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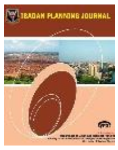

Spatio-temporal Analysis of the Pattern of Land-Use Change of Ife Natural Forest Reserve in Ile-Ife, Nigeria

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Abstract
This study examined the potential application of GIS to detect the spatial pattern of changes in forest land-cover over 33 years (1986 to 2019) using remote sensing data from Landsat Imagery captured. Supervised classification based on a minimal set of informative transition classes was followed. These are human settlements (built-up), cultivated land (Agriculture), Water (no data), forest and undisturbed forest. The study concluded that the natural forest has depleted to the tune of 2,012.71 hectares of land over the period. This implies that human activities in the forest region pose the threat of chasing the undisturbed forest into extinction with a replacement of planted forest.

Keywords
Forest, Deforestation, Forest transition, Landsat imagery, Land-cover change, Reforestation, Remote sensing

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1. Introduction

The forest is a complex web of plants, animals and micro-organisms but may vary in type and composition with location and edaphic or certain eco-climatic factors (Baldrian, 2017). Forests also generally act as a carbon sink for carbon dioxide and other greenhouse gases that would otherwise be free in the atmosphere and contribute to ongoing changes in climate patterns (Chomitz, 2000). In economic terms, forestry provides opportunities for income generation through commercial and industrial harvesting of forest products and tourism (Kaimowitz, 2003; Sunderlin et al., 2005; Katila et al., 2017). Forest cover conserves soil and improves its fertility. It ameliorates local climate through sequestration of carbon dioxide, transpiration cooling and enhanced air humidity. Forest provides habitat to several species of animals. In terms of socio-economic contributions, forest timber and non-timber forest products (NTFPs) are raw materials for many industrial products. As a result, forests play a crucial role in the economic development of countries. Pressures on forests, especially in the tropical world to provide economic resources have been increasing rapidly because of the burgeoning population in the region. This has led to unabated deforestation, which has been recognised as one of the major drivers of biodiversity loss, as well as a threat to the existence of the global ecological lung. Intense human activities in the forest such as large-scale illegal logging, industrialisation, expansion of large rubber and oil-palm plantations within the reserve, uncontrolled hunting and rise in human population have led to massive destruction of forest cover and the unique wildlife of the Forest Reserve (Ajayi, 2011, White and Oates, 1999).

Studies have attributed that forest resources are being lost as a result of actions of people, groups and institutions that convert forested areas to other uses or interfere in forests to significantly diminish the forest ecosystem's productive potential (Kyere-Boateng and Marek, 2021). Human activities such as shifting cultivation, extensive agriculture activities, private and government logging companies, mining and oil corporations, as well as ranchers, are examples of agents of gradual degradation and frequent removal of forest trees with insufficient reforestation (Baffour-Ata, Antwi-Agyei and Nkiaka, 2021; Putz et al. 2001). Loggers destroy trees and vegetation while building access roads to the desired location within the forest; conventional agriculture practices, such as open grazing or intensive collection of forest trees for fodder for grazing animals and fuelwood collection, expose the forest to further degradation. (Myers, 1991; Mather 1991; Kaimowitz and Angelsen, 1998; Orimoogunje, 2014).

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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; Abere and Opara, 2012; Nuissl. and Siedentop, 2021). The depletion of forest resources is thus a serious threat to both environmental stability and the socio-economic 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). Urbanisation also makes area available for development, bringing a growing number of people to the forest's edge (Baffour-Ata, Antwi-Agyei and Nkiaka, 2021; Wilkie et al. 2000). DeFries et al. (2010) noted that the urban population growth in Africa is associated with forest loss and that poor data quality has plagued country-level information on forest areas in the region. In Nigeria, the urban population increased by 45% and 48.9% in 2004 and 2010 but deforestation tends to occur at 4000 km2/year; forested area tends to decrease by 10.8%, annually, since 2010 (United Nations Statistics Division 2013).

On the other hand, whereas conservation of forest resources is the major aim for establishing forest reserves in most countries, many forest reserves are still not adequately managed to the extent that they can ensure the fulfilment for which they are created (FAO 2007), especially in developing countries. For example, in Nigeria, the National Policy on Forestry and Forest Management (Federal Ministry of Environment 2006) is focused on: (a) ensuring rational exploitation of our forest resources to satisfy local consumption and attain a significant export level in the long term, (b) regulation of forestry activities to ensure ‘‘conservation and environmentally sound management practices’’, (c) strengthening of forest protection activities in marginal areas to prevent harmful changes in such areas and (d) encouraging afforestation and reforestation programmes to reverse the effects of deforestation; may be adequate provisions for forest conservation in the country, problems arise in the implementations of many environment-related policies in Nigeria (Okorodudu-Fubara 1998).

Mapping of forest land-use, land-cover and its change provides valuable information for managing land resources and for projecting future trends of land productivity (Al-Bakri., Salahat, Suleiman, Suifan, Hamdan, Khresat, and Kandakji, 2013). Change detection and mapping are necessary for a variety of environmental applications such as land-use planning, landscape monitoring, natural resource management, and habitat evaluation (Wang, Chen, Gong, Shimazaki and Tamura, 2009). These changes have an impact on the forest regions' ecological stability, making it necessary to identify and investigate the status of a resource such as forest cover, which is an important part of resource management and monitoring on a local and global scale (Marçal, Borges, Gomes and Da Costa, 2005). Geographic information systems (GIS) combined with remote sensing have shown to be one of the most reliable methods for determining the extent and pattern of changes in land-cover patterns over time (Quan, Xiao, Römkens, Bai, and Lei, 2013). To monitor changes in land-cover, the techniques also provide a feasible supply of data from which updated land-cover information may be retrieved effectively and affordably (Fichera, Modica, and Pollino, 2012). The focus of the study is the spatio-temporal analyses of the pattern of land-use change in the Ife Nature Forest Reserve in the Southwestern part of Nigeria, from 1986 to 2019. The specific objectives are to identify the changes that have occurred within the period covered by the images, determine the amount and rate of changes within the period of study, highlight the possible causes of these changes and suggest possible solutions to arrest the trend.

2. Materials and Methods

2.1 The Study Area

Ife Nature Forest Reserve is situated in the southwestern part of Nigeria. It occupies a total land area of 100.084 sq. km, and the area is bounded by some communities, including Oyere-Fadehan, Araromi Owu, Araromi Oke Odo, Omifunfun, Onigbodogi and Orisunbare. The population of each settlement mentioned above ranges between 10 and 1000. Ife Nature Reserve was one of the five forest reserves established in 1925 as the Shasha Forest Reserve before the creation of the state administration in Nigeria (Isichei, 1995). Others are Omo, Oluwa, Shasha and Ago Owu. It was however the only one in the group of the reserves that is not yet backed up by a Gazette. The people are predominantly farmers, who often produce certain food and cash crops in large amounts for sale in nearby periodic markets. Many of the farmers cultivate within the forest reserves, and a discussion with some of them suggested that they were allowed by the forest officials to cultivate certain food crops. The reserve currently provides employment opportunities for the populace, including forest guards, technical managers and administrators at the Ministry office, but is capable of employing far more if focused on improvement.

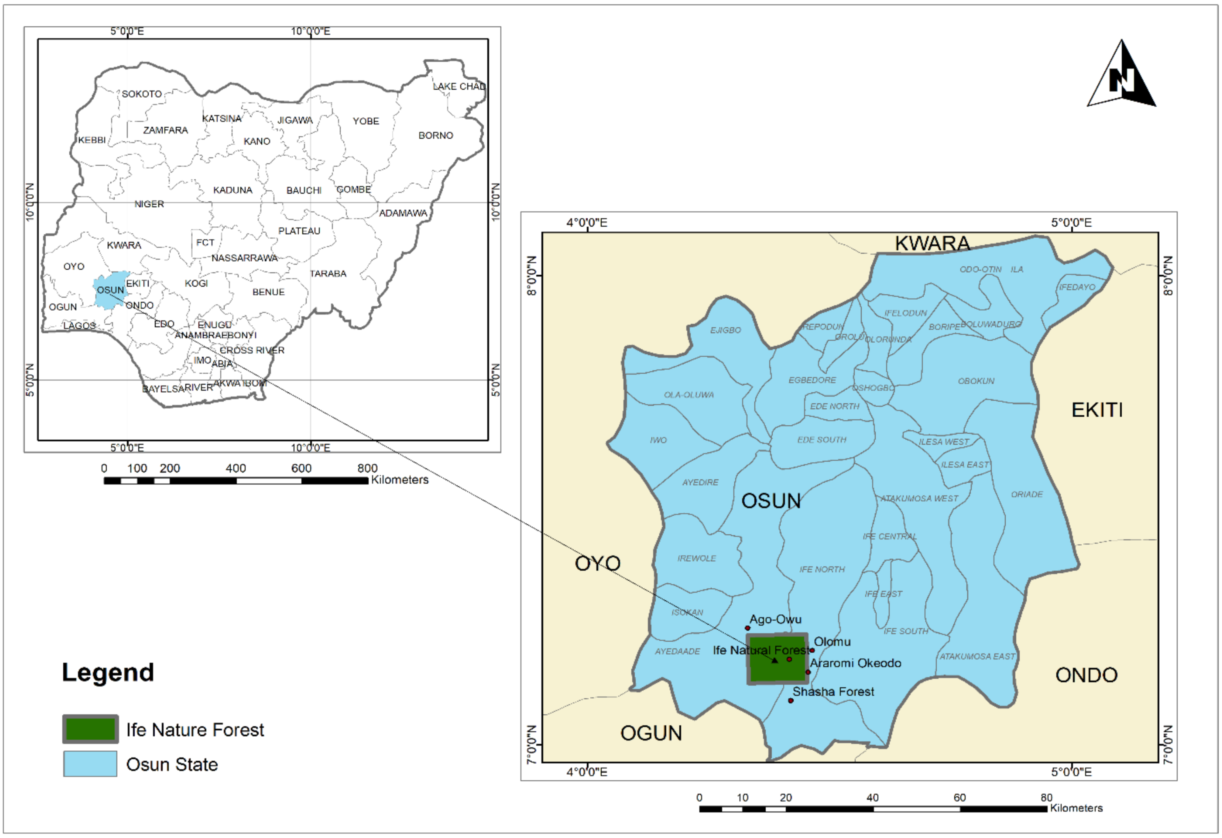

Figure 1: Ife Nature Forest Reserve

The Ife region, in which the reserve is located, is made up of four local government areas (LGAs): Ife East, Ife North, Ife Central and Ife South. The last two being the main areas occupied by the nature reserve are essentially rural regions, except for the LGA headquarters, which can be classified as semi-rural or urban Ile-Ife. Farming has traditionally been the primary source of income in the region, and commerce has just lately become more significant (Ademola 2006). Furthermore, due to increased knowledge and education, particularly as a result of the ‘housing' of higher institutions (universities and colleges) in recent years, a variety of contemporary job options have displaced popular farming in the region.

2.2 Data Sources and Image Selection

Cloud-free Landsat images of the study area that coincided with the dry season were obtained from the archives of the United States Geological Surveys website at an interval of 16 and 17 years respectively from 1986 to 2019. The quantity variation in the intensity of forest transition over the period of 33 years from 1986 to 2019 was assessed using remote sensing data from Landsat Imagery captured on 17th December, 1986, 3rd January, 2002 and 27th December, 2019 with 30m (MSS), 28m (TM), and 28m (EMT) respectively. Radiometric calibration, atmospheric corrections and dark object subtraction were performed on all the images. These procedures are important to ensure that all changes are at the earth's surface and not due to atmospheric conditions, sensor variation or solar illumination differences (Munroe *et al.*, 2007). Validation data were collected to estimate the accuracy of the land-cover classifications. Field validation data were gathered during dry season field surveys in December 2019. Land-cover validation data for 2019 were drawn from high-resolution Google Earth imagery and orthophotos.

2.3 Image Preprocessing and Land-cover Classification

Geometric correction and validation, sub-setting of scenes to span the research region, radiometric calibration, atmospheric correction and pixel re-sampling were all important phases of picture pre-processing for this work. Ground control points and a digital elevation model (DEM) were used to adjust the Landsat pictures for geometric correctness. However, it is important to note that the accuracy achieved is dependent on the quality of control points and the resolution of the DEM used in the geo-rectification process. All images were compared to a certified geometrically corrected satellite image of the research region to ensure that they were geometrically adjusted. To maximise every spectral information contained in the satellite images, all forms of atmospheric effects caused by scattering and absorption from the earth's surface radiation at the time of acquisition were performed (Lu et al., 2000). Before image classification and change detection analysis, all forms of noise contained in the Landsat satellite images were removed by converting the raw digital numbers (DN) to at-reflectance values. The noise sources were instrumental errors, changes in views and illumination and atmospheric effects were eliminated (Huang et al., 2002, Iqual, 2012).

2.4 Image Classification and Change Detection Analysis

A supervised classification based on a minimal set of informative transition classes: human settlements (built-up), cultivated land (agriculture), water (no data), forest and undisturbed forest was followed. The agriculture category is composed of areas dominated by cultivation: oil palm, banana, cocoa plantations and open spaces. The forest is composed of secondary forest and abandoned agricultural land with pockets of degraded forest. The undisturbed forest areas include rainforests with layers of dense tree canopies in most places. The use of baseline classes should be useful for large-scale mapping of land-cover change in complex and heterogeneous areas, owing to the difficulties in discriminating some Incipient Forest Transition in some areas.

Analyses were conducted at a 28m spatial resolution. The method used was previously described by Christie, Steininger, John, Peal (2007), Harper, Steininger, Tucker, John, Hawkins (2008) and Leimgruber, Kelly, Steininger, Brunner, Muller, (2005), among others. It was specifically designed for cover change analysis. The cited locational accuracy of TM and ETM+ Landsat data is 28m and 30m (Tucker, Grant, Dykstra, 2004). To minimise false change caused by locational inconsistency between dates to less than one pixel width (that is. between 15 and 28.5 m), all dates of Landsat imagery were co-registered. A subset of the data collected from the field survey were combined with existing maps and Google Earth image data to assess the accuracy of maps derived from image analysis.

3. Results and Discussions

The quantity variation in the intensity of forest transition over the period of 33 years from 1986 to 2019 was assessed using remote sensing data from Landsat Imagery captured in (on) 17th December, 1986; 3rd January, 2002 and 27th December, 2019 with 30m (MSS), 28m (TM), and 28m (EMT) respectively as presented in Table 1.

Feng et al. (2018) and Kamusoko (2017) assert that remote sensing and GIS are important in mapping and geo-referencing urban landscape across the countries of the world, especially in studies that bothers on analysing urban land-use transition. Hence, this study examined the land-use transition in the Ife Forest region, by determining the percentage of variation of changes in the use of natural forest. In this study, land-cover change was computed by examining the differences in each land-cover.

Table 1: Remote Sensing Data Set Used for the Study.

S/n	Data type	Date of capture	Resolution	Classification	Source
1.	Landsat imagery	17 Dec. 1986	30 m (MSS)	Medium Resolution	Earth Explorer
2.	Landsat imagery	03Jan. 2002	28 m (TM)	Medium Resolution	Earth Explorer
3.	Landsat imagery	27Dec. 2019	28 m (ETM)	Medium Resolution	Earth Explorer

Source: Field survey, 2020

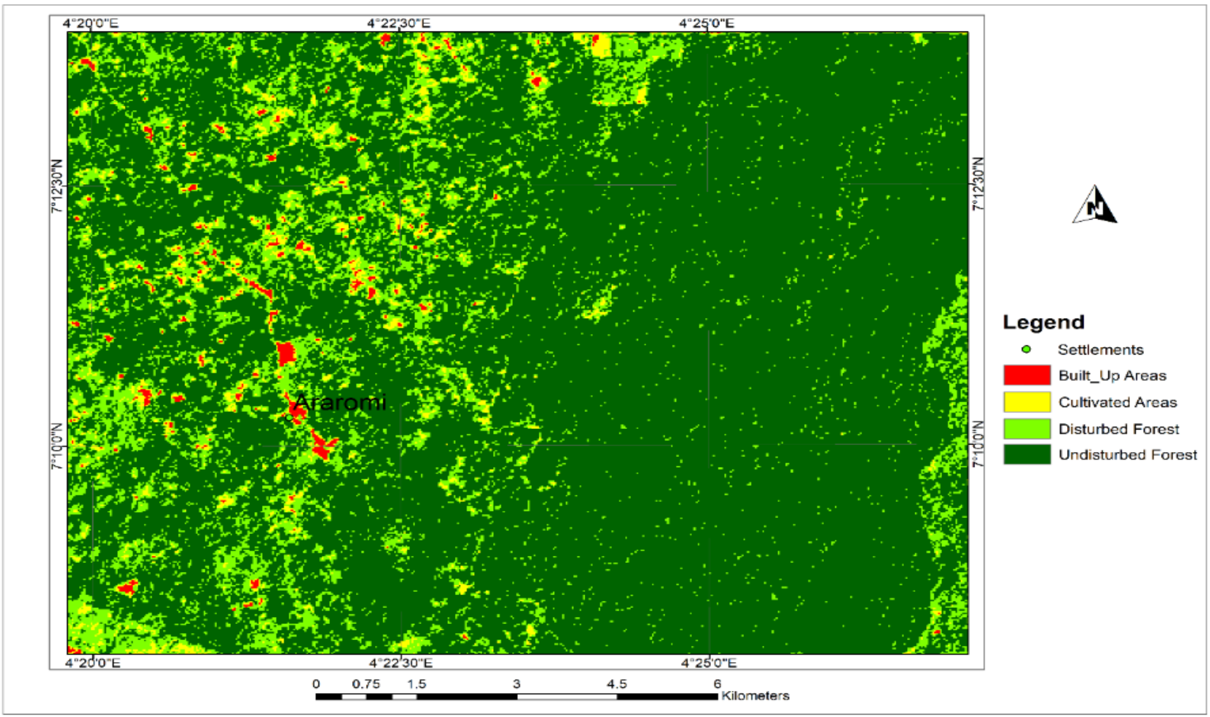

Figure 2: Land Change Land-cover Analysis in Ife Forest Reserve for 1986

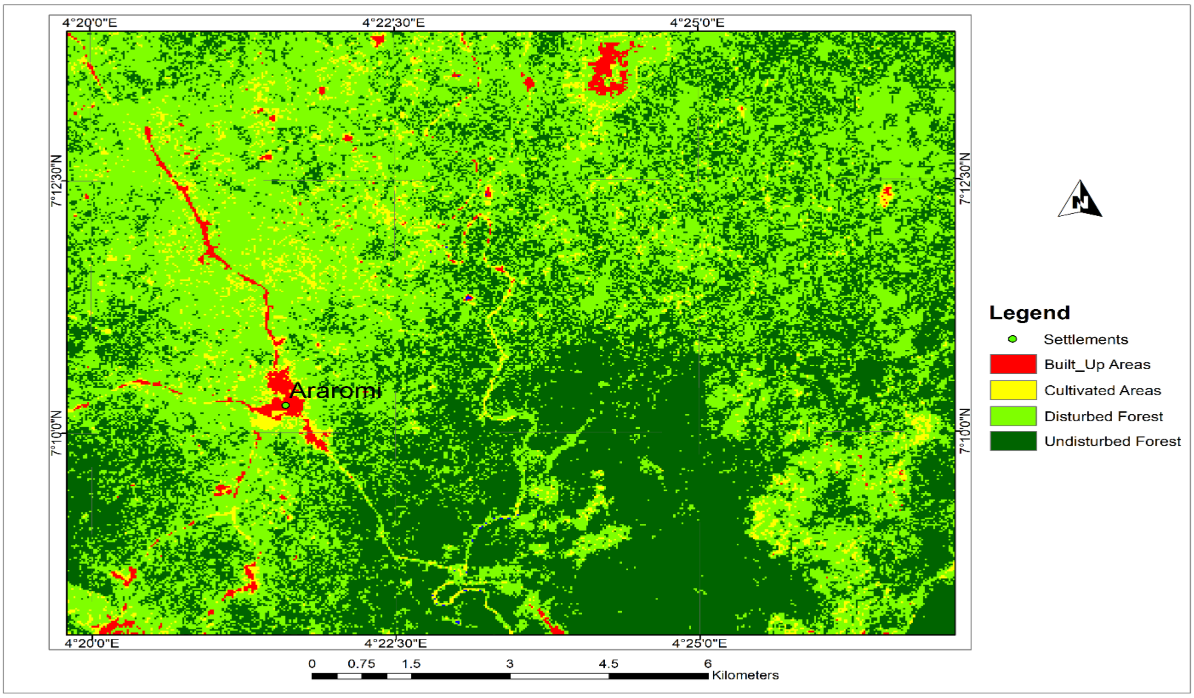

Figure 3: Land Change Land-cover Analysis in Ife Forest Reserve for 2002

Findings as presented in Table 2 revealed the land-use land-cover analysis in the study area for the study periods. From the findings, there are four classifications of land-use within the forest reserve. These are human settlements, cultivated land, forest and undisturbed forest. In 1986, settlement accounted for land-coverage of 97.71 hectares representing 0.64% of the entire forest reserve, while cultivated land-covered 413.11 hectares forest land-covered 6904.53 hectares and undistributed forest accounted for 7740.58 hectares These represented 2.73%, 45. 56% and 51.07% of the entire forest reserve. Invariably, only 3.3% of the forest reserve was allocated for cultivation and building houses, meaning that the forest is still largely in taped state as presented in Figure 5.

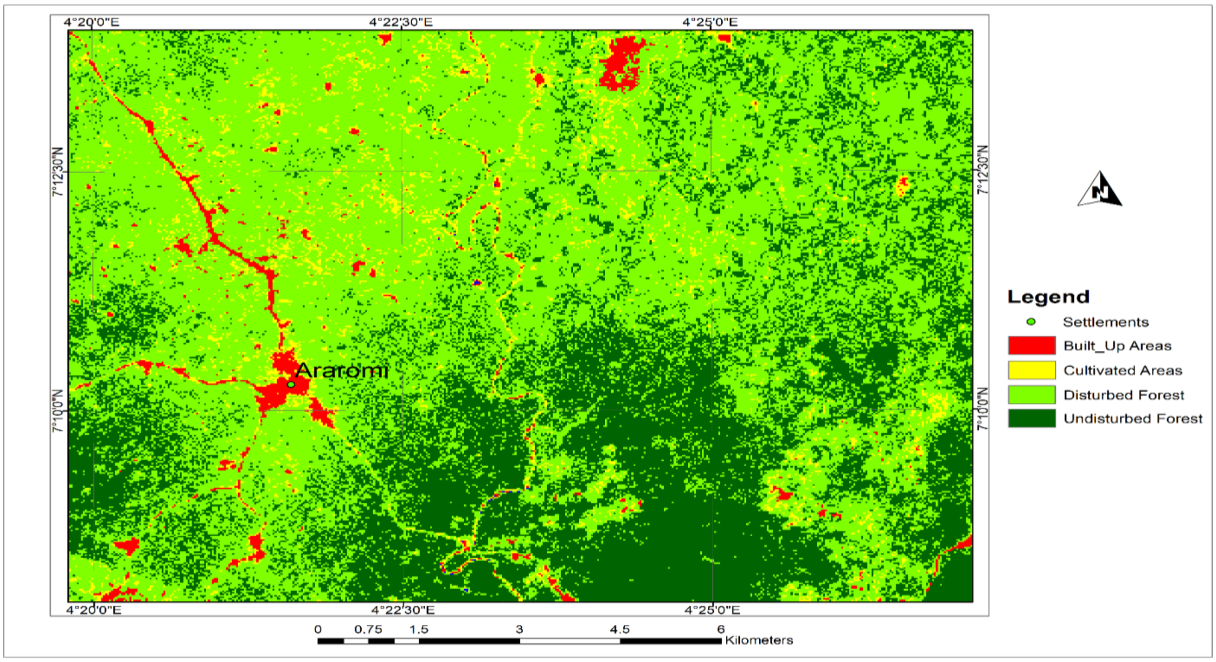

Figure 4: Land Change Land-cover Analysis in Ife Forest Reserve for 2019

Table 2: Land Change Land-cover Analysis of Ife Forest Reserve for 1986, 2002 and 2019

	1986		**1986 - 2002**	**2002**		**2002 - 2019**	**2019**	
Cass	**Area (Ha)**	**%**	**Change (%)**	**Area (Ha)**	**%**	**Change (%)**	**Area (Ha)**	**%**
Settlement	97.71	0.64	0.88	230.86	1.52	0.47	301.96	1.99
Cultivated	413.11	2.73	-0.92	273.83	1.81	2.72	686.08	4.53
Forest	6904.53	45.56	6.35	7867.21	51.91	10.09	9396.27	62
Undisturbed forest	7740.58	51.07	-6.31	6784.03	44.76	-13.28	4771.63	31.48
Total	**15155.94**	**100**	**0**	**15155.94**	**100**	**0**	**15155.94**	**100**

Source: Field survey, 2020

The study further revealed the same trend in 2002 with a slight expansion of settlement and cultivated land. However, there is a drastic expansion in the forest covering 7867.21 hectares representing 51.91% of the entire forest land, whereas undisturbed forest covers 6784.03 hectares representing 44.76% of the forest land. This means that the settlements expand into cultivated land leading to a decline of 0.92% and forest land expands into the undisturbed forest and a decline of 6.31% was observed as presented in Figure 5 and Table 2.

Findings reveal that 2019 accounted for the most expansion in three land-use such as settlements, cultivated land and forest, whereas a great decline was discovered in undisturbed forests. Settlement had a 0.47 expansion to attain 301.96 hectares representing 1.99% and cultivated land recorded a 2.72% expansion to attain 686.08 hectares representing 4.53% of the entire forest land.

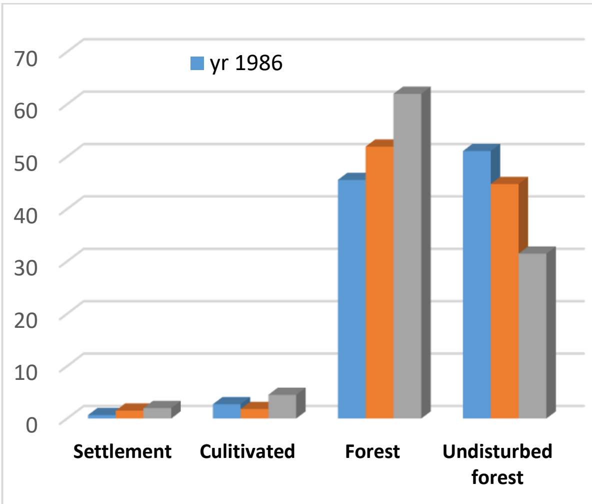

Figure 5: Land Change Land-cover Analysis in Ile Forest Reserve for 1986, 2002, and 2019

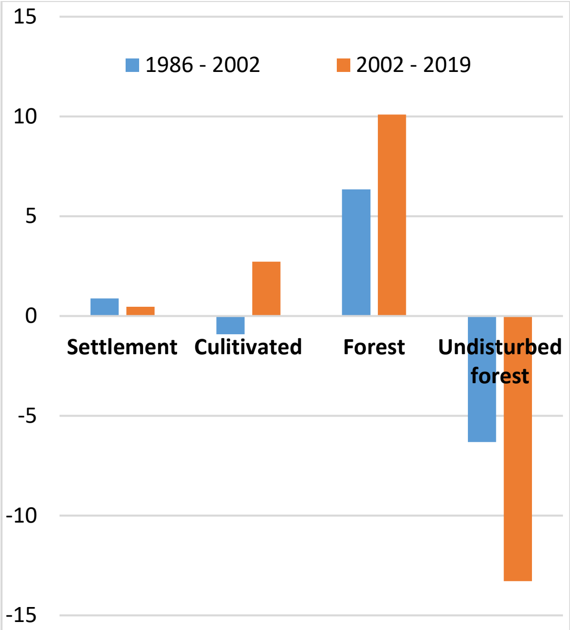

Figure 6: Land-cover changes in Ile Forest Reserve (1986, 2002, and 2019)

Forest had a 10.09% expansion, making 9396.27 hectares representing 62% of the total land area and undisturbed forest declined by 13.28% reducing the undisturbed land to 4771.63 hectares representing 31.48% of the entire forest reserve. This is an indication that the undisturbed forest witnesses decline across the year and gradually, the disturbed forest keeps expanding at the expense of the undisturbed. The implication of this finding may lead to the tragedy of the commons where the common pooled-resources are neither conserved nor preserved, having adverse effects on the local community, adjoining communities and the nation at large. This may cause wildlife extinction, human and wildlife conflicts, exhaustion of renewable and non-renewable resources, and Climate impact (global warming) among other implications.

4. Conclusion and Recommendation

The study however concluded that the undisturbed forest has depleted to the tune of 2,012.71 hectares of land over the period of 33 years, meaning that the undisturbed forest depleted at an average of 60.99 hectares annually. Furthermore, planted forest area increased at an arithmetic progression of 3.65% interval evident from subtracting percentage change from 1986 to 2002 from 2002 to 2019. Invariably, this connotes that human activities in the forest region pose the threat of chasing the undisturbed forest into extinction with a replacement of planted forest. Hence the need for the following appropriate policies to save the undisturbed forest:

- The appropriate authorities in charge of the forest region should criminalise the indiscriminate felling of forest trees.
- The part of the forest presently undisturbed should be turned into a sacred place that is out of bounds to all humans except for forest rangers.
- Strengthening of forest protection activities in marginal areas to prevent harmful changes in such areas.
- Encouragement of massive afforestation and reforestation exercises should be embarked upon to save the forest region.

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