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Change Detection Analysis and Deforestation Rates in Oluwa Forest Reserve, Ondo State, Nigeria

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ABSTRACT: Land use and land cover (LULC) intensified by the conversion of natural resources for food purpose, urbanization, and other socioeconomic benefits as affected forest reserves and made them undergo rapid, wide-ranging changes. This study examined the use of GIS and remote sensing techniques to gain a quantitative understanding of the spatiotemporal dynamics of LULC. Maximum likelihood classifier approach was used to detect LULC changes in the study area of 1989 to 2019 using three Landsat images from 1989, 2004 and 2019. The observed changes were indicative of a decrease in the expanse of the forested area of (1989 to 2004), with 1989 having (89.2%) and 2004 (74.1%) with a differential range loss of (-15.1%), and a differential annual rates of deforestation of (-1.236436715). During the following 15 years (2004 to 2019) the annual rate of deforestation has increased to (1.303364215) with year 2019 recording (90.1%). The overall annual deforestation rate in the forested area of the studied period (1989-2019) is 0.033464, which implies that there is a percentage gain in forest. It is observed in this study that the highest deforestation rate was registered between 1989 and 2004. Non-forest occupied 10.8% in 1989 increasing in year 2004 by25.9% with a positive annual rate of change (5.831312231) and negative annual rate of change (-6.411388077) between 2004 to 2019, meaning there was loss in non-forest cover. The overall annual deforestation rate in the non - forested area of the studied period (1989-2019) is -0.29004. According to this evolution, the annual rate of deforestation was estimated to be (0.033464%) for the three defined periods in the forested area. So therefore to avoid drivers leading to changes in land use land cover stressing the complexity that is related to sustainable management of protected areas, urgent action is necessary to reduce loss of biodiversity due to deforestation and land degradation.

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The increasing populace of humans in Nigeria and other developing countries has led to undiscerning use of land resources not considering the short and long term socio-economic and ecological effects (Chima and Ihuma, 2014). The forest is an integral part of the environment that offers unquantifiable benefits and services that makes life on earth possible by contributing to national economic development of many countries (Othow *et al,* 2017). The rapid increase in the world population, which necessitates an increase in anthropogenic activities, has resulted in speedy alteration in the land use and land cover (LULC), leading to forest deterioration and transformation of fertile land to urban construction with significant impact on the ecosystem (Al-sharif and Pradhan, 2014). It has been recorded that many countries in the world are faced with rapid, wide-ranging changes in land use e.g., human activities and various utilization of the land and land cover e.g., physical characteristics of the land surface (Mas, 1999). Deforestation has many negative effects on the environment. The most dramatic impact is loss of habitat for millions of species with serious implication for eco – tourism and loss of biodiversity. Deforestation also drives climate change, and is considered to be one of the contributing factors to global climate change (Bradford, 2015). Nigeria has one of the highest rates of deforestation in the world, having continuously lost about 410,100 hectare per year between 2005 and 2010 at a rate of 3.12% per annum (Ozor and Odo, 2008). The main drivers of deforestation in the country have been agriculture, logging, grazing, urbanization, road construction and mining (FAO, 2010, Ozor and Odo, 2008). Most of the endangered animals of the world and over 1.6 billion people depend on forest for their livelihood (FAO, 2010), but then according to (Chima and Ihuma, 2014) deforestation is still persistent despite the apparently massive environmental consequences associated with it. (Al-Idrissi *et al,* 1996), also emphasized in the region of Al-Jabal Al-Akhdar how many of these forests are losing their forest lands resulting to a great

threat of deforestation for agriculture expansion, urbanization, and various other purposes. Deforestation is a non-homogeneous process and it's of interest to focus on the worst affected area in economic or legal reasons (Ramseh *et al,* 1997). The rate of deforestation has been estimated variously for different parts of the world, in Nigeria, the annual rate of deforestation has been estimated as ranging between 3% to 5% (Ojo, 1993). Tropical forests are among the richest and most complex terrestrial ecosystems supporting a variety of life forms of not less than half of all species on earth (Phillips, 1996) and a tremendous intrinsic ability for self-regeneration if properly maintained. Sahney, (2010), also stated that the world's forest is currently been faced with the challenge of deforestation and it is estimated that about 145,000.06sqKm of forest is lost yearly. Currently, there are inadequate statistical data on the available forest cover of Nigeria and this makes it quite challenging to estimate and validate the amount of forest cover lost to deforestation. Therefore the application of remote sensing as an act of acquiring data from an object or a phenomenon without having physical contact with the object is most recommended in modelling and detecting changes in forest cover dynamics, because remotely sensed data offer a wide range of versatility and its application in monitoring forest resources cannot be over emphasized. The objective of this study is therefore to check the rate of deforestation, estimate amount of forest lost and identify the changes in Oluwa Forest Reserve of Ondo State, Nigeria over a period of 30years using remote sensing.

MATERIAL AND METHODS

Study Area: The study area is Oluwa Forest Reserve as shown below in (Figure 1). The Forest Reserve is located in Ondo State within the south-western Nigeria and in the rainforest vegetation belt. Oluwa Forest Reserve is located approximately between 6˚49′23″N, 4˚40′26″E and has a land area of 829km^2. The Forest Reserve lies approximately between 300M and 600M above the sea level (Iloeje, 1981). Most rivers and streams draining this area rise from the southern part of the Oluwa Forest Reserve, notable among the rivers are the Oni, Oluwa, Ominla and Owena rivers. The climate of the study area can be described as humid tropical one (Fosberg *et al,* 1961 and Garnier, 1961). Mean annual rainfall ranges from 1,200mm to 1,450mm and temperatures are high throughout the year with a mean of about 27°C and an annual range of about 3°C. The natural vegetation of the area is the tropical rainforest characterized by emergents with multiple canopies and lianas.

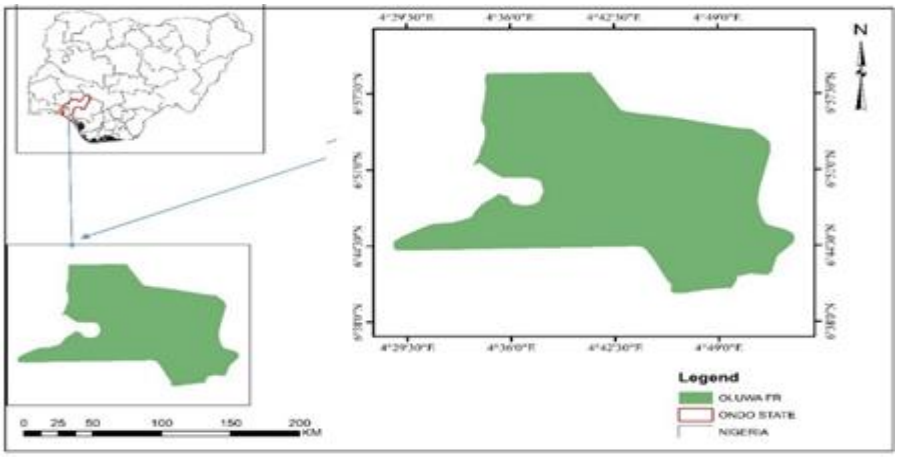

Fig 1: Map of the study Area

Data Collection: Landsat TM, ETM+ and OLI images of 1989, 2004 and 2019 were used for the study within the span of 30 years using Geographic Information System software (ArcGIS 10.3) version. Three Landsat satellite scenes for Path/Row 190/055 from three types of sensors were downloaded from the United States Geological Survey (USGS) website https://earthexplorer.usgs.gov/. (Table 1) shows the characteristics of the Landsat images used in this study. To assure the best comparability, images that were captured in March (dry season in the South-Western part of Nigeria) when the sky is usually clear, which enabled obtaining cloud-free imageries with the best visibility. The images were masked using the already vectored shape file of the forest reserve boundary to clip out the forest reserve from the Landsat images. The already clipped images were further processed using the maximum likelihood supervised classifier to classify the imageries into the following classes as shown below in (table 2).

Table 1: Characteristics of the Acquired Satellite Imageries

Spacecraft	Sensor ID	Path & Row	Spatial Resolution	Acquisition Date	Source
Land Sat 4	TM	190/055	30 M	03/12/1989	U.S. Geological Survey
Land Sat 7	ETM+	190/055	30 M	03/12/2004	U.S. Geological Survey
Land Sat 8	OLI	190/055	30 M	03/15/2019	U.S. Geological Survey

Table 2: LULC Classification Category

S/N	LULC Classification	Definition of Terms
1	Forest	A large area of land covered with trees.
2	Non- Forest	Area managed for uses other than for the production of timber.

*Annual Rate of Deforestation***:** Forest loss can be measured using satellite imagery and spatial analyses (Puyravaud, 2002).The annual rate of change is calculated by comparing the area under forest cover in the same region at two different times (Puyravaud, 2002). According to the (FAO 1995), the annual rate of forest change is derived from the compound Interest Law and should be calculated as stated in equation 1 below:

$$q = \left((A_2/A_1)^{1/(t_2-t_1)}\right) - 1 \qquad (1)$$

The annual rate of deforestation was calculated by comparing the area under forest cover at two different times. The period covered in estimating the rate of deforestation is from 1989 to 2019. Different methods have been used to estimate the annual rate of change. But in order to standardize the methods and avoid confusion, (Puyravaud, 2002) devised a new formula which is derived from the compound interest law and also the mean annual rate of change which is used in the context of this study in equation 2 below:

$$r = (1/(t_2 - t_1)) \times \ln(A_2/A_1) \qquad (2)$$

Where A_1 is the class area at the initial time (t_1) and A_2 is the class area at the final time (t_2) according to the land use-land cover maps i.e: t_1 is (first year 1989); t_2 is (second year 2004); A_1 is (value of first year); A_2 is (value of second year)

RESULTS AND DISCUSSION

LULC change detection of Oluwa Forest Reserve in 1989, 2004 and 2019: In 1989 Oluwa Forest Reserve recorded more of forest than Non forest areas. Forest in area percentage accounts for 89.2 %, while non forest area in percentage accounts for 10.8% as shown below in (table 3). The statistics as derived from the map for the LULC distribution for the study area in 1989 shows that Forest occupies the highest class with 89.2% of the total classes, which implies that the forest reserve was still intact or minimally tampered with as at the time under study. In 2004 forest cover in area percentage records 74.1% and non-forest records 25.9% which shows that there's still a significant increase in the percentage area cover of the forest compared to the non-forest area percentage. Thou from the classification of 2004 imagery, it was established that there is a transition in the status of the forest reserve in the span of 15 years which indicates that forest area as reduced from 89.2% in year 1989 to 74.1% in year 2004 and shows percentage change difference range of (-15.1%). While the non forest increased from 10.8% in 1989 to 25.9% in 2004 with a percentage change difference of (15.1%) within the period of the 15 years (1989 – 2004) as shown below in (table 3). In year 2019, forest is still on the increase with 90.1% area cover, while non–forest occupies 9.9%. It still implies that forest is on the increase in all of the study years it could be due to favoring environmental factors such as climatic weather, decomposition and conservation. The study area classification in 2019 established that there is a transition in the status of the forest reserve in the span of 30 years which indicates that forest area as increased from 89.2% in year 1984 to 90.1% in year 2019 which implies percentage change difference range by (0.9%), while non-forest decreased from 10.8% in 1989 to 9.9% in 2019 with a percentage change difference range of (-0.9%). Within the period of the 15 years (2004 - 2019) forest percentage change difference range of (16%) occurred meaning there was a gain, while there was a loss (-16%) for the non-forest as shown below in (table 3).

Table 3: LULC Statistics of Oluwa FR in 1989, 2004 and 2019

LULC category	**1989**	**2004**	**2019**	**Difference**	**Difference**	**Difference**
	Area (%)	**Area (%)**	**Area (%)**	**1989-2004%**	**2004-2019 %**	**1989-2019 %**
Forest	89.2	74.1	90.1	-15.1	16.0	0.9
Non- Forest	10.8	25.9	9.9	15.1	-16.0	-0.9

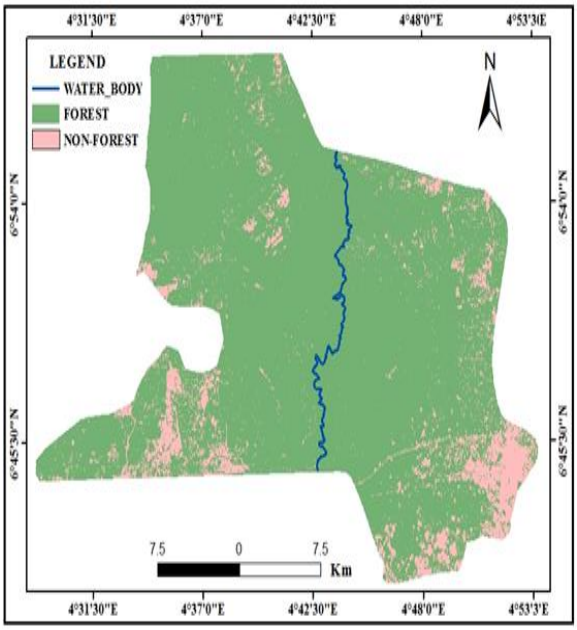

Fig 2: LULC of Oluwa FR in 1989

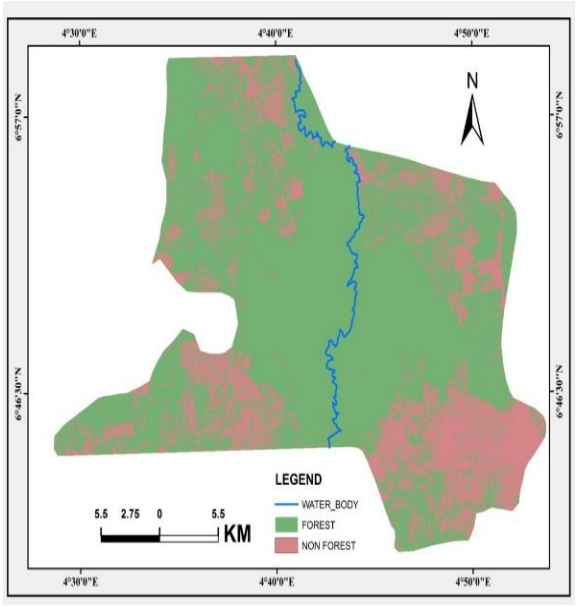

Fig 3: LULC of Oluwa FR in 2004

Deforestation rate of Oluwa Forest Reserve in 1989, 2004 and 2019: Deforestation is the process by which forested land is replaced by another type of non-forested land. Taking into account the forest cover an annual rate of deforestation was estimated. The forested area decreased slightly during the study period. It covered (89.2%) in 1989, (74.1%) in 2004 and in 2019 a drastic increase of (90.1%) was recorded. The results showed a differential annual rates of deforestation between the defined intervals of the studied period which are -1.236436715 from 1989 to 2004 meaning there was deforestation, i.e. forest loss. During the following 15 years (2004-2019) the rate has increased to 1.303364215, meaning there was percentage gain in forest.

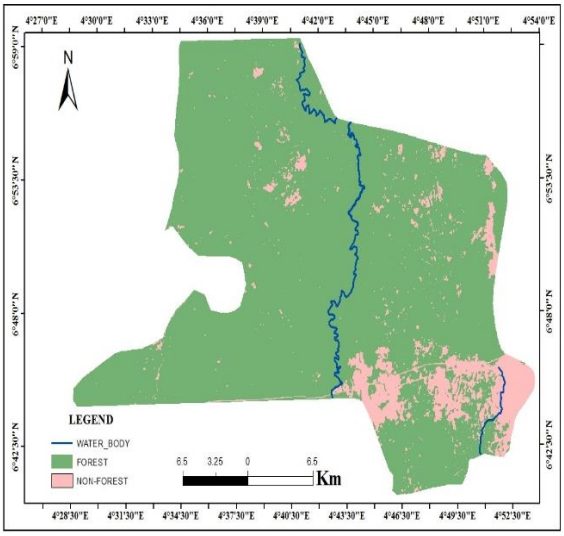

Fig 4: LULC of Oluwa FR in 2019

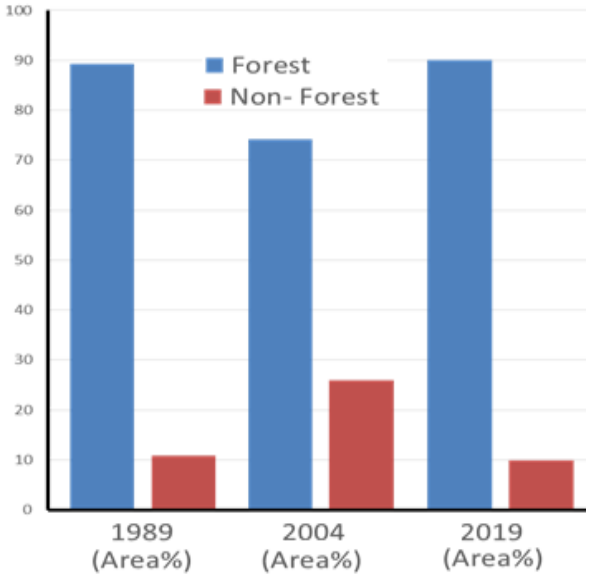

Fig 5: Bar chart showing % ARC of Oluwa FR in 1989, 2004 and 2019

The overall annual deforestation rate in the forested area of the studied period (1989-2019) is 0.033464. Non-forest occupied 10.8% in 1989 increasing in year 2004 by25.9% with a positive annual rate of change (5.831312231) and negative annual rate of change (-6.411388077) between 2004 to 2019, meaning there was loss in non-forest cover. The overall annual deforestation rate in the non - forested area of the studied period (1989-2019) is -0.29004, as shown in Table 4. Figure 5 is the graphical representation of the deforestation rate of Oluwa Forest Reserve.

Table 4: Percentage Annual Rate of Change of Oluwa FR in 1989, 2004 and 2019

LULC	1989 (Area %)	2004 (Area %)	2019 (Area %)	ARC (1989-2004)	ARC (20042019)	ARC (1989-2019)
Forest	89.2	74.1	90.1	-1.236436715	1.303364215	0.033464
Non - Forest	10.8	25.9	9.9	5.831312231	-6.411388077	-0.29004

*Conclusion***:** Remote sensing is an effective tool for mapping natural resources at a regional level. The outcomes of the investigation enumerated in this study highlight the importance of satellite digital image processing with the aid of GIS technology in mapping and detecting LULC changes. The rapid rate of deforestation is mainly occurring due to the following reasons of unsustainable large and small scale agriculture, forest fire, migration and population growth, illegal logging for construction purposes, charcoal and fuel wood production for cooking. In conclusion, it's recommended that high resolution imagery be used to enhance accuracy in further studies.

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