FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 3 No. 3, September, 2019, pp 83–94

REMOTE SENSING AND GIS APPLICATION FOR FOREST RESERVE MONITORING AND PREDICTION: A CASE OF GIREI FOREST RESERVE, ADAMAWA STATE, NIGERIA.

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ABSTRACT
In Nigeria, since the last three decades there has been a tremendous pressure on forest to provide economic resources leading to unabated deforestation and the potential negative effect of such changes on forest quality, quantity and production are wide. The objective of this study was to evaluate the effectiveness of Remote Sensing and Geographic Information System (GIS) Techniques in Forest Reserve Monitoring and Prediction using Girei forest reserve of Adamawa State, Nigeria as a case study. The images of Landsat TM 1987, ETM+ 2000, Nigeriasat-1 2010 and Spot5 2015 were analyzed to derived information on environmental changes between 1987 and 2015. The results revealed that fuel wood extraction and over cultivation are the main causes of deforestation in the area. It also revealed that forest area has reduced from 177.03 km^2 in 1987 to 75.98 km^2 in 2015. This implies that land-use such as build up areas and cultivated areas were increasing through the time i.e. from 3.33 km^2 in 1987 to 8.95 km^2 in 2015. This indicated that the rate of deforestation in the area is high at about 33.68 km^2 per year thereby confirming the perception of 58% of the respondent. Decrease in vegetal resource, decrease in rainfall and increase in temperature were observed as the most serious effect of deforestation in the area. The study recommends that government and traditional authorities should provide affordable alternative sources of energy to reduce pressure on fuel wood and the need to enforce environmental laws.

***Keywords**: Remote Sensing, GIS, forest reserve, monitoring, prediction, change detection.*

INTRODUCTION

Forest provides a wide range and variety of highly valuable ecological, economic and social services including the conservation of biological diversity, carbon storage, soil and water conservation, provision of employment and enhanced livelihood, enhancement of agricultural production systems and improvement of urban peri-urban living conditions (FAO, 1999; UNEP,2001; Sajjad A *et al* 2015.,). According to the World Rain Forest Movement (WRFM, 1990), 25 percent of our medicines come from the forests. Forest has global implications not just on life but on the quality of it. But Man, in his attempt to tap the resources of his physical environment for a better livelihood is seen in various ways struggling helplessly to get something from the environment, thus engages in activities that sometimes prove detrimental to the immediate environment in which he operates.

Many developing countries like Nigeria, are suffering from serious environmental degradation primarily because of the rapid growth in population which has not only brought about gross encroachment and damage to natural forest, wildlife, land, water and even air but has also brought unacceptable quality of life conditions in the human community environment (Harvey, 1998). Deforestation and desertification are the major environmental problems faced by Nigerian rural communities. Nigeria's vegetal resources are generally facing problems in terms of accelerating degradation and depletion of its forest cover (Kinyeye, 2005). The transformation of forested lands by human actions represent one of the great forces of global environmental change and one of the great drivers of biodiversity loss. The biggest threat to forest today is human activities, and despite increasing efforts regarding forest management and conservation, deforestation continues at a high rate to give space for other land uses. Forests are cleared, degraded and fragmented by wood harvest, conversion to agriculture, road construction, human-caused fire, and in myriad other ways making the effort to use and subdue the forest.

Following the advances in high resolution Remote Sensing Digital Data and Aerial Photography, mapping of the trends of cover changes have become relevant source of information for understanding land-cover pattern changes (Sheila A ., 2013). Presently, with the supplement of ground information, remotely sensed data are the main source of information about land-use pattern changes. The techniques are becoming an important part of watershed management, urban planning, hydrological modeling, drought prediction, and forest cover mapping (Sajjad A *et al* 2015). Remote sensed data provide advantages like synoptic coverage, consistency in data, global reach and readability, precision and maximum accuracy in data provision. According to Saleh and Ali (2012), one way to model deforestation is to make use of empirical models. Several studies have analyzed land-use change under these approaches

(Mertens and Lambin, 2000; Pontius *et al*., 2004; Pontius and Spencer, 2005; Rogan *et al*., 2008; Schneider and Pontius, 2001).

Timely and accurate information on natural resources is a prerequisite to their optimal utilization and effective management, particularly in remote and inaccessible areas. However, there is a need to obtain reliable data on vegetation resources at regional and micro-levels, which would help in planning forest management strategies for sustained yield and overall benefit of the society.

GIS is used to describe and analyze spatial data and relations over time and space, and is most commonly used to simply visualize characteristics of a land scape or an environment (Eklundh, 2003). However, at present, these tools are extensively being used for the assessment of the impact of fuel wood exploitation on the rate and spate of deforestation globally due to its high complex inter-relationship with other social variables on the surface of the earth.

Remote sensing and GIS have often provided an effective tool for monitoring changes in the environment. Remotely Sensing technology in combination with GIS can render reliable information on land use dynamics (Akinola, *et al.,* 2012).Venema *et al.* (2005) noted that proper forest monitoring and management can only be achieved by using remote sensing techniques and creating spatial representations such as maps to know the exact locations and extent of deforestation.

This study has been focused on the evaluation of the effectiveness of the application of Remote Sensing and Geographic Information System (GIS) techniques in monitoring forest reserve using Girei forest reserve of Adamawa State, Nigeria as a case study. The rate and extent of, and causes of deforestation were sought.

Study Area

Girei town lies north of the Benue River between Latitude 9° 21' 59.15" North and Longitude 12° 32' 59.77" East (Fig 1). It covers a total land area of 1151.64 square kilometers (Saka *et al.*, 2013). The town is in the central part of Adamawa State and it is about 15km from the State Capital (Yola). The geology of Girei area consist of two strati-graphic units, these are the quaternary river coarse alluvium and feldspar sand stone.

The alluvial deposits occur mainly along the bank of river Benue and its tributaries, consists of sand, clay, silt, silt-clay and pebble sand (Adebayo and Tukur, 1999). The landform type of Girei area is characterized by grouped hills of synclinical folds about 600 meters developed on cretaceous sand stone and lowlands (Tukur, 1999). The hills are found around Vunokilang extending to Bagale area with rough terrain inter spaced by extensive plains and isolated hills reached the highest peak in the Bagale hills where it stands at 1500 meter (Federal Survey Map, 1971). Climate factor of the area controls the regime and other characteristics of the river. The few rivers in the area are Mayo Pambambi, river Maita, Beti-Mayel, river Wuromodi, river Toja, river Gede, river Wari forming a dendritic drainage pattern that drained in to the Benue River which flows along the Southern part of the area (Adebayo and Tukur, 1999).

The area is characterized by two well defined seasons, which are rainy (wet) and dry seasons. The rainy season start from May through October, while the dry season commences from November and ends in April which is characterized by dry, dusty and hazy winds that brings harmattan dust from the Sahara desert through the influence of tropical continental air mass, it reduces visibility to less than 100 meters. The average annual rainfall is about 972mm with an average of 62 rainy days. The highest occurrence of rainfall is in the months of June, August and September (rainfall maxima), when intensity reaches 130mm, 124.0mm to 130.6mm. These seasons are strongly influenced by the North and South ward movement of Inter-Tropical Discontinuity (ITD) that supplies the area with its rainfall. Temperatures are relatively high almost all the year round. The temperature of the area ranges from 30ºC to 44ºC with cold dry winds that reduce the temperatures to about 25ºC during Harmattan period with the hottest months being April and May, with mean average temperature of 34ºC (Adebayo, 1999). The vegetation of Girei area is of sub-Sudan Savanna vegetation zone of Nigeria, which is characterized with short grasses, thick vegetation around hills and mountain ranges and inter sparse by short trees and shrubs (Adebayo and Tukur, 1999). The tree vegetation has over the year been modified by human activities such as farming which involve bush burning, fuel wood exploitation, deforestation and also construction works (Uyanga, 2000). Girei local government area has a population number of 129,955, with 66,906 Male and 62,949 Female, with an annual growth rate of 2.5 percent (NPC, 2007).

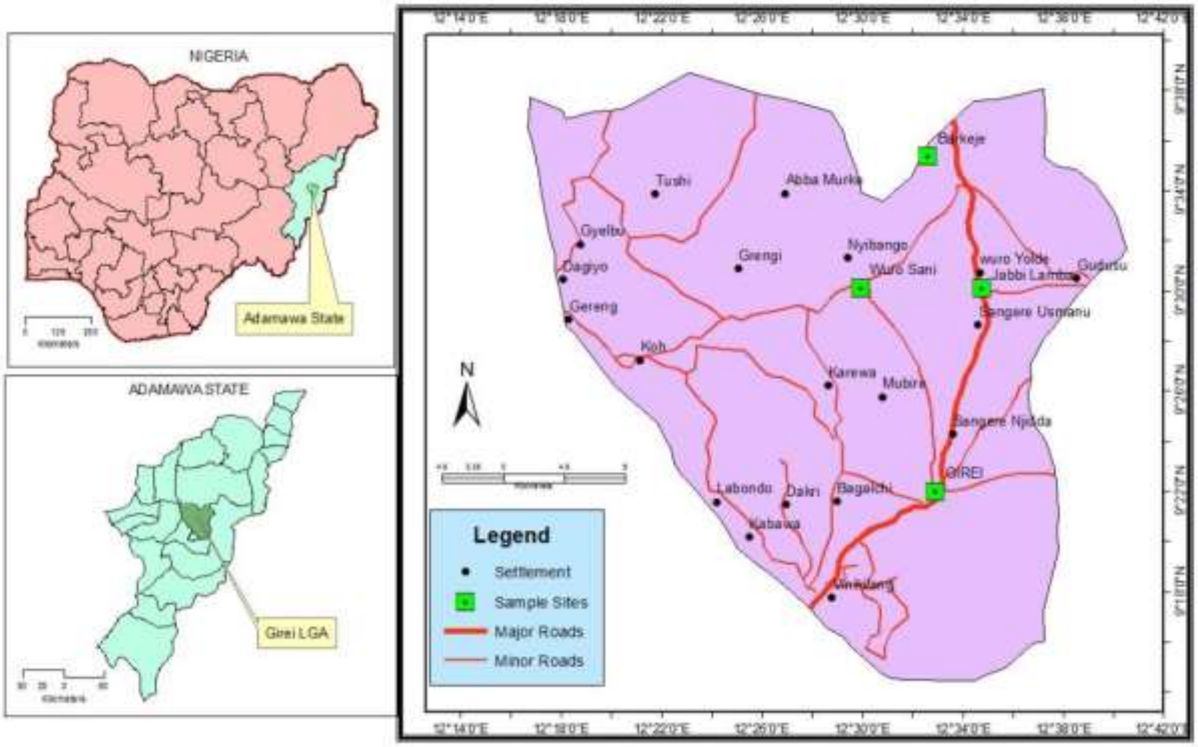


Fig. 1: Map of the study area.

MATERIALS AND METHODS

The data used for this study include satellite imageries such as Landsat TM 1987, ETM+ 2000, Nigeriasat-1 2010 and Spot5 2015 that are obtained from the National Centre for Remote Sensing (NCRS) based in Jos, Plateau State, Nigeria, for the period between 1987-2010; And National Space Research and Development Agency (NASRDA) based in Abuja, Nigeria at the development of space data acquisition for the year 2015. ArcGIS 10.3 versions, Eradas 9.3 GIS soft ware packages were also used to analyzed and perform feature identification, recognition, classification, overlay analysis, accuracy assessment, change detection and prediction for feature scenario.

Land-Sat data were processed using Eradas 9.3 for image transformation (Georeferencing using the acquired GPSs); image enhancement; extraction of the study area (clipping out the useful area of study); and image compositing.

Changes that occurred in the study area for the study period of 1987-2015;(28 years),were analyzed by crossing the classified landsat TM 1987 image with the classified landsatETM+ 2000 image through the OPERATION/RASTER/PROCESSING/CROSS/SHOW subroutine. The same procedure applied on the remaining classified Nigeriasat-1 2010 and Spot5 2015 images. Direct comparison of land use statistic was carried out highlighting the extent and rate of land use changes over the period of study. The total forest loss was calculated by using the intervals of 1987-2000, 2000-2010, 2010-2015 and for the total period of 1987-2015.

The future scenario made in this research stretch from 2016-2056 and consist of forest area calculations. The calculations was donned with an assumption that, the annual deforestation rate in the area will be fixed during the time period. The overall annual deforestation rate calculated for the intervals of 1987-2015 was used to create the future scenario.

RESULTS AND DISCUSSION

Land use Changes

While the land Use classification for the study periods are presented in figures 3,5,7 &8; the Land-use Land-cover (LULC) extents are presented in Figures 2, 4, 6 & 9 with a view to understanding the changes in forest estates during the period. The results shows that in 1987, forested areas occupied the highest expanse of land in Girei forest reserve with 33.89% (177.03 km^2) of the land mass; shrubs and farm lands occupied 23.83% (124.45 km^2); while built up environment took only 0.64% of the study area with 3.33 km^2 as shown in figures 2 and 3.

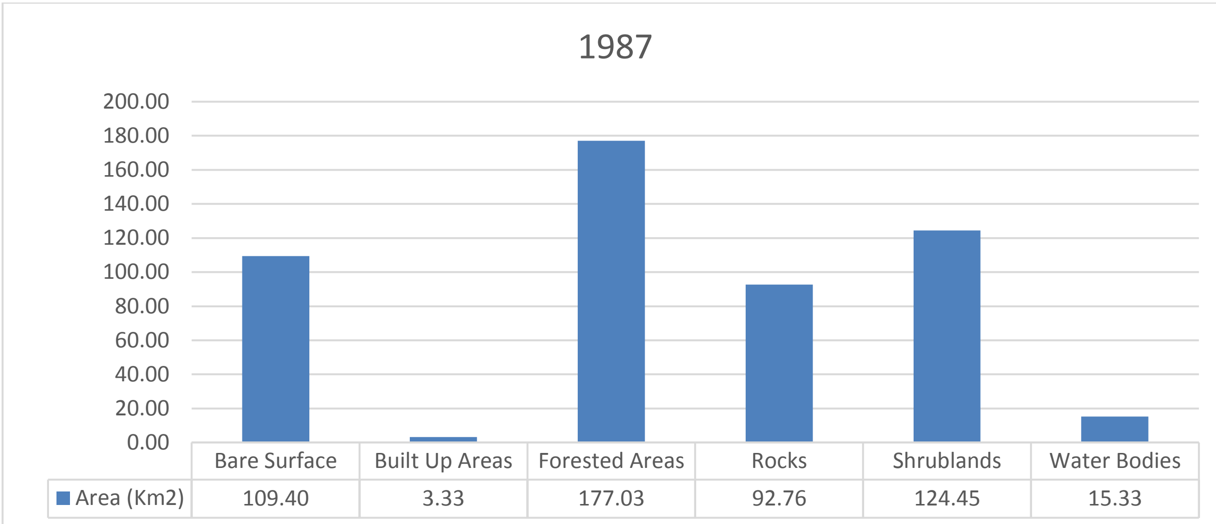


Fig. 2: LULC of the study area (1987)
Source: Field survey and laboratory analysis (2016)

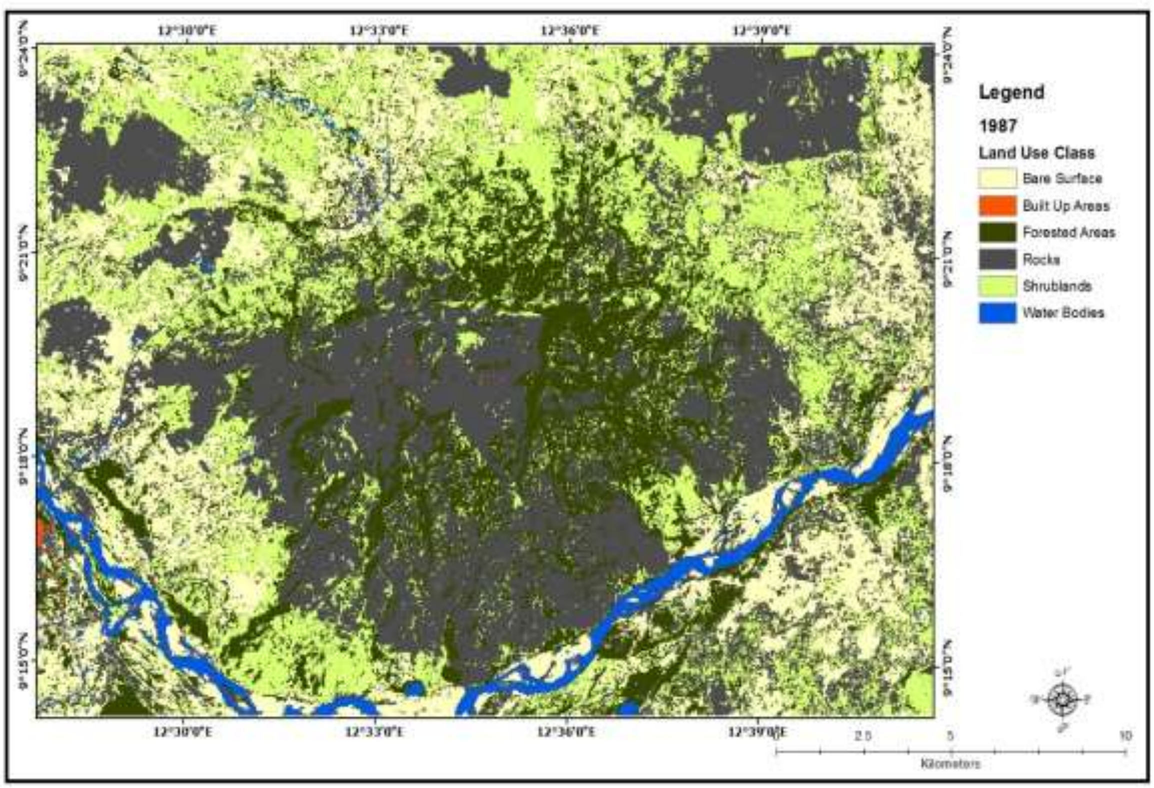


Fig. 3: Land Use Classification of the study area (1987)
Source: Laboratory analysis (2016)

As at year 2000, the forested areas has reduced to 125.53km^2, a reduction of -23.83%, while Built up areas has increased with 10.86% to 30.03km^2, Farmlands increased with 19.9% while bare surfaces and water bodies had very slight increases and decreases respectively as indicated in figure 4.

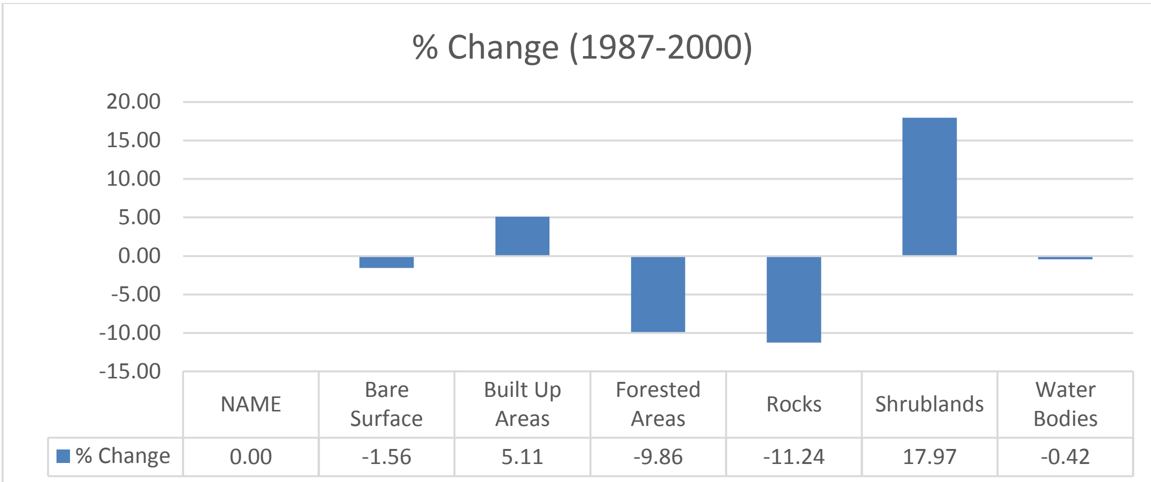


Figure 4: LULC changes in the study area (1987-2000)
Source: Field survey and laboratory analysis (2016)

This implies that conversion of forested areas to farmlands and built-up areas became prevalent during this period with the noticeable rise in built-up areas extent by 10%. Between 1987 and 2000. The conversion of forested areas to residences and in some cases farmlands is evident by the 19.9% increases recorded within the period under review.

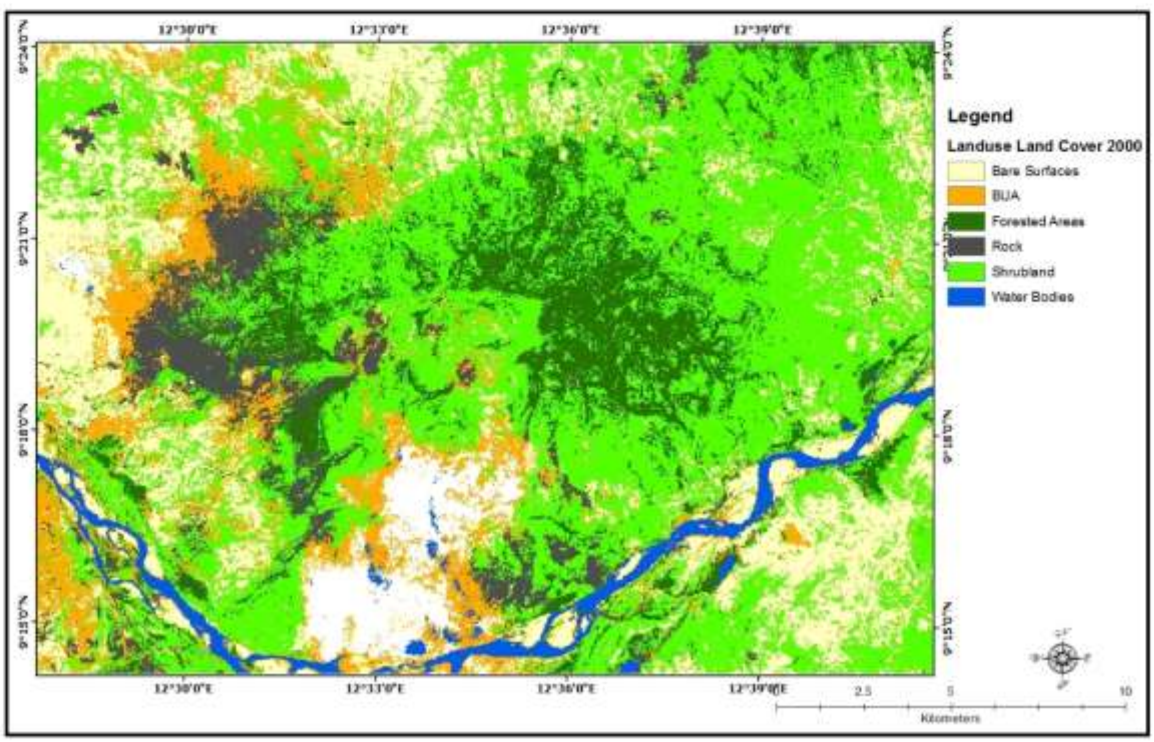
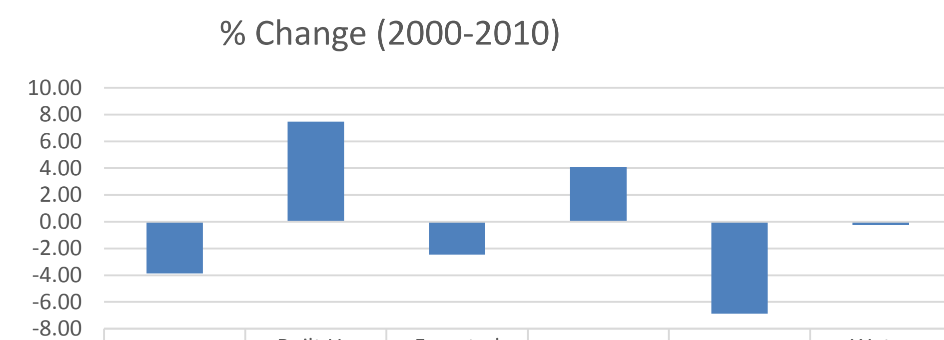


Fig. 5: Land-Use Classification of the study area (2000)
Source: Laboratory analysis (2016)

Between year 2000 and 2010, forested areas declined further by -2.45%, while built up areas picked up by 7.47%, bare surface reduced by -3.88%, and shrub lands reduced by -6.88% figure 6. This indicated that the trend of deforestation has continued in the area due to more clearance of forested land for residential areas to meet the pressing demand of more houses for the growing population. This is in line with David.L (2004), where he discovered that demographic processes are among the essential drivers of frontiers deforestation. He concluded that population dynamics are but one of several sets of factors determining human impacts on the environment.

Forested areas continued its declining trend by giving way for urban expansion and farm lands, farm lands such as Asmau Farm limited, Andabe Farm Nigeria Limited, Jibirojo Farm's Limited, Jibiro farms limited and BakariAgroallied Farm Limited was established Figures 6 and 7 shows the land use land cover extent of the study area in year 2000 and 2010 respectively while figure 6 shows a chart depicting the change.

Between 2010 and 2015, forested areas continued its downward trend with a decline of -7.04% in five years, the spate of increase in built up areas and bare surfaces had minute decreases in the near zero region (-0.95 and -0.63) respectively. Shrub lands and farmlands were the highest gainers with a high of 13.12% within the five years.



	Bare Surface	Built Up Areas	Forested Areas	Rocks	Shrublands	Water Bodies
% Change (1987-2000)	-3.88	7.47	-2.45	4.09	-6.88	-0.27

Fig. 6: LULC changes in the study area (2000-2010)
Source: Field survey and laboratory analysis (2016)

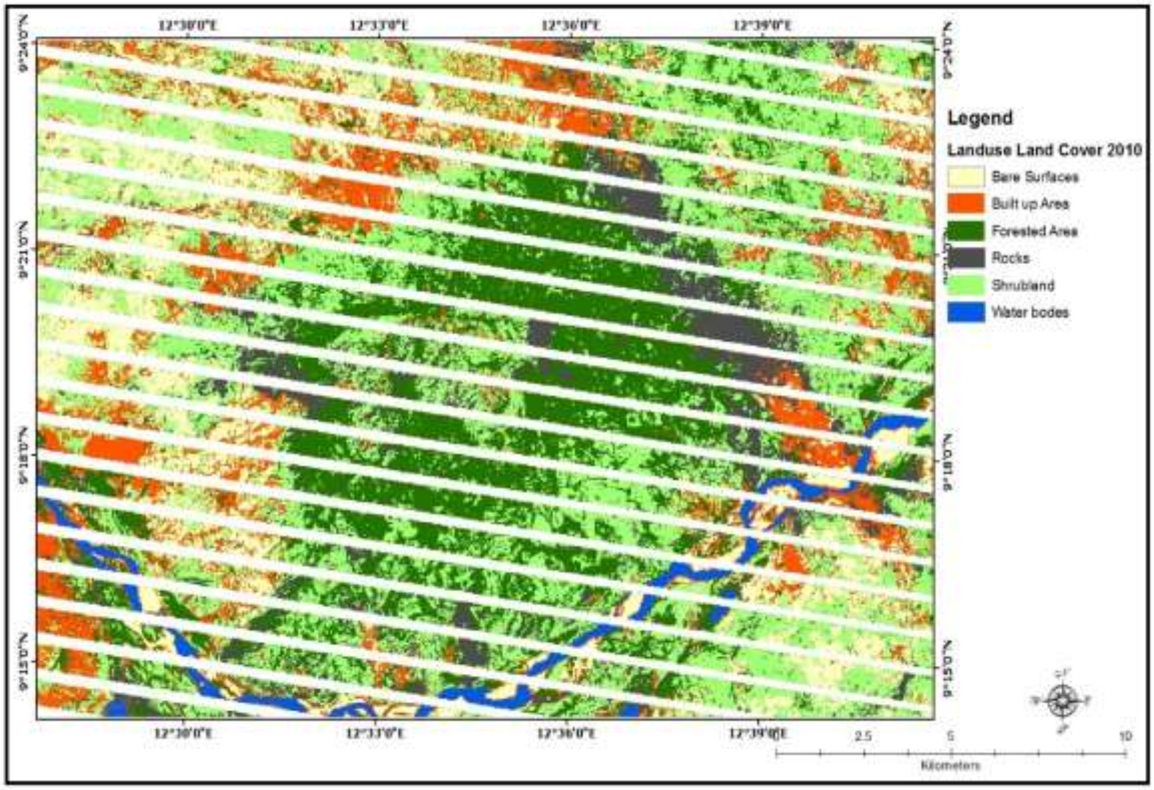


Fig. 7: Land-Use Classification of the study area (2010)
Source: Laboratory analysis (2016)

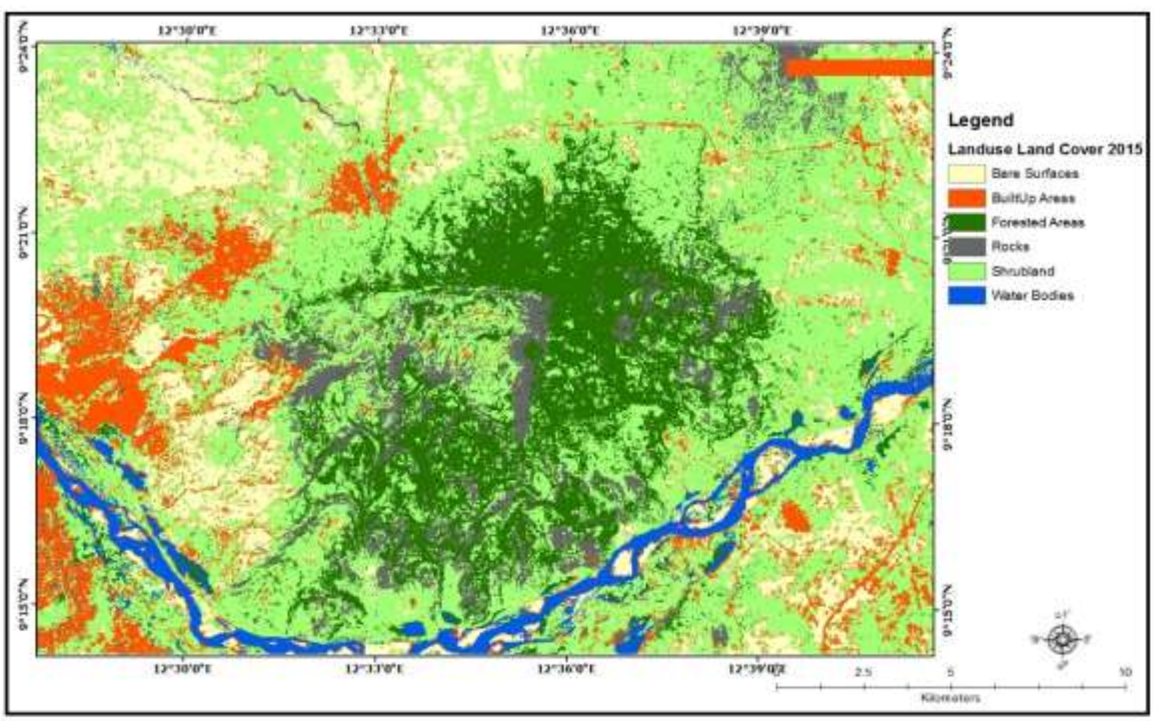
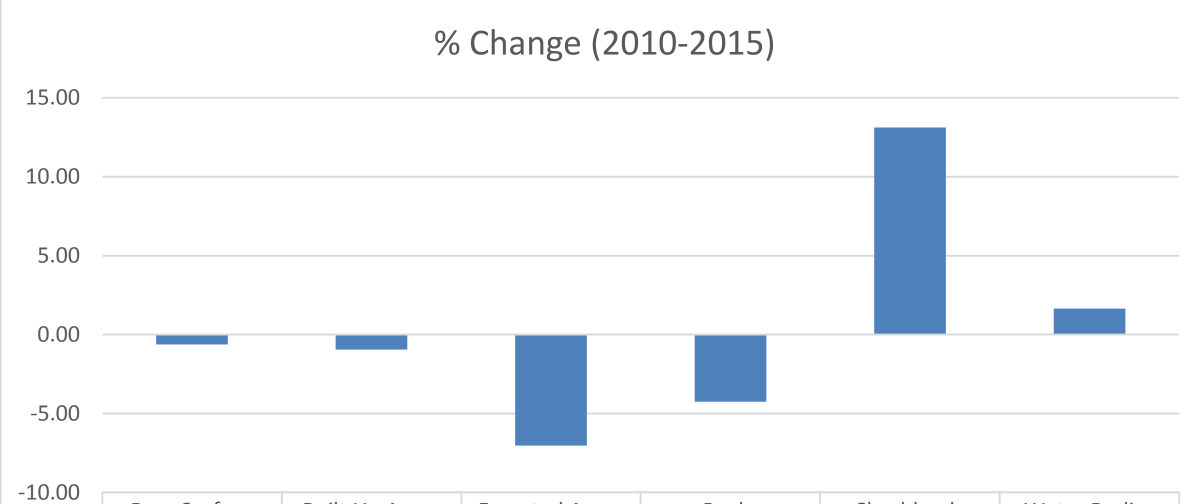


Fig. 8: Land-Use Classification of the study area (2015)
Source: Laboratory analysis (2016)



	Bare Surface	Built Up Areas	Forested Areas	Rocks	Shrublands	Water Bodies
■	-0.63	-0.95	-7.04	-4.25	13.12	1.65

Figure 9: LULC Changes in the study area (2010-2015)
Source: Field survey and laboratory analysis (2016)

This implies that while the spates of erecting buildings are reduced, the number of farmlands has increased drastically to manage the harsh economic realities of the period. The continuous decline of this forestry however is of major concern especially in this era of climate change and its adverse effects of which deforestation is a major contributor. Figure 8 shows the land-use land-cover of the study area in 2015 while figure 8 depicted the changes occurred. This in harmony with Akinola, et al (2012), where they identified five land use practices that are heavily depleting forest reserve; they are built up area i.e. settlement, farmland, fuel wood gathering, farming and logging

Changes in Forest Estate

An assessment of the changes in forest extent from 1987 shows that forest reserve in the study area has been on decline and this is due in parts to the extent of urban expansion as well as increase in farming activities during the period. The forest estate lost 101.05 km^2 of forest during the 28 year period under study (Fig 10).

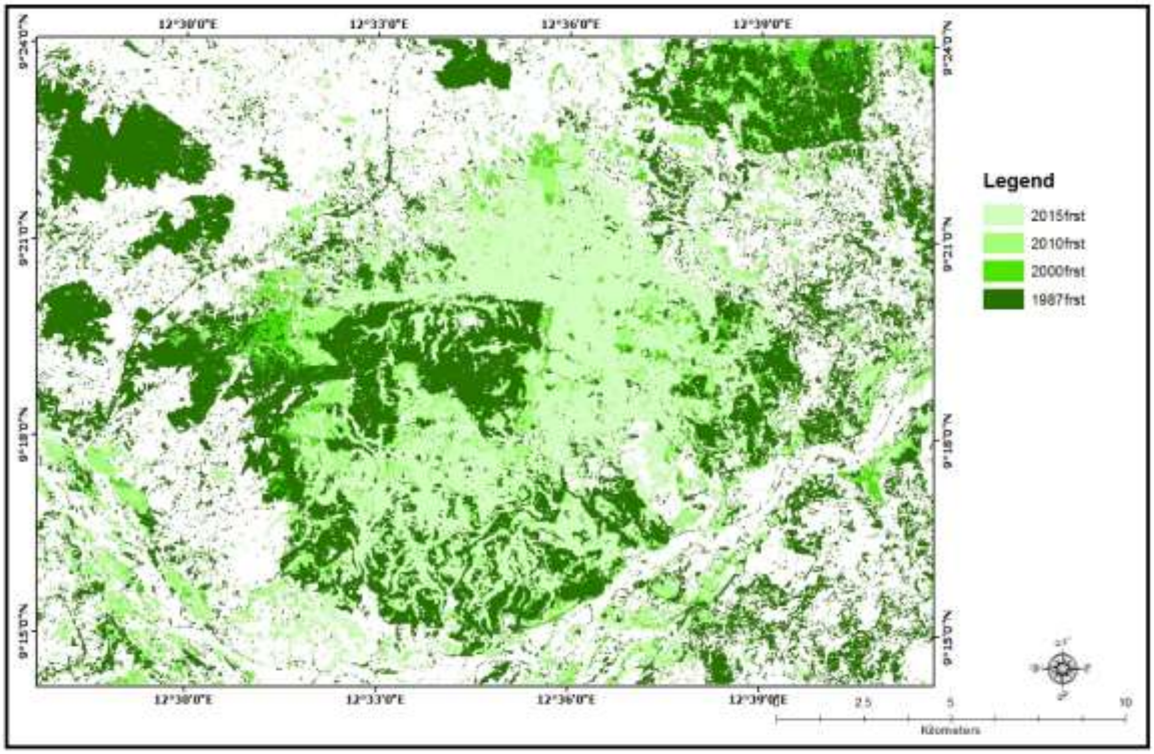


Fig. 10: Overlay of Forested Areas in the study area (1987-2015)
Source: Laboratory analysis (2016)

The trend of decline was plotted and the trend line equation shows that the forest estate will continue its decline by about 32 square kilometers for every decade if the current rate of exploitation is not checked. The R Squared shows a 95% certainty that decline in forest estates will continue as shown in (Fig 11).

Table 1: Calculated Annual Deforestation Rates and forest loss (1987-2015)

Deforestation			
Year	Rate (%)	Annual Forest Loss (ha)	Forest Loss in total (ha)
1987-2000	-9.86	51.50	669.50
2000-2010	-2.45	12.79	127.90
2010-2015	-7.04	36.76	183.80
1987-2015	-6.45	33.68	981.20

Source: Laboratory analysis (2016)

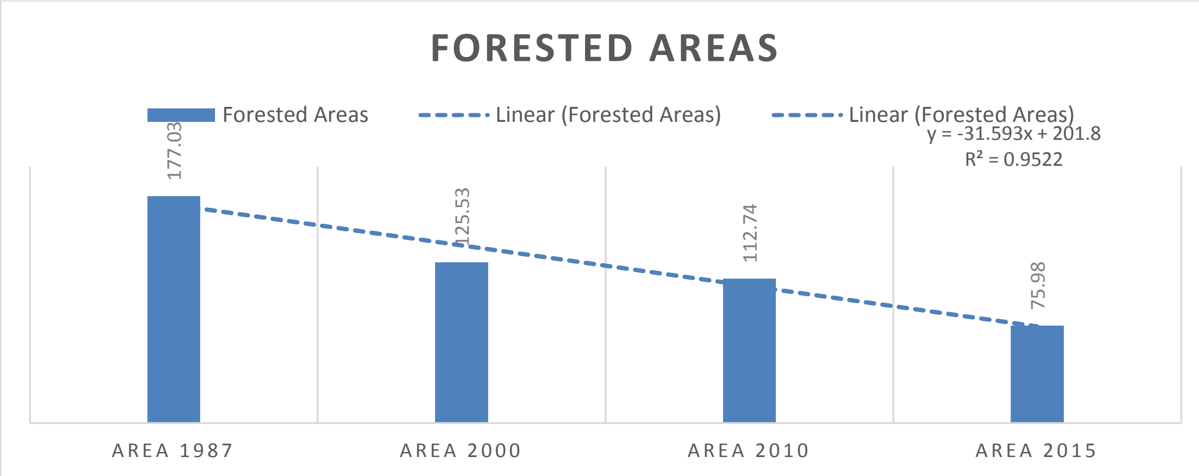


Fig. 11: Chart showing changes in forested areas in the study area (1987-2015)
Source: Field survey and laboratory analysis (2016)

Between 1987 and 2015, the total forest loss was 981.20 hectares, which corresponds to a loss of 14 percent of the total forested area that existed in 1987. The overall annual forest loss for the same time period was 33.68 hectares. This corresponds to a mean annual deforestation rate of -6.45 percent. Between 1987 and 2000 the yearly deforestation rate was -9.86 percent and during this period 669.50 hectares of the former forest was cleared. Between 2000 and 2010 the yearly deforestation rate decreased to -2.45 percent. Hence, the processes of deforestation has slowed down in the area and picked up from 2010 to 2015 where deforestation rates reaches -7.04 percent and a total of 183.80 hectares was cleared as indicated in table 1.

Table 2: Predicted Forested Area from 2016 to 2056.

Year	Forested Areas (ha)
2016	75.98
2026	69.53
2036	63.08
2046	56.63
2056	50.18

Source: Laboratory analysis (2016)

FUTURE SCENARIO

The future scenario stretches from 2016 until 2056 and it is based on the fixed deforestation rate of -6.45 per percent (Table 1). The annual loss of forest was calculated and the predicted forested areas are shown in table 2. By the middle of this century, the forested area will consist of only 50.18 hectares compared to 177.03 hectares in 1987.

This means that the area will have lost 45 percent of its forests in the year 2056 compared to 1987 table 1 & 2. Today there is approximately 75.98 hectares. Evidently, there is no existing sustainable forest management in the area. To stop this trend, investments in forest conservation must be made. It should be mentioned that this is a simplified future scenario, where no other factor than the deforestation rate is taken into account.

CONCLUSION AND RECOMMENDATIONS

The study concluded that there is an alarming increase in the rate of deforestation in the study area - 125.53km^2 per year (1987-2010). This loss in natural vegetation results to increase in bare surface whereas increase in build-up areas and farm lands led to decrease in vegetation. Additionally, fuel wood gathering and over cultivation are the most causal factor of deforestation with total average of 45% and 35% respectively. Others are over grazing, population growth, urbanization and bush burning.

Based on the conclusions, the study recommends that people should proffer other means of domestic energy other than fuel wood, which is the most popular source of energy in the area. For example, kerosene and gas should be used, as this will relieve the vegetal cover from indiscriminate use. Also, unnecessary cutting down of trees should be stopped. Slash and burnt system of farming should be stopped by the farmers, as this will render the lands helpless and therefore, erosion of all types will set in, hence soil nutrients will be washed away. It is paramount to encourage vegetation conservation, sustainable development and use of vegetation resources and wildlife, as the well-being of the people is closely related to the quality of their environment. Above all, there is the need for stiffer laws concerning cutting down of trees to be made and enforce by the government. Indeed, defaulters should be given stiffer penalties as this will go a long way in maintaining the vegetal resources in the area. Hence, there is a need to involve traditional rulers at the grassroots level for the enforcement of the laws, as this would in turn mitigate indiscriminate falling of trees for various purposes in the study area.

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