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Application of Remote Sensing Techniques and GIS for Forest Reserve Degradation Prediction and Monitoring (1986-2015): A Case Study of Omo Forest Reserve, Ogun State, Nigeria

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Abstract
Remote Sensing Techniques with Geographic Information System can provide dependable information on land use dynamics. This study therefore examines the urban growth effects in Omo Forest Reserve of Ogun State using remote sensing and GIS. Landsat ETM imagery of 1986 and Landsat ETM+ imagery of 2015 was used to identify and classify the assessment of human intervention on Omo Forest Reserve between the study years. A GIS database of the study area and their location within 29years (1986-2015) was generated and analyzed with the aid of GIS analytical functions. These includes: Supervised classification and Spatial Query. The result showed that the intensive rate of human intervention through farming activities in the forest reserve has resulted in the loss of vegetation in the area. It also shows that population growth among communities around the forest imposes a lot of pressure on the forest reserve and the vegetation in the reserve. Forest reserve has suffered seriously and if the present trend of deforestation continues; it is just a matter of time when the whole reserve would have been converted to a bare ground. This research highlights the increasing rate of modification of forest ecosystem by anthropogenic activities and the need to apprehend the situation to ensure sustainable forest management.
Keywords: Urban Growth, Supervised Classification, Spatial Query, anthropogenic activities

1.0 Introduction

The word 'forestry' was from Latin word 'foris' meaning outside the village boundary or away from habitat land and the 'forest' is referred to as an area occupied by different kinds of trees, shrubs, herbs and grasses maintained for productivity of wood and non-wood materials. (Moran & Ostrom, 2005).

They are the natural stands of woody vegetation in which trees predominate. The forests play a vital role in the environmental conservation and forest ecosystem is most complex, self-perpetuating and magnanimous from the point of view of flora and fauna. It is the most divergence pool. Because of the forest the natural regulatory processes excel producing one of the most stable ecosystems. They have an important role in socio-economic progress of country by providing a wide range of services essential for human welfare (Adetula T., 2001). The forest is a complex ecosystem consisting mainly of trees that buffer the earth and support a myriad of life forms. (Wikipedia).

Over the past decade, assessment of forest degradation has become one of the main targets of tropical forest monitoring. Information on the extent and level of forest degradation is required to support reporting obligations under international conventions, to design and implement forest-related policies and as input to potential payment mechanisms and incentive schemes (FAO, 1992).

Forest degradation can be generally defined as: the reduction of the capacity of a forest to provide goods and services (FAO, 1991). However, this general definition can be interpreted in numerous and potentially rather contradicting ways. Depending on the scope of the analysis, the evaluation of degradation in a given forest area can be based e.g. on (1) biological diversity; (2) forest health and vitality; (3) productive functions of forest resources; (4) protective functions of forest resources; and (5) socio-economic functions of forests (FAO, 1992).

Different drivers of tropical forest degradation (e.g. unsustainable logging or shifting cultivation) cause varying effects in forest ecosystems, ranging from structural changes such as canopy cover and biomass reduction to more subtle effects including e.g. minor alterations in ecosystem services. Furthermore, different types of forests (e.g. humid evergreen and dry deciduous forests) respond differently to the numerous types of activities taking place in tropical forest areas. Therefore, optimal approaches for monitoring forest degradation by remote sensing are likely to vary considerably depending on the driver of degradation, the type of forest concerned, the intensity of the impact as well as on the geographical location, and combined use of different data sources and methods may be required (De Sy et al., 2012).

Available records in the department of forestry shows that Nigeria has a total of 1160 constituted forest reserves covering a total land area of 10,752,702 hectares and this represents about 10% of the total land area. This excludes from the Games Reserves and National Parks. However, Federal Department of Forestry argues that deforestation in Nigeria is now progressing at the rate of 3.5% per annum.

Forest and forest plantation are very important natural resources relied upon by man for food, furniture, fuel wood, timbers, animal and plants to mention a few. In most developed countries, exploitation of these forest resources take place consistently for various purposes which varies from commercial to non-commercial, need for space in road construction shifting agriculture, firewood harvesting, construction of residential building, sand excavation etc.

There are several drivers of forest degradation which includes unsustainable selective logging (legal and illegal), shifting cultivation, small-holder forest encroachments, fuel wood collection, wood extraction for charcoal production, overgrazing, farming activities, fires and even changes of natural water regimes.

Excessive uncontrolled hunting for the commercial bush meat trade (Oates et al, 2008) was also decimating their wildlife populations. Despite the immense advantages of forests, agencies and organizations have reported great forest losses due to unfavourable forestry practices all over the world (FAO (1997).

Pressures on Omo forest reserve to provide economic resources have been increasing rapidly as a consequence of burgeoning population in the region. This led to degradation of Omo forest reserve which has been recognized as one of the major drivers of biodiversity loss which is mainly caused by forest encroachment, fuel wood collection, overgrazing, farming activities and built up area in the forest reserve.

The global drive towards sustainable environments provides critical need for studies on degradation on forest vegetation which provides useful information to resources managers with the help of GIS tools and technology.

Remote sensing (RS) and geographic information systems (GIS) have proved to be some of the most accurate means of measuring the extent and pattern of changes in land cover patterns over time (Lillesand et al, 2003, Quan et al, 2013). The techniques also provide viable source of data from which updated land cover information can be extracted efficiently and cheaply in order to monitor the changes in the land cover (Franklin et al, 2000, Fichera et al, 2012).

The spatial dimensions of land use and land cover need to be known at all times to enable policymakers and scientists to be sufficiently equipped to take informed decisions on land resources. Therefore, a wide range of scientists and practitioners, including earth systems scientists, land and water managers as well as urban planners seek information on the location, distribution, type and magnitude of land use and land cover change (Weng, 2002, Singh and Kumar 2012).The natural vegetation of the reserves has been destroyed and converted at a rapid rate from excessive logging, conversion to forest plantations (*Gmelina arborea*) and farming.

Mapping of land use/cover and its change provides in-valuable information for managing land resources and for projecting future trends of land productivity (Al-Bakri et al, 2013). Land use and land cover change-detection and mapping are an important requirement for a range of environmental applications, including land use planning, landscape monitoring, natural resources management and habitat assessment (Brooks et al, 2000, Chen and Wang, 2010). These changes have impacts on the ecological stability of the forest regions and, thus identifying and investigating the status of a resource such as the forest cover which is a crucial part in resource management and monitoring at local or global perspectives (Marçal et al , 2005).

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). Change detection is an important process in monitoring and managing natural resources and urban development because it provides quantitative analysis of the spatial distribution of the population of interest.

Macleod and Congation (1998) list four aspects of change detection which are important when monitoring natural resources:

i. Detecting the changes that have occurred
ii. Identifying the nature of the change
iii. Measuring the area extent of the change
iv. Assessing the spatial pattern of the change

Therefore, this study aim at integrating GIS and remote sensing technology in examining urban growth effects on the Omo Forest reserve during the year 1986 to 2015 in Ogun State. The specific objectives are:

i. To identify the changes that has occurred within the period covered by the images
ii. To determine the amount and rate of changes within the period 1986 to 2015
iii. To highlight the potential causes of these changes and suggest possible solution to stop the change.

2.0 The Study Area

2.1 Location of Omo Forest Reserve

The study covers the Ogun State Forestry Plantation of Omo Forest Reserve. Omo Forest Reserve is located between Latitudes 6° 35′ 09.90"N to 7^0 06′ 04.94"N and Longitude 4′ 04′ 27.28"E to 4^0 35′ 22.16"E extending over an area of about 57km by 57km. Having elevation of 76 meters (249.3ft). Located in Ogun State, about 135km north-east of Lagos and some 20km from the coast, Omo Forest Reserve lies within a tropical lowland rainforest and it has the most complex and productive vegetation type in the country; estimated that it supports about 8000 species of plants. The reserve's terrain is undulating and elevation reaches about 300m on some rocky hills. The eastern border is formed by the Omo river which, with its many tributaries, drain the reserve. Omo is contiguous with five other, highly degraded, Forest Reserves, the largest of which is Oluwa Forest Reserve to the east. The Omo river lies somewhere within the 132,000 hectares of land, which make up the forest reserve. Within this expanse of land is a 460-hectare forest block, to the south of the confluence of the Omo River, which has its tributary in the Owena River. This 460 hectare block is constituted of a so-called 'virgin' forest which has been declared a Strict Nature Reserve (SNA) and a Biosphere Reserve by the government. The Omo forest Reserve is bounded by Ijebu Igbo and Osun Forest Reserve and Oni River in the East. The Oni River flows down from North to South West and Meets Shasha River at a point after Sunmoge thereby entering the Lekki Lagoon at Orubu.

2.2 Climatic Condition Around Omo Forest Reserve

The reserve lies within the Equatorial belt and has an average annual rainfall is over 2,000mm. November or part thereof I often times dry along with December and January each year. Sometimes, double maximum of rainfall is experience when a dry period would exit between July and August break. Temperatures are high in the dry season when up to 33^{0}_{c} could be reduced. The rainy season I lower and ranges between 21^{0}c and 28^{0}c.

2.3 Relief, Drainage, Geology and Soil

Omo Forest Reserve, on the average is more than 100m above sea level. The area is hilly and undulating without significant hillock and peaks. The relief generally is characteristics of anticlines and synclines. The drainage pattern of Omo Forest Reserve is complex because of the geology and soil. The synclines often exhibit heavy loamy and clay soils which support poor drainage. On the other hand, where the soil is sandy with layers of gravel underneath, the infiltration capacity is very high coupled with high level of leaching.

The geology formation is Precambrian basement complex with gneisses, quartzite and schist. The forest soils are dominantly ferralitic, old and highly weathered. The texture of the forest is usually loamy and sandy, becoming heavier at greater depths, frequently with layers of gravel found between 30-60cm; the soils tend to be acidic with low cations exchange capacity.

They are characterized by quick and complete transformation of organic matter and removal by leaching of the products of decomposition including soluble salt, exchangeable bases and silicon. Burning of forest trees and forest litter raises the pH level and provides a suitable soil for raising food crops in the first year. Without proper soil maintenance, the fertility depreciates fast from the second year. If the soils are not maintained under forest cover, surface soil erosion would set in.

2.4 Vegetation

The vegetation is mixed moist semi-evergreen rainforest. Due to selective exploitation in the past, the forest is largely mature secondary, with pockets of primary forest along river courses and in other areas where log extraction is difficult.

3.0 Materials/Method

3.1 Method of Data Collection

For this study, data were acquired from a number of sources. Since the nature of cover monitoring requires images of different time period, and that change detection analysis is carried out most effectively with not less than 2 images of the study area. The satellite images of the study area were acquired and classified using ERDAS Imagine. Figure 1.0 shows the flow chart of the study.

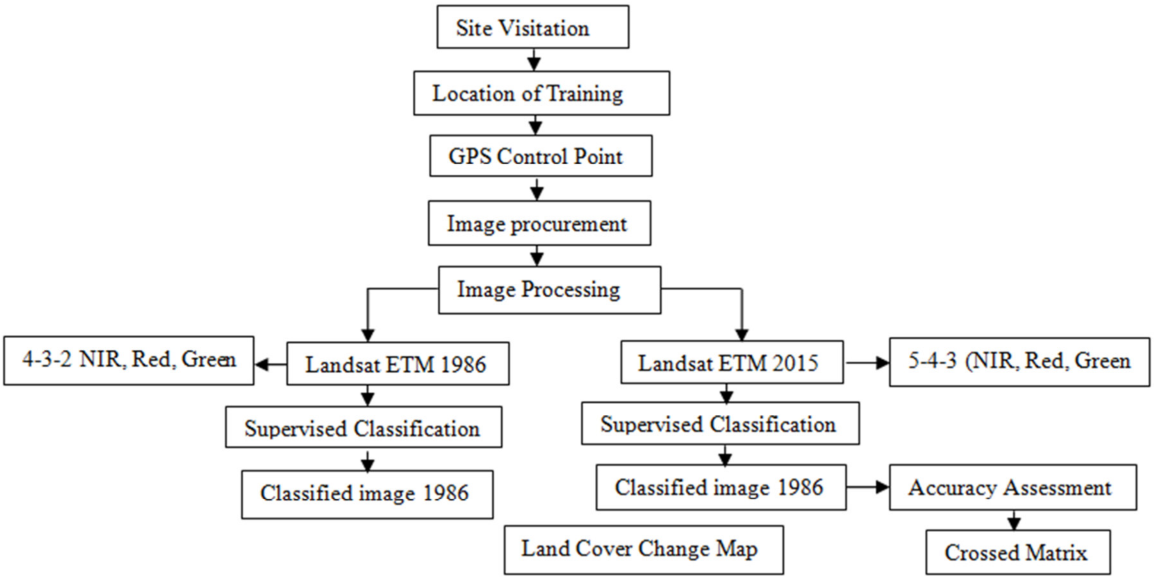


Figure 1: Flow Chart of Research Methodology

3.2 Data Acquisition

For this study, data acquisitions were from two major sources, namely the primary data source and the secondary data source.

Primary data source includes the coordinate's determination of some locations in the study area with the use of the Global Positioning System (GPS) which were acquired during the visit to the site to serve as Ground Control Points (GCPs) and aid in ground trothing which is shown in table 1. The scene of images captured is Path 190, Rows 055. Since the nature of land cover monitoring requires images of different time period, and that change detection analysis is carried out most effectively with 2 images of the study area, one LANDSAT ETM 1986 and ETM+ 2015 Satellite images of Ogun State were acquired with spatial resolution of 30m which serve as the Secondary data.

Table 1: Coordinate of GPS used as Ground Control Point

Northing (m)	Easting (m)	Elevation (m)
758594.488	650356.050	105.156
757868.492	649400.287	104.851
757876.132	650365.842	95.095

Source: Authors' Compilation

3.3 Data Conversion

Data are observation we make from monitoring the real world, collected as facts or evidence that may be processed to give them meaning and turn them into information Heywood (1988). Data can therefore be said to be main body of any study most especially remote sensing and geographic information system. For this study, The satellite images of the study area were acquired, stacked, clipped out of the study area, make the colour combination of both images of different band which was 4-3-2 (NIR, Red, Green) for Landsat ETM 1986 and 5-4-3 (NIR, Red, Green) for Landsat ETM+ 2015 images respectively and classified using ERDAS Imagine.

The image of the study area of Landsat ETM 1986 and Landsat ETM+ 2015 was georeferenced and having the same georeferenced properties and the coordinates of georeferenced image was compared with coordinates of GPS obtained during field visitation as it is shown in (table 2). The coordinate acquired when georeferenced the image was used to show the terrain, equal elevation (contour), 3D Surface and 3D Wireframe, earth curvature of the study area and these is shown in figure 2 (a-d).

Table 2: Georeferenced Coordinate of the study area

Georeferenced Coordinate of the study Area		
Northing (m)	Easting (m)	Elevation (m)
758369.679	649600.568	105.461
758492.239	649605.748	105.156
758514.34	649818.737	116.129
758526.841	650003.51	103.632
758527.593	650160.687	97.841
758416.732	650273.667	93.269
758216.011	650323.969	101.194
758071.289	650301.662	106.07
757920.173	650190.651	94.183
757924.42	649955.175	85.039
757935.859	649764.192	99.06
757930.393	649568.653	111.252
758107.965	649477.896	100.584
758175.34	649735.579	100.889
758120.415	649971.198	97.841
758187.86	650144.458	108.204
758332.454	650121.638	103.632
758381.559	649891.869	110.642
758358.861	649685.021	110.328
758481.107	649796.421	115.214
758592.697	649397.325	94.183
758594.488	650356.05	105.156
757868.492	649400.287	104.851
757876.132	650364.842	95.098
758228.601	649889.539	103.327

Source: Author Compilation (field work)

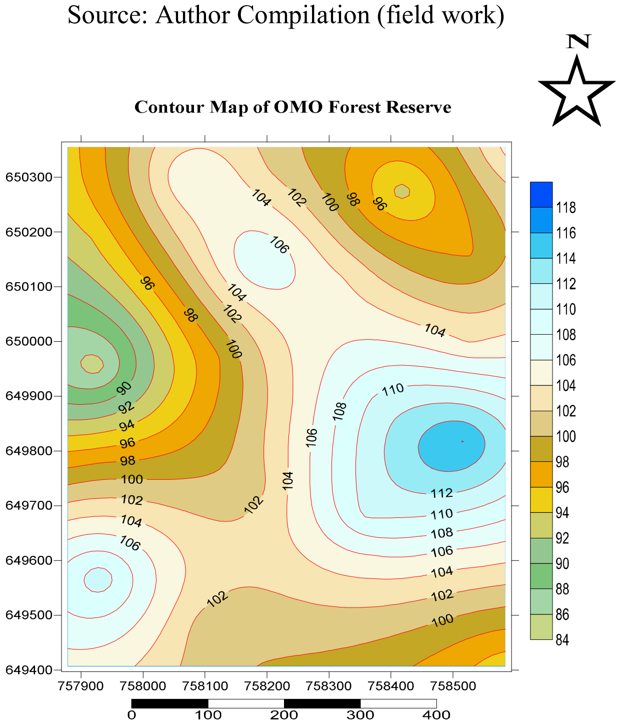


Figure: 2aContour map of the study area

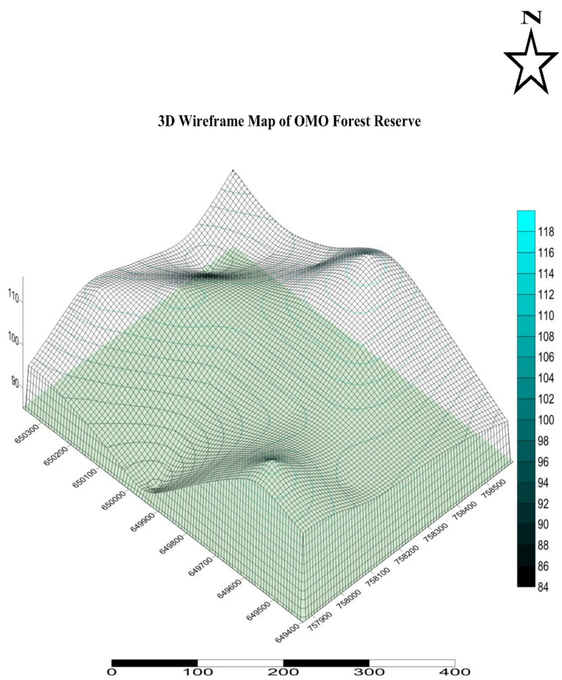


Figure: 2aContour map of the study area

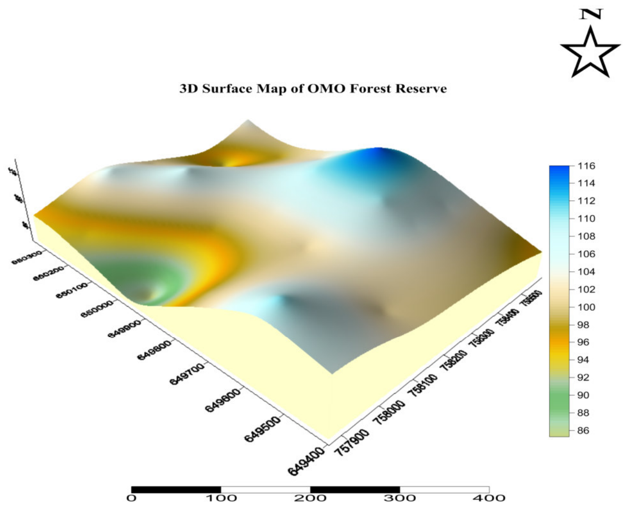


Figure 2c: 3D Surface of the study area.

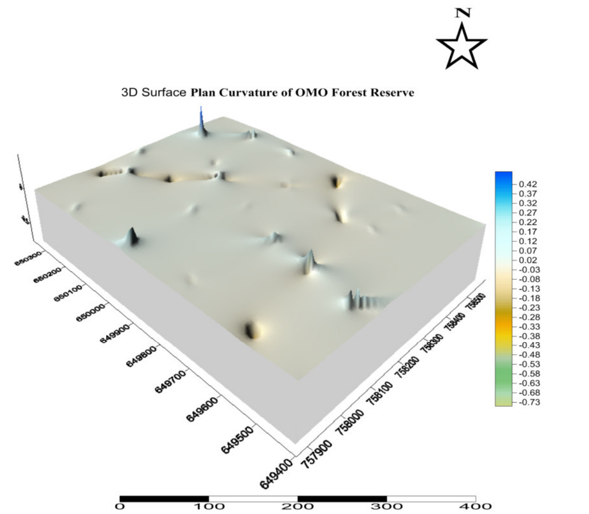


Figure 2d: Earth curvature of the study area.

Five categories of Land use / Land cover (LULC) which serve as training site were identified for this study as it is shown in table 1and they are;

- Water Body
- Vegetation
- Built up area
- Farm land
- Road

3.4 Image Classification

The two images were imported into Erdas imaging 9.3 for classification in which the extraction process of differentiated classes or theme from raw remotely sensed digital satellite data were done (Meyer, 1994). Each cluster of observations belongs to a class. Each area occupies its own class in the feature space which means that specific area of the feature space corresponds to a specific class. As each class has been defined in the feature space, the pixel of each image observed can be compared to this class and assigned to the corresponding class. There must be different spectral characteristics for different classes to be distinguished as it is shown in (figure 3), which can be identifying by comparing spectra reflectance curve. Image classification can be limited if classes do not have distinct clusters in the feature space and the results of such image classification will not be reliable. Cartographic map was produced which serve as the composite map showing portion occupied by each land use/land cover types as it is shown in figure 2. Change-detection maps were produced using ArcGIS 10.2 software as it is shown in figure (4a&b, 5a&b, & 6a&b). The images were each classified separately into built up area, forest plantation, farmland, vegetation and water body. The forest areas were further classified as natural (closed) forest and plantation

CARTOGRAPHIC MODEL

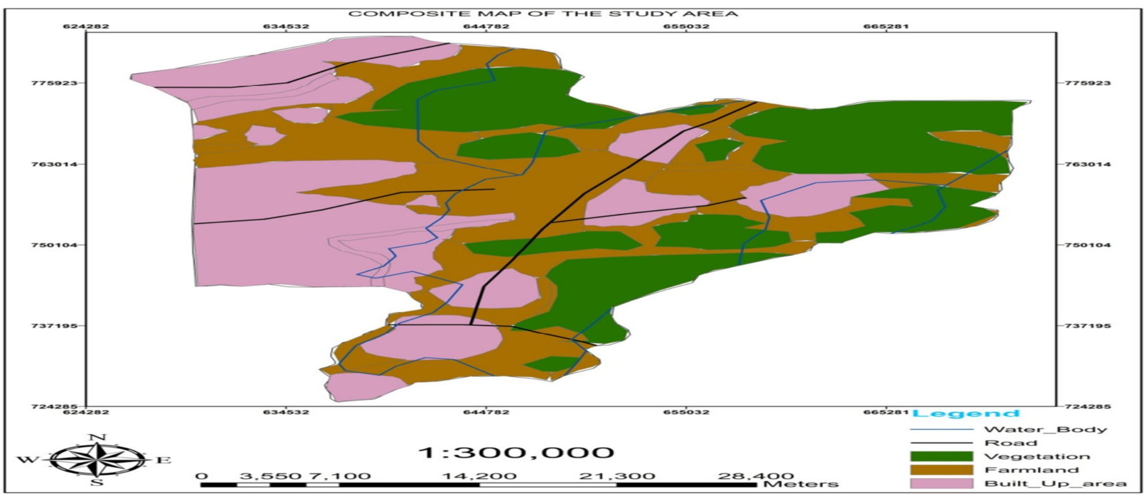


Figure 2: Composite map of the Study Area

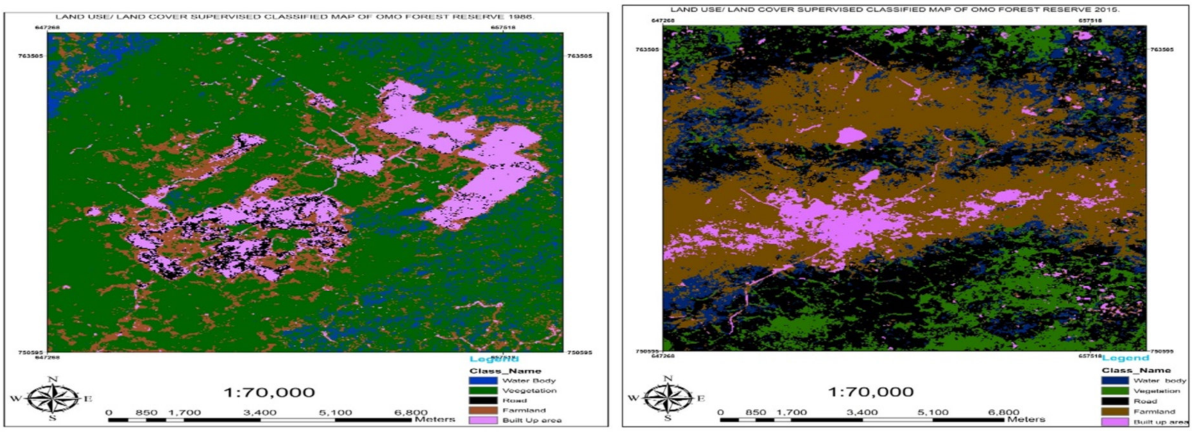


Figure 3: The land use/ land cover maps of 1986 and 2015 image.
Source: Authors

3.5 Accuracy Assessment

The promotion of classification accuracy has been always the focus of the research on abstracting the information on vegetation coverage types with the method of remote sensing classification (Congalton, 1991). The accuracy of the resulting thematic map was quantified using ground referenced data (Whithcomb et al, 2009). The five land cover types (vegetation, farmland, water body, built up area and road) were successfully confirm based on the *field check* assessment carried out during the fieldwork and ground truthing exercise using GPS. The overall classification accuracy, producer's accuracy, and the user's accuracy were then estimated (Tso and Mather, 2001, Congalton and Green, 2009). Five forest land cover/Land Use categories were identified and classified in the study. Overall accuracy for the Landsat ETM 1986 and ETM+ 2002 imageries were 92% and 87% respectively, with Kappa of 72% and 67%.

3.6 Cross Matrix and Change Map

The classified images of 1986 and 2002 were crossed and a matrix obtained using the ERDAS software to identify what has changed between the two years. The amount of changes that have occurred and the direction of changes were calculated and the final land cover change map produced in the GIS environment.

3.7 Land Use Mapping and Distribution

A supervised (full Gaussian) maximum likelihood classification was performed for the two images 1986 and 2015 and the final classification products provide an overview of the major land use / land cover features of OMO Forest Reserve for the year 1986 and 2015. Maximum-likelihood classifier assumes that the each class in each band can be described by a normal distribution (Foody, 2002, Otuke and Blaschke, 2009). This was as a result that the study area has been well known through constant field observation, in which the spectra characteristic of each class in the sampled area has been identified. Ground truth information was used to assess the accuracy of the classification

4.0 Spatial Analyses and Information Presentation

4.1 Spatial Analyses

This is the process of exposing the database to manifold GIS capability tests like spatial query and other GIS analysis. The ability of GIS is to carry out spatial analysis which differentiates it from other information systems. The database is organized into layers in order to provide rapid access to the data elements that might be required for geographic analysis.

The tabulation and area calculations differences and percentage change provide a comprehensive dataset in term of the overall land scope and the type and to know which changes has caused degradation in the Forest as this can be shown in (table 3 and 4).

Table 3: Land use/Land covers Distribution between 1986 and 2015.

YEAR	1986	2015	1986-2015	1986	2015
ACTIVITIES	**AREA(Ha)**	**AREA(Ha)**	**Difference Ha**	**AREA (%)**	**AREA (%)**
Vegetation	75538.8	15586.0	59952.8	56.65	13.78
Farmland	24669.3	47503.8	22834.5	18.45	41.99
Water Body	15605.6	11727.0	3878.6	11.70	10.38
Built up area	13337.9	28573.5	15235.6	10.00	25.26
Road	4197.33	9716.0	5518.67	3.20	8.59
Total	**133348.93**	**113106.3**	**107420.17**	**100**	**100**

Source: Authors

Table 4: Land use /Land cover Statistics in %

Land Use/ Land Cover	% Change (1986_2015)
Vegetation	-42.87
Farmland	23.54
Water Body	-1.32
Built up area	15.26
Road	5.39

Note: + = change Increase; − = change decrease.
Source: Authors

4.2 Spatial Search/Query

This is the most common GIS analytical function. Spatial query was applied to the dataset to yield the extent of changes on both 1986 and 2015 image in area of built up area differences, farmland differences, vegetation extent. This was implemented by building a query language which was created in ArcGIS software 10.2. Single criterion analysis was generated for the two images which can be shown in query (1-3), figure (4c&d, 5c&d and 6c&d) .

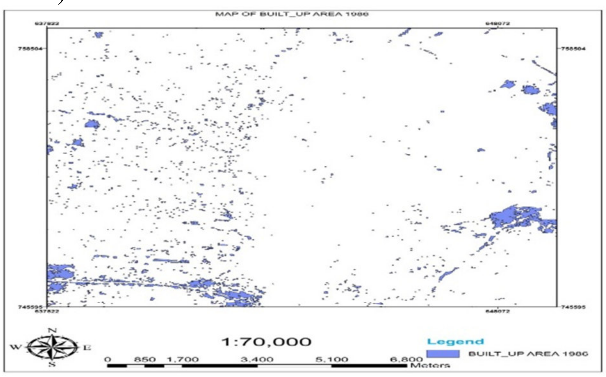


Figure 4a: Map shows Built up area in 1986 image

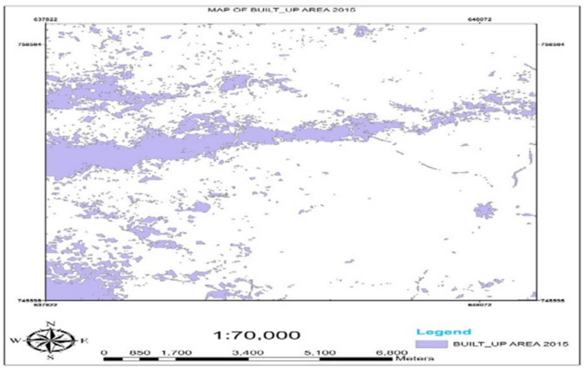


Figure 4b: Map shows Built up area in 2015 image

Query1: To display built up area in 1986 and 2015 image
Syntax:"Class_Name"= "Built up area"

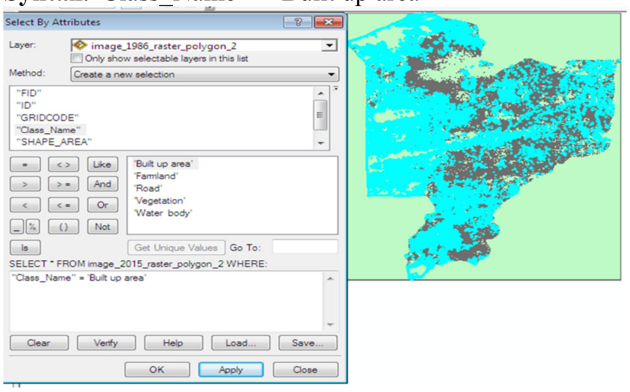


Figure 4c: Query for built up area in 1986 image

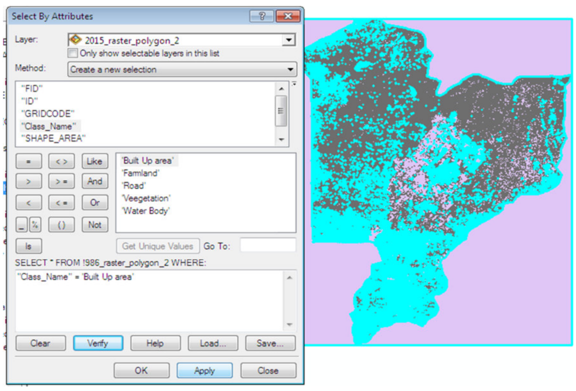


Figure 4d: Query for built up area in 2015 image

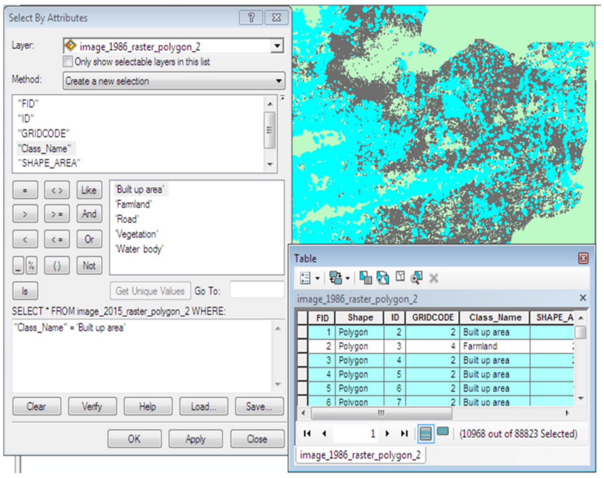


Figure 4e: Result for built up area in 1986 image

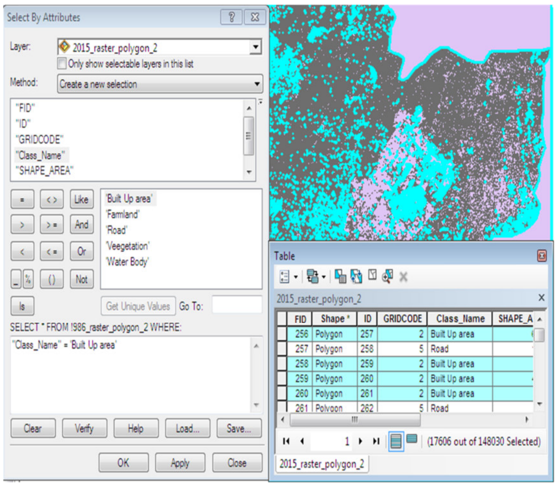


Figure 4f: Result for Built Up area in 2015 image

Source: Authors

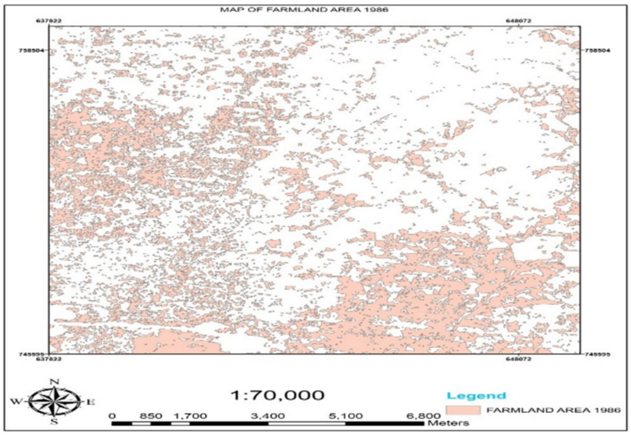


Figure 5a: Map showing Farmland area in 1986 image

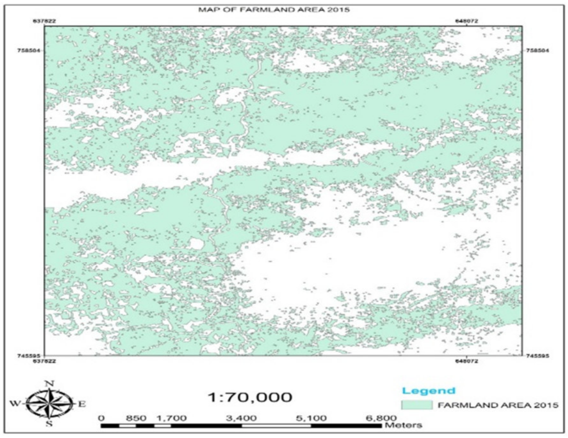


Figure 5b: Map shows Farmland area in 2015 image

Query 2: To display Farmland area in 1986 and 2015 image.

Syntax:"Class_Name"= "Farmland"

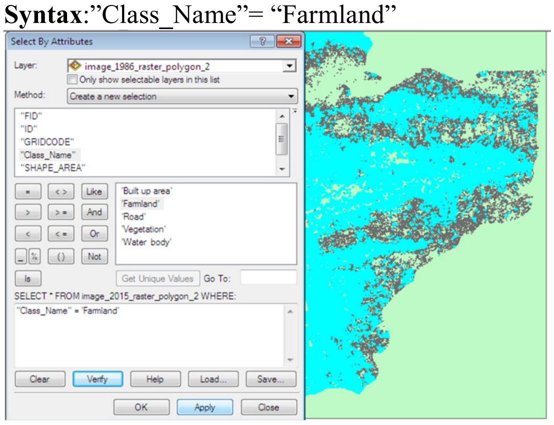


Figure 5c: Query for Farmland area in 1986 image.

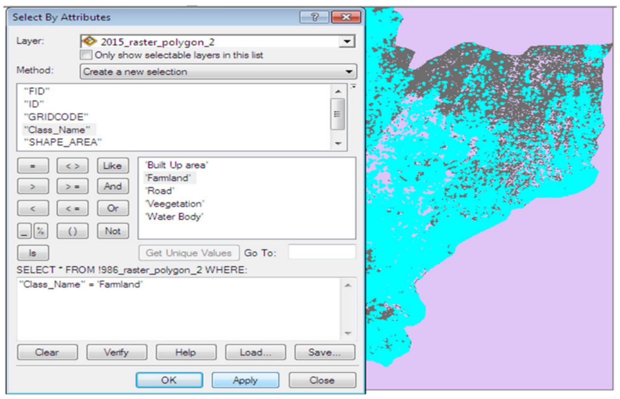
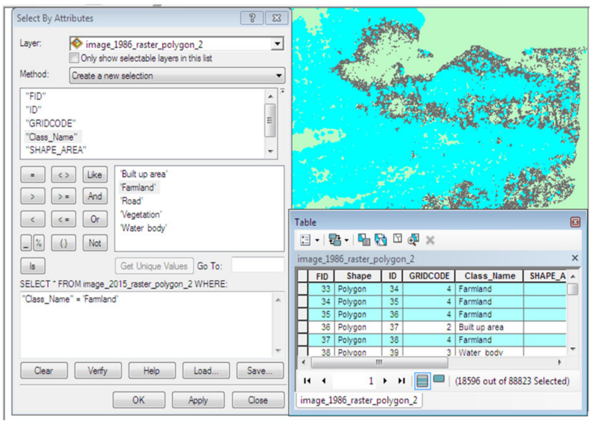


Figure 5d: Query for Farmland area in 2015 image.



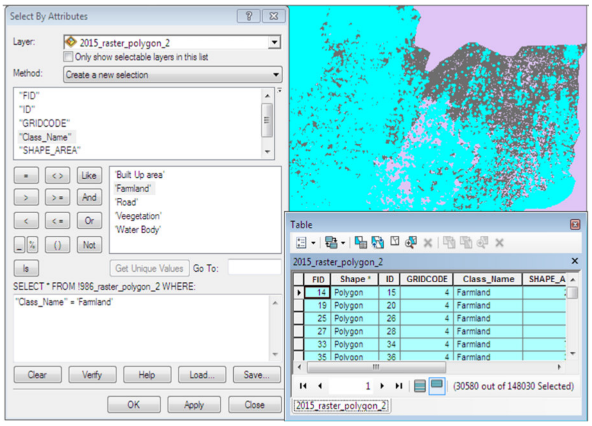
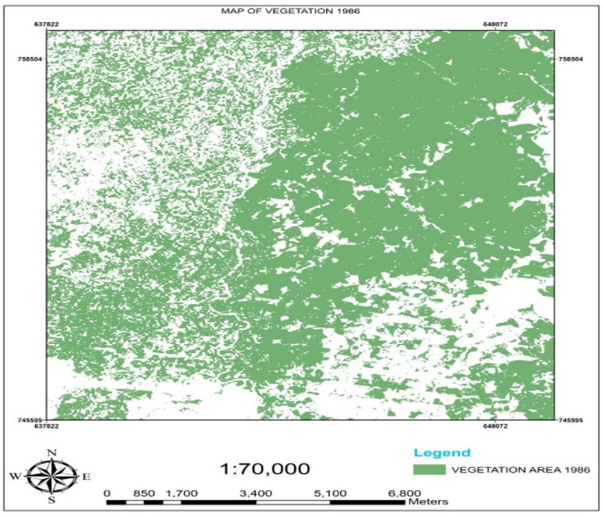


Figure 5e: Result for Farmland area in 1986 image

Figure 5c: Result for Farmland area in 2015 image

Source: Authors



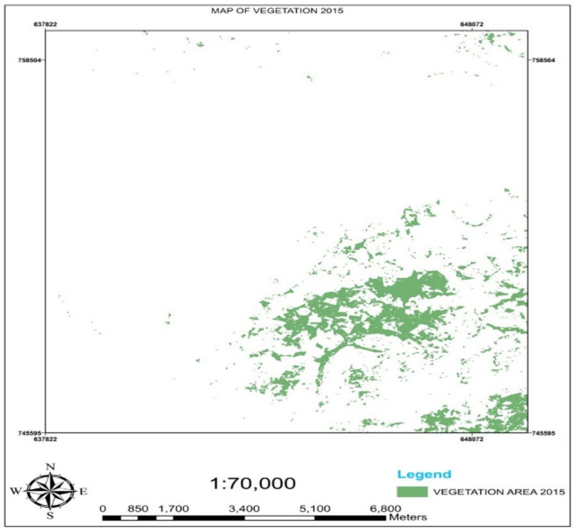
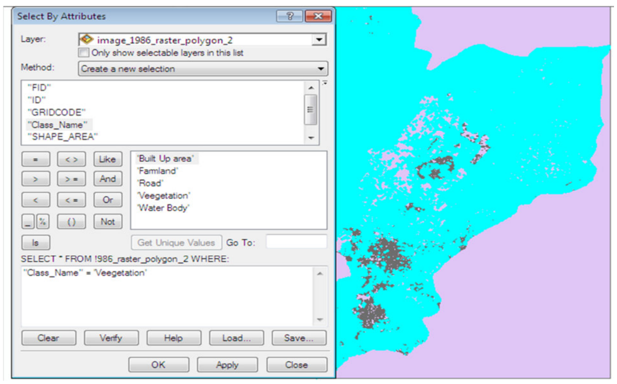


Figure 6a: Map shows Vegetation area in 1986 image

Figure 6b: Map shows Vegetation area in 2015 image.

Query 3: To display Vegetation area in 1986 and 2015 image.
Syntax:"Class_Name"= "Vegetation"



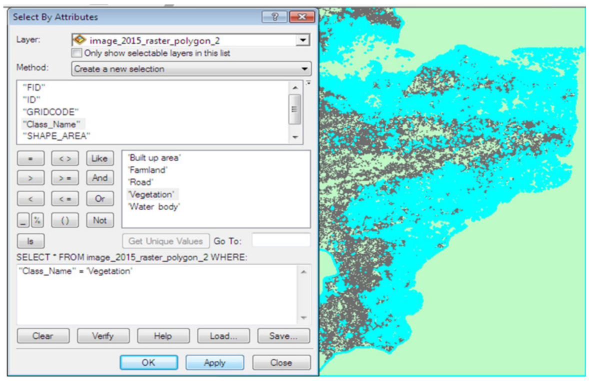


Figure 6c: Query for Vegetation area in 1986 image

Figure 6d: Query for Vegetation area in 2015 image

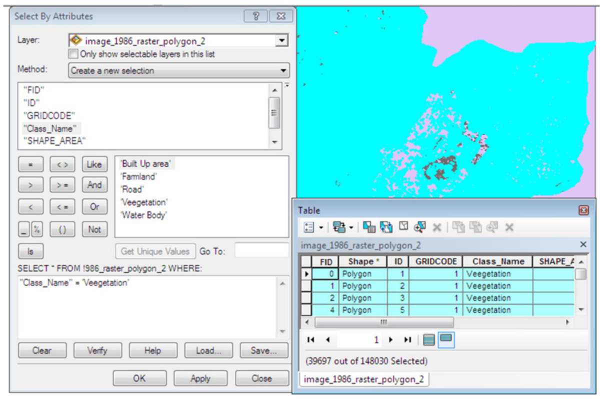


Figure 6e: Result for Vegetation area in 1986 image

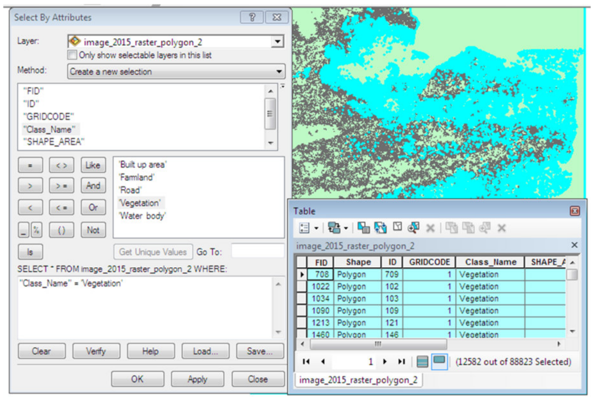


Figure 6f: Result for Vegetation area in 2015 image

Source: Authors

4.3 Discussion of Finding

The 1986 and 2015 land use/ land cover practice in the depleting OMO Forest Reserve were determine in order to ascertain the causes of degradation. Five major classes were identified and classified as the land use /land cover practices which are water body, built up area, farmland, vegetation, and road. However amongst these five major classes, two classes were identified as land use practiced that was heavily depleting the reserve; they are built up area and farmland. Query for vegetation was done to know the extent of how these two sources affect OMO Forest reserve from the two images.

$$\text{(Trend) percentage change} = \frac{\text{observed change X 100}}{\text{Sum of change}}$$

4.3.1 Area of Land Use / Land Cover Classes Lost To Other Classes

In the year 1986 vegetation account for 75538.8 ha (56.65%) while in 2015 vegetation account for 15586.0 ha (13.78%) as it is shown in chart (1, 2, 3) which shows large decrease (negative) in vegetation area by 59952.8 ha or (42.87%) of the total land cover within time period covered and this shows how the reserve been degraded. Water body account for 15605.6 ha (11.70%) in 1986 and 11727.0 ha (10.28%) in 2015 image as it is shown in chart (1, 2, 3) which shows change decrease (negative) by 3878.6 ha (1.42%) of the total land cover within time period covered. This shows that the intensive rate of human intervention through farming activities in the forest reserve has resulted in the loss of vegetation in the area. It also shows that population growth among communities around the forest imposes a lot of pressure on the forest reserve and the vegetation in the reserve.

4.3.2 Area of Land Use / Land Cover Classes Gained By Other Classes

The study shows that Farmland account for 24669.3 ha (18.45%) in 1986 image and 47503.8 ha (41.99%) in 2015 image as it is shown in chart (1, 2, 3) which shows positive change increase (Positive) in farmland by 22834.5 ha or (23.54%) of the total land cover within time period covered. Built up area account for 13337.9 ha (10.00%) in 1986 image and 28573.5 ha (25.26%) in 2015 image as it is shown in chart (1, 2, 3) which show change increase (positive) in built up area by 15235.6 ha or (15.26%) of the total land cover within time period covered. Road account for 4197.33 ha (3.2%) in 1986 image and 9716.0 ha (8.59%) in 2015 image as I is shown in chart (1, 2, 3) which shows change increase (increase) in road by 5518.67 ha or 5.39% of the total land cover within time period covered. All these activities were leading to degradation of the forest natural biodiversity which can cause Global warming.

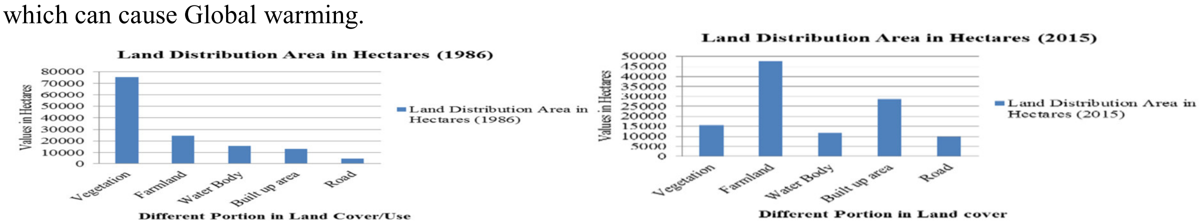


Chart 1: Bar chart showing land cover/ land use changes for 1986 and 2015image

Source: Authors

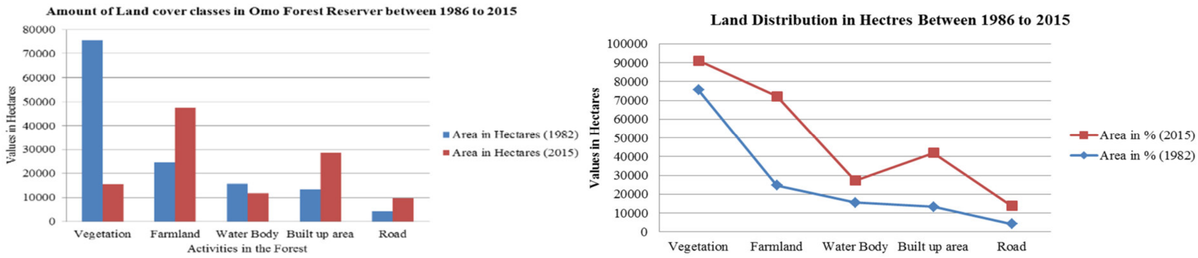


Chart 2: Amount of Land cover/Land use Distribution between 1986 to 2015

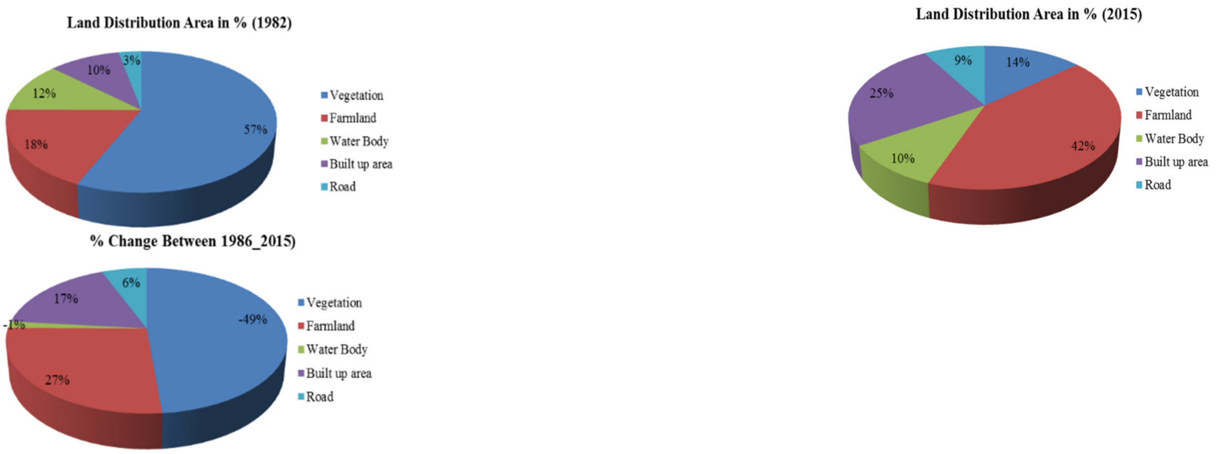


Chart 3: Land cover/ land use distribution (%) and percentage changes between 1986 and 2015 images respectively.

5.0 Conclusion

Landsat images ETM 1986 and ETM+ 2015 satellite remote sensing data were used to identify, classify, assess and interpret OMO forest reserve degradation in Ijebu east Local Government, Ogun state south west Nigeria .
GIS database of land use/ land cover categories and their changes within 29 years (1986 and 2015) was generated and analyzed. Generally, the result showed that the forest reserve was retreating due to several anthropogenic activities of man such as illegal felling of wood, farming activities, forest fire, built up areas. The rates at which the reserve has been degraded have made the area a shadow of their former selves. The local communities showed that at the rate at which the degradation of the reserve is going on, the conversion of the forest plantation to a bare ground is just a matter of time. From this study, Landsat ETM data and ETM+ data are important sources of imagery data for mapping and monitoring the dynamics of land use/ land cover in tropical rain forest.

Recommendation for Further Research

The Authors wish to recommend that Government policies that will be strict be put in place in preserving forest reserves from illegal occupations. Alternative source of energy for fire wood should be promoted in order to reduce the pressure on the forest. Non-timber forest product promotion trade should be developed to reduce the constant felling on timber resources so as to enhance rural living. Any form of forest plantation degradation should be stopped fourth with, having realized the purpose for which the reserve was meant for. The available vegetation area and the farmland must be converted into forest plantation of exotic fast growing species.

Finally, the technology of remote sensing and GIS should be employed in major studies, concerning national issues such as deforestation, desertification etc.

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