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ANALYSIS OF THE SPATIO-TEMPORAL CHANGES IN KARLAHI FOREST RESERVE

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Abstract: The analysis of the spatio-temporal changes that occurred in Karlahi Forest Reserve of Fufore Local Government of Adamawa State was carried out and it was aim at analyzing the trend of forest cover changes. this research adopted remote sensing methodological approaches that is, the used of acquired imageries (Landsat ETM, ETM+ and LC8) to classify Land Cover types within the forest reserve. The result of Spatio-temporal analysis of change that occurred within the Karlahi Forest reserve revealed a rapid decrease in vegetation cover types over the years. That is, 94.8 Km^2 out of the 122.5 Km^2 in 1989, 68.1 Km^2 in 1999, 29.8 Km^2 in 2008 and 23 Km^2 in 2019 these changes in woodland also retreat to shrubs with 22.6 Km^2 in 1989, 15.9 Km^2 in 1999, 17.9 Km^2 in 28 and 10.1 Km^2 in 2019. The decrease in woodland and shrubs was inversely proportional to bare surface with 5.1 Km^2 in 1989 to 89.4 Km^2 in 2019. This means that anthropogenic activities within the forest reserve is increasing thereby degrading the Karlahi Forest Reserve as the spatial pattern of change within the forest reserve is woodland to bare surface and shrubs to bare surfaces. this increase in bare surface is attributed to fertile soil as notice in several studies, logging activities, charcoal extraction and local policy also contributed to the degradation of the forest which are also notice by many authors that forest reserve with good soil for agriculture encourages extensive farming activities and this played in Karlahi Forest Reserve especially at the lower region of the reserve. It is recommended that Land Cover information should be incorporated in the study of forested area most especially in forest/game reserve.
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1. Introduction

Human activities have re-defined the nature of the environment, thereby interfering and altering the ecosystem and landscape throughout the world (Kushwaha, Nandy, Ahmad & Agarwal, 2011). The unchecked use of resources by humans have resulted into a global change in land use leading to deforestation as a consequence of over exploitation and mismanagement of the resources. Forest functions are many which include habitats for organisms, modulation of hydrological flow and soil conservation which forms one of the important aspects of the biosphere. Hence, the demand for the conservation of Forest is critical in preventing global warming and building of a sustainable society. (Pawar & Rothkar, 2015).

Drius, Carranza, Stanisci and Jones, (2016) noted that terrestrial ecosystems serve as sources and sinks for carbon. Their research underscored the impacts of land use and land cover changes on the global climate through carbon cycle. Furthermore, much larger impacts of land use/land cover changes on ecosystem in relation to biodiversity, soil degradation and the ability of ecological systems to support humans, were identified by numerous scholars (IPCC, (2019); Dibaba, Demissie and Miegel (2020); Liu, et al (2021)). Thus, providing a threshold for understanding and predicting land use/land cover changes, particularly deforestation and forest degradation which are paramount to forest management, biodiversity and conservation is important. Recently, many studies have revealed that Land Use/Land Cover changes are driven by a myriad of intricate processes which include interventions at different spatial and temporal scales (Kushwaha et al., 2011; Roshan et. al, 2019). The understanding of the process of Land Use/Land Cover change has led to a shift in paradigm, from a view of the effect of human impacts on the environment as leading mostly to deterioration of earth system processes to emphasis on the potentials for ecological restoration through land management.

The degradation of tropics forests has severe long term environmental and socio-economic consequences which often result to change in climate, habitat degradation and species extinction (IPCC, 2019), The degradation of environmental resources is highly noticeable in the developing countries especially in the areas of forest and forest resources which were characterized with logging, agricultural activities and urbanization. In Nigeria, The Nigeria Environmental Study Team (NEST, 1991) revealed that 10% of the country's land area is forest, this translates into about 9.6 million hectares. The team further revealed that the forests are being degraded under persistent human pressure. Specifically, the team noted that Nigerians regard the natural vegetation as an inexhaustible bounty of nature, hence treat it casually through ruthless cutting, burning and clearing of the forest and these activities result the country to loses about 350,000 ha of forest and natural vegetation annually (Adekola & Mbalisi, 2015). Another major problem faced in the management of forest resources of Nigeria are human encroachment as well as the effect it has on climate change in all the geo-political zones of the country, as its losses 351000 km^2 of its landmass to desertification which is advancing Southward at 0.6 kilometer annually (Aigbe & Oluku, 2012).

Remote Sensing and Geographic Information System are some of the most recent and common methodologies employed in the study of forest cover changes. Remote Sensing is a process of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy for the processing, analyzing and application of information gathered into various fields of research (Canada Centre for Remote Sensing Tutorials, 2018). These techniques in forest cover change detection and monitoring have been used to assess variations in forest cover over two or more time periods caused by environmental conditions and human actions as noted by (Kreuter et al., 2001) (Zhongmin et al.,2003). Furthermore, data obtained through Remote Sensing enables accurate identification and outlining of various forest types, these data are available at various scales and resolutions to meet local or regional demands. Both imagery and the extracted information can be incorporated into a GIS for further analysis as slopes, ownership boundaries, or roads (Canada Centre for Remote Sensing Tutorials, 2018).

In spite the significant role the forest plays in the life of mankind, man continues to destroy it through diverse anthropogenic activities such as hunting, bush burning, animal grazing, lumbering, fuel wood extraction, farming and mining. Disturbances created by these activities influence forest dynamics and tree density. It also impacts negatively on the forest leading to destruction of biodiversity and habitat for terrestrial animals. Constant deforestation, degradation and loss of biodiversity have negative repercussions on the livelihoods of most people dependent on forest resources, as this trend remains unabated.

Recent studies have shown that deforestation and forest degradation increase continuously at a million hectares per annum (IPPC, 2019) with a 25% degraded area in the world (GEF, 2021: Richard and Michal 2021) and in line with the outline problems monitoring the state of Karlahi Forest Reserves changes over three decades in vegetation cover become necessary and in line of this the research aim at analyzing the Spatio-Temporal changes within the Karlahi Forest Reserve.

2. Material and Methods

Karlahi Forest reserve is situated in Fufore Local Government Area of Adamawa State. It is located between latitudes $8^0 49'30''$N and $9^0 00'$N, of the equator and longitudes $12^0 36'0''$E and $12^0 45'0''$E of the prime meridian. Its land area is estimated at about of 105.44 sq Km. Karlahi Forest Reserve is bounded by the Toja Stream to the North and Beti Stream to the South-to-South Eastern part.

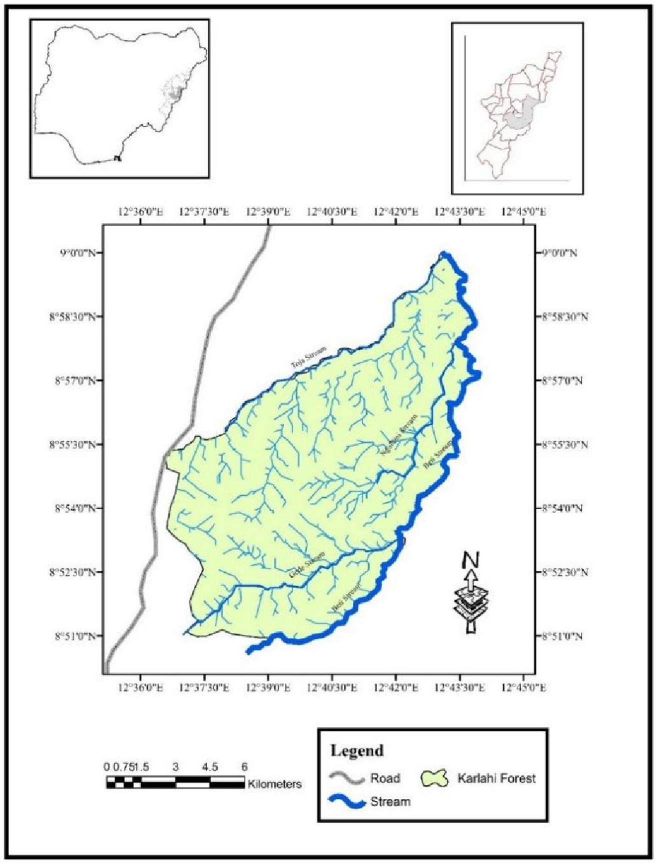

Figure 1: Study Area
Source: Researcher 2020

Relief of the study area lies between the range of 197m and 346m above sea level and characterized by a gentle slope. The area is predominantly constituted by arable and range lands. The area is bounded to the North by a plain with elevations ranging from 197m and 242m above sea level, and to the south by the Varre hill (Figure. 1.3). The dynamics of land use are conditioned by relief areas with high slope, this factor increase the fragility of the system and decrease the possibility of anthropic use, which makes area with low relief (Slope) vulnerable to many agents of deforestation (Karrasch & Hunger, 2017).

Climate 0f the study area is characterized by humid tropical climate; marked by distinct wet and dry seasons in which the wet season lasts for Six to seven months with annual precipitation values ranging from 656.70mm to 1260.10mm (UBRDA, 2018). The months of July and August has the highest rainfall while the driest months are January, February and December (UBRDA, 2018). The dry season which predominantly occurs from November to May is characterized by high mean evaporation values, mostly from the months of January to March/April with mean monthly values ranging from 115.40mm to 255.76mm (Adebayo, Tukur and Zemba, 2020) and annual values ranging from 1585mm to 2922.87mm (UBRDA, 2018).

2.1 Data Types and Sources

For the purpose of this study the following data were used:

Landsat image data of Landsat TM was used for year 1989, ETM+ for year 1999 to 2008 and Landsat 8 for year 2019. The images used for land cover classification and calculation of spatial matrixes were obtained from the United State Geological Survey website of the forest reserve for the periods of the study (Earth explorer, 1989-2019.). Data used in this study were obtained mainly from secondary sources Which are obtained from books, journals, unpublished materials and Landsat imageries.

2.2 Method of Data Collection

The qualitative data collection tools used in this study is the Remote Sensing data collection tool which is the Multitemporal Satellite Image: Remote Sensing data include all the satellite images (Landsat TM, ETM+ and Landsat 8) were used in the research. The images were obtained from the United State Geologic Survey website (https://earthexplorer.usgs.gov/) which are of various resolution as shown in table 1. the imageries have the optimal ground resolution and spectral bands to efficiently track land use and to document land change.

Table 1: Landsat Types and resolution.

Period	Landsat Type	Resolution	Date of Capture
1989	Landsat 5 (TM)	30	October 24, 1989
1999	Landsat 7 (ETM+)	30	November 04, 1999
2008	Landsat 7 (ETM+)	30	November 02. 2008
2019	Landsat 8	30	November 10, 2019

2.3. Data Processing

1. Satellite image pre-processing

An integrated approach of remote sensing and GIS techniques were applied in this study to generate a land cover map, analyze the forest cover changes. Remote sensing images from Landsat satellites were processed for evaluating the forest cover dynamics. Image classification was carried out using a supervised image classification approach applying a standard nearest neighborhood algorithm in ArcGIS 10.5. Forest cover change were analyzed.

2.4 Forest Cover Change Analysis

The changes that occurred within the Karlahi Forest Reserve were analyzed using the following steps.

1. The forest cover maps for the selected years were generated using the Land Cover Modeler of ArcGIS 10.5. The forest transition maps for both time interval reveals the extent of changes within the landscapes across the study area.
2. In order to calculate annual rates of forest transition, both forest cover and forest transition maps were used as inputs. These calculations were based on the assumption that the annual deforestation and afforestation in total forest cover will not be constant (Chintamani, 2009).
3. For change transition, a statistical analyses of change information in earlier and later images were computed using the cross tabulation and the post classification comparison of change detection in a form of a table and a spatial matrix which is basically the rate of change and the probability of change of the classified imageries were then calculated. This methodology was applied also for temporal change detection by subtracting the later image class area from the earlier image class area.

3 RESULT AND DISCUSSION

3.1 The Temporal Changes in Karlahi Forest Reserve

Karlahi forest Reserve witness changes and these changes over the three decades of study which were shown on table 2.

Table 2: Land Cover Areas of Karlahi Forest Reserve

Land cover	1989 Km^2	1999 Km^2	2008 Km^2	2019 Km^2
Woodland	94.8 (77.4 %)	68.1 (55.6%)	29.8 (24.4%)	23 (18.7%)
Shrubs	22.6 (18.4 %)	15.9 (12.9%)	17.9 (14.6%)	10.1 (8.3%)
Bare Surfaces	5.1 (4.2 %)	38.5 (31.5%)	74.8 (61%)	89.4 (73%)

Result from table 4.2. shows that bare surfaces cover 5.1 Km^2 (4.2%) area in 1989, but increased to 38.5Km^2 (31.5%) in 1999, 74.8 Km^2 (61%) in 2008 and 89.4 Km^2 (73%) in 2019 (Figure 4.1). These increase in bare surface cover is attributed to fertile soil of the lower region of the forest reserve which are gleyic cambisols and eutric regosol which and are good soil for agriculture, hence encouraging extensive farming and logging activities within the forest reserve, particularly the lower region of the forest.

These changes within the Karlahi Forest Reserve are in correlation with the policy adopted by the Fufore Local Government area and the traditional council which are:

1. Farmer within a forest reserve were tasked one bag of whatever they cultivate.
2. Tax on animal is one hundred naira per animal head.
3. Developmental levy of one hundred naira per each male living within the forest reserve.

These policies do affect the forest ecology function as its consequence to extensive cutting down of the woodlands to give way for farming activities thereby making the major ecological function

of the forest (habitats for animals and livelihoods for humans, watershed protection, prevent soil erosion and mitigate climate change) inaccessible thereby making the deforested area to be vulnerable to erosion, as well as loss of habitats.

Fuelwood extraction, charcoal making, farming activities, illegal logging and uncontrolled grazing is becoming the major treat to the land cover changes in Karlahi Forest Reserve. These trend in karlahi forest reserve correlate with the finding of Ba et al., (2014) were they noted that fuelwood gathering and over-cultivation are the major causal factor of deforestation in Fufore Local Government area of Adamawa state where Karlahi Forest reserve is located. Adamu (2019) also noted that fuel wood gathering and over cultivation are also the causal factor of deforestation in Girie Forest reserve. These drivers of forest degradation affect mostly all the forest area in Nigeria as in the case of Jeminiwa et al. (2020) in the Mokwa Forest Reserve of Niger State where the researcher identified that drivers of degradation were charcoal extraction, commercial farming, overgrazing and fuelwood extraction which is also in agreement to the research of Suleiman, Wasonga, Mbau, *et al.* in Falgore Game Reserve in Kano where they noted that forest cover transitions are largely attributed to intensification of anthropogenic activities in and around the forest and these activities are excessive fuelwood collection, timber logging, and poor grazing management. Ogunleye et al. (2004) that the loss of plant diversity within the Olokemeji forest reserve in Ibadan is due to farming activities which is rapidly increasing as well as agricultural expansion and plantation establishment which contribute to indigenous plant loss in the reserve. These anthropogenic activities which are mainly logging, fuelwood exploration, charcoal exploration and farming activities within the forest reserve result to an extensive exploration of the forest reserve thereby brought about a decline in the extent of the woodland within the forest reserve as the forest was logged in several places for timber and to make room for the cultivation of crops as well as establishing of new settlement as shown in plate 1 and 2.

Plate 1: Woodland Exploration within Karlahi Forest Reserve within the Karlahi Forest reserve

Plate 2: Nomadic Settlement (Bare Surfaces)

Source: Researcher 2020

The increase in the Bare Surfaces within the Karlahi Forest Reserve is also attributed to increasing population in the immediate forest area (Fufore Local Government) and it surrounding environment (Jada, Mayo Belwa, Yola South and Yola North Local Government Area). Population growth in these areas joint with other factors such as poverty and corruption do contribute to forest loss and environmental degradation in Karlahi Forest Reserve (KII, 2021) as well as the demand for forest and agricultural products to feed the adjacent growing rural and urban populations continue to placed pressure on the available forest resources for sustenance and survival. Also, population growth also increases the demand for housing and construction which results in a general forest decline in Karlahi Forest Reserve.

Issue of fuel wood extraction and crop cultivation in forest areas within the state and the country had become the major agent of deforestation as study conducted by Adamu in 2019 in Girei Forest Reserve also reveal that fuel wood extraction and farming activities is the major cause of deforestation in the reserve. This findings gives reasons that the increasing loss of the indigenous woodland would continue as in table 5.1 which shows a trend of 94.8Km^2 (77.4%) in 1989, 68.1 Km^2 (55.6%) in 1999 and 29.8 Km^2 (24.4%) in 2008 and 23 Km^2 (18.7%) in 2019 these changes is attributed to the establishment of new farm/nomadic settlement within the forest as majority of the woodland lost is around the newly established settlement (Plate 5.2) thus, having implications for biodiversity conservation within the study area as shown in Figure 3.2, 3.3, 3.4 and 4.5. the loss of woodland signifies loss of Biodiversity which has far reaching consequence on the local Environment by accelerating soil erosion and loss of habitat for wildlife.

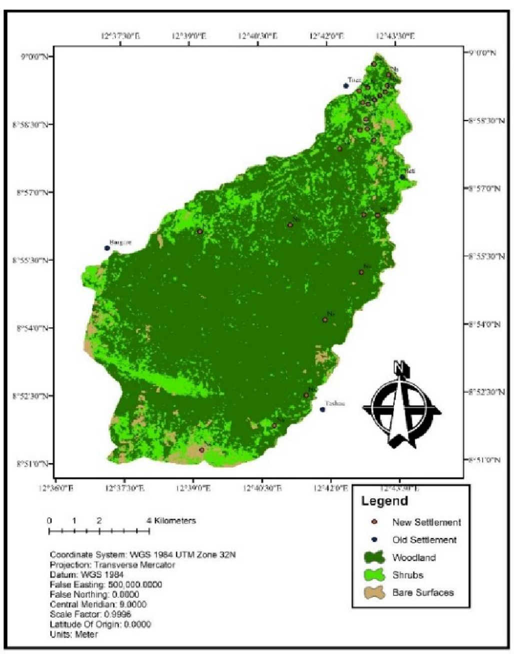

Figure 3.1: Karlahi Forest Reserve Landcover Classes of 1989

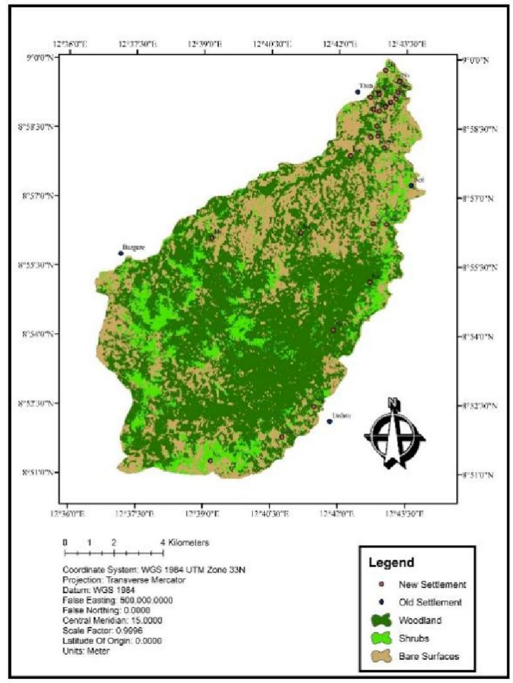

Figure 3.2: Karlahi Forest Reserve Landcover Classes of 1999

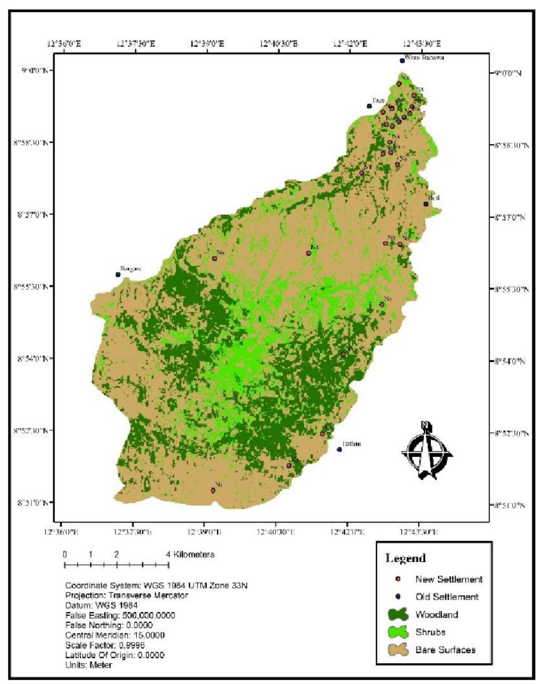

Figure 3.3: Karlahi Forest Reserve Landcover Classes of 2008

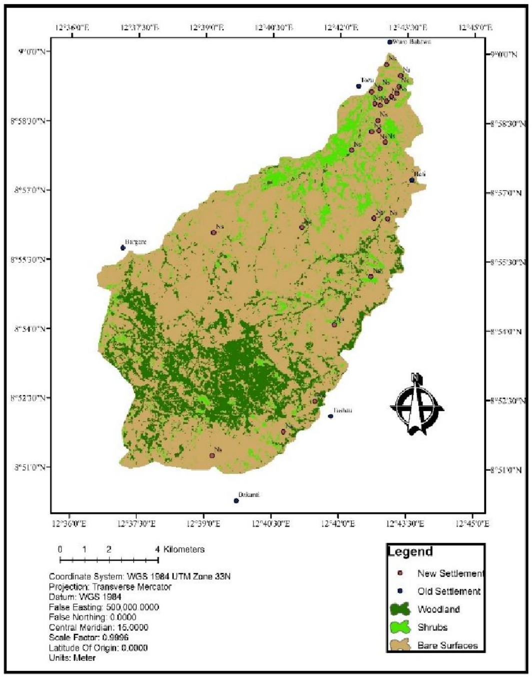

Figure 3.4: Karlahi Forest Reserve Landcover Classes of 2019

Source: Researcher, 2020

Adedeji, Tope-Ajayi and Abegunde (2015) conducted a study on Gambari Forest Reserve of Oyo state, Nigeria and They concluded that decrease in forest (woodland) is attributed to conversion of forest land to farmland through felling which is the major case found in Karlahi Forest Reserve, as bare surfaces within the study area increase at 27.3% in 1989-1999, 29.5% in 1999-2008 and 5.7% in between 2008 to 2019. These reflect on the vegetation of the area as it shown in table 2

The finding of Sunday (2020) in his publication on *Takeover of Nigerian reserve highlights uphill battle to save forest* correlate with the finding of the current research where he concluded that most of the farming activities within the Akure-Ofosu Forest Reserve in Southwestern Nigeria as well as the logging activities were legitimized by the authorities. Suleiman et al., (2017) analyses the Spatial and temporal change in Falgore Game Reserve in Kano and concluded that the primary drivers of forest resource degradation in the region were found to be excessive fuel wood collection, overgrazing and forest fire which some of the drivers played in Karlahi forest such as the fuelwood extraction, overgrazing expansion but the forest fire is minimal as a result of the growing community within the forest which also serve as a driver of forest degradation.

The relative increase in shrubs between 2008 to 2019 which is 10.1 Km^2 (8.3%) is as a result of woodland/shrubs tend to be regenerating (Plate 4.5) in so many areas within the forest reserve especially the higher relief zones which is as a result of insecurity which makes people afraid to go to such areas for cultivation as well as fuel wood extraction.

Plate 3: Vegetation Regeneration within Karlahi Forest Reserve

Source: Researcher 2020

3.2.1 Rate of Land use cover Change

This section looked at the rates of change of the land Cover classes which are positive and in negative direction over the time under study (1989-1999, 1999-2008 and 2008-2019) in Karlahi Forest Reserve and these changes are shown in table 3

Table 3: Rate of Land Cover Changes

	1989-1999 *(Km^2)*	1999-2008 *(Km^2)*	2008-2019 *(Km^2)*
Woodland	-2.67	-4.26	-0.62
Shrubs	-0.67	0.22	-0.71
Bare Surfaces	3.34	4.03	1.33

Source: Researcher, 2020

Non adherence to forest policies on sustainability in Karlahi Forest Reserve have result consequential effect on the decrease of shrubs/woodland at a rate of -0.67, 0.22 and -1.33 Km^2 at a respective year of 1989-1999, 1999-2008 and 2008-2019. This changes in woodland and Shrubs lead to an increase in bare surfaces at a rate of 3.34Km^2 per annum in 1989-1999, 4.03 Km^2 per annum in 1999-2008 and 1.33 Km^2 per annum in 2008-2019 as shown in Figure 4.7. and these changes is with a greater implication on the ecological function which are raising a diversity of species, carbon storage, nutrient cycling, water and air purification and maintenance of wildlife habitat and as well as its social function (traditional resource uses).

Praveen and Jayarama (2013) conducted a study on *Analysis of Land Use/Land Cover Changes Using Remote Sensing Data and GIS, Tirupati, India.* In their study they find out that there is significant expansion of built-up area and on the other hand, there is decrease in forest areas. This study clearly indicates the significant impact of population and its development activities on Land Cover change. The only variation is that Tirupati is a community that is not only restricted to humans but rather than a community with and adjacent forest cover in which people exploit to give way for settlement. But in all the Karlahi Forest Reserve and the Tirupati were affected by the same anthropogenic agent which is man and this is clearly shown on the spatial distribution of the newly established settlement within the forest reserve. Grazing is one of the major cause of forest degradation in Karlahi Forest Reserve as large area of woodland was converted to grazing region and these had become a major issue in various forest area of the Adamawa State as well as the world at large as noted by Ba, et al. (2014) on their research title: *local residents' perception on the causes and effects of deforestation in Fufore Local Government Area, Adamawa State*, revealed that human activities such as lumbering, grazing and development of new rural settlement are gradually depleting the forest. Farias et al., 2020 in their research work title the impact of rural settlement on the deforestation of the amazon also noted that pasturing is among the major causes of deforestation in the region and this agreed with the situation in Karlahi Forest reserve. This also support the current finding on Karlahi Forest Reserve that the settlement within the forest reserve played a major role in degrading the woodlands and shrubs of the forest reserve.

Conclusions

Front-line link with the current findings on this research, it was concluded that Karlahi Forest Reserve Landcovers changes drastically as bare surfaces is increasing rapidly and this increase in bare surface is attributed to fertile soil as notice in several studies, logging activities, charcoal extraction and local policy also contributed to the degradation of the forest which are also notice by many authors that forest reserve with good soil for agriculture encourages extensive farming activities and this played in Karlahi Forest Reserve especially at the lower region of the reserve

Recommendations

Adamawa State Ministry of Environment and Natural Resource Development has been established to effectively prevent flora and fauna destruction. The study of the Karlahi Forest Reserve reveal that a greater part of the forest reserve was altered and this can make it difficult for the Karlahi Forest Reserve stake holder to conserve the total area of the forest reserve. Protecting the total area of the forest reserve area from the device anthropogenic activities within the forest reserve can attempt to remedy the effect of the anthropogenic activities which it may cause in the future especially when the present insecurity within the forest come to an end. Lack of known audit of the forest resources in Karlahi Forest Reserve makes the area not to benefit from the policy of federal government on national parks and reserves to give priority to the local communities when it comes to employment as forest guards. Nigeria Conservation Foundation

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