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Application of Satellite Remote Sensing and Geographic Information System in Monitoring Deforestation at Ikwe Forest Reserve, Benue State, Nigeria

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ABSTRACT

The decline in forest cover of Ikwe Forest Reserve at Igbor, Benue State, Nigeria is analysed using Satellite Remote Sensing and Geographic Information System (GIS). Landsat 5 TM data of December 12, 1986 and Landsat 7 ETM+ data of December 19, 2016 covering the study area are acquired for analysis. Six land use/land cover (LULC) types, comprising three forests (forest gallery, light forest and shrub) and three non-forests (marsh, eroded surface and bare surface) types are derived from both imageries. To analyse changes in LULC types from 1986 – 2016, the LULC image of 2016 is overlaid with that of 1986. The result indicates that there is a decline in forest cover, comprising forest gallery, light forest and shrub by 375ha (39%), marsh by 136ha (34%), eroded surface/built up area by 44ha (25%) from 1986-2016. However, the area of bare surface, representing forest clearings or deforested areas, has increased by 555ha (112%). Similarly, only 87ha (6%) of forest cover has appeared over deforested areas within the period of study. The result indicates a net decline in forest cover of 288ha (33%) and an annual decline rate of 2.8% respectively. Integrating the local communities in conserving the forest resources of the resort will aid in combating the forest decline. Such communities should be provided with agriculture and other economic incentives such as subsidized fertilizers, improved seedlings, pesticides and herbicides, preservation and storage facilities.

Key words: *Forest, GIS, Deforestation, Change Analysis, Endangered ecology*

INTRODUCTION

Forests are ecological as well as socio-economic resource. Forests cover conserves soil and improves its fertility; ameliorates local climate through sequestration of carbon dioxide, transpiration cooling and enhanced air humidity; and provides habitat to several species of animals. Socio-economically, forest timber and non-

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timber forest products (NTFPs) are raw materials to many industrial products. As a result, forests play a crucial role in the economic development of countries (Rawat, Sexana and Dasgupta, 2004). Deforestation results in loss of species, destruction of species habitat and biodiversity, silting of streams and rivers, disruption of the water cycle, and a significant contribution to the global warming (Rawat, Sexana and Dasgupta, 2004). The depletion of forest resources is thus a serious threat to both environmental stability and socio-economic wellbeing of countries. It is in recognition of the vital role of forest and tree cover towards global environmental stability that the United Nations Framework Convention on Climate Change (UNFCCC) has listed forests among the key issues in reversing the current global warming (United Nations, 1998).

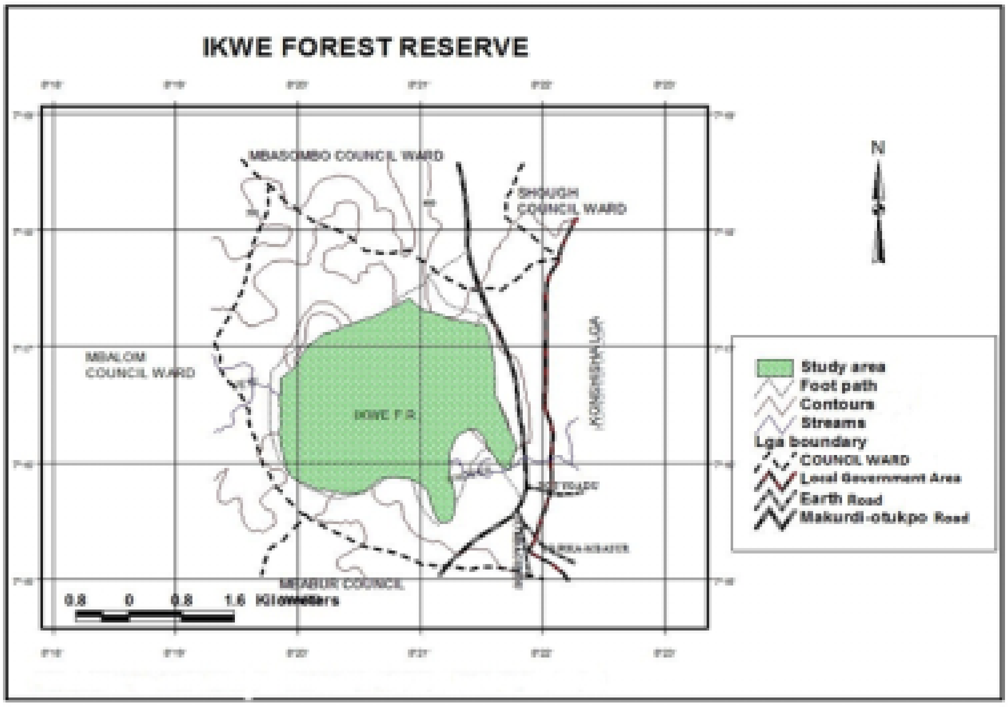
Nigeria has abundant forest resources. The country is endowed with forests that are rich in biodiversity, from the coastal and mangrove forests in the southern part to forests in the Sahel zone in the northern part of the country. According to Federal Department of Forestry (1997) report, over 4600 plants species exist in Nigeria and forests in the country are habitat to about 274 species of mammals, 831 species of birds, 104 species of snakes and 19 species of amphibians. However, hectares (ha) of both protected and unprotected forests in the country are lost every year due to anthropogenic factors such as logging and lumbering, subsistence and mechanized agriculture, fuel wood harvesting, road construction, mining and urbanization.

Studies have shown that forest cover in Nigeria had decreased from 14.9 million ha in 1980 to 10.1 million ha in 1990 and to 9.5 million ha in 1996 (Federal Department of Forestry, 1997). Satellite remote sensing, in conjunction with geographic information system (GIS), has been widely applied in environmental change and monitoring. This is because satellite remote sensing has the ability of repetitive data coverage of the earth's features and can acquire data of places that are inaccessible or difficult to reach by ground observation (Ndukwe, 1997). It also collects multi-spectral, multi-resolution and multi-temporal data that are valuable in understanding and monitoring different aspects of environmental change (Weng, 2001). GIS technology provides a flexible environment for entering, analysing and displaying digital data from various sources necessary for feature identification, change detection and database development (Weng, 2001).

In forestry studies, satellite remote sensing, with GIS, has been utilized in mapping forest resources, monitoring forest cover change or depletion and identifying endangered tree species at all spatial scales be it local, regional and global (Westman, Strong and Wilcox, 1989). Consequently, Westman, Strong and Wilcox (1989) have analysed deforestation in Mabira, southern Uganda from 1973-1988 using Landsat TM/ETM+ data. Their result showed that 35.5% (101.4km^2) of forest cover of the area was depleted, 7.0% (20.1km^2) of new forests appeared with an annual forest decline rate of 2.2% for the 15-year period. Similar study in Aberdare Range, Kenya has shown a decline in forest cover by 45,219.53ha (30%) from 1987-2016 (Ochego, 2003). In India, Rawat, Sexana and Dasgupta (2004) have utilized satellite remote sensing in mapping forest cover of India. They report that forests cover about 675,538km^2, 20.55% of the country's geographical area, while non-forests covered occupied the remaining 2,611,725km^2. The need for accurate information on the depletion of forest resources in Nigeria is paramount in forest conservation policy, particularly in actualizing the National Forest Policy of having a minimum of 25% of the geographical area of the country under forest and tree cover. Hence, this study is carried out to assess the Application of Satellite Remote Sensing and Geographic Information System in Monitoring Deforestation at Ikwe Forest Reserve, Benue State Nigeria. The major objectives of the study include (i) to examine the nature and pattern of forest decline in Ikwe Holiday Resort, (ii) to assess the net and annual rate of deforestation in the study area from 1986-2016, (iii) to identify the major factors of forest and tree cover loss in the area and (iv) to highlight the major policy options of forest conservation and preservation most suitable in the study area.

Study Area

Ikwe Forest Reserve, formerly Ikwe Game Reserve, is located at Igbor settlement on Latitude 7°15 and Lat. 7°17N and Longitude 8°20 and 8°22E, about 30km south of Makurdi, along Makurdi-Enugu highway, in Gwer East Local Government of Benue State, Nigeria (Fig. 1). The game reserve was established in 1958 by then Government of Northern region with total area of about 2,000ha (20km^2). The resort is located within a series of conical sedimentary hills of 274m. Apart from tourist attraction, it is a hydrological source of many streams and a habitat to several species of plants and animals. There are three dominant tree species in the resort. *Khayasenegalensis* (mahogany) is found in the western part, mostly along stream courses while *Daniellaoliveri* (chiha) and *Isoberiniadoka* (akovol) are found mostly at the lower and upper slopes of the hills respectively. Other tree species such as *Parkiabiglobosa* (locust bean), *Prosopsisafricana* (iron tree) and *Vitellariaparadoxa* (shear butter) are also common (Federal Department of Forestry, 1997). Some of the animals that were found in the resort include antelopes, grass cutters, buffaloes, alligators, crocodiles and pythons but most of these animals have been displaced owing to the alteration of their habitat due to deforestation. For the purpose of this study, a 5.04 x 4.03 km subsection of the forest reserve is used which covers about 2,034ha.



METHOD

To analyse the spatial and temporal changes in forest and tree cover in the study area, Landsat 5 TM data of December 19, 1986 (subject imagery) and Landsat 7 ETM+ data of December 12, 2016 (reference imagery) of the study area were acquired for analysis. The data were acquired in December to minimize the effect of cloud cover on the satellite imageries. Both Landsat 5 TM (Thematic Mapper) and Landsat 7 ETM+ (Enhanced Thematic Mapper plus) have the same bandwidths (except the Panchromatic (PAN) band which is only available in the ETM+ sensor) and resolutions (except band 6 which is 120m resolution for TM sensor and 60m resolution for the ETM+ sensor). Both Landsat 5 TM and Landsat 7 ETM+ are high resolution (30m) data that can be effectively used to monitor changes in forest cover in the study area.

The detail procedure for deriving LULC types from Landsat data, according to Weng (2001), involves image enhancement to increase the volume of visible information of the imageries. After image enhancement, the imageries were then rectified to common Universal Transverse Mercator (UTM) coordinate system using a 1:50,000 scale topographical map of the study area. This converted the imagery format into a topographical map format. Each of the imageries was then radiometrically corrected due to image distortion or "noise" that would have occurred during data acquisition. Hence, both imageries were acquired in December; no correction due to cloud cover was carried out.

The Landsat imageries were first classified using supervised classification to derive the various land use and land cover types. False colour composites were then created from bands 2 (green), 3 (red) and 4 (near infrared (NIR)) from both Landsat imageries of 1986 and 2016 in order to extract changes in LULC types. Change detection (losses and gains) among the LULC types was performed by overlaying the classified image of the reference year (2016) with that of the subject year (1986) using the Integrated Land and Water Information System (ILWIS) Academic 3.0 image processing GIS software package. Change analysis was computed by analysing changes in area covered by individual land use/land cover types in 1986 and 2016, and also the conversion among the LULC types from 1986-2016. The annual rate of the decline in forest cover in the study area was computed from the formula (Westman, Strong and Wilcox, 1989):

$$X^n = b/a \qquad (1)$$

Where n = is the time taken (in years) between the measurement periods;
a = is the initial forest cover and
b = is the total forest cover at the end.

RESULTS AND DISCUSSION

The classified images for 1986 and 2016 are shown in figures 2 and 3 where vegetation is represented by red colour. About six LULC types were classified from both the Landsat 5 TM and Landsat 7 ETM+ imageries of the study area based on their spectral signatures using bands 2, 3, and 4. These include bare surface, eroded surface, marsh, shrubs, light forest and forest gallery. In this study, forest cover includes shrubs (undergrowths or growing trees), light forest and forest gallery. Marsh areas cover rock outcrop, burnt surface, tarred road and decayed vegetation whereas eroded surface also includes housing structures. Similarly, bare surface represents areas where vegetation is either removed or crops harvested.

Land use/land covers change analysis

The result of land use/land cover change analysis from 1986 – 2016 is presented in table 1. It can be inferred from the table that in 1986, bare surface covered 497ha, about 24% of the total land area of the resort. In addition, about 241ha (12%) was covered by forest gallery, 285ha (14%) by light forest, 427ha (21%) by shrub, 403ha (20%) by eroded surface respectively. However, in 2016, all the LULC types have decreased in area except bare surface. Forest gallery and light forest have decreased to 126ha and 235ha representing a loss of 115ha and 50ha respectively (table 1). Shrub has the largest decline in area of 210ha while bare surface has increased in area by 555ha (112%). Generally, the area of forest cover has decreased from 953ha (1986) to about 578ha (2016), indicating a loss of about 375ha (39%) and an annual decline rate of 2.8% for the 14-year period.

Bare surface derived most of its area from shrubs (236ha) and least from forest gallery (56ha) respectively (Tables 2 and 3), while 28ha (22%) and 0.4ha (0.3%) of the forest gallery were derived from light forest and eroded surface respectively. Bare surface, an indication of deforestation, gained 56ha, 109ha, 236ha, 189ha and 133ha from forest gallery, light forest, shrub, marsh and eroded surface but only contributed 14ha, 39ha, 34ha, 61ha and 19ha to forest gallery, light forest, shrub, marsh and eroded surface respectively (Table 4).

Generally, about 401ha (11%) of bare surface was derived from forest cover while bare surface only contributed about 87ha (6%) to forest cover. This suggests a net decline (loss-gain) in forest cover of 288ha (33%) for the 14-year period. From Tables 2, 3 and 4, it is evident that other LULC types contributed significantly to bare surface, indicating an overwhelming increase in deforestation at the expense of other land use/land cover types.

Table 1: Change in individual land use/land cover types in 1986 and 2016 (ha)

Land Use/Land Cover types	**1986 Area**	**% Change**	**2016 Area**	**%Change**	**Gain (+) Loss (-)**	**%**
Forest gallery	241	12	126	6	-115	48
Light forest	285	14	235	11	-50	18
Shrub	427	21	217	11	-210	49
Marsh	403	20	267	13	-136	34
Eroded surface	181	9	137	7	-44	24
Bare surface	497	24	1052	52	+555	112
Total	**2034**	**100**	**2034**	**100**		

Source: Author's Analysis (2017).

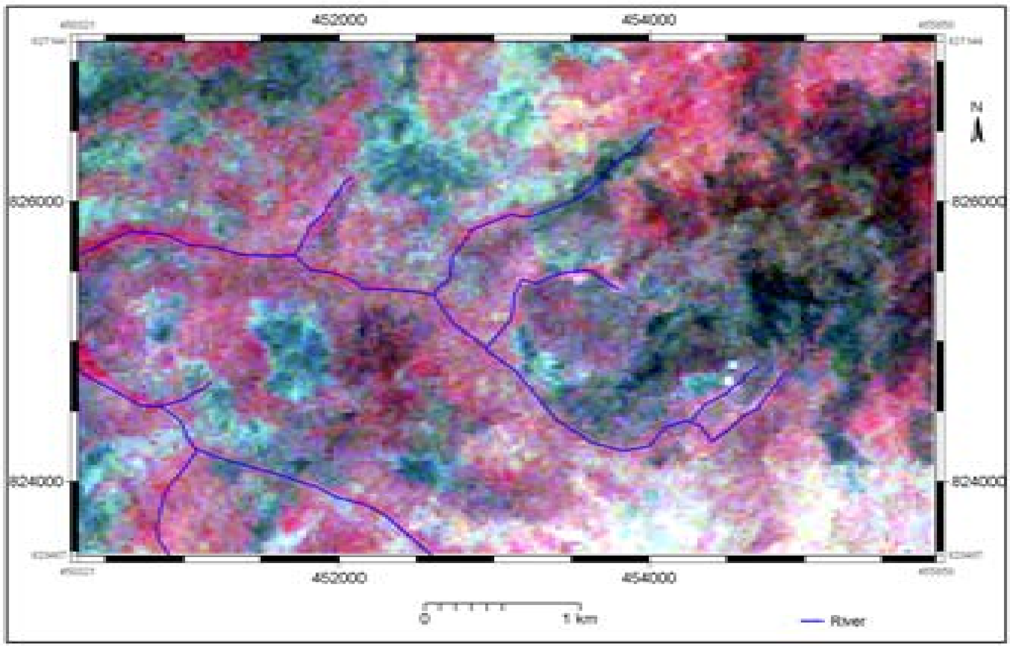


Fig 2: Ikwe Forest Reserve FCC Image of LandSat 1986

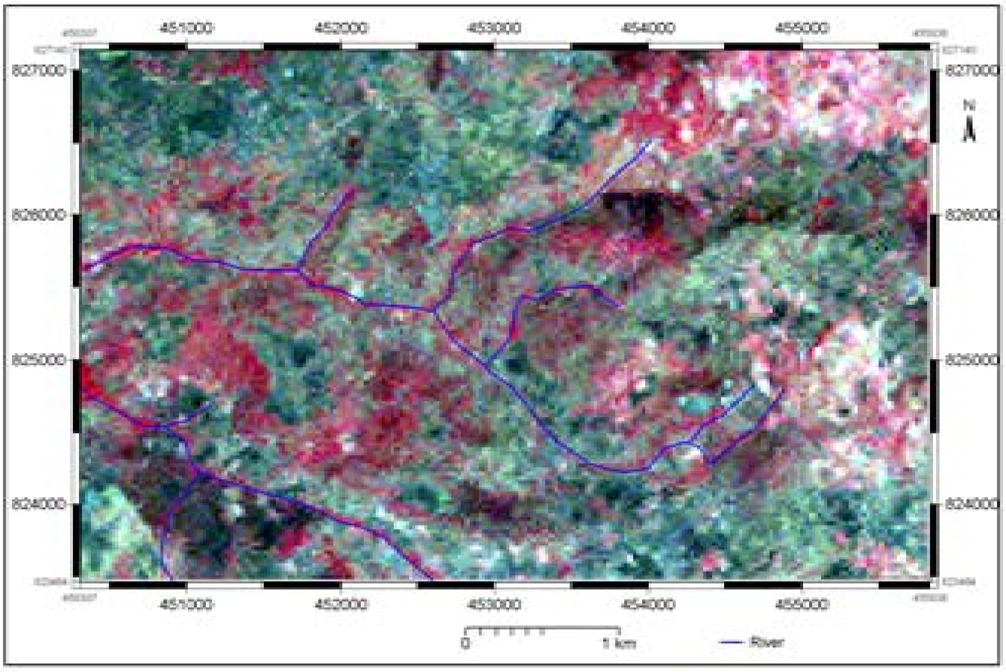


Fig 3: Ikwe Forest Reserve FCC Image of LandSat 2016

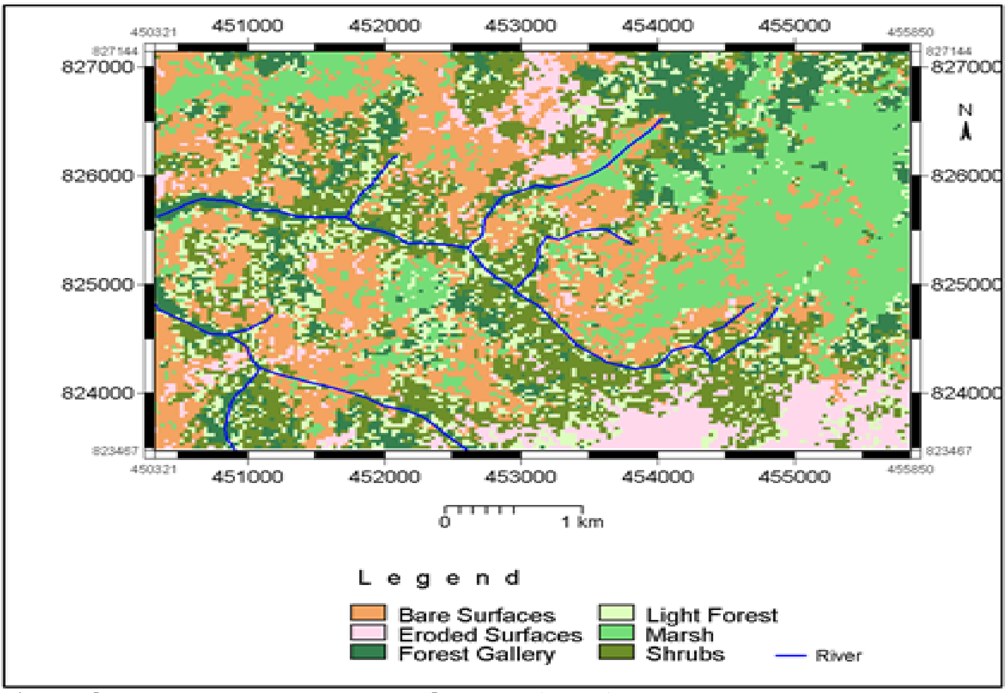


Fig 4: Ikwe Forest Reserve's Land Cover (1986)

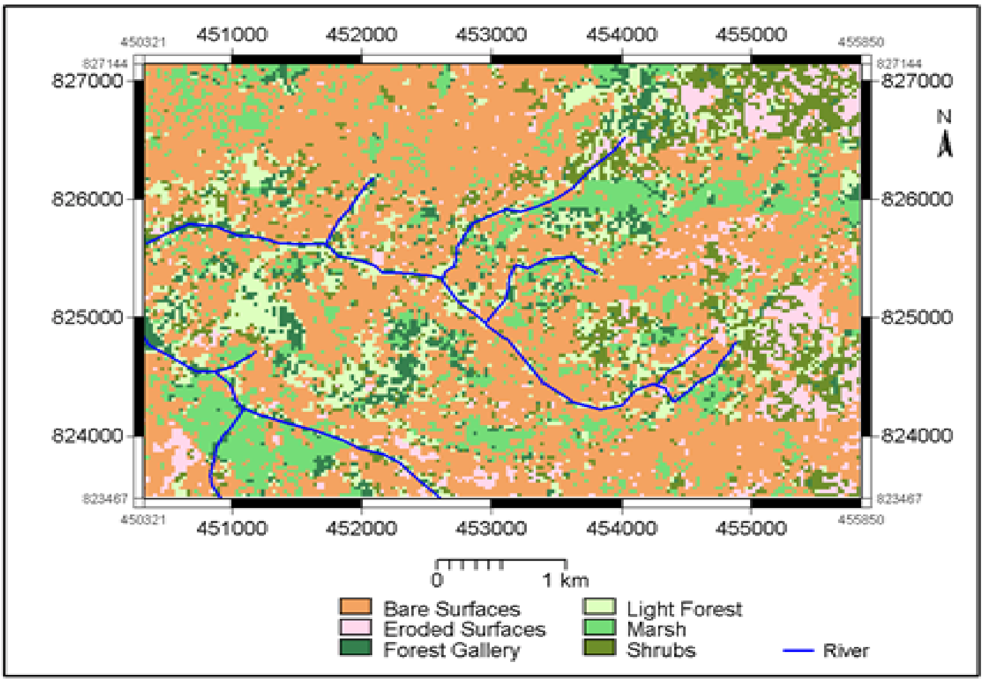


Fig 5: Ikwe Forest Reserve's Land Cover (2016)

Table 2: Land use/land cover change matrix 1986-2016 (ha)

Land Use/land Cover types	Forest gallery	Light forest	Shrub	Marsh	Eroded surface	Bare surface	Total
Forest gallery	47	52	38	25	23	56	241
Light forest	28	59	36	36	17	109	285
Shrub	18	53	45	51	24	236	427
Marsh	18	29	51	79	38	189	404
Eroded surface	0.4	3	14	15	16	133	181
Bare surface	14	39	34	61	19	330	497
Total	**125**	**235**	**218**	**267**	**137**	**1053**	

Source: Author's Analysis (2017)

Table 3: The highest and least contributors among land use/land cover types

Land Use/Land Cover types	Highest contributor	Area (ha)	%	Least contributor	Area (ha)	%
Forest gallery	Light forest	28	22	Eroded surface	0.4	0.3
Light forest	Shrub	53	23	Eroded surface	3	1
Shrub	Marsh	51	23	Eroded surface	14	6
Marsh	Bare surface	61	23	Eroded surface	15	6
Eroded surface	Marsh	38	28	Light forest	17	12
Bare surface	Shrub	236	22	Forest gallery	56	5

Source: Author's Analysis (2017)

Table 4: Gain and loss by Bare surface

Land use/land cover	Gain (ha)	%	Loss	%
Forest gallery	56	5	14	3
Light forest	109	10	39	8
Shrub	236	22	34	7
Marsh	189	18	61	12
Eroded surface	133	13	19	4

Source: Author's Analysis (2017)

CONCLUSION AND RECOMMENDATION

The study illustrates the effectiveness of utilizing satellite remote sensing in conjunction with GIS in monitoring the loss in forest and tree cover at the micro or local level. The result of the study reveals that the area cover of forest gallery, light forest, shrubs, marsh and eroded surface has decreased by 115ha (48%), 50ha (18%), 210ha (49%), 136ha (34%) and 24ha (24%) from 1986 - 2016. The result also shows that the forest cover, comprising forest gallery, light forest and shrub, has declined by 375ha (39%) suggesting an annual decline rate of 2.8% within the same period. However, only bare surface, indicating deforested areas, increased in area cover by 555ha (112%) over the 14-year period. This increase in the area of bare surface was at the expense of other LULC types especially forest and tree cover. Moreover, only 87ha (6%) of the forest cover had appeared in cleared or deforested areas thus representing a net decline in forest cover of 288ha (33%).

The decline in eroded surface and housing structures clearly show that population pressure is not a major factor of deforestation in the study area. Over the years, there has been a gradual movement of the natives from the Igbor settlement to the fringes of the resort for the purpose of exploitation. Most of these natives have converted the reserve into farm plots of various sizes for the cultivation of yam, maize, soya bean, rice, sorghum, millet and also used timber as fuel wood. This clearly shows that land tenure, poverty and subsistence farming are the major factors responsible for the decline of forest cover at the Ikwe Forest Reserve.

Integrating the local communities in conserving the forest resources of the resort will aid in combating the forest decline. Such communities should be provided with agriculture and other economic incentives such as subsidized fertilizers, improved seedlings, pesticides and herbicides, preservation and storage facilities. Bore holes should be provided to such communities as well as loan facilities at minimal interest rate. These measures will enhance the living standard of these communities and also direct their attention away from reserved/unreserved forests which they often considered as their ancestral heritage.

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