



Geographical Information System (GIS) Tools And Forest Resources Management In Northern Nigeria

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ABSTRACT

This article focuses on the reliability of Remote Sensing (RS) and Geographical Information System (GIS) in the acquisition of basic data and methods that are used to monitor and manage vegetation resources. Landsat MSS satellite images, Landsat Operational land imager and field survey were the materials and methods used for the study. Results of the analysis revealed that woodland (6.5%) and crop/bare land (8.1%) experience a steady decreasing trend. The findings further showed that the annual rate of change for crop/bare land is alarming culminating to about plus 50% within the period of study while that of woodland and grassland has been minus 15.59% and 3.9% respectively. In view of the valuable status of vegetation cover in the provision of food, shelter, wildlife habitat, fuel, daily supplies and medicinal ingredients and paper, monitoring of vegetation cover and its growth is indispensable.

Keywords: Remote Sensing, Geographical Information System, Forest management, Vegetation change

INTRODUCTION

For effective management of resources, three elements might be put together, that is information about the resources, relevant policies on how they may be managed as well as participation of all the stakeholders in the process. Forests are valuable resource that provides goods and services, such as, food, shelter, fuel and daily supplies that include medicine and paper. Forest helps in providing habitat for wildlife and also improves land quality (UNFCCC, 2007). Forests play an important role in balancing the Earth's CO₂ supply and exchange.

There is nothing as practical and cost efficient for obtaining a regional overview of vegetation cover than remote sensing techniques. (Ayhan, *et al.*, 2004). About Seventy percent (70%) of the local population depend on forest resources to earn their living; they obtain fruits, leaves and stem for food, medication and wood for house construction and fire. But these valuable resources are facing serious challenges today mainly due to population pressure, agricultural and industrial activities. Verburg *et al.* (2006) revealed that, as a whole in the world about six million hectares of forest lands have changed due to logging, agricultural, mining and other human activities. In another study the reasons behind forest degradation as revealed by Mulugeta and Melaku (2007) include the growing need for fuel wood and agricultural land and overgrazing by livestock, coupled with improper forest and land tenure policies.

In view of these and many other related problems Nigerian forest resource needs to be properly management so as to attain maximum satisfaction required from the resource and for the societal sustainable development. Goodland and Ledoc (1987) revealed that, to attain sustainable development of any resource, renewable resources (such as forest) should be used in a way that does not degrade them and non-renewable resources used so that they allow an orderly societal transition to renewable energy sources. Hence, sustainable development for any

resource could only be achieved through monitoring and management. Moreover, since various categories of forest resource might usually experience spatio-temporal changes at local, regional and global scale of course, monitoring the health of forest is crucial for sustainability. Depletion of key species such as mangrove, removal of shade trees from a potential crop tree or disappearance of a large biota acting as CO₂ sink all affect man and his environment in a negative way, which also necessitate the needs for monitoring and management of the resource. The major aim of this work is to explore the capability of geospatial tools toward forest resources studies and management.

The major problem lies with the appropriate method to be employed to attain the desire objectives, but with the development of RS and GIS sustainable development of forest resource through monitoring and management of the resource become simpler. This is because since 1972 when Landsat was launch, remote sensing technology has been used to monitor natural resources for proper management of the entire universe. Remote sensing is the science and art of acquiring information about a phenomenon; objects or surface features from a distant platform, usually a satellite or airborne sensor without direct contact with an object (Sonti, 2015). Satellite data obtain through RS are available at varying spectral, spatial and temporal resolutions and are useful to mapped broad forest types, detect and delineate major forest changes over time (Leckie, 1990). On the other hand, GIS is an essential tool for forest management because it answer the questions such as location, condition, trends, pattern and modeling techniques that helps in forest management activities (Upadhyay, 2009).

The use of these technologies either individually or in combination according to Anon (2015) spans a broad range of applications and degrees of complexity. Historically, Remote Sensing has been an important tool for vegetation resource data

collection in various forms. Therefore, integrating data from different types of remote sensors for forest inventory is strongly encouraged (Leysen and Goosens, 1991). The structure of data obtained from RS permits its input into GIS environment for processing, analysis, mapping and display. At a global scale such as the vast area of the tropics large volume of data is required to identify and classify vegetation resource. Based on this, coarse resolution scanners with high temporal resolution are needed such as, NOAA AVHRR which has a twice daily over pass. Figs. 1, 2 and 3 shows the major characteristics of

vegetation cover at global, regional and local levels which serve as a base line data. Fig. 1 represent vegetation cover classification as derived from AVHRR satellite. The figure further shows that North America have been mainly dominated by evergreen and mixed forest, shrub and brush rangeland is found in Australia and some part of South America, North Africa, Arab land and some part of the middle Asia are dominated with barren ground while Tundra is found in the extreme end of North America and Northern part of Russia.

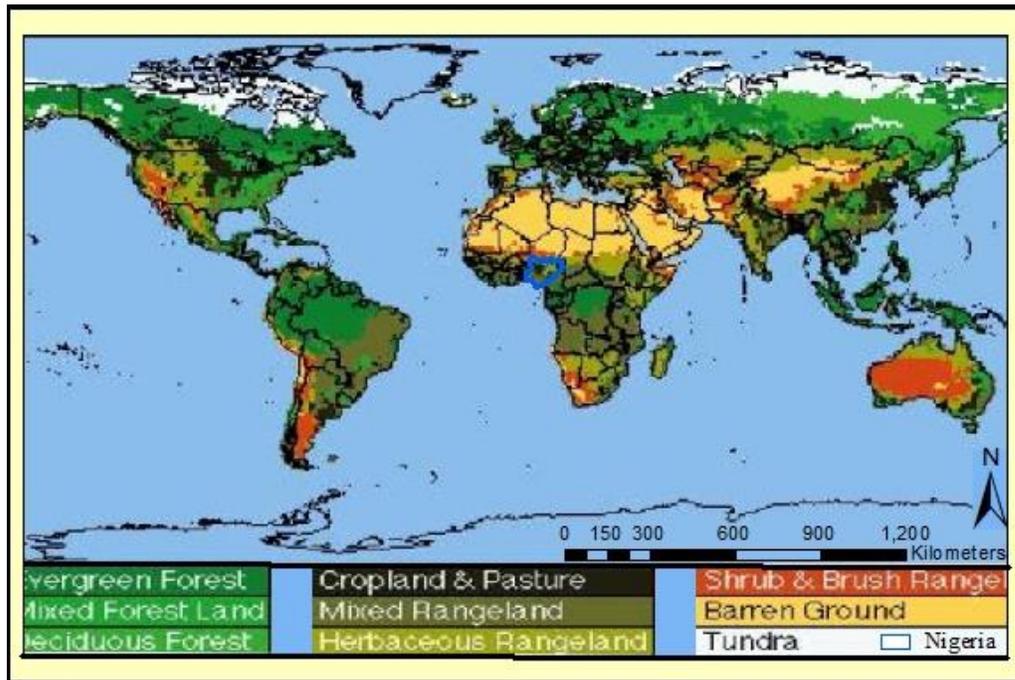


Fig. 1: Global vegetation cover classification. Source: NASA (1994)

The larger coverage and resolution of AVHRR enable its data to be used in deriving map of global biomes as shown in Fig. 2, the dark blue and green areas represent dense vegetation while pink and dark red areas represent sparse vegetation. Other high resolution scanners that are used in global cover age are Landsat series and Spot which have repeated cycles of around

two weeks. Teuber (1990) and Stone et al. (1991) stated that, Landsat TM imagery has been used in several efforts to interpret the accuracy of and even calibrate AVHRR imagery. Satellite data has also been used to monitor biomes production of coastal zones as shown in Fig. 3 whereby about 825m pixel are covered with biomes with six channel optimization.

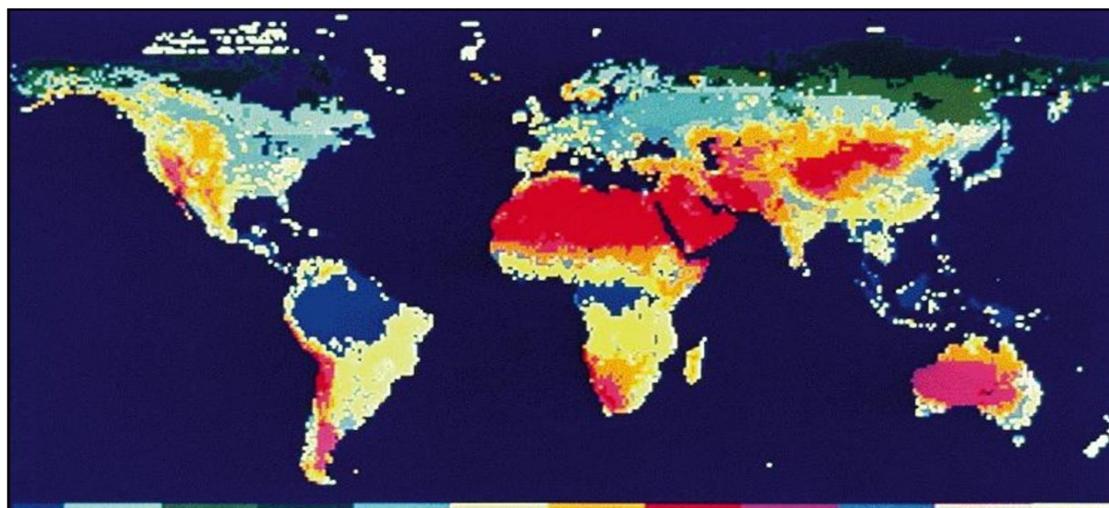


Fig. 2: Global biome map. Source: NASA (1994)

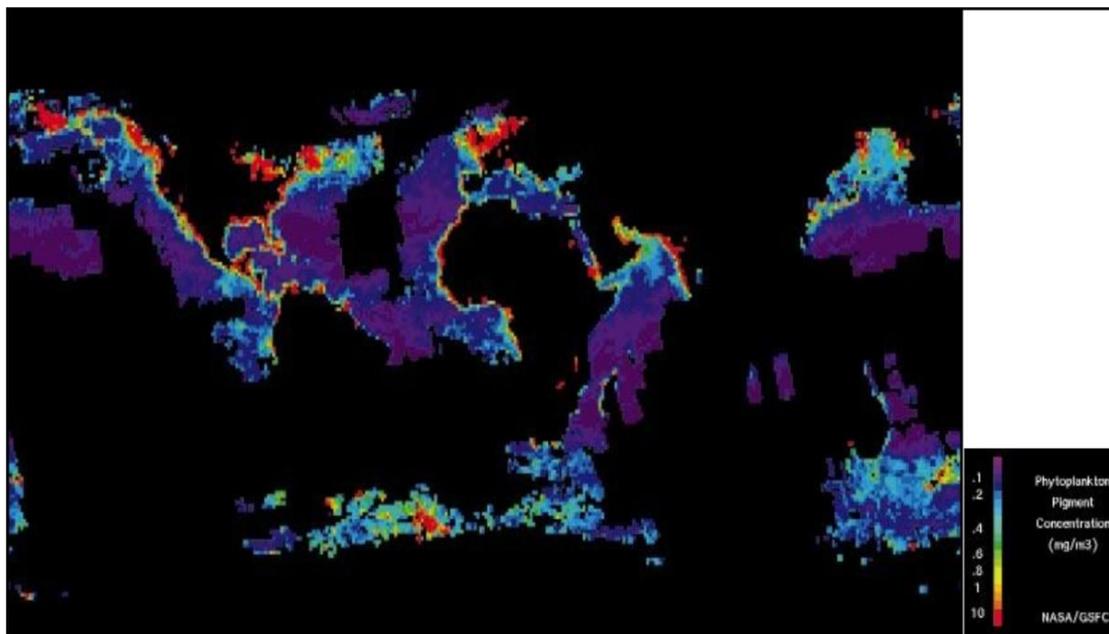


Fig. 3: Coastal zone biomes map. Source: NASA (1994)

In fact, remote sensing and GIS technologies have been used to monitor changes in vegetation cover, resulting from large scale deforestation and other incidences such as, pests and pollution. The GIS technologies for forest management may be seen based on two broad and related aspects; the resource inventory and monitoring as well as analysis, modeling, and forecasting to support decision making. The two categories has been used in many part of the world and Nigeria such as; A study conducted by United States Environmental Protection Agency (EPA) using Landsat Thematic Mapper (TM) imagery as reported by Hewitt (1990) that, the study identified sixteen distinct spectral classes of xeric riparian habitats which further aggregated in to three classes namely: water, riparian and non-riparian areas in the eastern Washington State of USA. Stone et al. (1991) in Rondania of Brazil uses Landsat MSS of 1980 and TM of 1986 imageries to define area and deforestation rates for a study area of approximately 30,000KM². The researchers found that 3168KM² of new clearing occurred between 1980 and 1986. Similarly, in United State of America Rock and Vogelmaun (1989) uses Landsat TM to assess and monitor damage in coniferous forests in the state of Vermont. The researchers found that the most useful spectral reflectance data were TM4 and TM5, whereby the higher the ratio of the two bands (TM5/TM4), the higher the damage that had occurred. Landauer (1989) reported a three-year project initiated in Germany in 1986 to establish methods to detect, classify, and map forest decline using a combination of landsat MSS and airborne multi-spectral imagery. The result revealed that characteristics spectral signatures could be identified for different tree species (spruce, pine, and beech) depending on the degree of decline.

In Canada, Holder et al. (1990) pilot a project that linked a fire growth model with a GIS to evaluate its potential to minimize the costs of controlling and managing forest fires. The researchers present the capability of GIS in two part demonstration in which, the first part only GIS was used and in

the second part a forest growth model was combined with a GIS. Wachiye et al. (2013) in Kenya also conducted a study on forest cover change and vulnerability analysis. In Nigeria Abdullahi et al (2017) uses remote sensing and GIS techniques to examine the role of rainfall on the spatio-temporal density of vegetation in Sudano-Sahelian Ecological Zones using NDVI data between 1998 and 2014. The researchers found that areas with high vegetation cover decreases by about 9.51%. Muazu et al. (2018) also conducted a research on the spatio-temporal trend of vegetation density in Northern Guinea Savannah Zone of Nigeria using Landsat imageries. Despite quite a number of studies were conducted on vegetation cover distribution, in Nigeria and elsewhere in the world and the important of forest resource in Bauchi State studies of this nature is very limited hence, this study focuses on the distribution and changes of vegetation cover in Bauchi state of Nigeria between 1976 and 2015 for proper monitoring and management

Study Area

The study area lies between Latitude 9.498188°N and 12.521480°N and between Longitude 8.729070°E and 11.023273°E (Fig. 4). The population of the area is estimated to be 4,351,007 in 1991, 4,653,066 in 2006 and projected population of 5,515,303 in 2011 (NBS, 2012). The study area falls within guinea savannah zone of Nigeria, vegetation cover of the area is dominated with woodland in the hills, lowlands and high land area, grass cover and crop land which give rooms for various agricultural activities and rearing of animals. The nature of the vegetation has been associated with the population pressure and characteristics of the climate in the area where by temperature is high throughout the year with a mean maximum of about 34°C and mean minimum of about 20°C The area has an average annual rainfall of about 1,104.5mm in 2005 and about 1,621.3mm in 2009. The annual mean Relative humidity at 1500 GMT reach about 35.2% and about 44.3% at 0900 GMT, annual mean radiation of the area is about 21.7mm while evapo-transpiration is about 5.3mm

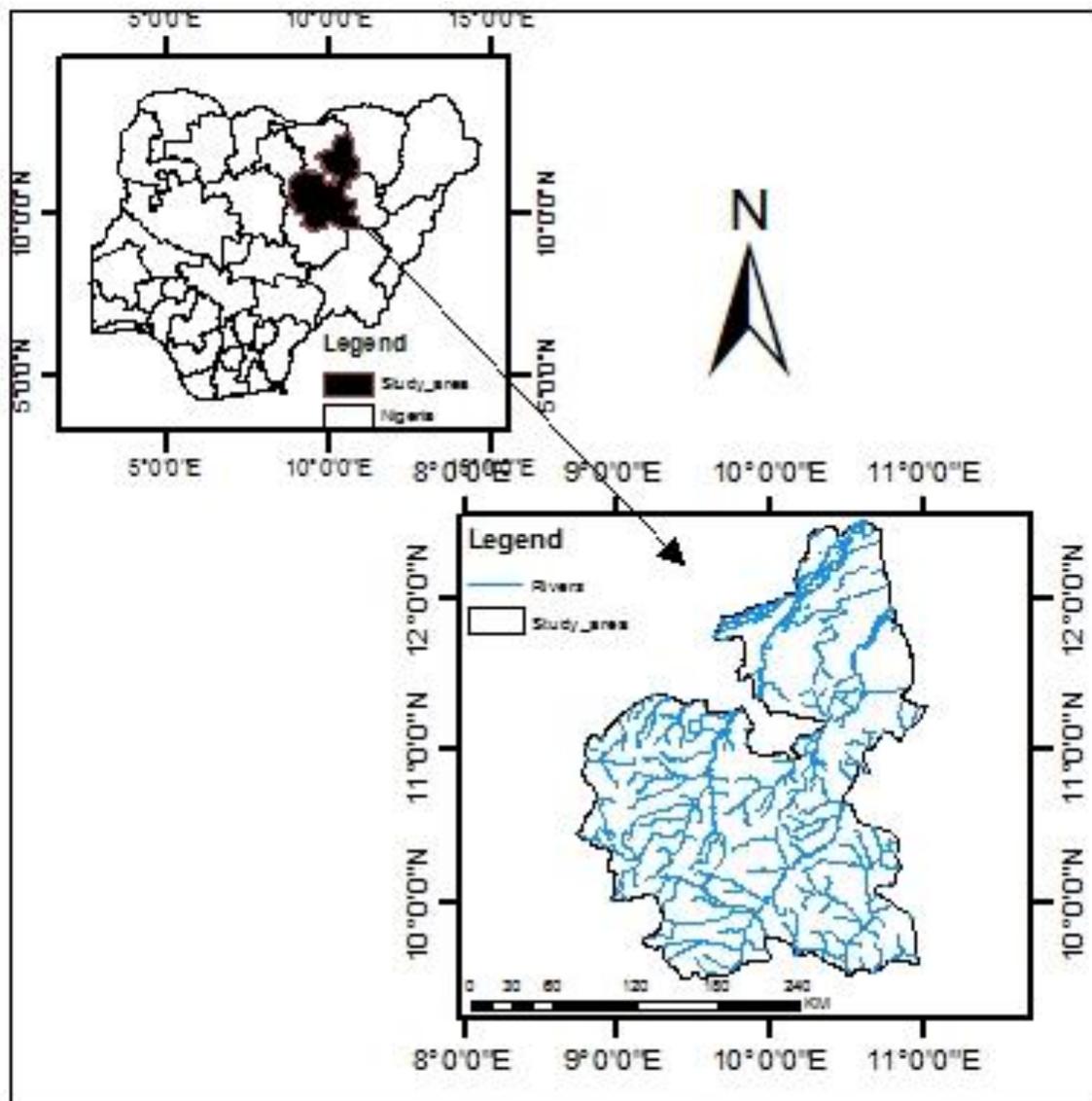


Fig. 4: Map of the study area. Source: GIS lab, ABU, Zaria

Materials and methods

This study made use of Landsat MSS of 1976 and Land sat Operational Land Imager (OLI) of 2015 with spatial resolution of 30m, these data was download from United State Geological Survey (USGS) achieve.

Data Analysis

The method of data analysis used for this study was based on Remote Sensing and GIS analysis using image classification techniques in Arcgis 10.2 environment. An image classification technique is the process of assigning pixels to various classes; it is the identification of the pattern associated with each pixel position in imagery (Mather, 1999). This study employed the use of the two most frequently used techniques that are; the supervised and unsupervised.

Maximum Likelihood Classifier (MLC) of supervised techniques was use on the Landsat MSS imagery of 1976. A vegetation map of Bauchi State in 1978 develops by the Department of Forestry, Ministry of Animal and forest resources NIRDA were used as based map for generating of

training sites. Their classification came up with seven land cover classes: Shrubbed woodland hills and mountain complex, Shrubbed woodland lowland complex, Woodland Shrubbed land, Shrubbed grassland and grassland Shrubbed, Woodland grassland, Riparian vegetation and Settle area/Cultivated land. In this study however, the classification scheme was modified to presents: crop/barren land, grassland and woodland areas. During the analysis, the researchers examine the frequency of all spectral bands of the imagery using Histogram, Scattered plot, mean and covariance.

As for the OLI imagery of 2015 due to vast extent of the study area which restrict the researchers from visiting the entire area of study Iso cluster technique of unsupervised classification were first carry out on the imagery. The advantages of unsupervised classification is its power of implementing the classification automatically without prior knowledge of the area by the analyst; and therefore the tendency of making human error is minimised because the software algorithm automatically show unique classes as distinct units. The disadvantages of unsupervised classification on the other hand

include the limited control of the classification menu by the analyst, which may lead to producing classes that are not of interest to the analyst (Tso and Mather, 2009). Because of this limitation supervised classification were finally carry out on the already classify imagery using unsupervised classification to came out with the same classes as that of MSS imagery.

To analyze trend of the forest and other vegetation cover in the study area, a table showing the area in Kilometer square and the percentage change for the study period measured against each class was developed. Percentage change to determine the trend of change was then calculated by dividing observed change by sum of changes multiplied by 100. In obtaining annual rate of change, the percentage change is divided by 100 and multiplied by the number of study year (39 years).

RESULTS AND DISCUSSION

Identification of major vegetation covers classes

Fig. 5 and 6 shows the ability of remote sensing and GIS to map and monitor the distribution and changes of land cover in Bauchi state of Nigeria. The results in figure 5 and 6 and Table 1 revealed that, woodland occupied the highest land area of

about 65.3% in 1976 but decrease to about 58.8% in 2015, this was followed by crop/barren land with 17.8% in 1976 but it increased to 25.9% in 2015 while grassland which occupied the lowest area of only 16.9% in 1976 it decreases to 15.3% in 2015. These results indicated that, woodland in Bauchi state is the highest vegetation cover from 1976 to 2015, even though the area occupied by this type of vegetation is reducing while those occupied by crop/barren land is generally increasing. The findings of this study is in line with that of Hiernaux et al. (2009) in Sudano-Sahelian Ecological zones of Nigeria; Sahebjalal and Dashtekian (2013) in Iran; Gadiga and Dan (2015) in Yobe and Abdullahi et al.(2017) in Sudano-Sahelian Ecological zones of Nigeria who study the spatio-temporal distribution of vegetation cover in their respective areas and finds that vegetation resources especially forest cover are continuously decreasing both in height and density. Hence, the findings of this study try to reveal that human activities especially farming is encroaching the available forest resource in Bauchi State. The maps produce in this study also shows how geospatial tools could be use to conduct research even to areas that are difficult to reach by human transport system due to the density of vegetation cover or how they are dangerous.

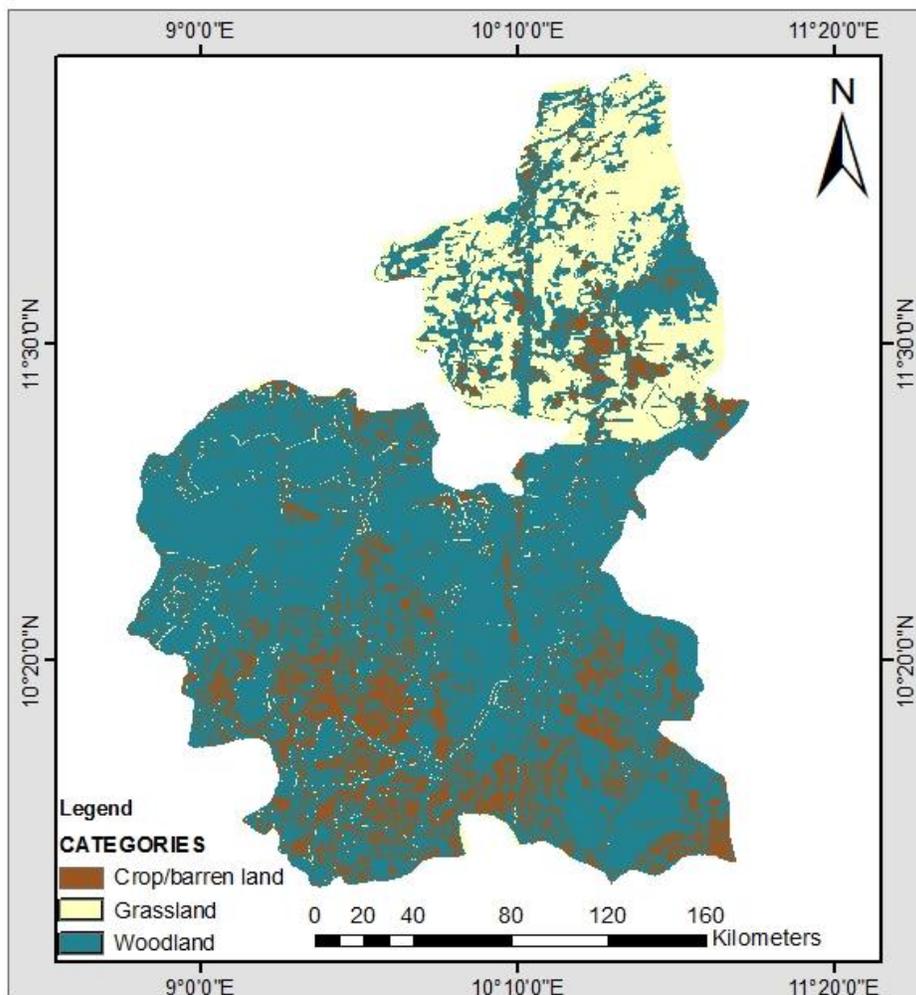


Fig. 5. 1976 vegetation cover of Bauchi State. Source: Author’s Data Analysis, 2018

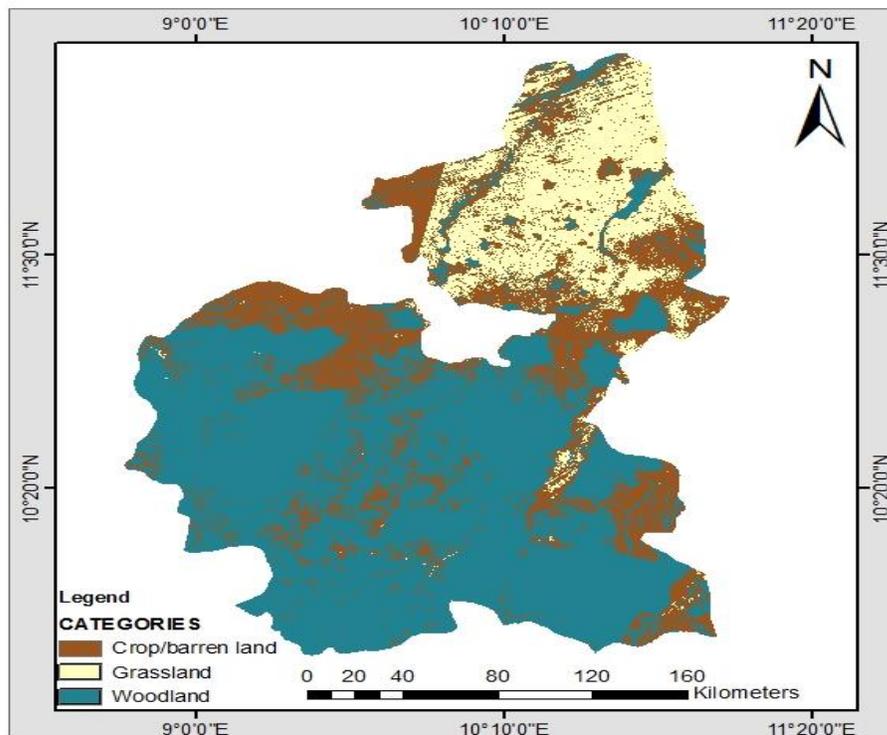


Fig. 6. 2015 vegetation cover of Bauchi State. Source: Author’s Data Analysis, 2018

Table 1: Aerial extent of vegetation covers classes in the study area (1976 and 2015)

PATTERN	1976		2015	
	Area (Km ²)	Area (%)	Area (Km ²)	Area (%)
Woodland	31452.3	65.3	28319.7	58.8
Grassland	8160	16.9	7374.2	15.3
Crop/ barren land	8570.7	17.8	12489.1	25.9
TOTAL	48183	100	48183	100

Determination of percentage and annual rate of change

The results in Table 2 showed the percentage and annual rate of change of vegetation cover in the study area, it revealed that the percentage change of crop/bare land within the study period has been raised by 50% while that of woodland fall by 39.97%. The annual rate of change within 39 years of the study for crop/barren land has been plus 19.5 but that of woodland has been minus 15.59 and minus 3.91 for grassland. The findings of

this research is supported by that of Mua’zu et al. (2018) in Northern Guinea Savannah Zone of Nigeria who revealed that areas occupied by very high vegetation cover are decreasing at the rate of 7.67% while those occupied by Low density are on increased by 3.09%. This finding is therefore tries to indicate how crop/barren lands double all other categories of land cover, where it generally increases while other decreases.

Table 2: Percentage change and Annual rate of Changes of vegetation cover classes in the study area (1976 and 2015)

PATTERN	Change % change		Annual Rate of Change
Woodland	-3132.6	39.97	-15.59
Grassland	-785.8	10.03	-3.91
Crop/ barren land	3918.4	50.00	19.5
TOTAL	7836.8	100	0.0

CONCLUSION

In this paper, the capabilities of remote sensing and GIS applications in the area of sustainable forest management have been reviewed. Despite the diversity of applications, however, significant conclusions can be drawn about the role of geospatial techniques in forestry and vegetation resource management.

It clearly shows that vegetation resource especially woodland are on the decreasing trend in the study area at the rate of 15.59% while crop/barren lands increases at the rate of about

50% within the study period. It is also concluded that vegetation resources especially forest are dynamic in nature, and are mostly affected by many coexisting processes such as deforestation, urbanization and wild fire which need to be monitored and manage through modern technologies such as, remote sensing and GIS.

Based on the findings of this research, it further revealed that geospatial technologies could be effectively used to address the problem associated with the changes that occur on the vegetation resources.

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