemed abrupt although between 2005/2006 through to 2009/2010 there seems to be more low and somewhat little changes broadly. Accordingly, the world's productive land covers are in decline due to anthprogenic activities [17]. as well as natural phenomenon like flooding, soil erosion and vegetation changes being experienced in the study as the imageries in Figure 3 have shown.



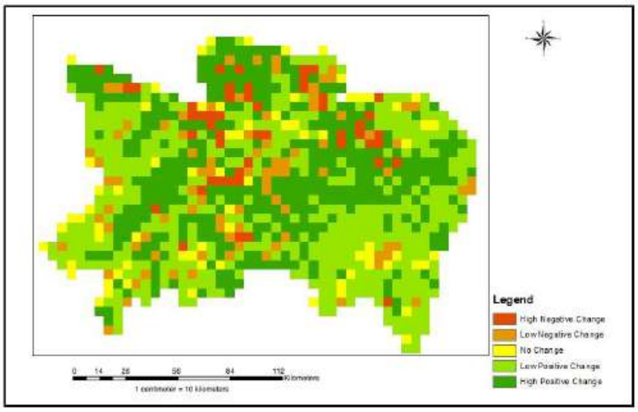
NDVI Changes between 2000 and 2001



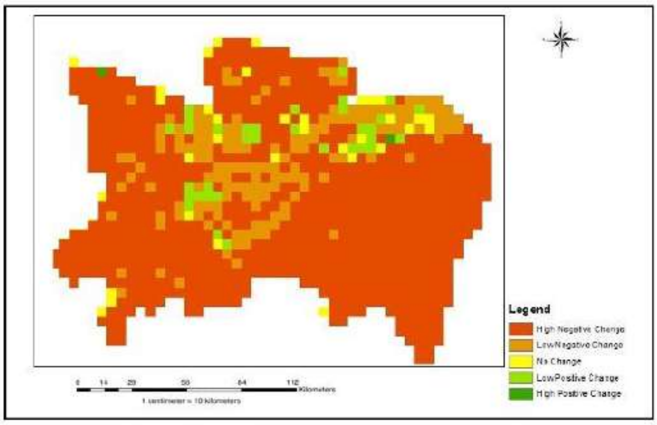
NDVI Changes between 2001 and 2002



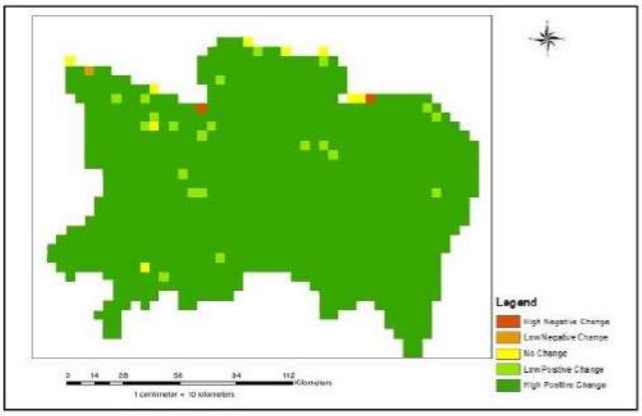
NDVI Changes between 2002 and 2003



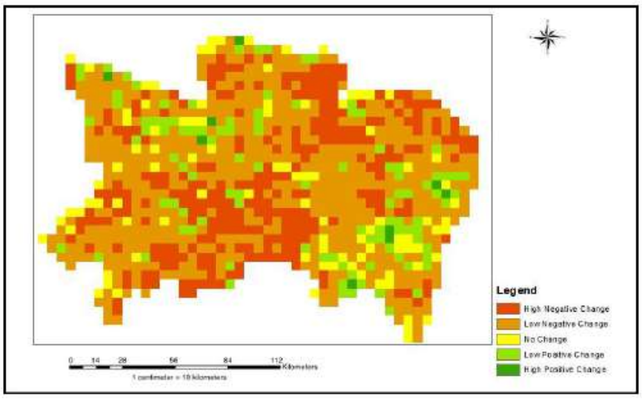
NDVI Changes between 2003 and 2004



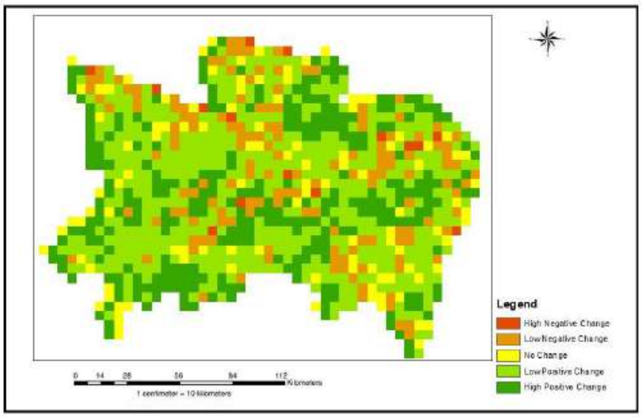
NDVI Changes between 2004 and 2005



NDVI Changes between 2005 and 2006

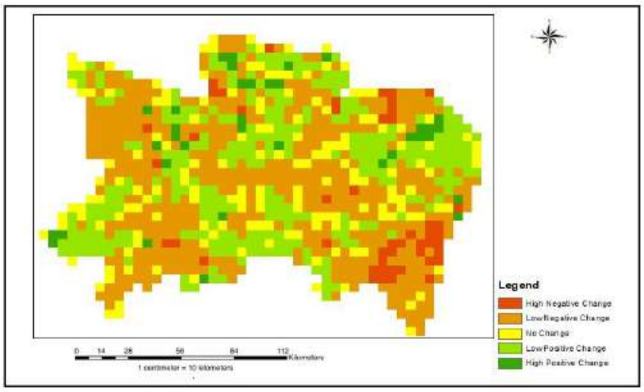


NDVI Changes between 2006 and 2007

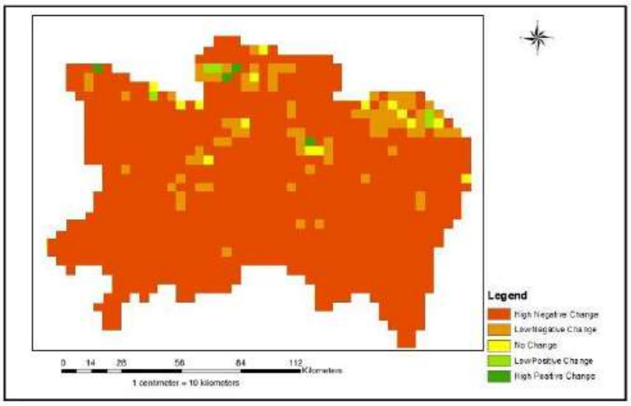


NDVI Changes between 2007 and 2008

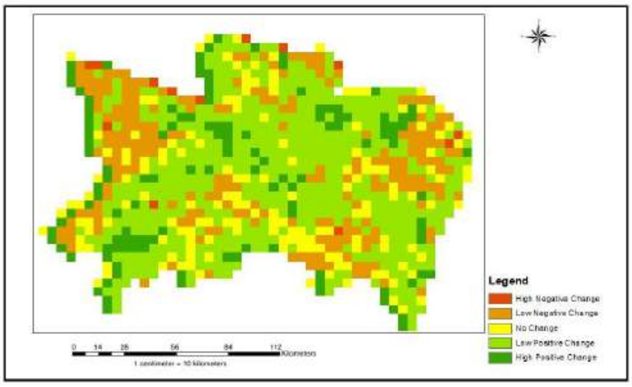
Figure 3. Successive changes in Vegetation from MODIS-NDVI



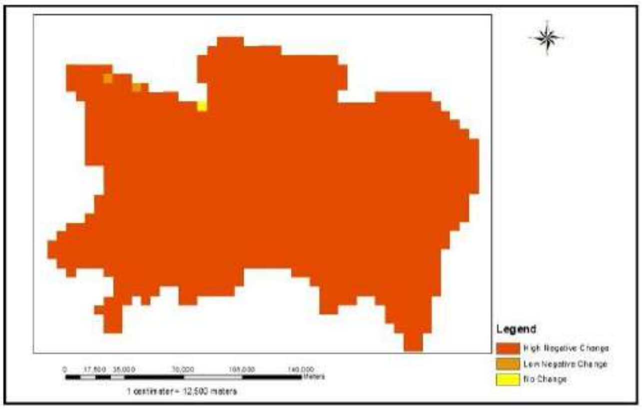
NDVI Changes between 2008 and 2009



NDVI Changes between 2009 and 2010



NDVI Changes between 2010 and 2011



Quasi Ten-year Changes between 2000 and 2011

However, although soil is very influential to agricultural and vegetative productivity, it is also a key element of land resources that plays vital role in terrestrial ecosystems [18]. Furthermore, based on the findings of [19]. there are primary causes of land degradation such as deforestation, overgrazing and other agricultural activities which are likely to play vital role in the decrease of vegetation in some parts of the study area as the MODIS-NDVI change imageries have indicated in some of the images particularly in Figure 3. On the other hand, the assertions of [9] may concur that these broad vegetation changes exhibited on the imageries presented in Figure 3 may likely be similar to changes in plant coverage or species composition that are commonly linked to global warming or soil erosion, which affects vegetation in a slow and continuous manner.

According to [17] water erosion is more prevalent in Benue state which is due the frequent annual floods, and this is most likely to affect the changes in vegetation negatively. A look at the quasi ten-year change image (2000-2011) in Figure 3 suggest that though most of the vegetation in local government areas are negatively affected, areas of more concern are located in Agatu, Apa, Otupko, Ukum and Katsina-Ala which appeared to have more high negative vegetation changes given the different rate of overcutting of vegetation and fuelwood utilisation. This is because according to [20] the main cause of land degradation that relates to vegetation changes in the forested and guinea savanna region where this study area is located is overcutting of vegetation to obtain timber and fuelwood as well as other products for the increasing population.

5. Conclusions

The results of this study demonstrated that vegetation changes can highlighted and extracted from an area of less than 50,000 square kilometers by utilizing remote sensing and GIS techniques as an experimental analysis using MODIS-NDVI imageries of 250 meters spatial resolution. Accordingly, the findings from the study indicated that for every two successive end-year change images in the time series, the amount of vegetation cover and the trend in Benue State shows different patterns because some local government areas within the study area experienced low, moderate or high increase or decrease in vegetation from MODIS-NDVI with pockets of hot spots changes though broadly. However, for a more comprehensive result on the trend and changes in vegetation of MODIS-NDVI particularly in those hot spots locations a high spatial resolution satellite dataset will be required.

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