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Predictive analysis of future rainforest cover depletion in Oghara, Delta state, Nigeria

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ABSTRACT

This study utilizes remotely-sensed data and GIS techniques to predict future spatial changes in rainforest vegetation in Oghara, Nigeria. It aimed at determining the changes in size of rainforest cover from 1991 to 2019 as a basis for predicting its future size in 2050. Data were obtained from Landsat 5 TM images for 1991 and Landsat 7 ETM+ images for 2002 and 2019. The IDIRISI Selva 17.0 software which integrates the cellular automaton filter and Markov processes was used to analyse the data. The software packages used for land use/cover change detection are ENVI software version 5.3 for image pre-processing, image classification, accuracy assessment, post-classification process, thematic change detection and statistical results, and ArcGIS desktop version 10.3 (ESRI) for editing boundary of the study area, post-classification processes, map layout and visualization. The study revealed that the size of forest cover decreased from 142.49km^2 or 53.94% of the total area in 1991 to 81.30km^2 or 30.78% in 2019 and predicted to further decrease to 60.52km^2 or 22.91 percent in 2050. Thus, indicating a high rate of deforestation in the study area. The study recommends the establishment of forest reserves, enactment and enforcement of laws on forest protection and education of population on the importance and sustainable use of forest resources.

Keywords: Deforestation, Landsat images, rainforests, remote sensing, Geographical Information System (GIS).

1. INTRODUCTION

Human activities such as agriculture, industrialization and urbanization undoubtedly modify the natural land cover of the earth's surface in various ways, one of which is deforestation; a process of conversion or transformation of a forest vegetation or stand of trees to a non-forest vegetation as a result of clearing, cutting or removal of trees (Dahal, 2021). In other words, it refers to forest cover change. It is estimated that Nigeria has lost 81 percent of its forests in the last fifteen years and more than half of its primary forest in the last five years (Mongabay, 2010; Okereke, 2015). Earlier, Salami (2006) asserted that the rate of deforestation in Nigeria is 1.36 per cent per annum, and is accounted for by lumbering, which dates back to the colonial period. Furthermore, Mongabay (2010), citing statistics from the International Institute of Tropical Agriculture

(IITA), stated that Nigeria loses over 400,000 hectares of forest annually to deforestation. Consequently, modelling and ascertaining the future status of forest vegetation is a critical component of many natural resource management and decision-making processes.

Changes in land cover is a criteria to ascertain the present and future size of forest vegetation: analysing the causes and effects of land cover transition and gaining a better understanding of a region's land use structure (Verburg *et al*, 2004). The use of land cover change models is multi-dimensional. For example, they were used in biodiversity studies (Verburg *et al*, 2008), for estimating loss of vegetation cover (Echeverria *et al,* 2006), for forest management (Kamusoko *et al*, 2013; Gautam *et al*. 2021), and in urban expansion and planning (Sun, *et al,* 2007; Otokiti *et al*. 2021). Furthermore, Kamusoko *et al.* (2013) identified three types of landscape models: namely, entire landscape models, distributional landscape models, and spatial landscape models. Of these types, spatial landscape models seems to be most commonly used since the spatial details including natural and human processes have greater impacts on land cover change system. More so, progress in remote sensing and geographic information system (GIS) and their application in the determination in the spatial distribution of phenomena has enhance the application of spatial landscape models (Bielecka, 2020). For instance, Enaruvbe and Atafo's study (2014) on deforestation in part of the Niger Delta Region between 1987 and 2013 used remote sensing data and geographical information system. Also, Olayiwola and Igbavboa (2014) used similar data to monitor the growth of Benin City between 1987 and found out that urban growth in the city directly resulted in depletion of vegetation resources. Omo-Irabor (2011) study of the vulnerability of mangrove vegetation in parts of the Niger Delta, Nigeria also made use of satellite images, GIS techniques and spatial multi-criteria analysis (SMCA). However, none of these studies predict future changes in land cover.

Nevertheless, most studies on modelling and predicting future status of forests utilising data from remote sensing images are on other geographical regions (Fuller *et al*, 2011; Chicas*et al*, 2016, Lambin, 1997; Mas *et al*, 2004). Hence, this study focuses on predicting future changes in size of rainforest vegetation in Oghara. Specifically, its objectives are to; (i) determine the extent of forest cover changes from 1991 to 2019 in Oghara and (ii) predict the future size of forest cover in 2050.

2. MATERIALS AND METHODS

Study Area

Oghara composes of twenty settlements which share the same primogeniture and Pamol Estate. These settlements are divided into two sub-groups: namely, Ogharefe and Oghareki, and situated in Ethiope West Local Government Area (LGA) of Delta State, in the southern part of Nigeria. It lies within latitudes $5^0$54' 01'' N and 6^0 4' 25.00" N; and longitudes 5^0 36' 00" E and 5^0 46' 00.41"E, over an area of about 264.15 square kilometres, as depicted in Figure 1. It is bordered by the River Ethiope and its adjoining tributary in the east and south respectively. To the north, it is bordered by the Osiomo/Ologbo River, and to the southwest by Koko town in Warri North Local Government Area of Delta State.

Oghara experiences uniformly high rainfall with annual average of about 266.5cm, and a mean temperature between 24^0C (75.2^0F) and 27^0C (80.4^0F) throughout the year. The area is marked by two distinct seasons: the dry season and the rainy seasons. The dry season occurs between November and February, while the main rainy season begins in February till October. Rainfall is heaviest in July and no month is completely rainless; with January, being characterized by rainfall of up to 2.5cm of rainfall (Aweto and Igben, 2003). Between December and February, the area experiences cool, dry and dusty weather called the 'harmattan'. In addition, diurnal variation of temperatures is low with seasonal variation of about 25^0C (82^0F) in the rainy season and 28^0C (82^0F) in the dry season. Relative humidity is between 60 and 90 per cent (Udo, 1970).

Oghara is located in the lowland evergreen rainforest belt rich in valuable trees such as mahogany (*Khaya Spp*), african walnut (*Lovoa trichilioides*), iroko (*Chlorophora excelsa*), abura (*Mitragynaciliata*), sapele wood (*Entandrophragma cylindricum*) and obeche (*Triplochiton scleroxylon*). However, there are mangrove and fresh water swamp forests along major river basins with the preponderance of *Conocarpus erectus* and other woody species that grow at the edge of the mangrove swamps. The fresh water swamps is vegetated mostly by floating grass, screw pine (*Pandanas candelebrum)* and raffia palm (*Raphia hookeri*) (Igben. 2012).

The 2006 provisional national population census put the population of Oghara at 202,712 persons, made up of 102, 750 males and 99,962 females (NPC, 2006). However, the population of the area is estimated to be over 300,000 persons in 2020 using the national growth rate of 3 percent. There are primary and comprehensive health-care facilities in Oghara in addition a tertiary health institution (Delta State University Teaching Hospital). Educational institutions cover the primary, secondary and tertiary levels, consisting of both private and public types. One of the government owned polytechnics in Delta state is located at Otefe-Oghara and a private university, Western Delta University is also located in the area. In addition, the area is home to the Navy Headquarters. Logistic Command and a Squadron of the Nigerian Police (Mobile Unit), The East-West Road, which links the

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western part to the eastern part of the country, pass through the area. These facilities, couple with large expanse of fertile land for agricultural activities makes it very strategic for diverse economic activities: hence the high rate of urbanization.

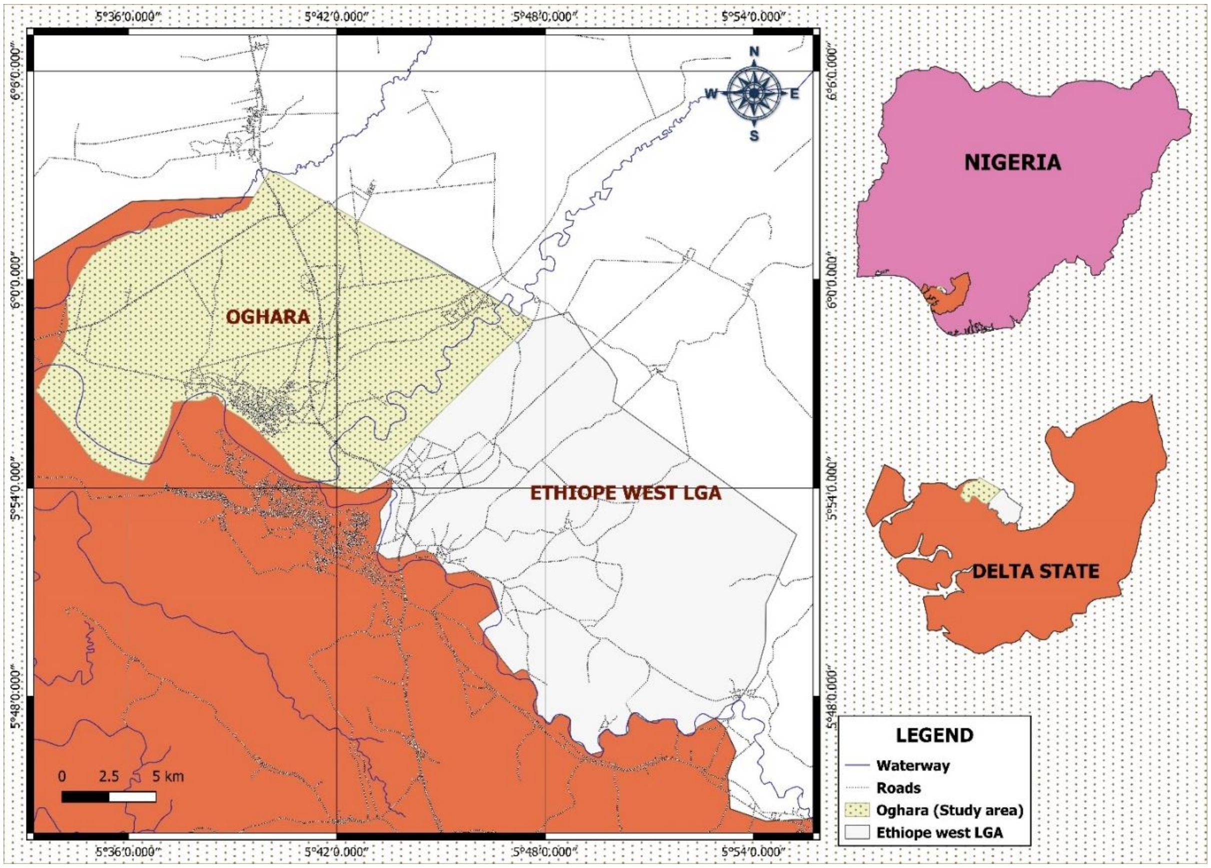

Figure 1: The study Area

Data Source and Acquisition

Landsat satellite imagery was employed in this study. Images from Landsat 5 TM and Landsat 7 ETM+ were used. The study area path and row scene (189/56) were obtained by a search function on the United States Geological Survey (USGS) website. This study accessed a 28-year temporal resolution study. Landsat 5-TM image was downloaded for the year 1991 and Landsat 7 ETM+ image for the year 2002 and 2019. In order to get quality images, all images downloaded had less than 10% land and scene cloud cover. Attempts were made to download images of same day across the years but the unavailability of quality images with less than 10% land and scene cloud cover necessitated the use of images of different days but within a week.

Table 1: Metadata for images obtained

Satellite Sensor	Scene Date	Path/row	Spatial resolution
Landsat TM	24/12/1991	188/56	30 × 30
Landsat ETM+	30/12/2020	188/56	30 × 30
Landsat ETM+	28/12/2019	188/56	30 × 30

Data Analysis

The IdirisiSelva 17.0 for future projection was used in this study. This software integrates the cellular automaton filter and Markov processes. The cellular automata (CA) is a popular spatially explicit land use modelling tool. The output of the CA model emerges from interactions between individual cells which are the fundamental modelling unit (Siddhartho, 2009). With this attribute, CA is commonly considered as powerful technique for modelling complex land use change (Gharaibeh *et al*, 2020). CA is enhanced by its natural affinity with GIS and remotely sensed data use (O'Sullivan and Torrens, 2001).

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The software packages used for land use/cover change detection study are: (i) ENVI software version 5.3 (Harris Geospatial Solutions, 2014) used for image pre-processing, image classification, accuracy assessment, post-classification process, thematic change detection and statistical results. (ii). ArcGIS desktop version 10.3 (ESRI) used for editing boundary of the study area, post-classification processes, map layout and visualization.

Analysis Process

Land cover detection process in this study can be grouped into three main processes; namely, image pre-processing, image processing and finally post-classification comparison as presented in Figure 2. Image pre-processing involves radiometric correction, geometric correction, scenes mosaic (Area with more than one scene) and masking study area. Image processing is the second stage which produces thematic classification maps of the three period images; this process consists of visual interpretation, training land use/cover samples, maximum likelihood supervised classification and finally the accuracy assessment of the classified images. The last stage is the post-classification process which includes classification refinement, change detection analysis, change detection maps and statistical report.

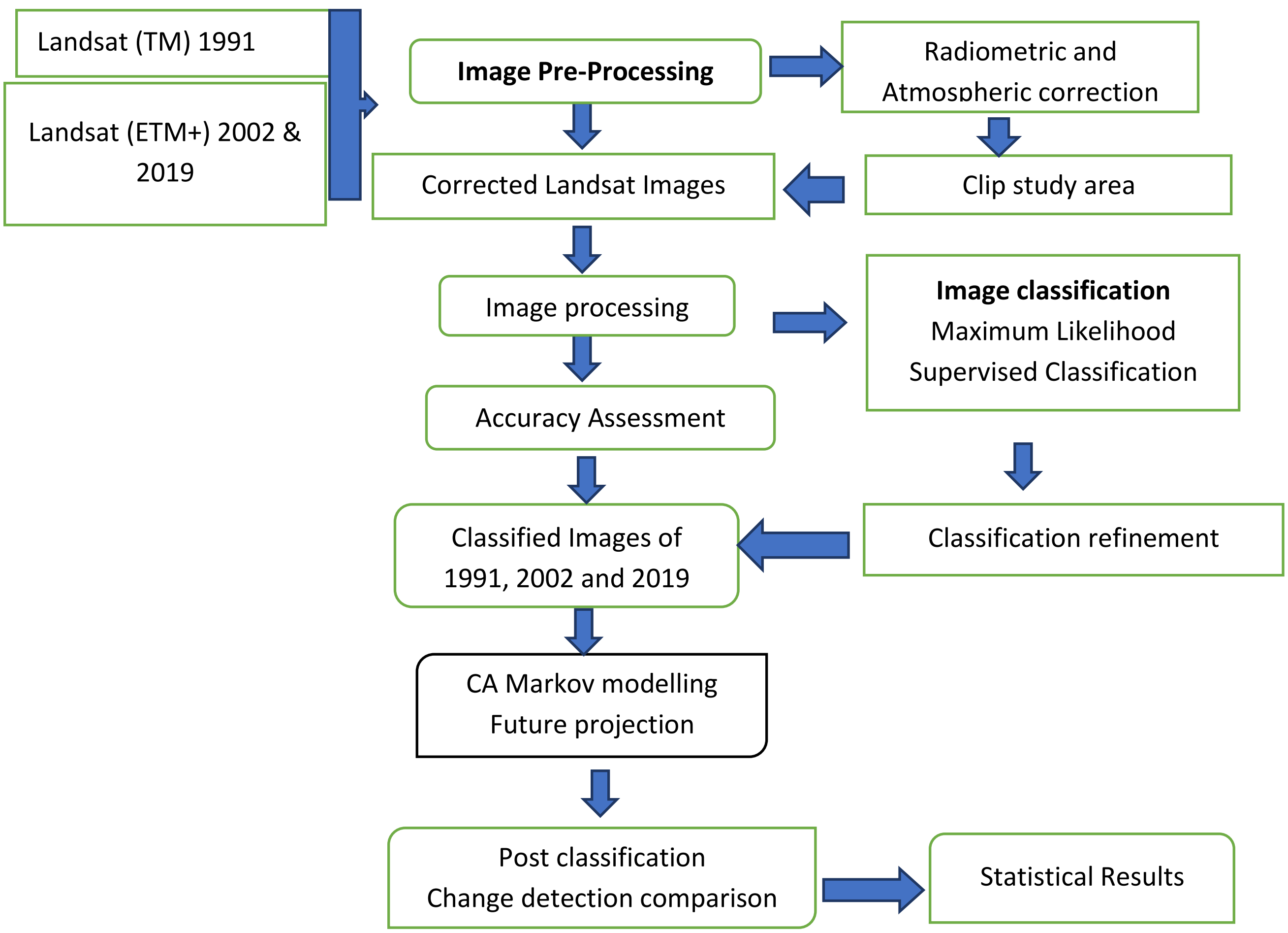

Figure 2: Procedure for Rainforest Cover Change Detection and Future Projection of Oghara

Image pre-processing

Pre-processing of satellite images for change detection is very important (Andualem *et al*, 2018). It is an essential process to remove noise and increase the interpretability of image data; this process is necessary for time series analysis (Yichun, Zongyao and Mei, 2008). Satellite image processing composed of techniques and procedures which includes radiometric and atmospheric correction, geometric correction and masking study area. Radiometric and atmospheric correction for scene illumination, atmospheric conditions and correction for variations of the viewing geometry and instrument response characteristics to create a consistent and reliable image database (Abdelrahman, 2018). This study adopted pre-processing operations including radiometric and atmospheric correction and image enhancement and study area masking using ENVI 5.3 software.

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Image processing

Maximum likelihood supervised classification technique was used for the image classification of earth's surface characteristics of Landsat images. In order to apply supervised classification method on Landsat images, five classes from the Anderson level 1 classification were adopted; namely, built-up area, barren land, water bodies, mangrove, cultivated/grassland and forest land covers.

Image classification

For supervised classification, training signature samples were carefully collected. The study area was classified into five land use land cover classes. The selected training samples were by the identification of land use/cover classes from Landsat images. Multiple band combinations of Landsat images, shown in Figure 3, were used to aid the visual interpretation of land cover types from image**s.**

3. RESULTS AND DISCUSSION

Forest Cover Changes in Study Area

The changes in the size of rainforest cover in Oghara, Delta State between 1991 and 2019 is considered as a basis to predict the forest cover in 2050. As presented in figure 3 and table 2, forest cover decreased from 142.49km^{2}or53.94% of the total area to 81.30km^{2}or 30.78% and is predicted to further decrease to 60.52km^{2}or 22.91 percent. Conversely, there is a proportionate increase in other land cover types: between 1991 and 2019, built-up areas increased from 12.10 km^2 to 22.72 km^2 and are predicted to rise to 36.43 km^{2}by 2050. Mangrove areas experienced the least decrease from 51.27 km^2 to 48.56 km^2 between 1991 and 2019 and are predicted to decrease to 43.20 km^2 by 2050. Cultivated/grassland areas increased from 50 77km^2 to 102.66km^2 and are predicted to increase further to about 113.70km^2. Areas covered by water bodies increased from 7.52km^2 to 8.80 km^2 and are predicted to increase to 10.34 km^2 by 2050.

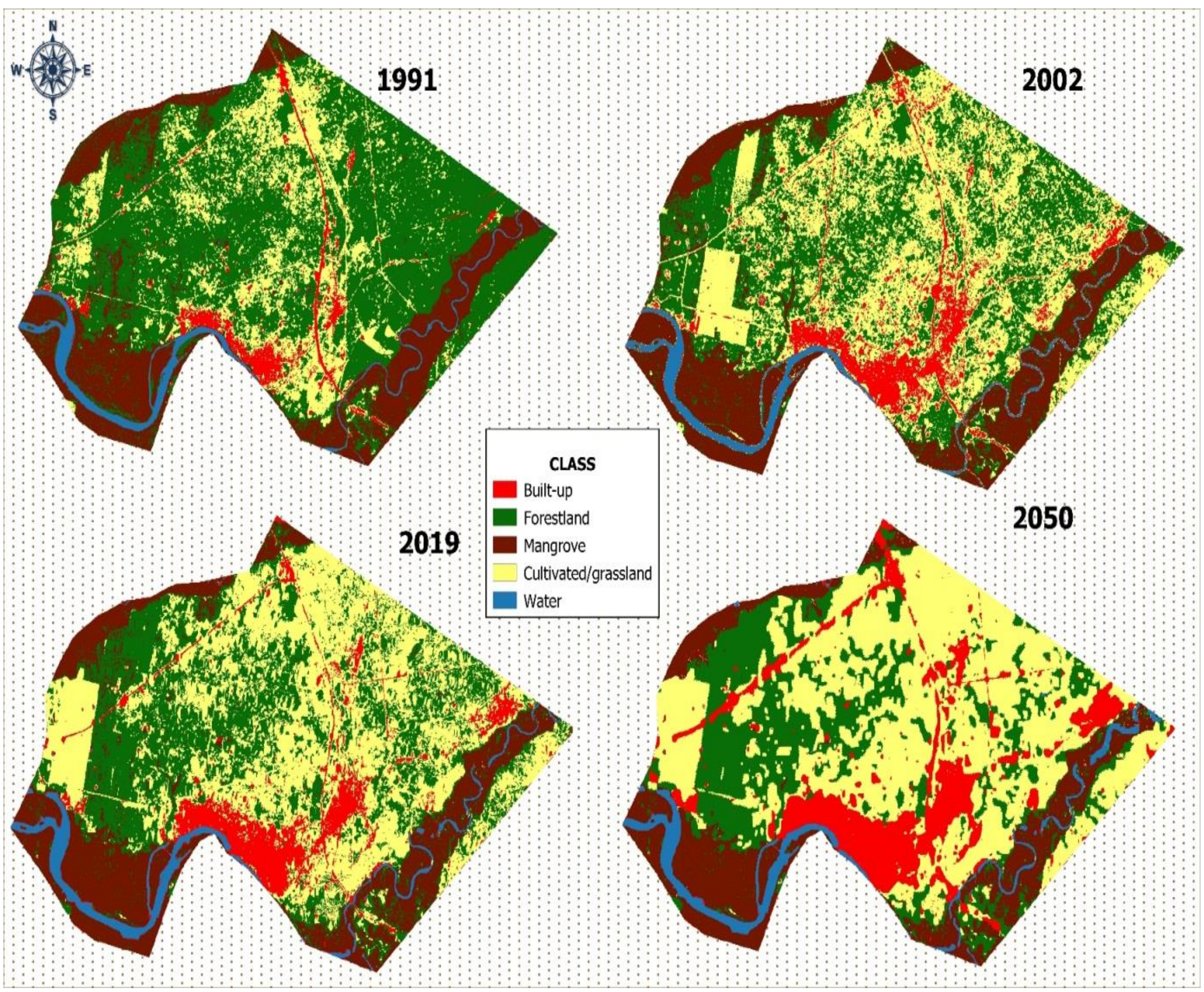

Figure 3: Land cover types in Oghara between 1991 and 2019 with 2050 prediction

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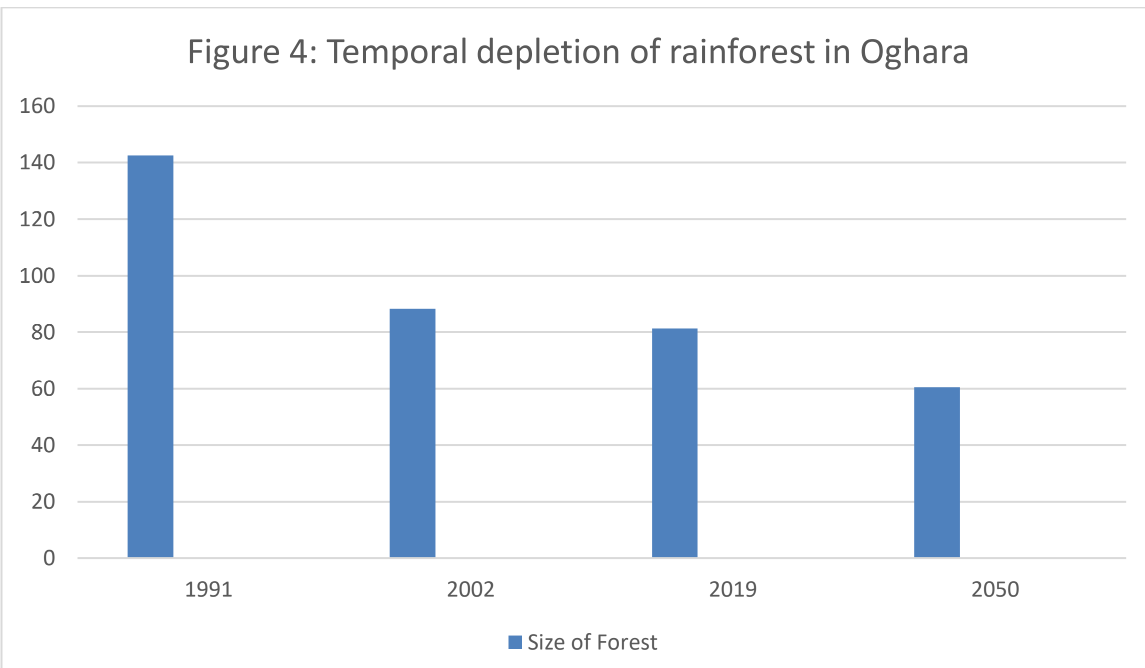
Table 2: Types of Land cover in Oghara between 1991 and 2019 with prediction for 2050

Land Cover Types	1991 (Km^2)	2002 (Km^2)	2019 (Km^2)	2050 (Km^2)
Forest	142.49	88.32	81.30	60.52
Built-up	12.10	22.72	22.84	36.43
Mangrove	51.27	50.02	48.56	43.20
Cultivated/grassland	50.77	95.67	102.66	113.70
Water	7.52	7.44	8.80	10.34

The size of forest cover is isolated and presented in Figure 4.



4. CONCLUSION

The study predicts the spatial changes in forest cover in Oghara, a conglomerate of twenty settlements in Ethiope West Local Government Area of Delta State, Nigeria in 2050. To do this, the study considered changes in land cover between 1991 and 2002, and 2002 and 2019 as a basis or the prediction. The data obtained from Landsat 5 TM images for 1991 and Landsat 7 ETM+ images for 2002 and 2019 were processed with IdirisiSelva 17.0 software which integrates the cellular automaton filter and Markov processes. The ENVI software and ArcGIS desktop version 10.3 (ESRI) were used for image pre-processing, image classification, accuracy assessment, post-classification process, thematic change detection and statistical results, and for editing boundary of the study area, post-classification processes, map layout and visualization respectively. The results of the study showed that the size of forest cover decreased from 142.49km²or53.94% of the total areain1991 to 81.30km²or 30.78% in 2019and predicted to further decrease to 60.52km²or 22.91 percent in 2050.

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Against the backdrop of increasing deforestation, the study recommends proper enforcement of laws governing forest protection and raising awareness and education of inhabitants of the area to the importance of forests. These measures will aid in preventing the adverse impacts which human activities are predicted to have in Oghara by 2050.

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This study has not received any external funding.

Conflicts of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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