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Original Article

Evaluation of Land-Use and Land-Cover Changes in Oba Hills Forest Reserve, Osun State, Nigeria

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ABSTRACT

The study involved assessment of changes in Oba Hills Forest Reserve between 1984 and 2020 and simulated future scenario in the wake of rising impactful land uses in the protected forest land. Landsat TM, ETM+, and OLI/TC of 1984, 1990, 2000, 2010, and 2020 were acquired from the United States Geological Survey. Ground-truth data were collected to enhance imagery re-classifications. The acquired images were pre-processed and processed using ArcGIS 10.5 to characterize land-use and land-cover changes in the area. Past changes between 1984 and 2020 were evaluated, and a possible future outlook was determined. Image classification accuracy was assessed using Kappa's and other accuracy statistics and confusion matrix. Five land-cover classes were distinguished. The result revealed consistent losses of forest covers over 36-year period. There was a gross loss of 42.7% (1519 ha) in total forest covers within the period at 1.2% yr^{-1}. Specifically, primary and secondary forests shrank by 12.3 and 66.8% between 1984 and 2020, respectively, whereas agriculture and grassland rose by 145.2 and 258.8% at 4 and 7.2% yr^{-1}, respectively. Prime drivers of forest losses were subsistence agriculture and cocoa farming cum illegal timber extractions through flitching. These may have had severe negative impacts on faunal population while subjecting forest-dependent rural populace to livelihood challenges. On the other hand, critical components of the ecosystem may also be in jeopardy due to forest degradation, fragmentation, and eventual loss of high conservation values. Therefore, effective forest protection and conservation means, like providing alternative livelihood means, afforestation programs, and multi-stakeholder fore st management strategies, are advised.

Keywords: Agriculture, anthropogenic activities, forest degradation, land-cover change, simulation

Introduction

Forests have been reported to occupy between 30 and 33% of the world terrestrial ecosystems (Keenan et al., 2015). However, the recent happenings in the tropics may have put the exact figures in doubt. This ecosystem has seen series of modifications in the last few decades due to geometric increases in human population, and the need to meet the wood and other demands of the burgeoning figures, in terms of the numerous environmental services need and goods or forest produce (Adeyemi & Ibrahim, 2020). Forests have been adjudged to be highly crucial and undoubtedly critical to the continued existence and survival of man (Gibson et al., 2011; Yam-Bahadur, 2019).

Sutton et al. (2016) noted the negative impacts of deforestation and land degradation to include a loss of over USD$6.3 trillion arising from impaired ecosystem services value, equivalent to 8.3% of global gross domestic product (GDP) in 2016. In particular, Africa has not been immune to various consequences of land degradation, as about 65% of arable land, 30% of grazing land, and 20% of forests were already reported to have been lost. This translates to an annual loss of 3% in GDP and 2.8 million hectares losses in forest lands per annum (Zingore et al., 2015). According to Food and Agricultural Organization of the United Nations (FAO), over 25% of Africa was already in deserts, as of 2018 (FAO, 2018).

In Nigeria, there has been a continuous decline in natural forest covers, from about 18.9% in 1990 to 7.7% in 2015 (FAO, 2015). Based on the trend, Aliyu et al. (2014) inferred that Nigeria could possibly face gross scarcity in timber and fuel-wood supplies in the near future. Orimoogunje (2014) hinted that the remaining forest areas of the country could totally disappear within the next three decades, if the forces of damage and degradation were unchecked. In view of these, there is therefore a need to assess and monitor the current extent of forest-cover

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changes and the disturbances, within the shortest possible time, with better accuracy, and in a cost-effective way.

Land-use and land-cover (LULC) change analysis presents a strong indicator of ecosystems disturbances and change process, especially in the tropics. It also reflects anthropogenic and natural modification of land surface (Jacob et al., 2015). In sum, the LULC patterns are a reflection of natural and socio-economic factors, and their utilization by man in time and space (Adeyemi & Ibrahim, 2020; Bairavi & Anandharajakumar, 2016). These changes may be driven by a combination of natural and anthropogenic causes. Since forest-cover changes occur over time and are influenced by recognizable factors, they can be studied, detected, analyzed, and may be used to predict future changes ahead of such occurrences, so that measures are taken to mitigate them. According to Abubakar (2015) and Adeyemi and Ibrahim (2020), land-cover evaluation is a prime parameter to meaningfully plan for sustainable use of forest resources.

Change detection is a process of identifying differences in geographical surface phenomena over time, and it involves paring of remote sensing with geographic information system (GIS) techniques (Attri et al., 2015; Bruzzone & Bovolo, 2013; Rwanga & Ndambuki, 2017). The information derived imparts practical uses in various applications, including but not limited to deforestation, land management, and damage assessment. In agreement with Orimoogunje (2014) and considering the forest-cover dynamics in Nigeria, the main aim of environmental management should be the protection of the natural living space of humankind and integration of limited resources in making decision on all economic issues and activities. At the heart of this remains an effective means for gathering information that offers the best inputs for a sound decision-making.

According to Maliyat and Datt (2010), increased biotic activities, as a result of increased population and urbanization, have been identified as key factors of over-exploitation in Osun State, where Oba Hills Forest Reserve is situated. The National Population Commission and National Bureau of Statistics (2018) projected human population in the state to be over 5 million in 2019. The interaction of these millions of people with the environment has left indelible impacts on the forest landscape. However, the extents of damage done to the forest reserve as a result of the impacts are not yet known.

Akinsorotan et al. (2019) noted that the livelihood of the rural dwellers is detrimental to the existence of the reserve, but the extent of forest degradation has not been reported. Also, Asifat and Ogunbode (2019) have reported the involvement of women in forest wood exploitation, which serves as a major source of energy within Oba Hills Forest Reserve. However, little is known about the total exploitation level and the current status of the reserve, as modified by anthropogenic forces and the magnitude of transformation. Therefore, the main objective of this study was to determine the current conservation status of Oba Hill Forest Reserve by evaluating forest cover situation as well as changes over the years in the reserve, using remote sensing technique.

Methods

The Study Area

The study was carried out in Oba Hill Forest Reserve, located within Iwo, Ola-Oluwa, and Ejigbo Local Government Areas of Osun State in south-western Nigeria. It covers an area of about 4930 ha, between latitudes 7°41′25″ and 7°49′15″N and longitudes 4°4′10″E and 4°7′30″E (Figure 1). The reserve falls within the tropical humid climate region, where the wet and dry seasons are distinct. The dry season is between November and February, while the wet season is mostly between March and October. The mean annual temperature is 27°C, with an annual rainfall range of between 1200 and 1450 mm (Akinsanola & Ogunjobi, 2014).

The topography of the area is uneven and characterized by ridges, hills, and valleys. It is a small reserve encompassing three hills with a wide

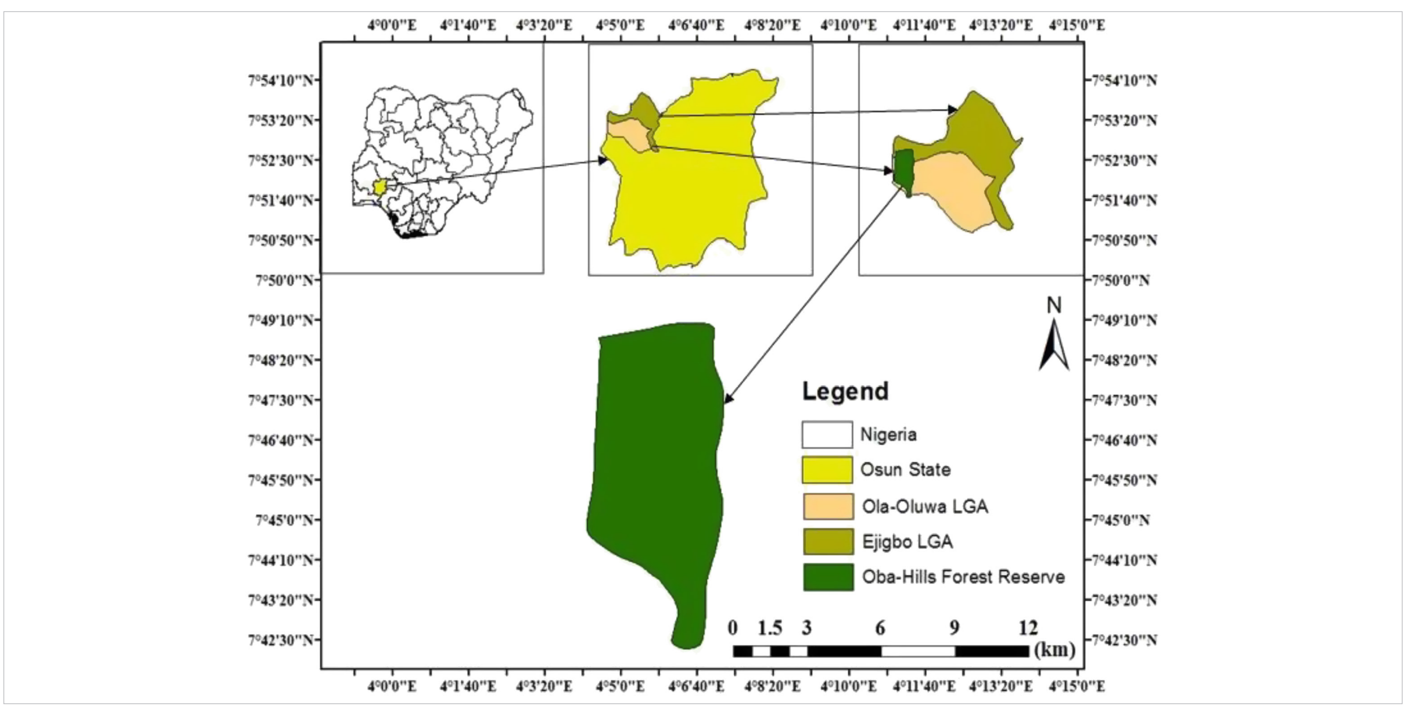

Figure 1.
Map of the study area.

valley running between. The area is generally underlain by basement rocks categorized as migmatite gneiss, quartzite, politic schist, biotite granite hancockite, granite, gneiss, and porphyritic granite, according to Rahaman (1976). The vegetation of the area is similar to that of the tropical rainforest, where there are high trees and shrubs, and the vegetation here is characterized by the presence of thick tropical evergreen forest.

Selection of Images

This study was based on the analyses of satellite imageries of the study area coupled with field verifications. Therefore, the first task was to select the satellite sensors and associated images, as appropriate. The satellite image data were acquired from United States Geological Survey (USGS). The selected images include Landsat TM, ETM+, and OLI/TC of 1984, 1990, 2000, 2010, and 2020 with features shown in Table 1.

Ground Truthing

The field checks were conducted using a hand-held GPS receiver, digital camera, and field note. A total of 280 ground control points (GCPs) were randomly established using GPS. Observations of LULC characteristics in different locations were recorded. According to Jensen (1986), the ideal number of ground control points required to be tested in the land-use classification map is determined from:

$$N = \frac{4(p)(q\sim)}{e^2} \quad (1)$$

where N = number of points required; P = expected percent accuracy; $q\sim$ = difference between 100 and p; e = maximum allowable error.

For an expected 90% accuracy and allowable error of 5%, the minimum number of points required is 144. This shows that the number of GCPs (280) established on the field is far higher than the ideal number of checkpoints required. Ground control points were collected and the coordinates (together with descriptions) using Microsoft Excel, were imported into ArcGIS, and added to the GIS database as an event theme. These were converted into a data layer. This theme of field coordinates was then used as a base for assessing accuracy of the classified images. The use of handheld GPS as against the traditional method of pixel selection made the field verification exercise very reliable.

Image Processing

The acquired images were processed and analyzed in ArcGIS 10.5 using the Geo-tiff format. The first operation was to composite the images. Bands of interest were selected and stacked. From the stacked bands, a color composite of bands (4, 3, and 2 for Landsat TM and ETM+; 5, 4, and 3 for OLI/TC images) was generated and re-sampled, following Adeyemi and Adeleke (2020) and Adeyemi and Ibrahim (2020). This combination has been regarded as efficient and adequate, when using Landsat image data for LULC classifications involving vegetation, farmland, water body, wetland, bare surface, and built-up area. Figure 2 shows the composite images of Oba Hills Forest Reserve between 1984 and 2020. Bands 4, 3, and 2 (Red, Green, and Blue filters, respectively) were selected and composited from the imagery of 1984 (Landsat 5; TM), 1990 (Landsat 4; TM), 2000 (Landsat 7; ETM), and 2010 (Landsat 7; ETM+). Similarly, bands 5, 4, and 3 were composited from the 2020 imagery (i.e. Landsat 8 OLI/TC). These filters are a reversal of the true color band combination, resulting in a false color composite with a basic aim of creating a visual map of the area. It ensures visualization of near-infrared wavelengths and far near-infrared. The red, green, and blue bands of a true color image were reversed in a typically false-color scheme to show the green in blue, the red in green, and the infra-red in red (Figure 2).

Table 1.
Characteristics of Satellite Images Used

SN	Landsat Type	Date
1	Landsat 5 (TM)	18/12/1984
2	Landsat 4 (TM)	27/12/1990
3	Landsat 7 (ETM+)	06/02/2000
4	Landsat 7 (ETM+)	16/01/2010
5	Landsat 8 (OLI/TC)	05/02/2020

Using ArcGIS 10.5, the required (composited) bands were layered, and the area of interest was extracted from the imagery of each period. Isocluster classification technique was used to determine the LULC classes, followed by a re-classification to deduce the exact land-use and its corresponding area coverage.

Land-Use and Land-Cover Change Analysis

Change detection for LULC were done using pre-classification and post-classification steps and approaches, as done by Adeyemi and Ibrahim (2020). The pre-classification change detection involves matching pixel for pixel to process multi-date imageries of the same area so as to generate changes. In this case, the digital number (DN) of cells in image of time t_0 were matched and correlated with the DN value for the image of time t_1 using change detection algorithm. The result represents the change area.

As a way of determining the LULC change, LULC layers of the selected dates were overlaid with one another in the ArcGIS environment. Change analysis was then performed by intersecting the different multi-temporal LULC layers (for the selected dates). A contingency matrix of change was then developed using a pivot table. This was done to examine the LULC changes within the study period.

The record (row) totals indicate the area extent of each LULC class in the base year (1984), and the field (column) totals represent the area of each LULC class in current year (2020). Reading down each row of the table, the transition (loss) of a row header (class) into other LULC classes in year 2020 was indicated. Also, by reading down each column, the transition (gain) from each LULC class to the column header (class) in year 2020 was indicated. Therefore, the column represents gains from other LULC classes to the column header, while the row represents losses of row headers to other LULC classes.

Trend Analysis

The magnitude of change (area) and the percentage change for each study period were evaluated following Alawamy et al. (2020), with modifications. The change in magnitude, percentage trend, and annual rate of change for each LULC class was estimated using:

$$MC = A_f - A_i \quad (2)$$

$$T = \left(\frac{A_f - A_i}{Ai} \times 100\right) \quad (3)$$

$$R = \left(A_f - A_i \times \frac{1}{t}\right) \quad (4)$$

$$ARC = \left(\frac{A_f - A_i}{A_i} \times \frac{1}{t}\right) \times 100 \quad (5)$$

where A_f = area in final year; A_i = area in base/initial year; MC = magnitude of change (ha); T = trend (%); R = rate of change (ha); t = periodic interval; ARC = annual rate of change (%).

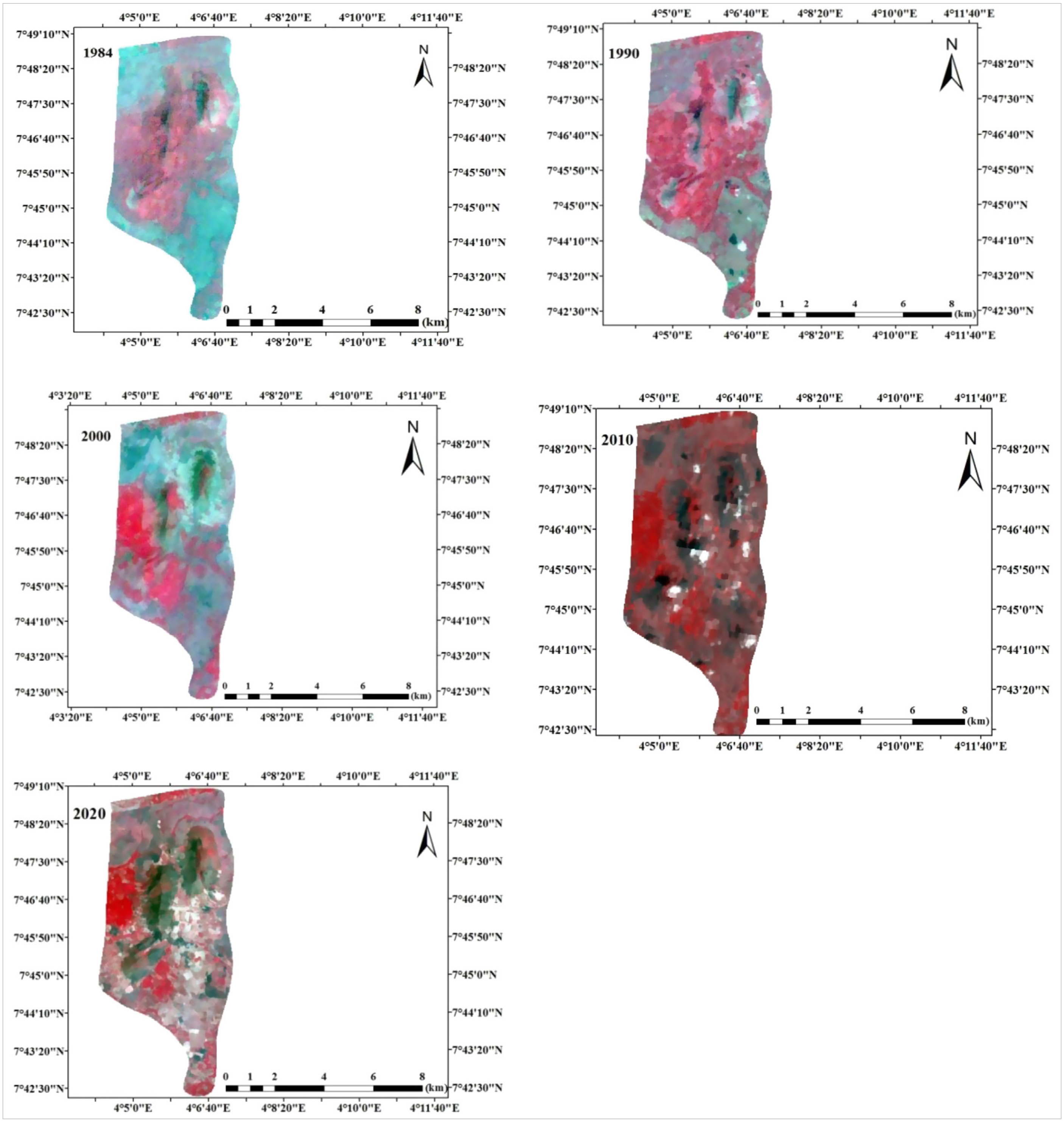

Figure 2.
Composite images of Oba-Hills Forest Reserve for the five data-periods.

Vegetation Index

The normalized difference vegetation index (NDVI) is considered the most frequently used vegetation index. The NDVI is a dimensionless index that describes the difference between visible and near-infrared reflectance of vegetation cover, and it is used to estimate the density of green vegetation on an area of land. The NDVI was adopted as an important index for its suitability to differentiate vegetation from other types of land cover and to determine the overall state of the vegetation in the reserve. It also allows defining and visualizing vegetated areas on the map as well as detecting abnormal changes in the growth process of the vegetation (Bro-Jørgensen et al., 2008). It was computed as:

$$\mathrm{NDVI} = \frac{\mathrm{pNIR} - \mathrm{pRED}}{\mathrm{pNIR} + \mathrm{pRED}} \quad (6)$$

where ρx represents the reflectance at wavelength band x.

The values of NDVI range between −1 and 1. The common range for green vegetation is 0.2–0.8.

Accuracy Assessment

Confusion matrix was used to assess the image classification accuracy of the LULC classes for 2020. The GCP data, collected in February 2020, during the dry season, was used for image classification and overall accuracy assessment in combination with the classified raster image. The overall accuracy evaluated the relationship between the remote sensing-derived map and the assumed true map in total area in each land-use category. However, it does not provide for compensating errors that occur in the various categories. Specific errors of omission and commission on each land-use class were required to compliment the overall estimated accuracy. The GCPs were analyzed for error matrix using the omission and commission error computation method. Omission and commission errors were estimated for the different LULC classes, as well as producer's and user's accuracies. The accuracy for each class was estimated, and the accuracy statistics were determined based on Rwanga and Ndambuki (2017):

$$P = \frac{\sum_{i=1}^{k} n_{ii}}{n} \times 100 \quad (7)$$

where n_{ii} = number of correct points; n = total number of ground control points; P = overall accuracy, expressed in percentage.

$$\text{Producer's accuracy} = \frac{a}{a+b} \quad (8)$$

$$\text{Specificity} = \frac{d}{b+d} \quad (9)$$

$$\text{Commision error} = 1 - \text{Specificity} \quad (10)$$

$$\text{Ommision error} = 1 - \text{Sensitivity} \quad (11)$$

$$\text{Equivalent to User's accuracy} = \frac{a}{a+b} \quad (12)$$

$$\text{Negative Predictive Power} = \frac{d}{c+d} \quad (13)$$

where a = number of times a classification agreed with the observed value; b = number of times a point was classified as X when it was observed to not be X; c = number of times a point was not classified as X when it was observed to be X; d = number of times a point was not classified as X when it was not observed to be X; Total points accurately classified = n = (a + b + c + d).

The Khat statistics yielded by Kappa analysis was computed as:

$$K_c = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{ri} \times x_{ci})}{N^2 - \sum_{i=1}^{r}(x_{ri} \times x_{ci})} \quad (14)$$

where r = number of rows and columns in error matrix; N = total number of observations (pixels); X_{ii} = observation in row i and column i; X_{ri} = total for row i; X_{ci} = total for column i.

A Kappa coefficient equal to 1 means perfect agreement, whereas a value closes to zero means that the agreement is no better than would be expected by chance.

Future Projection

Markov chain analysis was used to describe land-use change from one period to another. This was used as the basis to project future changes for the reserve, based on the current scenarios as:

$$F = A \times x_i + C \quad (15)$$

where F = future trend; A = annual rate of change; x_i = number of interval (years) for the ith year being predicted; C = area extent in the current year.

Results

Land-Use and Land-Cover Classes of Oba Hills Forest Reserve

The classification of the time-series images yielded five land-use types in the study area, as described in Table 2.

Table 3 presents the spatial extents of the LULC in Oba Hills Forest Reserve as at 1984, 1990, 2000, 2010, and in 2020, while Figure 3 presents maps showing the different LULC types in those years with graphical representation of the gradual LULC transitions in Figure 4. In 1984, secondary forest covered an area of 1987 ha, representing 40.3% of the reserved area while primary forest covered a total of 1,574 ha (about 32% of the reserve). In the same year, agricultural land was 569 ha (11.5%) in extent. Bareland and grasslands were 418 ha (8.5%) and 382 ha (7.7%), respectively.

In 1990, primary forest increased to 1855 ha (37.6%) of the area, while grasslands and agricultural lands increased to 875 ha (17.7%) and 656 ha (13.3%), respectively. However, secondary forest contracted to 1232 ha (25%) with bareland reducing to 312 ha (6.3%) of the forest reserve. Between 1990 and 2000, primary and secondary forests contracted to 1326 ha (26.9%) and 899 ha (18.3%), respectively. Agricultural land and grasslands increased to 1826 ha (37%) and 494 ha (10%) of the reserve area with bareland covering about 385 ha (7.8%). By 2020, primary and secondary forests reduced to 1380 ha and 662 ha, losing 12.3 and 66.8% of their original extents to agriculture (1395 ha) and grasslands (1231 ha), which rose by 145.2 and 258.8%, respectively. Details of the steady transitions in LULC are shown in Table 3.

Table 4 shows the NDVI values of the area, while Figure 5 presents the NDVI maps between 1984 and 2020. The highest value for the NDVI (0.51) was in 1990, which indicates the increase in vegetation and corresponds to the increase in flora concentrations and drastic reduction in bareland extent in that year. The lowest NDVI value (−0.536) was in 2010.

Land-Use and Land-Cover Changes in Oba Hills Forest Reserve Between 1984 and 2020

Table 5 and Figure 6 present changes in LULC classes in the forest reserve between 1984 and 2020. Between 1984 and 1990, primary forest, agricultural land, and grasslands increased by 281, 87, and 493 ha, respectively. Meanwhile secondary forest contracted by −755 ha, as a result of parts growing into a closed canopy. Between 1990 and 2000, primary

Table 2.
Description of Current Land-Use Classes Oba Hills Forest Reserve

LULC	Description
Bareland	Areas with little or no account of vegetation cover. It includes hill tops, sandy zones, rocky terrains, and open lands without devoid of any form of flora.
Grassland	Areas dominated by grasses with very few scattered shrubs.
Agricultural land	This consists of lands under subsistence farming with crops such as yam, rice, cassava, millet, and vegetables as well as cash crops, including concentration of cocoa, plantain, and oil palm.
Secondary forest	This includes areas with fairly open tree canopy with noticeable signs of past exploitations and new regenerations.
Primary forest	This is an area with natural vegetation, having reasonably closed tree canopy. It includes both natural forest and forest plantation.

Note: LULC, land-use and land-cover.

Table 3.
Land-Use and Land-Cover Spatial Extents Between 1984 and 2020

	1984		1990		2000		2010		2020	
LULC	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
Agricultural land	569	11.5	656	13.3	1826	37.0	1292	26.0	1395	28.3
Bareland	418	8.5	312	6.3	385	7.8	209	4.3	262	5.3
Grassland	382	7.7	875	17.7	494	10.0	856	17.0	1,231	25.0
Primary forest	1574	31.9	1855	37.6	1326	26.9	1625	33.0	1380	28.0
Secondary forest	1987	40.3	1232	25.0	899	18.3	948	19.2	662	13.4
Total	4930	100	4930	100	4930	100	4930	100	4930	100

Note: LULC, land-use and land-cover.

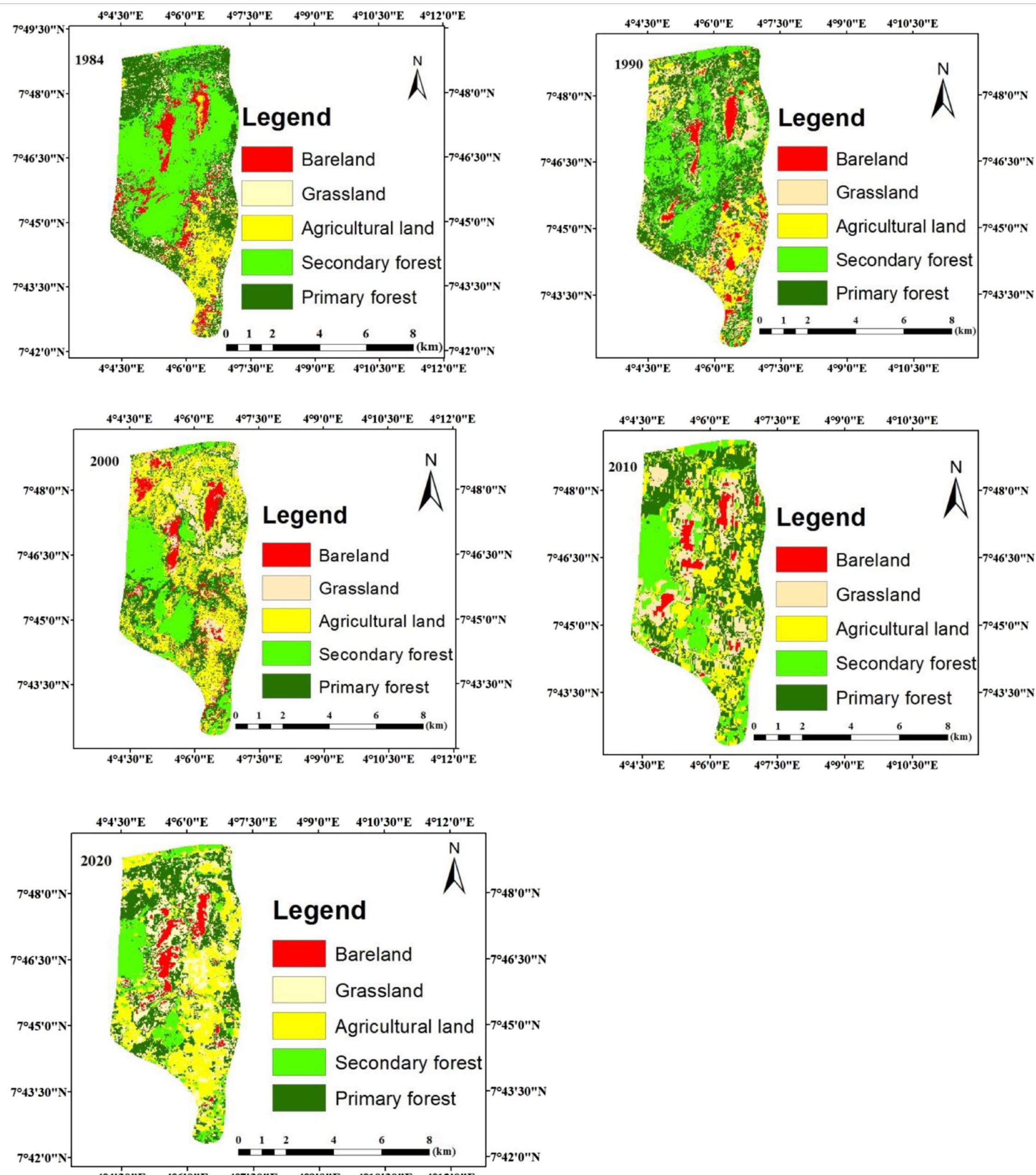

Figure 3.
LULC maps of Oba-Hills Forest Reserve between 1984 and 2020.

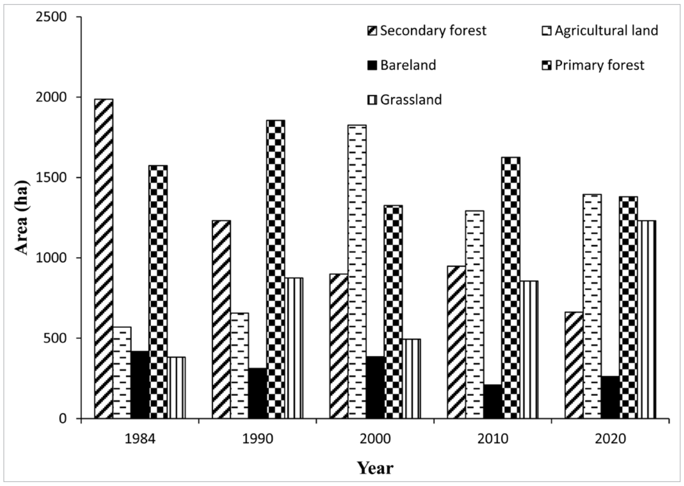

Figure 4.
Spatial extents of LULC between 1984 and 2020.

forest, secondary forest, and grassland contracted by −529, −333, and −381 ha, respectively, with corresponding increases in bareland and agricultural land. The changes within the entire period (1984–2020) revealed losses of −1325 ha (66.7%) and −194 ha (12.3%) in secondary and primary forests, at an annual rate of 1.9 and 1%, respectively, while grassland (849 ha) and agricultural land (826 ha) increased by 222.3 and 145.2%, at an annual rate of 6.2 and 4%, respectively.

Tables 6 and 7 present the confusion matrix and classification accuracy statistics generated, while Table 8 presents the summary of the accuracy statistics generated. User's accuracy is a more relevant measure of the classification's actual utility in the field. Bareland was found to be more reliable with 96.43% of user accuracy. The commission error reflects the points, which were included in the category, while they really did not belong to that category. The value was highest in the case of grassland. The omission error reflects the number of points, which were not included in the category, while they really belonged to the category. The omission error in case of primary forest was highest (27.8%) with 25 points, which actually belonged to this category but not being categorized as such.

The overall classification accuracy was 84.6% with the average commission and omission errors being 3.9 and 12.3%, respectively. The average user's accuracy and producer's accuracy were 86.4 and 87.7%, respectively. The average specificity was 96.1%. The overall Kappa coefficient of 80.24% was obtained, which is rated as substantial.

Table 9 presents the contingency matrices of changes within Oba Hills Forest Reserve between 1984 and 2020. The diagonal figures represent the static land cover while other figures represent the matrices of transition from one LULC class to another. The percentage being represented by the change is also presented (in parentheses). The frequency of land transformation from the contingency matrix showed that the study area experienced rapid LULC transformations within the period. Between 1984 and 2020, primary forest lost 1.5% to bareland, 21.9% to grassland, 32.1% to agricultural land, and 6.6% to secondary forest. About 38% of the primary forest cover remained unchanged. Within the period, 46.9% of agricultural land remained unchanged. It however lost 5.6, 23.8, and 2.5% to bareland, grassland, and secondary forest, respectively, while primary forest gained 21.1% of farmland. About 24% of secondary forest remained unchanged, but it lost 5.4, 26.5, 19.5, and 25.2% to bareland, grassland, agricultural land, and primary forest, respectively. Details are shown in Table 9.

Figure 7 shows the transitional map revealing changes among the LULC types within the study period. The major drivers of changes in the area were agricultural intensification, timber over-exploitation, fuel-wood and charcoal production, uncontrolled bush burning, and over-grazing and over-exploitation of non-timber forest produce.

Table 4.
Descriptive Statistics for the NDVI Maps Between 1984 and 2020

	NDVI statistics		
Year	Minimum	Maximum	Mean ± SD
1984	0.05	0.30	0.18 ± 0.08
1990	−0.02	0.50	0.27 ± 0.18
2000	−0.31	0.00	−0.13 ± 0.11
2010	−0.54	0.42	0.05 ± 0.32
2020	0.04	0.30	0.16 ± 0.09

Note: NDVI, normalized difference vegetation index; SD, standard deviation.

Land-Use and Land-Cover Simulation for the Study Area

The changes in LULC between 1984 and 2020 were used as the bases for prediction. Table 10 and Figure 8 present the simulation for the LULC types in the study. The results revealed a decline in most of the LULC types except the grasslands and agricultural lands, which are expected to increase to about 3589.3 and 3689.4 ha in the year 2120, respectively, *ceteris paribus*.

Discussion and Conclusion

The results showed that natural forest covers were lost within the period considered. The dynamism in the nature of forest cover losses clearly indicates over-exploitation and conversion to other land uses, resulting from significant human interference in the reserve. This is similar to the findings of Elijah et al. (2019), who attributed significant decreases in dense forest cover to anthropogenic activities within Gashaka-Gumti National Park, Nigeria. More so, Nanda et al. (2014) noted that conversion of forests to other forms of land management is the general trend in mountainous areas due to increasing human population and limited productive agricultural lands in those areas. This might also be the reason for the decrease in forest cover since most part of the reserve and environs are very hilly, as reflected in the name of the reserve. Another major change was the observed increase in grassland cover due to over-exploitation, resulting in degradation of forest resources, thereby exposing the forest land to erosion and leaching of nutrients. This increase in grassland cover resulting from the observed anthropogenic activities within the reserve has the tendency to negatively impact forest regeneration since such land cover would attract cattle herders for grazing their animals with attendant trampling and compacting of forest soils.

More lands were converted to agriculture and grasslands on annual basis. This constitutes a major threat to the existence of the forest reserve. This is in line with the observations of Wasige et al. (2019) that annual forest clearing for agriculture was threatening to the existence of natural forest cover. This is consistent with the finding of Asifat et al. (2019), who reported that portions of the forest reserves were turned to farm settlement due to agricultural intensification and rural settlement expansion. Agricultural intensification in gazetted forest areas is detrimental to the existence of the forest reserve. As noted by Wahab and Alarape (2018), destructive activity through farming in the forestland has negative consequences on economic trees, as most of these are susceptible and already nearing extinction. The expansion of farmlands could be attributed to increased demand for food by the growing population in the surrounding communities and a lack of livelihood alternatives and survival strategies.

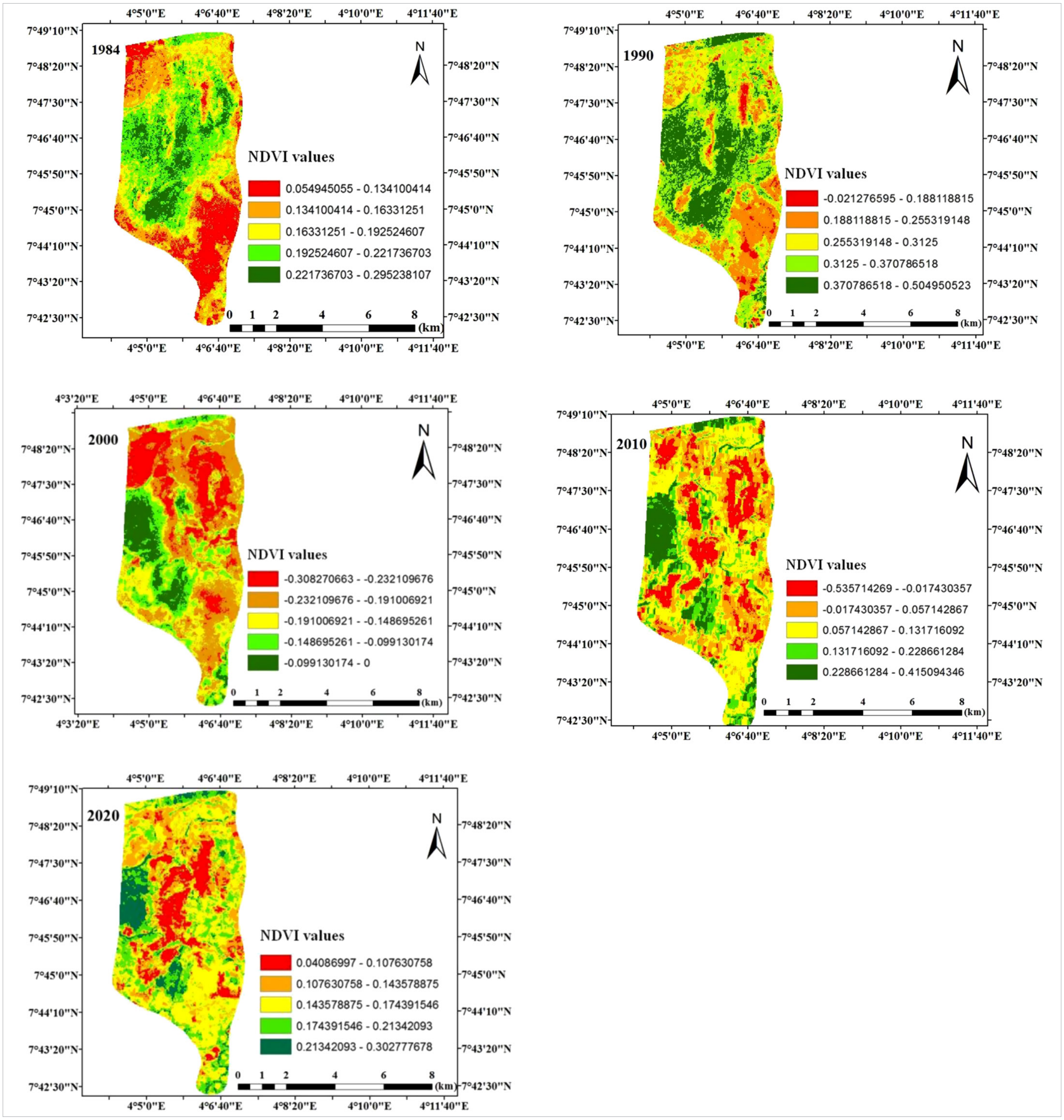

Figure 5.
NDVI maps of Oba-Hills Forest Reserve between 1984 and 2020.

The demands for fuel-wood, timber, and other forest-tree products also contributed to the loss of forest cover and quickened deforestation processes in the area. According to Gidey et al. (2017), these changes can negatively impact the environment through climate change and loss of carbon sinks. Although, any unauthorized entry or all forms of human activities such as farming, logging, grazing, and hunting, known to be illegal, may have been monitored by the forest guards, farming and grazing are visibly expanding. This may be due to the increasing population within the surrounding communities and consequently increasing demand for food and grazing land. In establishing the effect of human intrusion, Ashaolu et al. (2019) noted that most communities in Osun State earn their livelihoods through farming, logging, and fuel-wood production without replacement. Similarly, Akinsorotan et al. (2019) observed that 88% of the villagers encroached the reserve areas to farm or plant crops as well as engaging in other illegal activities for survival on annual basis, leading to forest depletion. The implications of these are that such changes in LULC arising from anthropogenic factors could potentially result in increased incidences of soil erosion, increasing reservoir sedimentation and contractions of streams and rivers, soil degradation, drought, and loss of biodiversity and livelihoods.

Table 5.
Magnitude of Change in LULC Between 1984 and 2020

Period	PF (%)	SF (%)	AL (%)	Bareland (%)	Grassland (%)
1984–1990	281 (17.9)	−755 (−38.0)	87 (15.3)	−106 (−25.4)	493 (129.1)
1990–2000	−529 (−28.5)	−333 (−27.0)	117 (178.4)	−73 (23.4)	−381 (−43.5)
2000–2010	299 (22.5)	49 (5.5)	−534 (29.2)	−176 (45.7)	362 (73.3)
2010–2020	−245 (−15.1)	−286 (−30.2)	103 (8.0)	53 (25.4)	375 (43.8)
1984–2020	−194 (−12.3)	−1325 (−66.7)	826 (145.2)	−156 (−37.3)	849 (222.3)

Note: SF, secondary forest; AL, agricultural land; PF, primary forest; (+), net gain; (−), net loss.

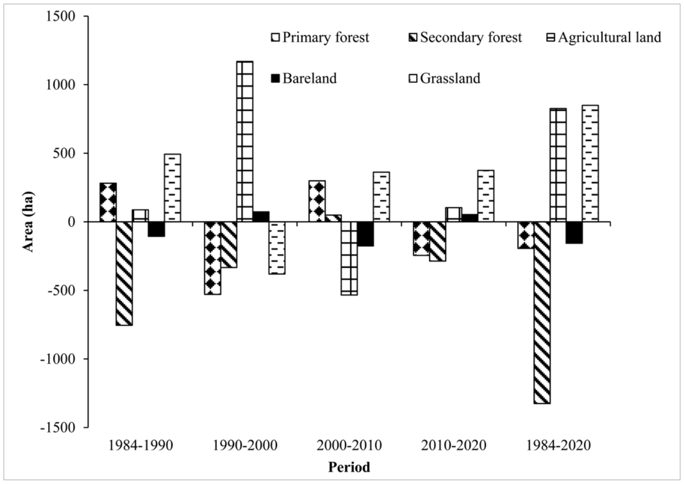

Figure 6.
Magnitude of changes in LULC between 1984 and 2020.

Nevertheless, with the exceptions of secondary forest (which is projected to be lost within the next 20 years), all LULC types are projected to still be in existence over the next 100 years, if the causal factors remained constant, minimized, or totally eliminated with aggressive forest regeneration activities. This contradicts Orimoogunje (2014), who opined that the remaining forest areas of the country would totally disappear by the year 2044. However, primary forest would continue to decline in area coverage, if pro-active steps are not taking to restore it, whereas, agricultural lands and grasslands would continue to increase in the reserve, in the face of non-provisions of viable alternatives. Continuous deforestation will certainly have significant negative consequences on water budget of the study area as well as on the socio-economic lives of the people with dire consequences on the environment.

The study has shown that there were tremendous changes in LULC of Oba Hills Forest Reserve (OHFR) in the past 36 years with a net annual forest loss of 2.2% (42.2 ha) to agriculture and grasslands. These changes may not be unconnected to population increase and expansion of settlements in the communities surrounding the reserves, as changes were traced to increasing demand for land for agricultural purposes and increasing demand for fuel-wood and timber as well as grazing activities.

The rate of deforestation in recent years was found to be more than the average trend in the last 36 years due to anthropogenic disturbances, which were observed to be on the rise and have steadily increased annually, in recent time compared to the overall trend within the period studied. The outcome of future projection highlights a situation of continuous forest losses with corresponding increases in agricultural land and grassland, if the causal factors remained unabated. Indeed, if the current trend of deforestation in the study area continues, the primary forest would lose about 20 and 40% of its current size in the next 50 and 100 years, respectively. Considering the ecological implications of the increasing anthropogenic disturbances in the area, there is a need for

Table 6.
Confusion Matrix for the LULC Map

LULC	PF	SF	AL	BL	GL	Row total
PF	65	0	1	0	3	69
SF	0	39	3	0	1	43
AL	9	0	58	0	6	73
BL	1	0	0	27	0	28
GL	15	0	2	2	47	66
Column total	90	39	64	29	57	279

Note: PF, primary forest; SF, secondary forest; AL, agricultural land; BL, bareland; GL, grassland.

Table 7.
Category-wise Accuracy Statistics for the LULC Classification

	Parameters					
LULC	Sensitivity	Specificity	CE	OE	UA	PA
PF	0.7222	0.9788	0.0212	0.2778	0.9420	0.7222
SF	1.0000	0.9833	0.0167	0.0000	0.9070	1.0000
AL	0.9063	0.9302	0.0698	0.0938	0.7945	0.9063
BL	0.9310	0.9960	0.0040	0.0690	0.9643	0.9310
GL	0.8246	0.9144	0.0856	0.1754	0.7121	0.8246

Note: PF, primary forest; SF, secondary forest; AL, agricultural land; BL, bareland; GL, grassland; CE,commission error; OE, omission error; UA, user's accuracy; PA, producer's accuracy.

Table 8.
Summary of the Accuracy Statistics from the Confusion Matrix

Variables	Percentages (%)
Omission error	12.3 ± 0.11
Commission error	3.9 ± 0.04
User's accuracy	86.4 ± 0.11
Producer's accuracy	87.7 ± 0.11
Negative predictive power	95.9 ± 0.05
Sensitivity	87.7 ± 0.1
Specificity	96.1 ± 0.04
Overall classification accuracy	84.6
Overall Kappa's coefficient	80.2 (Substantial)

Table 9.
LULC Transition Matrix for the Study Area Between 1984 and 2020

		LULC 2020 (ha)				
LULC		SF (%)	AL (%)	Bareland (%)	PF (%)	Grassland (%)
LULC 1984(ha)	SF	471.2 (23.5)	391.1 (19.5)	107.8 (5.4)	504.5 (25.2)	530.6 (26.5)
	AL	15.7 (2.53)	290.2 (46.9)	34.8 (5.6)	130.9 (21.1)	147.6 (23.8)
	Bareland	32.7 (7.8)	110.4 (26.4)	86.6 (20.7)	77.2 (18.4)	111.9 (26.7)
	Primary forest	104.1 (6.62)	504.6 (32.1)	23.7 (1.5)	595.0 (37.8)	345.0 (21.9)
	Grassland	36.1 (11.7)	114.8 (37.3)	6.3 (2.04)	84.5 (27.4)	66.3 (21.5)

Note: figures in parentheses represent percentages; AP, agricultural plantation; AF, agricultural land; PF, primary forest.

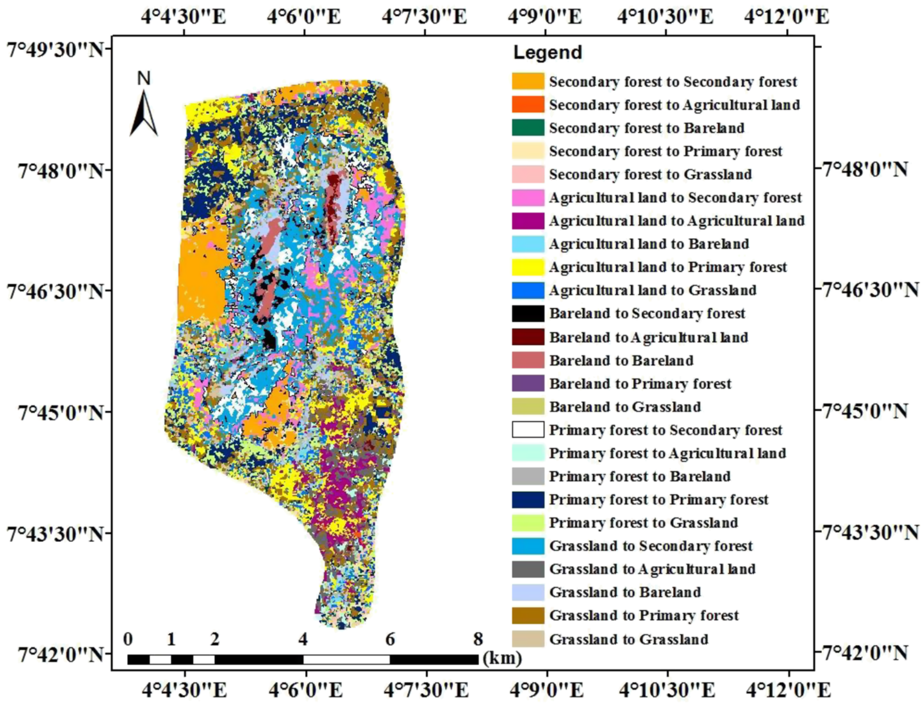

Figure 7.
Transition map for LULC types in the study area between 1984 and 2020.

Table 10.
Land-Use and Land-Cover projection in the Study Area for the Next 100 years

Years	PF (%)	SF (%)	AL (%)	BL (%)	GL (%)
2030	1326.1 (26.9)	293.9 (5.9)	1624.4 (32.9)	218.7 (4.4)	1466.8 (29.8)
2040	1272.2 (25.8)	−74.1 (−1.5)	1853.9 (37.6)	175.3 (3.6)	1702.7 (34.5)
2050	1218.3 (24.7)	−442.2 (−8.9)	2083.3 (42.3)	132.0 (2.7)	1938.5 (39.3)
2060	1164.4 (23.6)	−810.2 (−16.4)	2312.8 (46.9)	88.7 (1.8)	2174.3 (44.1)
2070	1110.6 (22.5)	−1178.3 (−23.9)	2542.2 (51.6)	45.3 (0.9)	2410.2 (48.9)
2080	1056.7 (21.4)	−1546.3 (−31.4)	2771.7 (56.2)	2.0 (0.04)	2646.0 (53.7)
2090	1002.8 (20.3)	−1914.4 (−38.8)	3001.1 (60.9)	−41.3 (−0.8)	2881.8 (58.5)
2100	948.9 (19.2)	−2282.4 (−46.3)	3230.6 (65.5)	−84.7 (−1.7)	3117.7 (63.2)
2110	895.0 (18.2)	−2650.5 (−53.8)	3460.0 (70.2)	−128.0 (−2.6)	3353.5 (68.0)
2120	841.1 (17.1)	−3018.6 (−61.2)	3689.4 (74.8)	−171.3 (−3.5)	3589.3 (72.8)

Note: figures in parentheses represent percentages.

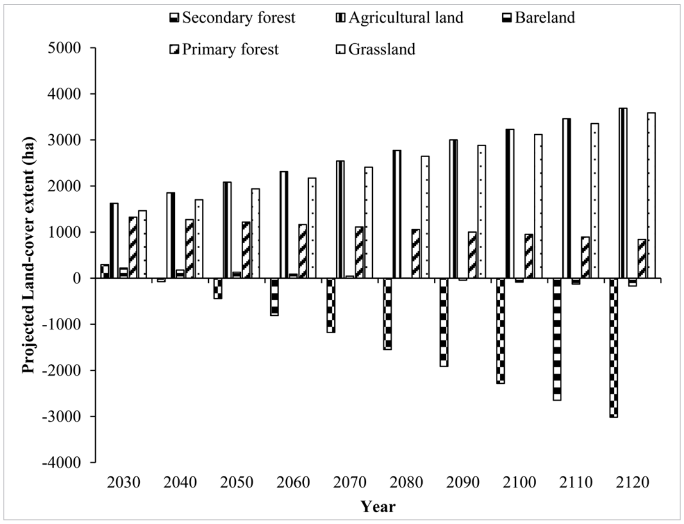

Figure 8.
Future projection for LULC classes in the area.

focused attention in order to effectively manage and conserve the reserve and its components to enhance sustainability.

The most worrisome implication is that Oba Hills Forest Reserve could, in no distant future, be deforested, amounting to a considerable decline in biodiversity and associated consequences would be unavoidable. Therefore, it is recommended that activities such as grazing, illegal exploitation of timber, and farming be minimized or totally checked. In addition, minimal-impact agro-forestry and taungya systems of farming can be encouraged in a participatory manner, so as to regenerate parts of the reserve without potential conflicts with the subsistence farmers. It is also thought that the intensity of human economic activities and the concentration of human populations around forest reserve may be on the rise, impacting largely on the forest cover. It is therefore pertinent to set limits and define goals of any regeneration programs to prevent possible compromise on the part of forest actors.

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