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Geospatial Analysis of Changes in Vegetation Cover over Nigeria

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Abstract. Vegetation cover over Nigeria has been on the decrease recently, hence the need for adequate monitoring using geo-information technology. This study examined the spatio-temporal variation of vegetation cover over Nigeria for thirty years with a view to developing a strategy for enhancing environmental sustainability. In order to predict the spatial extent of vegetation cover in 2030, the study utilised satellite images from between 1981 and 2010 using the Normalised Difference Vegetation Index (NDVI) coupled with cellular automata and Markov chain techniques in ArcGIS 10.3. The results showed that dense vegetal areas decreased in area from 358,534.2 km^2 in 1981 to 207,812 km^2 in 2010, while non-vegetal areas increased from 312,640.8 km^2 in 1981 to 474,436.4 km^2 in 2010 with a predicted increase to 501,504.9 km^2 by 2030, i.e. an increase of about 27,068.4 km^2 between 2010 and 2030. The study concluded that geoinformation techniques are effective in monitoring long-term intra- and inter-annual variability of vegetation and also useful in developing sustainable strategies for combating ecological hazards.

Key words:
Vegetation Cover,
NDVI,
GIS,
Spatio-temporal,
Remote Sensing

Introduction

Nigeria has the world's highest deforestation rate of primary forests according to revised deforestation figures from the Food and Agriculture Organisation of the United Nations (FAO 2005). Between 2000 and 2005, the country lost 55.7 percent of its primary forests – that is, forests with no visible signs of past or present human activity (FAO 2005). Broadly speaking, the natural vegetation over a geographical area is essentially a response to the climate and some other parameters such as edaphic and topographic factors (Fasona and Omojola 2005; Geist et al. 2005; Adefioye 2013). Nigeria's vegetation belts reflect this very close link between vegetation and climate, and hence the similarity in the west-to-east zonation of both climate and vegetation. With the south-to-north progressive decline in total rainfall and length of wet season, vegetation belts are demarcated in a west-to-east pattern characterised by transitional zones between one belt and another (Aweda and Adeyewa 2009). The increasing demand for land in the country, coupled with other anthropogenic activities threatening the existence of vegetal cover, demands effective measurement and understanding of the health dynamics of vegetal cover across the country. In the light of emerging issues such as: the prevalence of drought and desertification in the north of the country; incessant pastoral clashes; rapid runoff in the south-west; and devastating gullies in the south-east, there is a dire need for a quantitative and reproducible assessment of the vegetation cover to support policy development for sustainable development, resource conservation and food security (FORMECU 1996; Aweto 2001; FAO 2005).

Changes in ecosystem can be classified into three groups, which are 'seasonal', 'gradual' and 'abrupt change' (Verbesselt et al. 2009). Vegetation cover change in Nigeria has been classified as gradual (Mengistu and Salami 2007; Ademiluyi et al. 2008; Eludoyin et al. 2011) using the change detection capability of remotely sensed images to account for rate of deforestation and land use changes at various study sites. Results from these studies have been useful, although most of them have been restricted to areas of Nigeria adjacent to Chad, the south west and in the Niger delta region. Some scholars have focused on long-term changes in vegetation and pertinent climatic parameters (Flavio et al. 2008; Njoku 2008; Nwagbara 2008; Chima et al. 2009). To date, there is still a poor understanding of the long-term observation of intra- and inter-annual variability in vegetal studies over Nigeria using available remotely sensed imagery. Hoffer and Johannsen (1967) explained that for many ecological situations there may be the need to map many vegetation cover types over large geographic areas and at relatively frequent time intervals because such situations may differ from season to season and from year to year. Traditional assessment of vegetation condition relies on various methods of manual sampling which may be difficult to obtain over a broad area and also difficult to update on time (Areola 1977; FORMECU 1996). The emergence of geo-spatial tools and advancement in the concept of vegetation mapping has greatly increased research on land use cover change with the use of open source spatial data. This has provided an accurate evaluation of the spread and health of the world's forest, grassland and agricultural resources, which has become an important priority in environmental sustainability (Areola 1977; Moshen 1999). The use of remote sensing data (spatial data) in recent times has been of immense help in monitoring the changing pattern of vegetation. The increasing availability of remote-sensed data at various spatial, spectral and temporal resolutions offers the potential to monitor biophysical characteristics of ecological systems at various landscape scales (Salami 2000; Ademiluyi et al. 2008; Oyinloye et al. 2011; Adefioye 2013). These scholars have established that time-series remotely sensed data can be effectively and accurately used to monitor and examine the spatio-temporal dynamics of the nature of the health of vegetation cover.

This study therefore examines the spatio-temporal variation of the health of vegetation cover over Nigeria for thirty years using GIS and remote sensing techniques. It also assesses the relationship between rainfall variation and Normalised Difference Vegetative Index (NDVI) in order to predict the vegetation status for the next twenty years over Nigeria using a cellular automata/Markov chain model. All this is done with the main purpose of determining the indices of the NDVI from both AVHRR NOAA NDVI images and Moderate Resolution Imaging Spectro-radiometer (MODIS) data in order to assess its relationship with rainfall variability over Nigeria. The use of time-series remotely sensed data has shown great capabilities in studying vegetal compositions and variations (Salami 2000; Ademiluyi et al. 2008; Adefioye 2013) needed for adequate planning and an effective forest information management system. Similar studies have been carried out using a Markov Chain model with images, but mainly only on sections of the country (Adesina et al. 2015; Ayeni et al. 2015).

Study area

Nigeria is located between latitude 4°N and 14°N of the equator and between longitude 2°E and 15°E of the Greenwich meridian. Nigeria is in West Africa. It is bounded to the west by Benin Republic, to the north by Niger Republic, to the east by Cameroon Republic, to the north east by Chad Republic and to the south by the Atlantic Ocean. The total land area of Nigeria is approximately 923,768 square kilometres (Fig. 1).

The terrain ranges from southern coastal swamps to tropical forests, open woodlands, grassland and semi-desert in the far north. The highest regions are the Jos Plateau, 1,200–2,000 metres above sea level, and the mountains along the border with Cameroon. Nigeria has a tropical climate that varies from south to north and with elevation. Southern Nigeria faces warm, moist, south-westerly winds from the

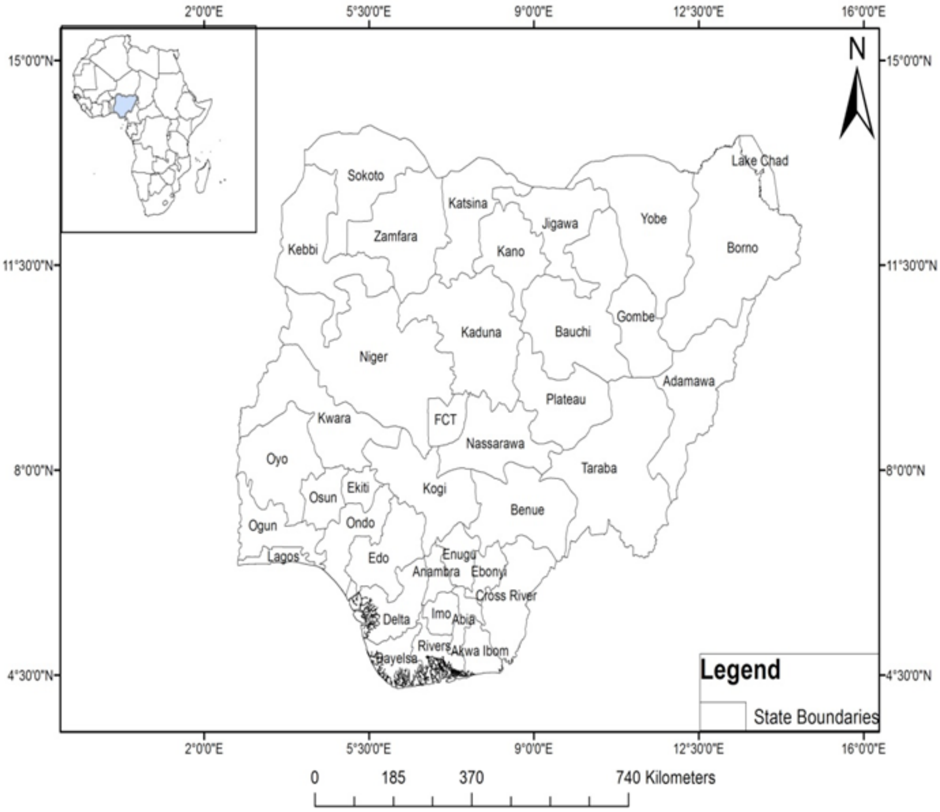

Fig. 1. Map of Nigeria, the study area

sea during much of the year and is hot, humid, and oppressive. Temperatures average about 27°C (80°F) and have only a small daily and seasonal variation. Rainfall, which is heaviest during the wet seasons, is about 1,780 mm annually along the western part of the coast and up to 3,810 mm in the east. Northern Nigeria is dominated most of the year by dry, dusty, north-easterly trade winds, called harmattan, from the Sahara.

The climate of the north is drier than that of the south and is marked by a greater range of temperature. The hottest month averages about 32°C (90°F); the coolest, 21°C (70°F). Most of central Nigeria receives 635 mm to 1,270 mm of rain each year. The principal rivers in Nigeria are the Niger and its main tributary, the Benue. Both are navigable over most of their courses within the country and together drain the greater part of Nigeria. Both offer hydroelectric power potential, some of which has been developed at the large Kainji Dam on the Niger. In the south, rivers tend to be short and carry relatively large amounts of water. In the drier north, many rivers carry water for only some part of the year. Nigeria shares Lake Chad with Niger, Chad and Cameroon. The natural vegetation of Nigeria varies with the climatic conditions, and particularly the amount of precipitation. Mangrove and swamp forests predominate in the delta and coastal zone; tropical rain forests in the humid south; and savannas in the subhumid central zone and the drier north. About one-eighth of Nigeria is covered with forests. Commercial use of the forests, however, is limited by inaccessibility, lack of solid stands, and poor timber quality in the drier areas.

Materials and methods

Data for this study were mainly acquired from two secondary sources; Normalised Difference Vegetative Index (NDVI) data derived from satellite images and rainfall values obtained from ground stations which were supplied by the Nigerian Meteorological Agency (NIMET). The schematic diagram of the process involved in the data acquisition and methodology used in this study is as shown in Figure 2.

AVHRR NOAA NDVI satellite imagery from 1981–2000 and Moderate Resolution Imaging Spectro-radiometer (MODIS NDVI) imagery data from 2001–2010 were obtained from Clarks Laboratory (Idrisi). The MODIS NDVI with spatial resolution of 250 m was resampled to AVHRR resolution of 1 km to enable compatibility between the two datasets. The resampling of the dataset was made possible using the resample tool from the Arctool box. ArcGIS 10 was used for most of the spatial analysis, while image processing of the data was carried out using IDRISI Taiga. Vegetation monitoring was performed at intervals of five years to ensure consistent monitoring and assessment of vegetation for thirty years while the twenty-year projection was made using a Markov chain and cellular automata in the landuse change modeller of the Idrisi software to determine the vegetation cover for the year 2030.

Markov analyzes two qualitative land cover images from different dates and produces a transition matrix, a transition area matrix, and a set of conditional probability images. CA_MARKOV is a combined cellular automata/Markov chain land cover prediction procedure that adds an element of spatial contiguity as well as knowledge of likely spatial distribution of transitions to Markov chain analyses. The threshold involved in characterising the vegetal distribution is based on the NDVI classes which range from -1 to +1. Values of -1 to 0 are interpreted as no vegetation, while between 0 and 0.4 is interpreted as sparse vegetation, and 0.5 to 1 is interpreted as densely vegetated.

Additionally, the rainfall data were obtained from Nigeria Meteorological agency (NIMET) for the study period. Inverse distance weight (IDW) was the interpolation method applied to monitor the distribution of rainfall which was acquired from twenty-five meteorological stations across Nigeria. Correlation and regression analysis were used to ascertain the level of relationship between rainfall and vegetation (NDVI) in Nigeria. A linear regression analysis was carried out with NDVI as the de-

Fig. 2. Cartographic model showing the procedure of data analysis

pendent variable and annual mean rainfall as the independent variable to examine the relationship between the two variables.

Results and discussion

Spatial pattern of rainfall and NDVI over Nigeria

The spatial pattern of NDVI and rainfall distribution over Nigeria for the study period revealed that the northern part of Nigeria experiences rainfall as low as 405 mm, especially at the north-eastern part of Nigeria bordering Lake Chad, with a corresponding low NDVI of -1.0 (Figs 3 and 4). However, there is a gradual increase in the NDVI value (0.5) and a corresponding increase in rainfall amount (2,649 mm) towards the southern part of Nigeria.

Generally, the observed trend in the average NDVI and rainfall amount across the meteorological stations in Nigeria (Fig. 5) indicates that the stations in the southern part, such as Akure, Calabar, Ikeja, Owerri and Warri, experience high rainfall, to the tune of about 3,000 mm, with a corresponding highest NDVI value of 0.5, while stations in northern Nigeria, most especially in the north east, such as Nguru, have the lowest rainfall amount of 500 mm and also the lowest NDVI value of -1.0, thus indicating a spatial distribution pattern of high NDVI values in the south to low NDVI values in the north.

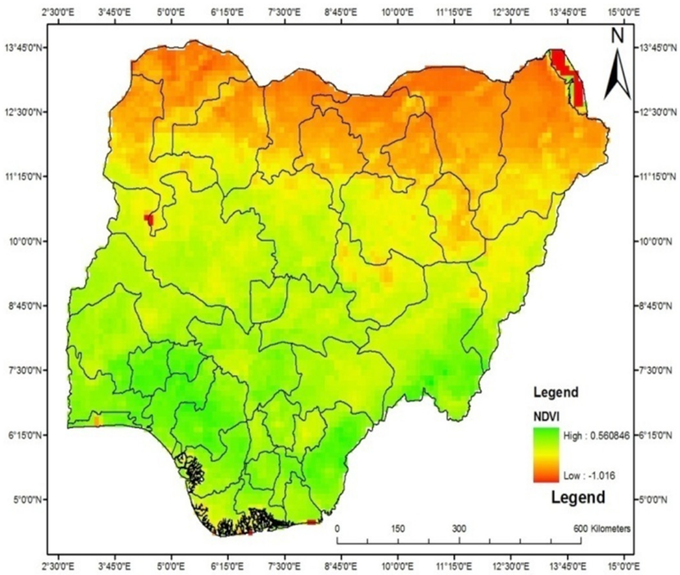

Fig. 3. Average NDVI (1981-2010)

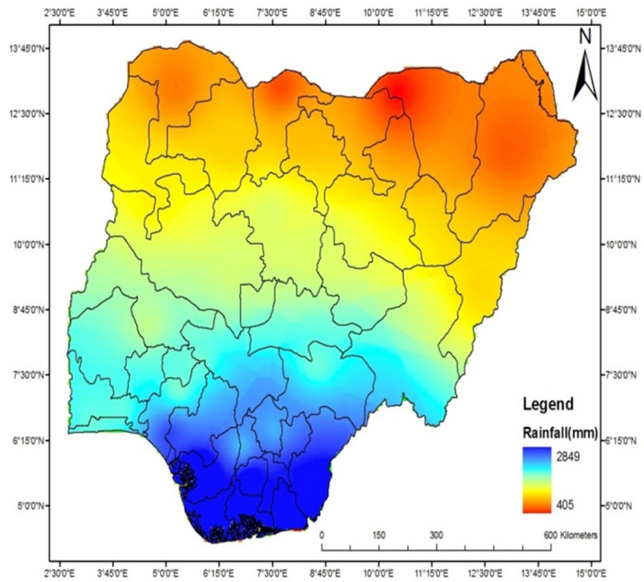

Fig. 4. Average rainfall (1981-2010)

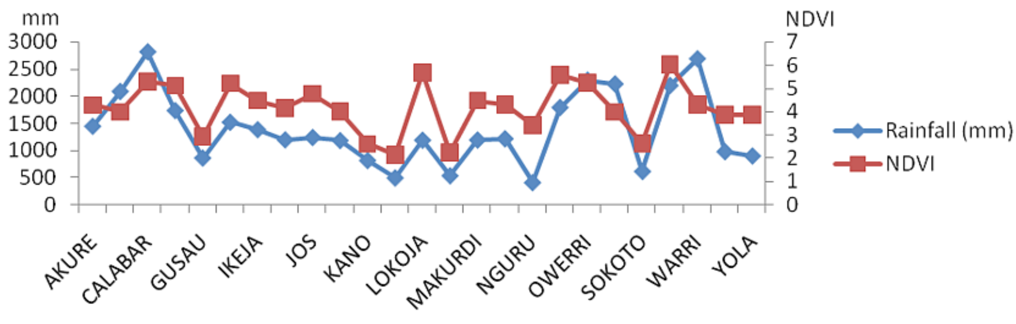

Fig. 5. Temporal trend of rainfall and NDVI across weather stations (1981-2010)

This confirmed the dominance of diverse vegetal types in the vegetation zones of the south compared to those of the north, which is sparse in nature. Moreover, there exists a significant relationship between vegetal vigour and rainfall over Nigeria. There exists an increasing correlation between rainfall and NDVI; as rainfall increased to 160 mm, the NDVI value increased to 0.4. The trend was then tested using simple linear regression analysis to understand the relationship between rainfall and NDVI, with the fit test revealing a correlation of 0.6.

This shows that there exists a positive correlation between amount of rainfall and normalised vegetal index. Hence, from the equation Y = 1,234.4x – 337.86 + Ɛ, a simple forecast of the vegetal health status of any area within the country can be predicted. Rainfall explains more than half of the variation experienced in the NDVI and, therefore, variability in rainfall is a key variable in explaining the spatial variation in NDVI status across the country (Peng et al. 2000; Rimal 2001; Lambin et al. 2003; Hongming et al. 2004; Eludoyin et al. 2011; Arome and Ejaro 2012). To understand the inherent dynamics between the relationship in Figure 6, a more robust statistical technique was employed to deconstruct the observed relationship. A Markov chain analysis, together with cellular automata, was used to predict a long term observation of vegetal distribution up to 2030 and explain the pattern of spread across Nigeria (Figs 7a–h and 9).

Spatio-temporal distribution of vegetation cover and long term projections

In 1981 the area that had no vegetation was about 312,640.81 km² – that is, 33.8% of the spatial extent of Nigeria – and it was predominantly in the north, while there was a densely vegetated area in the south of Nigeria of about 358,534.17 km² – that is, 38.81% of the total landmass (Fig. 8a). However, by 1985 (Fig. 8b), there had been a gradual change in the vegetal cover, in the sense that the dense vegetation in terms of coverage extent and pixel density reduced to 336,264.2 km² while areas with no vegetation increased to 343,769.55 km² (about 37.2% of the total area). Subsequently, the spatial extent of low vegetal cover gradually increased while there was a corresponding decrease in the dense vegetated area (Table 1).

In 2010, areas with no vegetation appear to have the highest areal extent, covering about 474,436.43 km², which is about 51.3% of the study area, while dense vegetation covers about 23.8% (about 220,608 km²) of the study area. This is due to increasing anthropogenic activity (gas flaring, bush burning, urbanisation, etc.) across the country and this calls for serious attention in the light of emerging climate change and its derivative effects.

It is evident from Table 1 that the prediction for the first projected year, 2020, which is a short-term estimate, shows that the trend in vegetation loss will continue to increase, as the area with dense vegetation will reduce to 207,812.01 km², which is 24% of the total land area of Nigeria, down from about 38.8% in 1981. Meanwhile the sparse vegetation is about 214,456.09 km² and the no vegetation area will increase to 501,504.89 km², which is 54.2% as against 51.3% in 2010 (Fig. 10). The long term

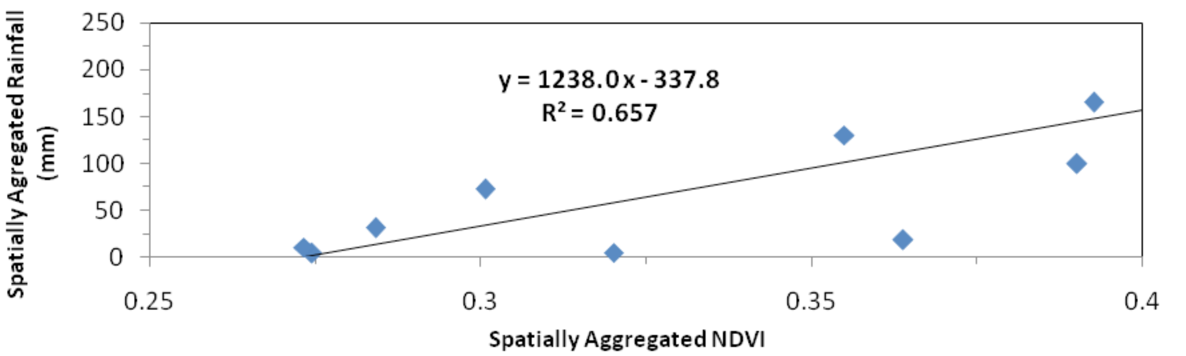

Fig. 6. Relationship between monthly mean NDVI and monthly mean rainfall (1981-2010)

Table. 1. Spatial extent of vegetation cover of Nigeria

Years	No vegetation (km^2)	Sparse vegetation (km^2)	Dense vegetation (km^2)
1981	312,640.8	252,598.0	358,534.2
1985	343,769.6	243,739.3	336,264.2
1990	359,764.6	253,213.2	310,795.2
1995	417,715.7	217,039.9	289,017.4
2000	426,943.6	219,623.7	277,205.7
2005	455,242.4	205,474.3	263,056.3
2010	474,436.4	228,728.6	220,608.0
2020	501,504.9	214,456.1	207,812.0
2030	501,504.9	224,964.4	127,730.0

projection further confirms that by the year 2030 dense vegetation will reduce markedly to 127,730 km^2, while the sparsely vegetated area will increase to about 224,964.4 km^2, as against 214,456.1 km^2 in 2020, while the non vegetal areas will remain at 501,504.9 km^2. Hence, it is expected that the densely and sparsely vegetated areas will undergo remarkable changes. In general, the trend showed that there has been loss of vegetation from 1981–2010 and more is likely if nothing is done to arrest the situation. Also, it was observed that there was a progressive loss in vegetation cover southwards and this is also expected to continue, thereby giving way to the prevalence of the derived forest and savanna ecosystem over Nigeria in the near future (Fig. 10).

Figure 10 shows that, initially, areas with dense vegetal cover in terms of coverage extent were greater than sparse vegetal units and non vegetal units. Within a space of five years, the graph shows a progressive increase in the percentage of areas with no vegetation and a concurrent decrease in the percentage of areas with dense vegetation. Since the turn of the 21st century, dense vegetal areas have been decreasing in magnitude below sparse vegetal units. This implies that the land area with dense vegetation is fast becoming sparse vegetation and then going on further to become an area with no vegetation. The decrease in percentage of area with dense vegetation was gradual from 1981 to 2020 but was predicted to be quite drastic between 2020 and 2030. The percentage of areas with sparse vegetation fluctuated. The increase in areas with sparse vegetation accords with other regional studies (Mengitsu et al. 2007; Ademiluyi et al. 2008; Eludoyin et al. 2011; Uchegbulam et al. 2013). The downward trend in dense vegetation area calls for a serious action plan which will aid in mitigating the rate at which the trend is advancing.

Conclusion

The study shows that there is a strong linear relationship between NDVI and precipitation in cases where monthly or seasonal precipitation is within a certain range. Southern Nigeria, where high rainfall amounts of about 3,000 mm are being experienced, also has the highest NDVI value of 0.5 while north-eastern Nigeria (Nguru) has the lowest rainfall amount (500 mm) coupled with the lowest NDVI value of -1.0, indicating a striking distributional pattern and relationship between rainfall and NDVI value across the country.

The results showed that dense vegetal areas decreased from 358,534.2 km^2 in 1981 to 220,608 km^2 as at 2010 – a loss of about 73% – while sparse vegetal areas showed an increase in spread from 252,598 km^2 in 1981 to 228,728.6 km^2 in 2010 – an increase of about 51.3%. Cellular Automata and Markov Chain (CA_Markov), a projection of the areal vegetal extent, was examined up to 2020, and it was predicted that areas with no vegetation will increase in spread to 501,504.9 km^2, while dense vegetal areas will reduce to 207,812 km^2. It was observed from the interval of five years that the trend was a general decline in the total landmass of dense vegetation in Nigeria, while there was an increase in the total landmass of no vegetation in Nigeria. The projected year also showed a similar pattern.

Times series remotely sensed data using Geographic Information Systems (GIS) has conclusively proven to be effective and accurate in monitoring

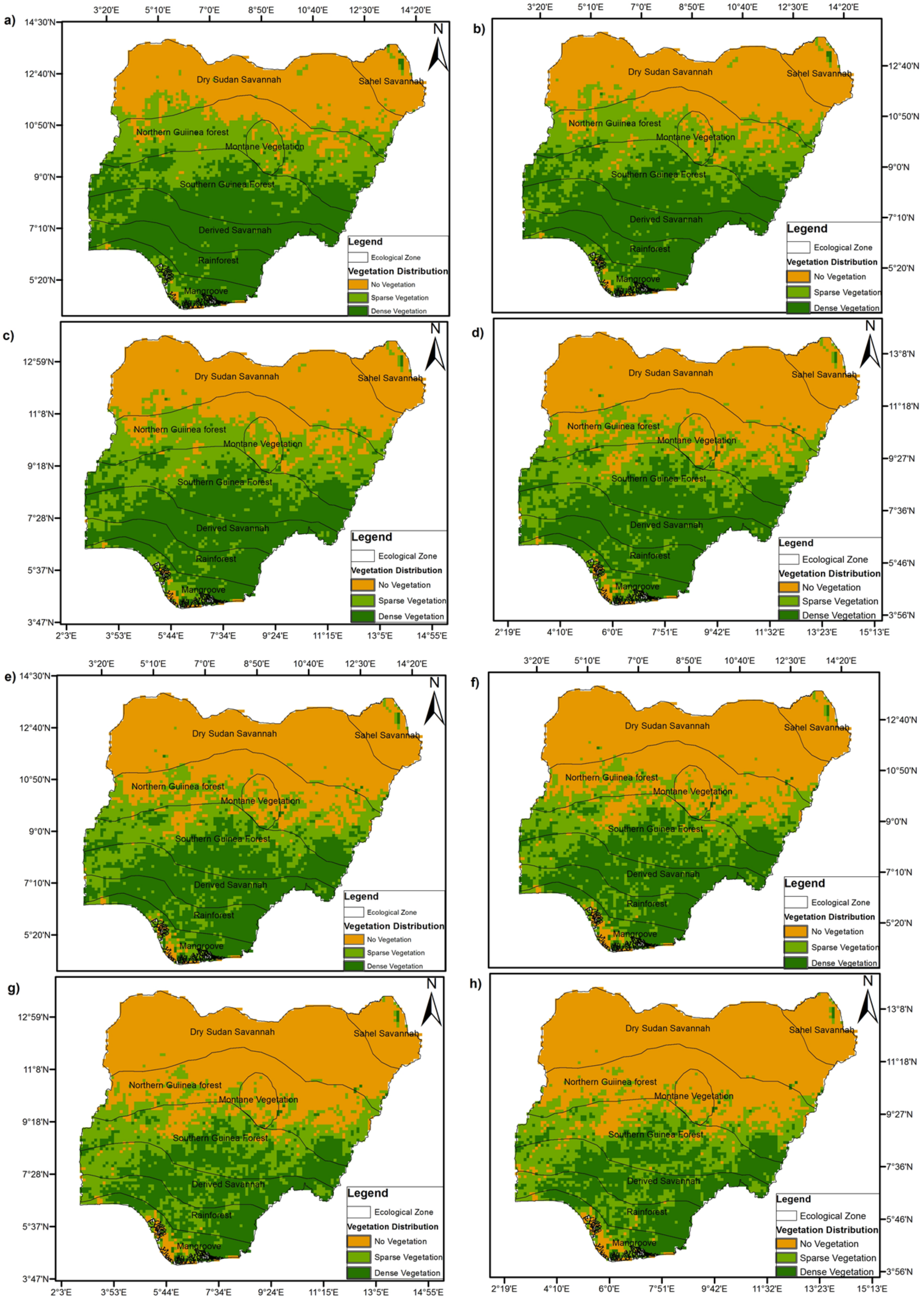

Fig. 7. Vegetation cover over Nigeria, 1981-2020 (a-h represent the spatial distribution of vegetation cover across Nigeria for the following years respectively: 1981, 1985, 1990, 2000, 2005, 2010 and 2020)

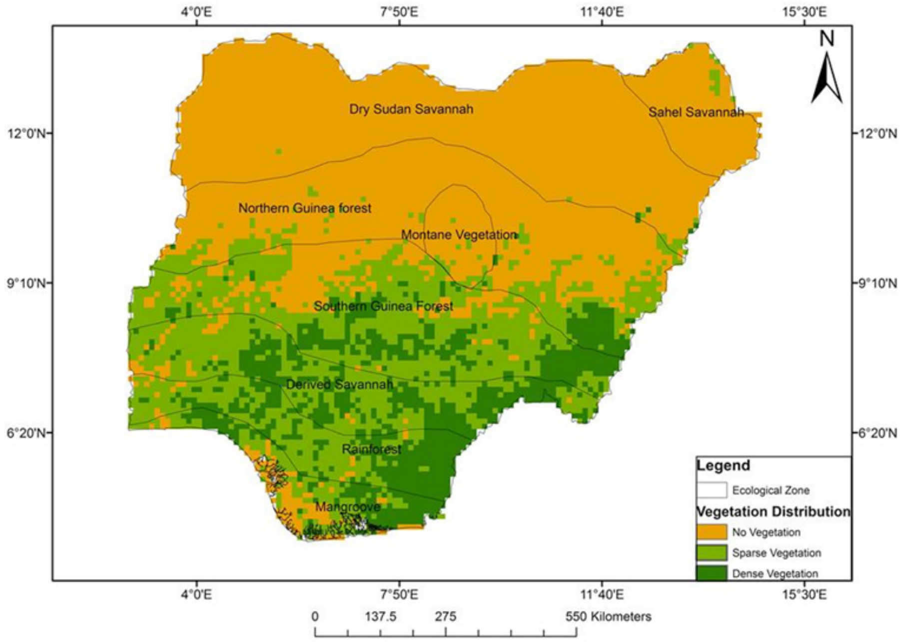

Fig. 8. Long term prediction of vegetation cover over Nigeria for 2030

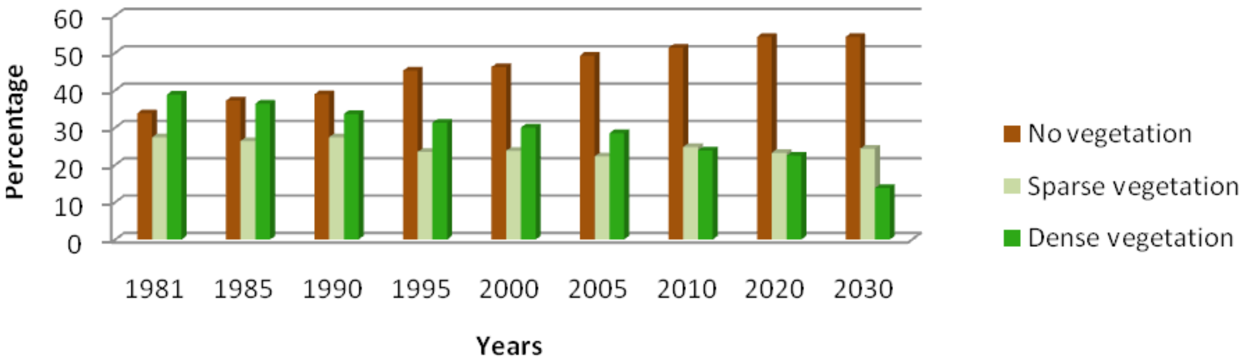

Fig. 9. Area extent of vegetation distribution (1981-2030)

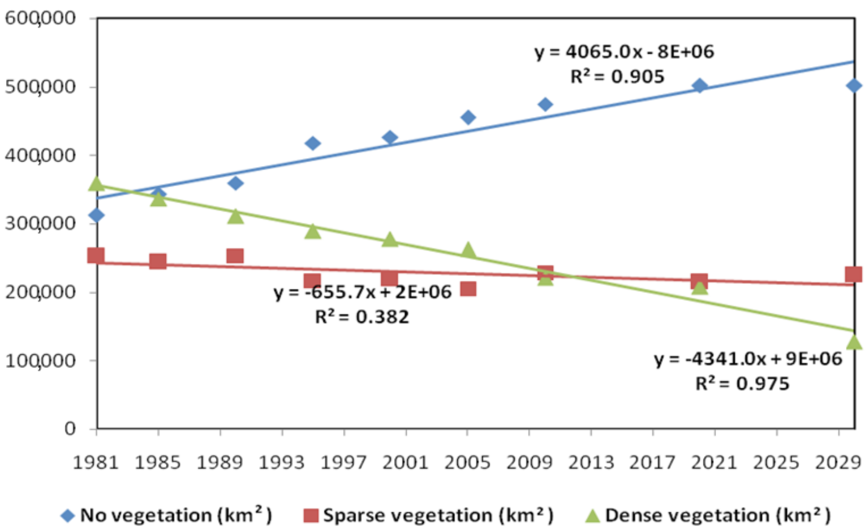

Fig. 10. Trend series of vegetal dynamics

and examining the spatio-temporal dynamics of the nature of vegetation cover in Nigeria because it provides consistent, valuable and repeatable measurements at a spatial scale. Therefore, it is an effective technique that needs to be adopted for the revival of a healthy and sustainable environment.

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