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Analyzing the Changing Pattern of Nigerian Vegetation Zones and Its Ecological and Socio-Economic Implications Using Spot-Vegetation Sensor

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***Abstract*—**This study assesses the major ecological zones in Nigeria with the view to understanding the spatial pattern of vegetation zones and the implications on conservation within the period of sixteen (16) years. Satellite images used for this study were acquired from the SPOT-VEGETATION between 1998 and 2013. The annual NDVI images selected for this study were derived from SPOT-4 sensor and were acquired within the same season (November) in order to reduce differences in spectral reflectance due to seasonal variations. The images were sliced into five classes based on literatures and knowledge of the area (i.e. <0.16 Non-Vegetated areas; 0.16-0.22 Sahel Savannah; 0.22-0.40 Sudan Savannah, 0.40-0.47 Guinea Savannah and >0.47 Forest Zone). Classification of the 1998 and 2013 images into forested and non forested areas showed that forested area decrease from 511,691 km^2 in 1998 to 478,360 km^2 in 2013. Differencing change detection method was performed on 1998 and 2013 NDVI images to identify areas of ecological concern. The result shows that areas undergoing vegetation degradation covers an area of 73,062 km^2 while areas witnessing some form restoration cover an area of 86,315 km^2. The result also shows that there is a weak correlation between rainfall and the vegetation zones. The non-vegetated areas have a correlation coefficient (r) of 0.0088, Sahel Savannah belt 0.1988, Sudan Savannah belt -0.3343, Guinea Savannah belt 0.0328 and Forest belt 0.2635. The low correlation can be associated with the encroachment of the Sudan Savannah belt into the forest belt of South-eastern part of the country as revealed by the image analysis. The degradation of the forest vegetation is therefore responsible for the serious erosion problems witnessed in the South-east. The study recommends constant monitoring of vegetation and strict enforcement of environmental laws in the country.

***Keywords*—**Vegetation, NDVI, SPOT-vegetation, ecology, degradation.

I. Introduction

VEGETATION is an important component of the ecosystem. Its health determines the wellbeing of other living organisms which the ecosystem depends on in order to fulfill many of its ecological functions. Biodiversity of the ecosystem also depend on a healthy vegetal cover for it to be sustainable. The destruction of vegetation cover through developmental activities will have serious consequences on the existence of wildlife as it provides them with forage and habitat thereby reducing the biodiversity of the ecosystem. The health of the ecosystem is closely linked to the condition of vegetation cover in an area, hence there is the need to sustainably manage and monitor the condition of vegetation at both local and global scale. According to [1] 'ecology and plant geography are largely concerned with the causes of pattern at all scale'. The patterns of vegetation can be determined by natural phenomena such as climate, soil, and topography. Pattern is arrangement, a concept usually associated with the notions of regularity, order, repetition, and scale [2]. Since natural arrangements are dynamic, natural pattern is best regarded as a manifestation of complex dynamic processes at work. Patterns, physical or biological, have to be discovered by observation and describe in precise terms before an understanding of natural phenomena can begin. However, human factors can modify the pattern of vegetation in diverse ways. Human land use and global climatic change have been responsible in one way or the other in affecting the development of vegetation. Land cover changes may be said to occur as a result of both human and natural induced factors, which interacts with terrestrial ecosystem to influence [3]-[6]. Human use of the land is not a static process but an extremely dynamic one. The unprecedented rates of changes in land cover on the local and regional scales, have led to alterations of global biogeochemical cycles, and loss of productive ecosystems and biodiversity. Such changes if unabated or controlled will lead to serious disruption of the ecological system on which humans depend for their existence. Land cover change has contributed in many ways to the loss of biological productivity and biodiversity in both terrestrial and aquatic ecosystem. These changes have been defined broadly to include the conversion of lands into croplands and pastures, the abandonment of agricultural lands, deforestation, reforestation, afforestation, shifting cultivation, and urban sprawl [7].

Human history revealed an escalating trajectory of alteration and transformations of the earth that sustains life and the changes over the last 300 years has been to increase the area of agricultural land and decrease the area of forests [8]. The major driving forces behind these changes include rapid population growth and consumption, lack of valuation of ecological services, poverty, ignorance of biophysical limitations, and use of ecologically incompatible technologies. Nigeria is faced with diverse environmental problems which include: soil erosion, deforestation, flooding, air pollution and loss of biodiversity

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which were as a result of the aforementioned driving forces. Studies around the world have shown that vegetation cover is undergoing a dramatic change at various scales [9]-[11]. According to [12] Nigeria is one of the countries witnessing unprecedented deforestation of about 3.5 % per annum. Such rate of deforestation cannot take place without serious ecological consequences on the biosphere, hence urgent action is needed to avert imminent catastrophes.

The ability to overcome these consequences will depend on our ability to understand the past, present, and future drivers of what is responsible for vegetation degradation. Therefore, adequate and up-to-date information is essential for environmental planning, toward achieving a sustainable development in the country. However, paucity of updated vegetation maps has hampered progress in proper monitoring and management of ecological resources in the country. References [13] and [14] emphasised the need for regular update of vegetation information in order to have a better assessment and management of the environment and the ecosystem. The traditional methods used in updating information regarding vegetation required a lot of fieldwork which are cumbersome, time consuming and involve high financial cost. Reference [15] observed that most vegetation maps produced by the traditional method are outdated by the time the maps are published. Therefore, in view of these challenges associated with traditional method, remote sensing offers cost effective and timely update of vegetation information. Using remote sensing techniques, vegetation information can be acquired and updated in real or near real time basis. Remote sensing of vegetation depends on the images acquired by sensors on board satellite in the Red portion of the visible and the Near Infrared regions of electromagnetic spectrum. There are many vegetation indices derived from these two bands (the Red and Near Infrared bands). Among the different vegetation indices in use, Normalized Difference Vegetation Index (NDVI) is the most widely used vegetation index in vegetation studies [16]-[21].

This study therefore examines the major vegetation zones in Nigeria in order to identify changes in the pattern of these zones within the period of sixteen (16) years.

II. Study Area

A. Location and Extent

Nigeria is located approximately between Latitudes 4 ˛ 00′ and 14 ˛ 00′ north of the Equator and between Longitudes 2 ˛ 2' and 14 ˛ 30' east of the Greenwich Meridian. It is bordered by the Republics of Niger to the north and Chad, to the east by the Republic of Cameroon, to the south by the Atlantic Ocean and to the West by the Republic of Benin (Fig. 1). It has a land mass of approximately 923,768 sq Km. About 35% of this land mass is believed to be arable while 15% is said to be used as pastures, 10% as forest reserve, 10% for settlements and the remaining 30% is considered uncultivable [22], [23].

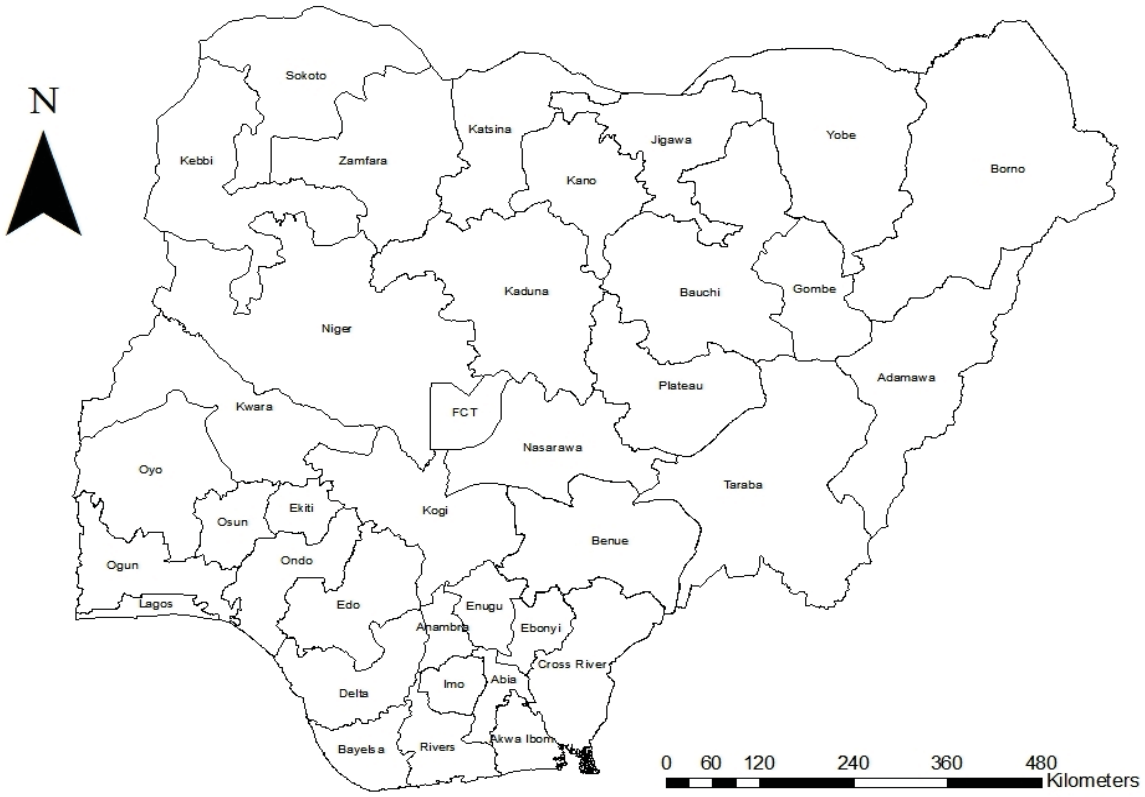

Fig. 1 The Study Area

B. Climate

Nigeria's climate is influenced by the latitudinal location of a place which becomes progressively drier from the equator as one move northward. Rainfall is a major climatic variable that indicates the difference between wet and dry seasons in most areas. The movement of the ITCZ determines the on-set and cessation of rainfall in the region. Rainy season starts in areas south of the Niger and Benue River valleys between April and May, whereas farther north, rainfall commences in the months of June or July with August being the peak of the rainy season. From December through February northeast trade winds, called harmattan, sweep across the country bringing moderate temperatures and lower humidity across the country. The harmattan wind is often laden with dust particles from the Sahara giving rise to characteristic 'harmattan haze' which reduces visibility [24].

C. Vegetation

Vegetation distribution in Nigeria is mainly influenced by climatic conditions more than any other physical factor. The varied climatic conditions have divided vegetation of the country into two broad ecological zones. These zones include; Forest and Savannah zones.

The Forest Zone is found in the southern parts and receives rainfall ranges between 3000 and 1500 mm per annum which are in contrast with that of the Savannah belts (Guinea, Sudan and Sahel) that are located within the Middle belt and northern parts of the country with an annual rainfall ranging between 1500 and 300 mm. The forest vegetation comprises of Mangrove forest and Rain forest

Mangrove Forest is found around swamps of the coastal creeks, estuaries and lagoons of southern Nigeria while the Rain Forest is found within the belt stretching from Ogun to Akwa Ibom. This area is characterized with an annual rainfall of about 1500mm-2000mm received within 8-9 months.

Savannah Zones covers approximately 80% of the country from the northern edge of the rain forest to the southern edge of the Sahara desert. This is a type of vegetation characterized by its continuous grass cover usually compact but could vary considerably with the season and type of savannah. The savanna zone is subdivided into Derived, Guinea, Sudan and Sahel savannah

Derived Savannah is also called open parkland. It is derived from the rain forest and is maintained by regular fire and farming activities. The region has an annual rainfall of 1275 - 2030mm and spreads over approximately 10 months.

Guinea Savannah is the largest vegetation belt in Nigeria. It covers the sparsely populated areas of the middle belts. This region is characterized by natural grassland, sparse woodland or trees. The area receives 1140 - 1520mm rainfall annually (March - November) in the southern guinea savannah and 1000 - 1270mm (April – October) in the northern guinea savannah.

Sudan Savannah consists of scrubby vegetation interspersed with tall trees dominated by species of the *Combratacae* family. Hence, it is known as mixed combrataceous woodland. This area is characterized by sparsely distributed short trees, with short and seasonal grass cover and receives rainfall of between 600- 1000 mm, lasting 4-6 months.

Sahel Savannah is the most northern vegetation zone, found in the Eastern corners of Jigawa, Yobe and Borno states. It consists of plants that are tolerant of dry conditions; these are mainly annual grasses, thorn bushes and small trees. The area is characterized by low rainfall, barely 500mm of rainfall annually with about 9-10 months of dry season [24].

III. Methodology

Satellite images that were used for this study come from the SPOT -Vegetation NDVI acquired by SPOT-4 sensor from 1998 to 2013. The images were selected on annual bases and within the same season (November) in order to reduce radiometric errors that might be introduced due to seasonal variations [25]-[27]. The NDVI images were composite images of 10 days i.e. 10 days of maximum value composite (MVC) NDVI images (S-10 product) at 1 km^2. NDVI indicates chlorophyll activity and is derived from the formula:

$$NDVI = (band\ 3 - band\ 2) / (band\ 3 + band\ 2)$$

where bands 2 represents image acquired within the red (0.61–0.68 µm) and band 3 is within the Near Infrared (0.78–0.89 µm) region of the electromagnetic spectrum respectively.

The resultant NDVI image gives a range of values from -1 to +1. The values that are less than 0 indicates absences of vegetation and values from 0.2 to 0.8 shows healthy vegetation [21].

The 16 NDVI images were sliced into five classes based on xpert knowledge of the area and from vegetation maps (i.e. <0.16 Non-Vegetated areas; 0.16-0.22 Sahel Savannah; 0.22-0.40 Sudan Savannah, 0.40-0.47 Guinea Savannah and >0.47 Forest Zone). ILWIS 3.7 software was used in slicing the NDVI images and in extracting the area of interest from the satellite images obtained from https://www.vito-eodata.be/. ArcGIS 10.2 software was used in visualization and map production. Image differencing was used to detect hotspots of vegetation degradation and regeneration in the country.

The rainfall data used in this study was obtained from http://gisclimatechange.ucar.edu/ and Nigeria meteorological agency. The rainfall data was correlated with the NDVI values. Excel 2007 was used in correlating the relationship between rainfall and NDVI.

IV. Results And Discussions

The results of the study revealed that the ecological zones and the rainfall pattern in the country don't have close affinity with each other. This is in contrast with the findings of [16] and [17] that show high correlation between rainfall and NDVI. However, the reasons can be attributed to human activities and high rate of vegetation degradation in the country [12]. The result from image analysis of the NDVI on Table I revealed that Forest and Guinea Savannah zones in the country have their lowest area extent of 22,894.69km^2 and 192,411.41km^2 in 2001respectively. However, the other vegetation belts show

reverse trends with the Sudan Savannah zone having the highest coverage of 561,517.56km^2 whereas the Sahel Savannah zone has coverage of 98,974.91km^2.

The expansion of the Sahel Savannah zone indicates dryness which consequently leads to the expansion of desert condition. The year 2005 witnessed increase in the area coverage of the Forest zone with a total area of 211,984.45km^2 which responded favorably with increase in rainfall received that year. The other zones however, witnessed decrease in the area coverage as shown on Figs. 2 and 3. The figures also revealed gradual changes in the pattern of vegetation zones in the country as against the previous smooth delineation of vegetation zones depicted in vegetation maps currently in the public domain [28]. The maps derived from the NDVI images show the encroachment of savannah type of vegetation into the southern part of the country, especially the southeastern region. This change in the pattern of vegetation of the southeast is responsible for the current ecological and social problems experienced in the region. The appearance of savannah type of vegetation in the region has contributed to large scale soil erosion and deadly clashes between farmers and herdsmen in recent times. The recent conflict in the region can be largely attributed to vegetation degradation which created openings for easy access of animals to grazing lands.

TABLE I
AREAL EXTENT OF VEGETATION ZONES IN NIGERIA BETWEEN 1998 AND 2013

Year	Non-Vegetation	Sahel	Sudan	Guinea	Forest
1998	27446.17	90896.47	391671.12	319235.27	83596.39
1999	16598.55	52707.02	393835.73	321047.48	128656.64
2000	44005.54	96734.05	490357.45	241284.02	40464.36
2001	37046.86	98974.91	561517.56	192411.41	22894.69
2002	43619.15	87953.28	463892.13	239506.47	77874.40
2003	13466.07	73949.34	417991.30	282759.50	124679.21
2004	27048.69	115998.27	415586.38	246531.62	107680.46
2005	23466.31	73989.83	357935.03	245469.81	211984.45
2006	21267.12	70290.67	381713.05	294437.61	145136.97
2007	21195.30	128334.88	415479.73	270083.16	77752.36
2008	24318.61	102540.26	453606.84	243036.61	89343.10
2009	25209.68	86999.24	381815.87	316785.10	102035.53
2010	11243.21	67220.33	391730.83	303994.73	138656.32
2011	18049.61	101736.40	358837.72	297388.65	136833.04
2012	8996.77	56720.08	392586.97	287055.07	167486.53
2013	14004.66	96388.68	429860.33	255405.41	117186.35

The country between 1998 and 2013 has witnessed an expansion of non-forested areas from 429,272 to 462,600 km^2 and the shrinking of forest areas from 511,691 to 478,360 km^2. This shows that country has lost about 33,300 km^2 of forest within the period under study (Figs. 4 and 5, Table II). However, constant monitoring and documentation of changes in vegetation cover of the country is required due to the influence of rainfall on NDVI results. Increase in rainfall received in a particular year can give a false impression of vegetation increase, hence the need for the usage of finer resolution satellite image to verify any false changes.

Vegetation change detection using image differencing method shows that the areas undergoing deforestation and regeneration are found randomly across the country with notable areas of deforestation found in the South-south region, Kogi State, Yobe State, Taraba state and in the riparian areas especially along River Niger and Lake Chad area. Fig. 6 shows hotspots of deforestation and regeneration while Table III shows the extent of changes in vegetation cover in the country.

TABLE II
FORESTED AND NON-FORESTED AREAS

Classes	1998	2013
Non-Forested Areas	429,272	462,600
Forested Areas	511,691	478,360

Generally, the explanation for recent changes in the pattern of vegetation of the country is mainly tied to human activities rather than climatic factors. This is so because of the weak correlation between rainfall and vegetation zones in the country despite the fact that the pattern of rainfall with increase aridity as one move northward from the coast has not change. The result of correlation further indicates that anthropogenic factors are influencing the pattern of vegetation in the country. The finding is in agreement with similar work carried out in the northern part of the country by [28] that human activities are the major contributor to vegetation change. Table IV shows correlation between rainfall and vegetation zones where the non-vegetated areas have a correlation coefficient (r) of 0.0088, Sahel Savannah zones 0.1988, Sudan Savannah zones -0.3343, Guinea Savannah zones 0.0328 and Forest zones 0.2635.

TABLE III
CHANGE DETECTION BETWEEN 1998 AND 2013

Classes	Area (Km^2)
Degradation	73,062
Unchanged	781,586
Restoration	86,315

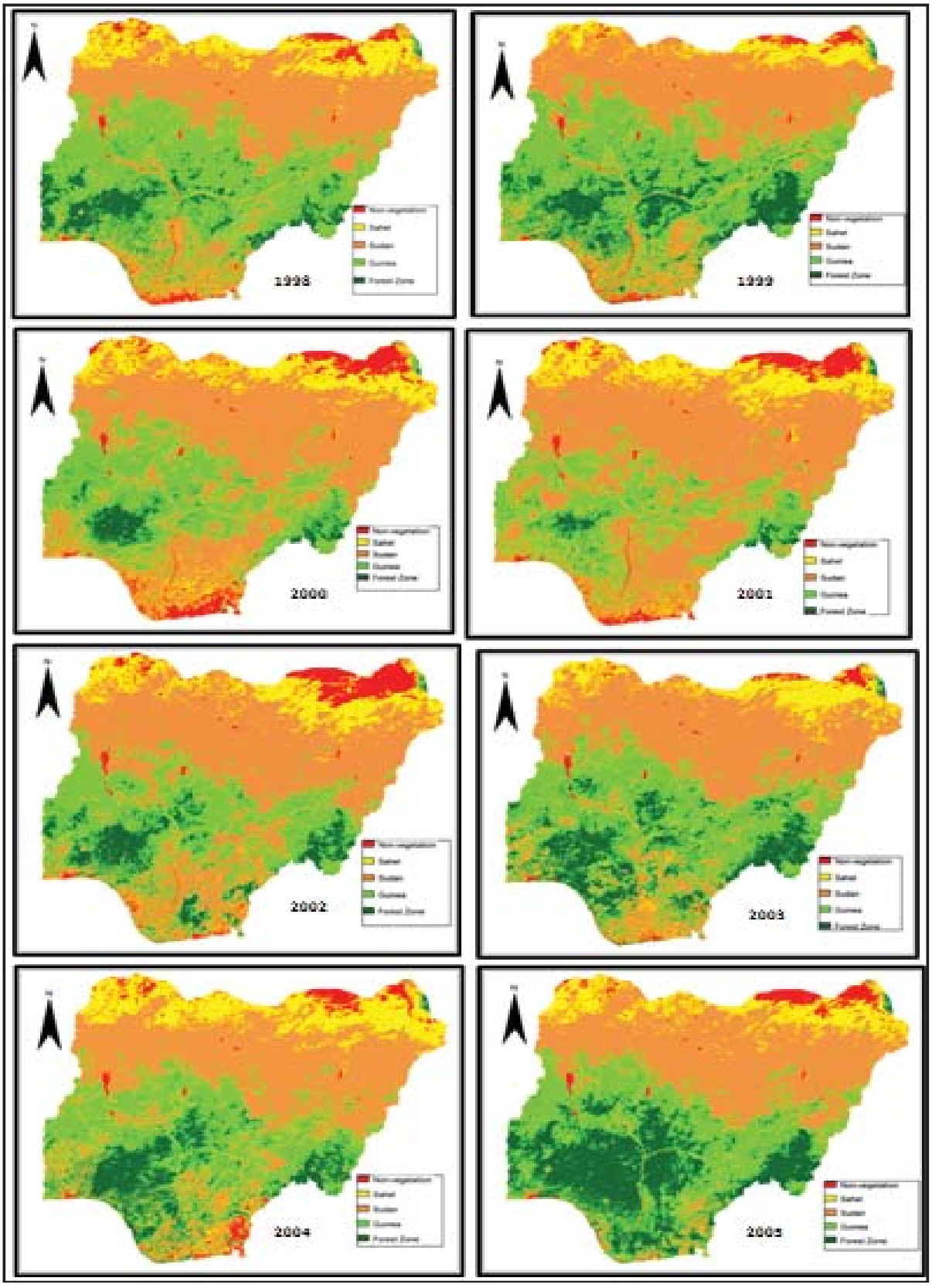

Fig. 2 Vegetation Zones (1998-2005)

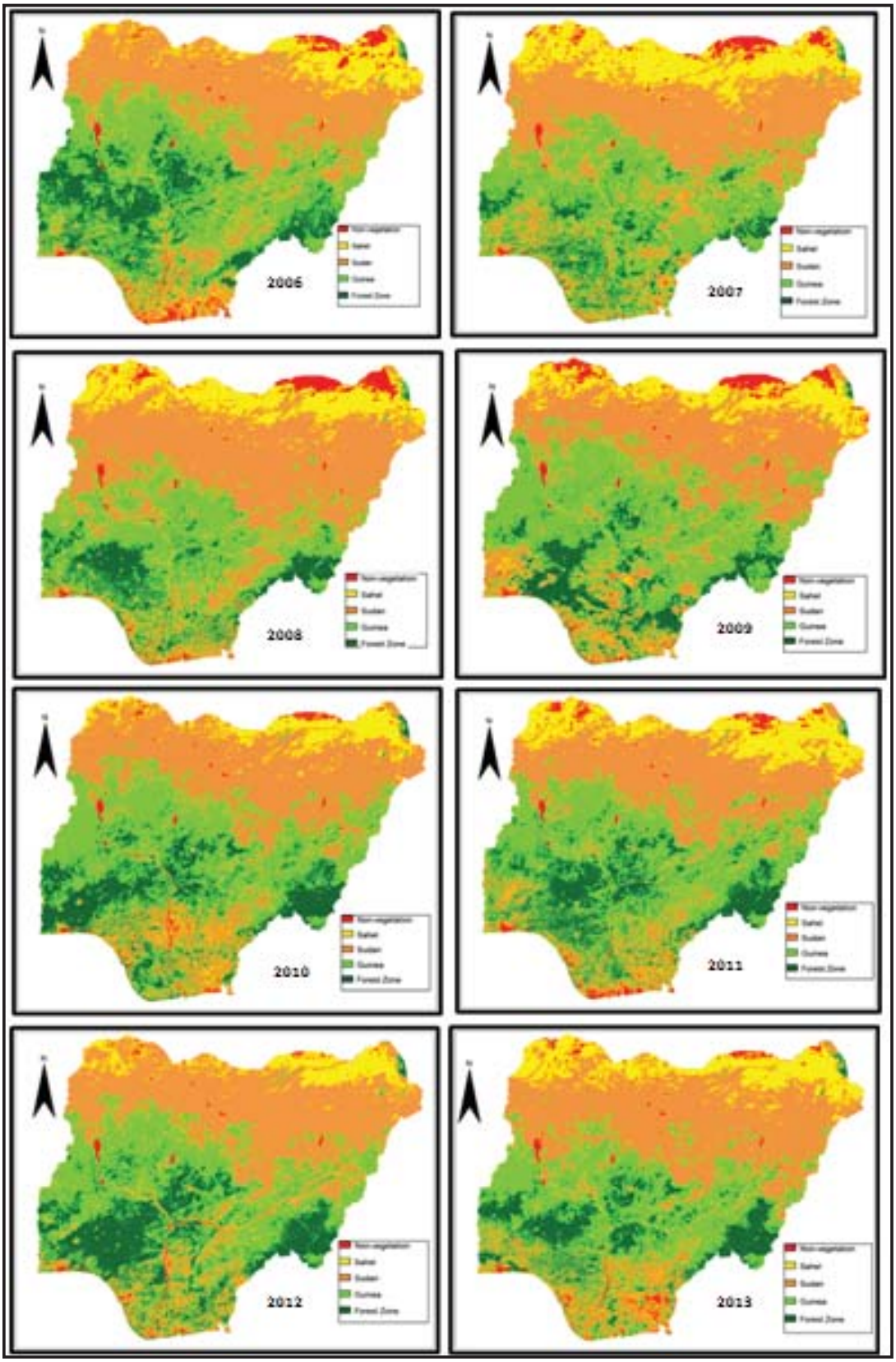

Fig. 3 Vegetation Zones (2006-2013)

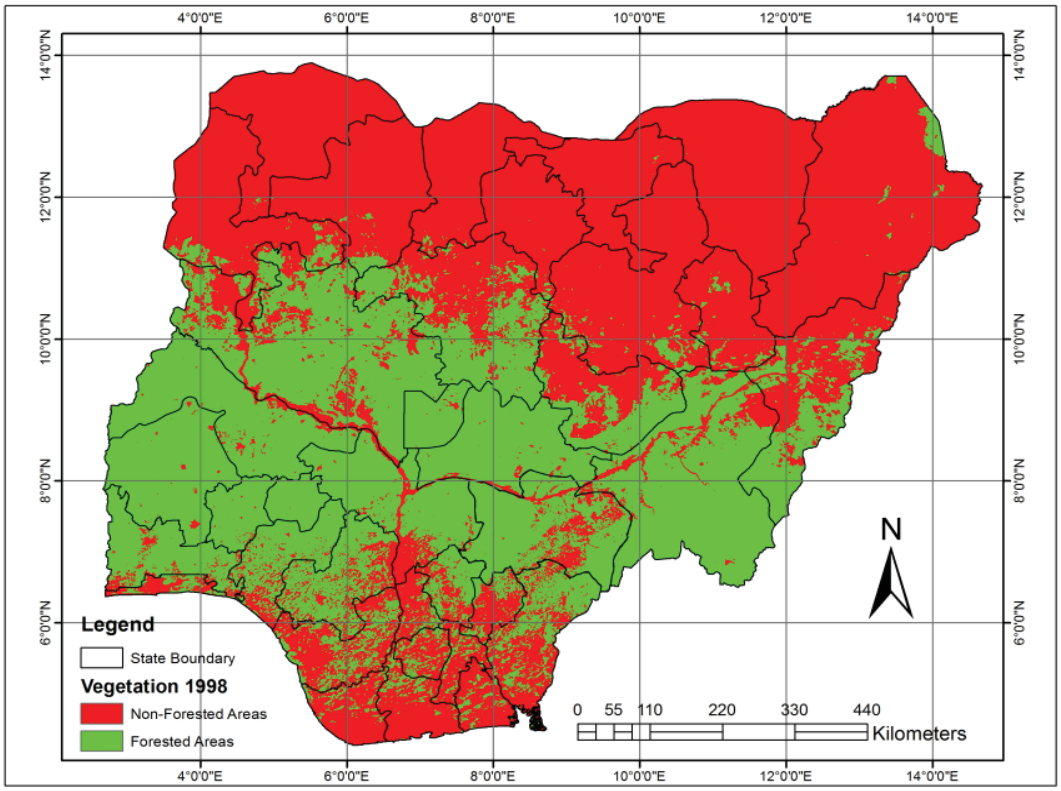

Fig. 4 Forested and Non-Forested Areas in 1998

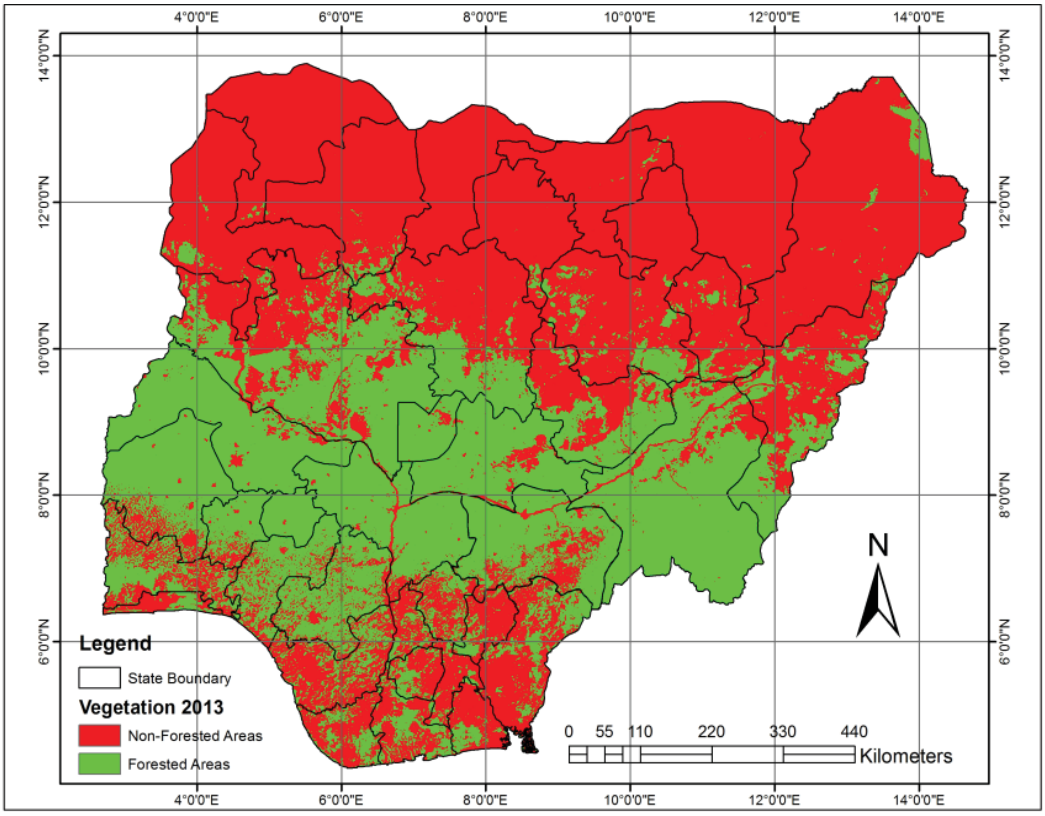

Fig. 5 Forested and Non-Forested Areas in 2013

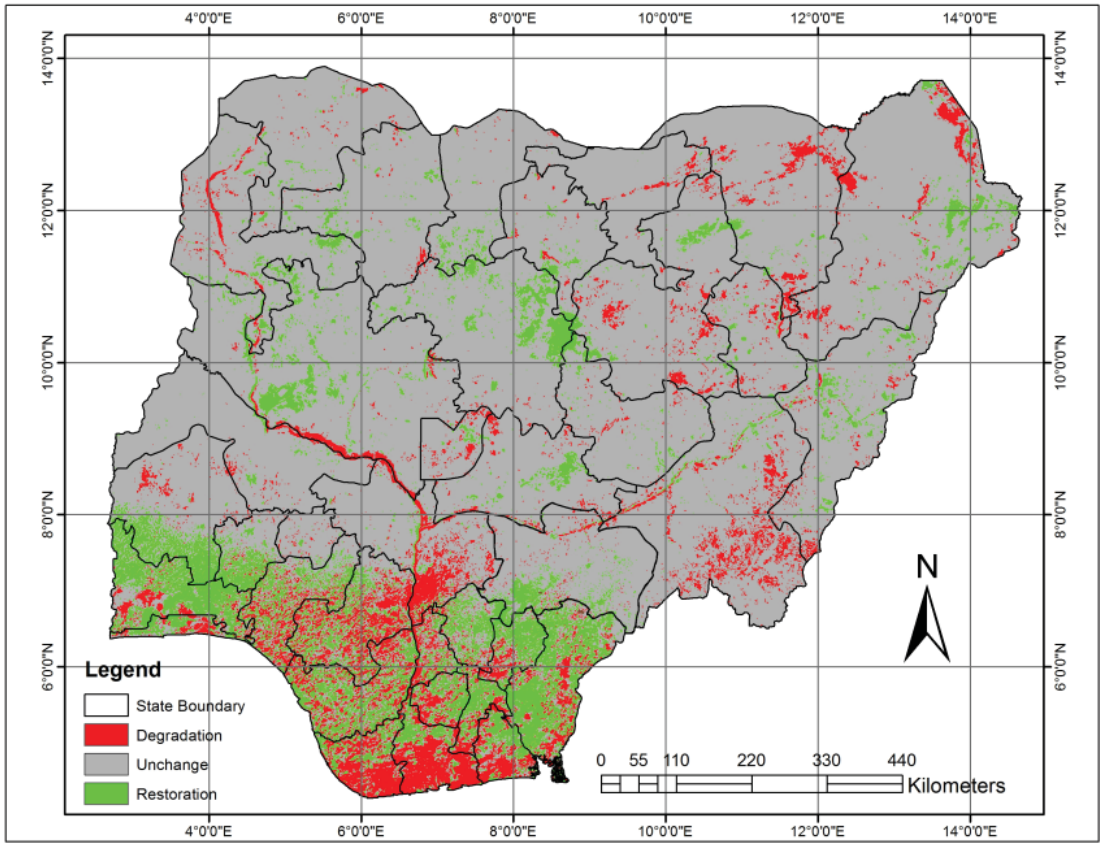

Fig. 6 Change Detection between 1998 and 2013

TABLE IV
CORRELATION ANALYSIS BETWEEN RAINFALL AND VEGETATION ZONES

	Rainfall	*Non-Vegetation*	*Sahel*	*Sudan*	*Guinea*	*Forest*
Rainfall	1					
Non-Vegetation	0.008804	1				
Sahel	0.198771	0.310850	1			
Sudan	-0.334318	0.673415	0.357002	1		
Guinea	0.032780	-0.613409	-0.465219	-0.736518	1	
Forest	0.263493	-0.621326	-0.531862	-0.848947	0.392227	1

The low correlation can be associated to the encroachment of the Savannah zones into the forest belt of the country as revealed from the image analysis.

V. RECOMMENDATIONS

Degradation of vegetation in any give area has serious implication on the ecosystem as wildlife habitats are destroyed and runoff increases. Hence, this process affects the functioning of vegetation in recharging underground water and consequently increasing the rate of soil erosion. The ecological problems of erosion and flooding witnessed recently in the country are directly or indirectly connected to vegetation degradation. Environmental degradation is known to contribute to social conflict in many communities especially in the developing countries where majority of the people depend on land resources for their livelihood. Therefore, destruction of vegetal resources will mean destruction of the means of production of people. This study therefore, recommends constant monitoring of vegetation and strict enforcement of environmental laws in the country in order to preserve the environment from further degradation. Restoration of degraded areas should be encouraged through community participation and government involvement.

VI. CONCLUSIONS

The study revealed that the pattern of vegetation zones in Nigeria has changed from having a strap pattern of different vegetation types arrange in a west to east direction to fragmented vegetation as a result of anthropogenic activities. The appearance of savannah type of vegetation in the southern part of the country has further revealed the influence of human activities on the current pattern of vegetation zones and the reason for low correlation with rainfall. Lumbering, farming and charcoal production are among the major activities that

contributes to vegetation degradation in the southern part of the country. The south eastern part of the country has been experiencing serious soil erosion and deadly conflict due to encroachment of herdsmen into farmlands. Vegetation degradation has open-up the area making it conducive for grazing and further accelerating the process of erosion. The northern part is also experiencing desertification as a result of vegetation degradation. Couple with the contemporary problems associated with climate change, vegetation degradation will further worsen the ecological problems thereby contributing to more conflicts and increase in environmental refugees. In view of the continuous degradation of vegetal resources due to human activities, constant monitoring of vegetation and strict enforcement of environmental laws in the country is recommended. This will help in conserving the vegetation, especially in the southeastern part of the country where gully erosion is claiming large expanse of fertile land and desertification in the extreme northern part is also threatening the regional ecosystem.

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