Land Use Land Cover Dynamics of Ise Forest Reserve, Nigeria

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ABSTRACT

Understanding the dynamics of Land Use Land Cover (LULC) is necessary for generating valuable information for informed decision-making in managing natural resources in the tropics. However, relevant information on these dynamics of forest cover is sparse, especially in Ise Forest Reserve. Therefore, this study aimed to assess the changes in land cover in Ise Forest Reserve between 2000 and 2020. Utilizing imagery from Landsat 7 and 8 acquired from the United States Geological Survey (USGS) database, covering the years 2000, 2010, and 2020, we employed a maximum likelihood algorithm to classify the images. Three LULC classes were identified: Forest, Farmland, and Settlement. Our analysis revealed significant shifts in land cover over the studied period. In 2000, forest coverage accounted for 87.5% of the reserve area in 2000, decreasing to 77.46% in 2020. Conversely, farmland increased from 10.74% in 2000 to 17.24% in 2020, while settlement areas expanded from 1.71% to 5.30% during the same period. These changes indicate the impact of anthropogenic activities in the area. In conclusion, LULC changes in Ise forest reserve revealed a concerning trend of deforestation and land cover change due to human activities. This research contributes valuable insights into the evolving landscape dynamics of the reserve, providing essential information for conservation efforts and sustainable land management practices.

INTRODUCTION

The depletion of natural forests in Nigeria has led to escalating concerns regarding their contribution to climate change, exacerbated by factors such as erosion and deforestation (Iwuchukwu *et al*., 2023). Forests are under significant pressure not only from climate change but also from increasing populations and greater demand for forest resources (Onyeneke *et al 2020).* Among the protected areas grappling with these challenges is the Ise Forest Reserve, situated amidst farmlands and human settlements, facing threats from extensive logging and agricultural encroachment (Ajibola and Ilesanmi, 2017). Despite its status as one of the last remaining forest fragments in southwest Nigeria, the reserve is besieged by intense anthropogenic activities, including farming, logging, and hunting (Ogunjemite *et al*., 2006) and priority conservation areas for the endangered Nigeria-Cameroun Chimpanzees (*Pantroglodytes ellioti*) in Nigeria with a degrading forest environment (Morgan *et al*., 2011).

Forests play a multifaceted role in mitigating climate change, acting as crucial carbon sinks and regulating global temperatures (Rajasugunasekar *et al*., 2023). However, projections indicate a worrisome increase in greenhouse gas emissions, exacerbating the global average surface temperature and precipitation levels.

(Allen and Ingram, 2002; Noguer *et al.*, 2001). Additionally, forests provide essential shade to preserve soil biodiversity and regulate evapotranspiration rates, crucial for maintaining ecological balance (Ojekunle 2014). The interplay between rising human populations, climate change, and land use dynamics underscores the interconnectedness of environmental challenges, highlighting the need for holistic approaches to conservation and sustainable land management. (Lambin *et al.* 2003; Lepers *et al.* 2005). Increasing acknowledgment has arisen regarding the significant connections among diverse global environmental concerns, including biodiversity loss, climate change, and alterations in land use (Heistermann, *et al.*, 2006). The 20th century witnessed a significant global shift in land use dynamics, driven by the exploitation of natural resources to meet developmental needs (Ramankutty *et al.*, 2005). Land use patterns reflect complex interactions between biophysical characteristics and human activities, shaping ecosystems and influencing global environmental issues such as biodiversity loss and climate change (Eze *et al.*, 2011).

The global climate system is affected by land-use and land-cover dynamics through bio-geophysical, biogeochemical and energy exchange processes. These in turn affect climate at local, regional and global scales. The terrestrial albedo is often altered by use and this is the reason why climate change has been attributed to land-use. Understanding the dynamics of these changes is necessary for generating valuable information for better decision making in the management of natural resources (Lu *et al.* 2003). This is because changes in land use and land cover have been directly linked to biodiversity loss, climate change, food insecurity, human health, and general environmental degradation (Dunjó *et al.* 2003 and Noguer *et al.* 2006).

Against this backdrop, this study investigates the dynamics of land use and land cover in Ise Forest Reserve from 2000 to 2020, leveraging satellite imagery to show the evolving landscape patterns and assess deforestation and anthropogenic encroachment. Employing advanced remote sensing techniques, we aim to provide comprehensive insights into ecological transformations within the reserve. Our research endeavors to bridge existing knowledge gaps regarding land use changes in Ise Forest Reserve and their implications for biodiversity conservation and ecosystem integrity. Through the comprehensive analysis of spatiotemporal trends in forest cover, farmland expansion, and settlement encroachment, we seek to inform evidence-based conservation strategies and policy interventions. By meticulously interpreting satellite imagery, this study contributes to a deeper understanding of the environmental dynamics shaping Nigeria's forest landscapes, advocating for sustainable management practices to safeguard biodiversity and ecological resilience.

METHODOLOGY

Study Area

The study was carried out in Ise Forest Reserve, Southwest Nigeria. It is located within latitude 7° 20' 22.48" N to 7° 25' 03.47" N, and longitude 5° 19' 59.84"E and 5° 25' 35.33"E. The protected area is about 9km to the southern part of the reserve along Akure-Benin expressway from Uso community in Ondo State (Olaniyi *et al.*, 2016). The annual temperature is between 25 ˚C – 28 ˚C while generally, the minimum temperature is 19 ˚C and the maximum temperature is 33 ˚C. The annual precipitation is between 1200mm. Specifically, Ise Forest Reserve receives 1380mm of rainfall annually (Ikemeh, 2013). The rainfall is steady and spread almost evenly throughout the wet season (April-October). The Ogbese River flows by the western borders of Ise Forest Reserve and a relatively smaller perennial river flows within the reserve close to Eastern edge (Ikemeh, 2013). Ise Forest Reserve is blessed with diverse fauna and flora species (Ogunjemite, 2011).

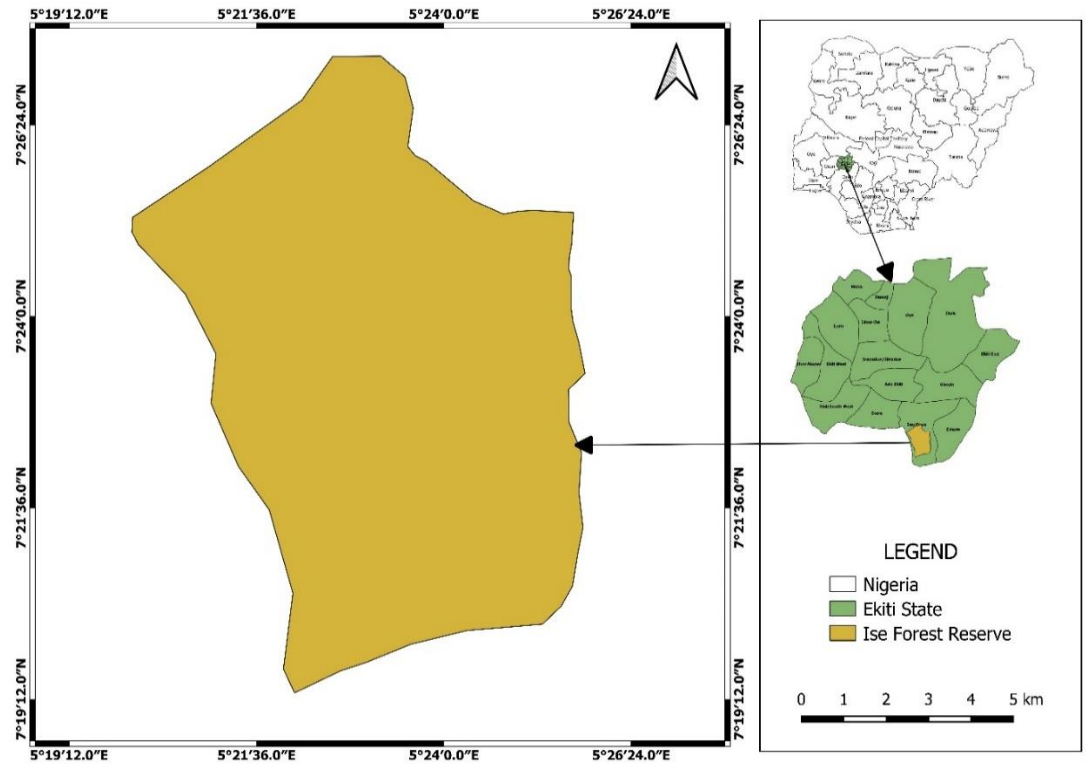

Figure 1: Map of Ise Forest Reserve

Data collection

Raster Data

To conduct this study, satellite data from Landsat 7 and Landsat 8 for the years 2020, 2010, and 2000 were acquired (path and row of 190/055 and 30 m resolution). These datasets were obtained from the United States Geological Survey (USGS) Earth Explorer platform (https://earthexplorer.usgs.gov/). ArcGIS and Quantum GIS (QGIS) software were used to analyze the image classification of the study area.

Data Analysis

Image Classification

Maximum Likelihood Algorithm (MLA) as used by (Alo *et al*., 2022) was utilized for the classification of the study area. MLA which is a supervised classification is the process of using samples of known identity (i.e. pixels already assigned to informational classes) to classify pixels of unknown identity (i.e. to assign unclassified pixels to one of several informational classes).

The classification of the study area was carried out on the imageries in Data Management Tools using ArcMap. A modified version of the Anderson (1976) scheme of land use/ cover classification was adopted: 1. Forested (areas dominated by trees), 2. Farmland (area with agricultural practices) and 3. Settlements (area with houses and other buildings) (Zhao *et al*., 2024).

Accuracy assessment

To assess the precision of the image classification outcomes, we utilized various evaluation methods. We conducted a comparison between the classified images and the reference dataset collected independently. Metrics such as user's accuracy (UA), producer's accuracy (PA), overall accuracy (OA), and kappa coefficient (k) were computed to quantitatively gauge the concordance between the classified results and the reference data. Accuracy Assessment was computed using the following equations:

$$\text{UA} = \frac{Total\ Number\ of\ correctly\ Classified\ Pixels\ in\ each\ category}{Total\ Number\ of\ Classified\ Pixels\ in\ that\ category\ (RowTotal)}\ x\ 100 \quad (1)$$

$$\text{PA} = \frac{Total\ Number\ of\ correctly\ Classified\ Pixels}{Total\ Number\ of\ Rreference\ Pixels\ in\ that\ category}\ x\ 100 \quad (2)$$

$$\text{OA} = \frac{Total\ Number\ of\ correctly\ Classified\ Pixels(Diagonal)}{Total\ Number\ of\ Rreference\ Pixels}\ x\ 100 \quad (3)$$

$$Kappa\ Statistics(k) = \frac{(TS\ x\ TCS) - \sum(Column\ Total\ x\ Row\ Total)}{TS^2 - \sum(Column\ Total\ x\ Row\ Total)}\ x\ 100 \quad (4)$$

Change Detection Analysis

Change detention analysis was carried out to determine the rate of changes over the years in the study area. The percentage change for each year and the rate of change between the years was calculated using the formula below.

Change was computed following: Change $(\Delta) = Y_2 - Y_1$ (5)

Average rate of change (AVR) was computed using: $\text{AVR} = \frac{Y_2 - Y_1}{T_2 - T_1}$ (6)

Percent Change Per Year (%Δ/yr.) was computed using: $\%\Delta/\text{yr.} = \frac{Y_2 - Y_1}{Y_1}$ (7)

Where Δ represents change; Y_2 and Y_1 are the area sizes in the initial year T_1 and final year T_2, respectively.

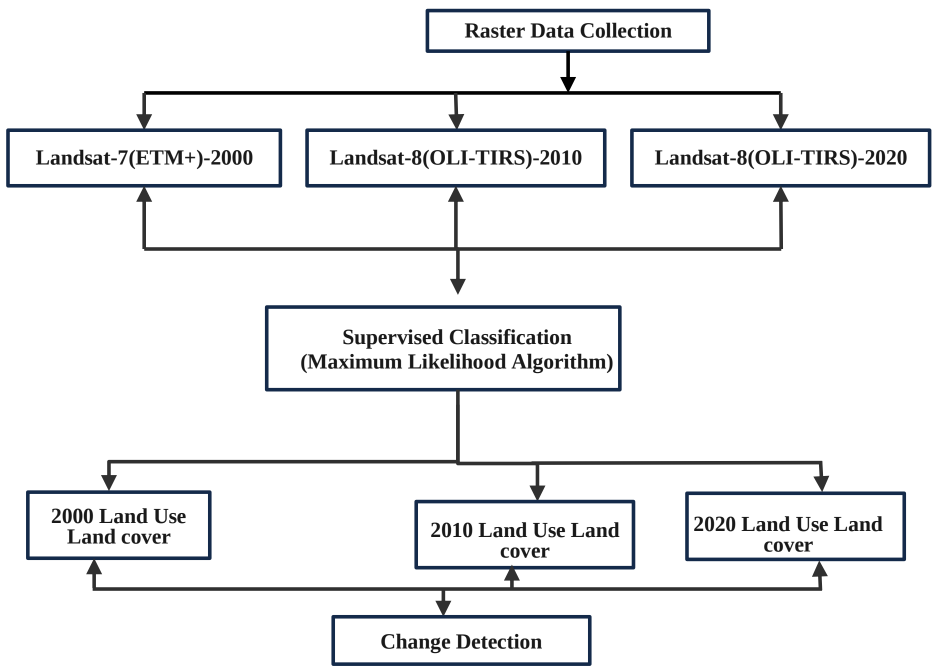

Figure 2: Framework of the methodology

RESULTS AND DISCUSSION

Ise Forest Reserve Land Use Land Cover

Table 1 shows the pattern of LULC of Ise forest reserve, which are Forest, Farmland and settlement for year 2000, 2010 and 2020.Out of the total area (97.16 km^2) the forest area had the largest coverage initially but experienced some fluctuations (Table 1 and Figure 4-6). In 2000, about 85.01 km^2 (87.5%) of the total area were covered with forest (Figure 4), which decreased to 79.68 km^2 (82.01%) in 2010 (Figure 5), and 72.26

km^2 (77.46%) in 2020 (Figure 6). The Farmland covered about 10.74% (10.44 km^2) of the total area in 2000 but increased to 13.62% (13.23 km^2) in 2010 and 17.24% (16.75 km^2) in 2020. However, settlements covered about 1.71km^2 which accounted for the 1.76% of the total area. This increased to 4.25 km^2 (4.37%) in 2010 and 5.15 km^2 (5.30) in 2020.

Table 1: Land cover type in Ise forest reserve from 2000 to 2020

Land cover type	**Area in Year 2000**		**Area in Year 2010**		**Area in Year 2020**	
	km^2	**%**	**km^2**	**%**	**km^2**	**%**
Forest	85.01	87.50	79.68	82.01	75.26	77.46
Farmland	10.44	10.74	13.23	13.62	16.75	17.24
Settlements	1.71	1.76	4.25	4.37	5.15	5.30
Total	**97.16**	**100.00**	**97.16**	**100.00**	**97.16**	**100.00**

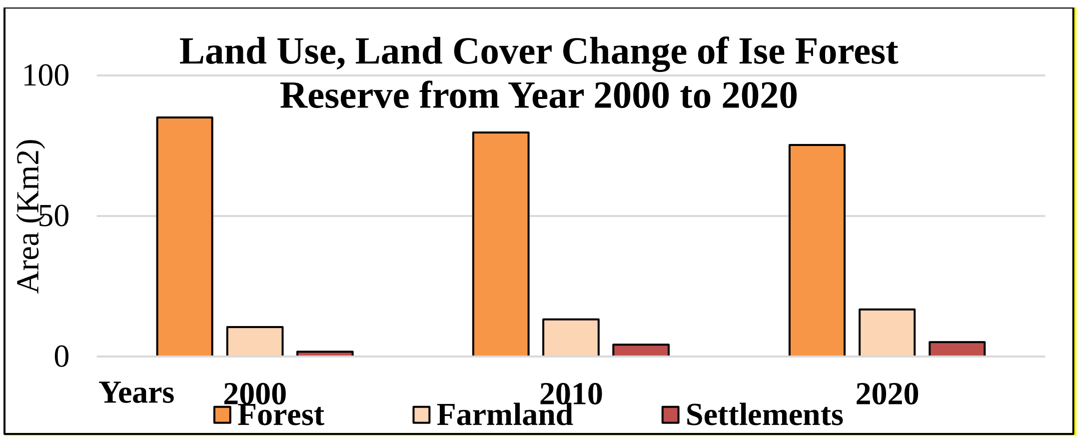

Figure 3: Graph showing the trends of the extent of land cover types in Ise Forest reserve during 2000 to 2020

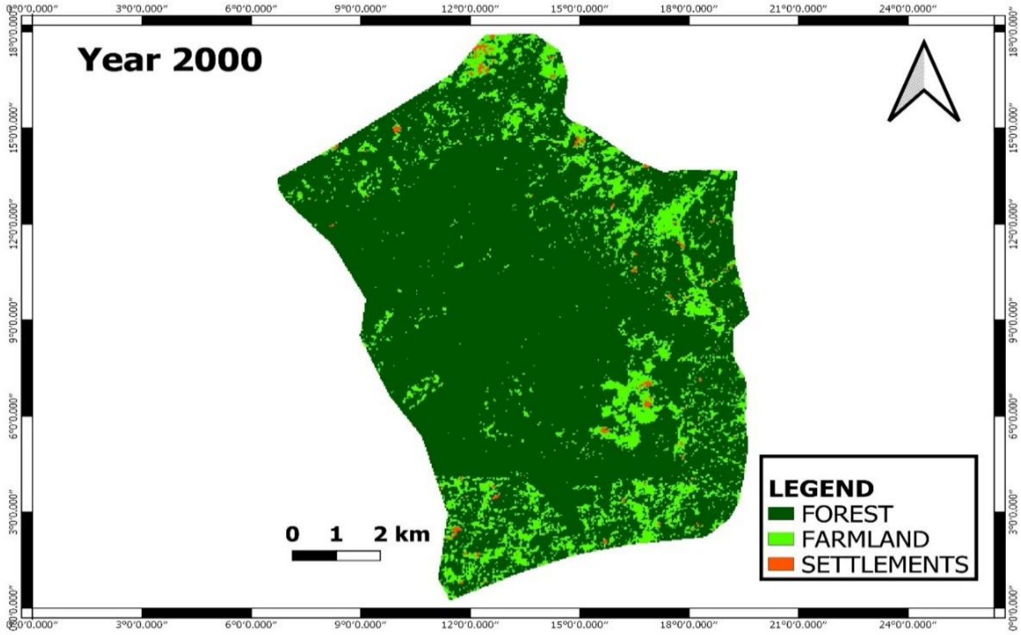

Figure 4: Land use land cover map of Ise forest reserve for year 2000

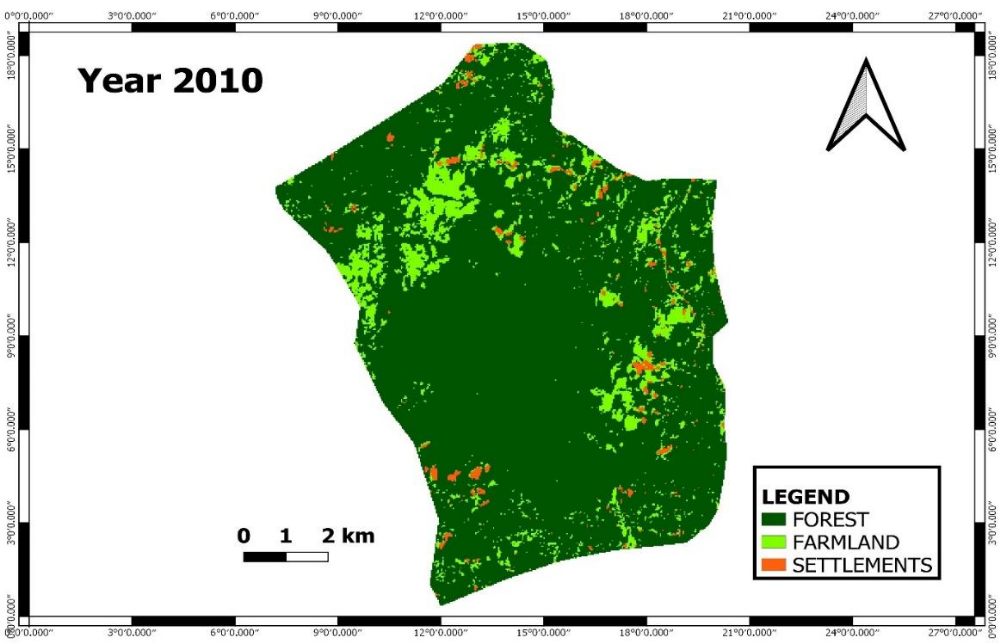

Figure 5: Land use land cover map of Ise forest reserve for year 2010

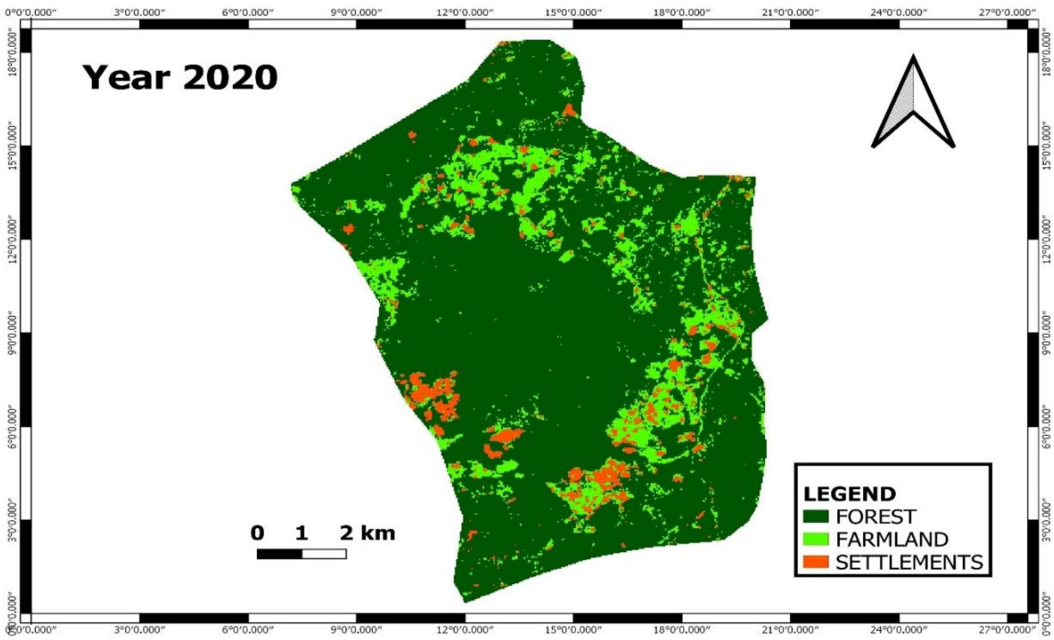

Figure 6: Land use land cover map of Ise forest reserve for year 2020

Change Detection Analysis

From Table 2, the trend of change from 2000 to 2010 shows that the forest had a negative change with a decrease of -0.53 km^2/yr. Farmland had an increase of 0.28 km^2/yr, while settlement had an increase of 0.25 km^2/yr. The trend of change from 2010 to 2020 shows that the forest had a negative change with a decrease of -0.44 km^2/yr while farmland and settlement had an increase of 0.35 km^2/yr and 0.09 km^2/yr respectively. The LULC trend for 2000 to 2020 shows that forest decreased with -0.98 km^2/yr, while farmland and settlement increased with 0.3 km^2/yr and 0.34 km^2/yr, respectively.

Table 2: Trend of Land cover change in Ise Forest Reserve during 2000 to 2020

Land Cover Types	**Area (km^2/yr)**		
	2000-2010	2010-2020	2000-2020
Forest	-0.53	-0.442	-0.98
Farmland	0.279	0.352	0.631
Settlements	0.254	0.09	0.344

Accuracy Assessment

Table 3 shows the error matrix which was carried out by verifying the land classification result with the google earth pro data. The user's, producer and overall accuracy with the kappa statistics(k) for the year 2000, 2010, and 2020 was computed. The overall accuracy for the year 2000, 2010 and 2020 were 94.91%, 93.42%, and 90.9% respectively. The kappa statistics(k) for year 2000, 2010 and 2020 were 93%, 91% and 90% respectively.

Table 3: Accuracy assessment table of Ise forest.

LULC	2000		2010		2020	
	Pa	Ua	Pa	Ua	Pa	Ua
Forest	96.94	100	100	99.56	100	90
Farmland	100	82.52	96.99	86.67	90	90
Settlements	100	100	99.87	100	90.91	100
Overall accuracy	94.91		93.42		90.9	
Kappa statistics(k)	0.93		0.91		0.9	

Where: Ua is User accuracy and Pa is producer accuracy,

DISCUSSION

Land use land cover changes has a serious implication for environment as Land use Land cover is directly related to the degradation over the period of time and results in many changes in the environment (Desta and Fetene, 2020). It is important to monitor the location and distribution of land use land cover in order to establish links between the policy makers and land users. The LULC classes used in this study area provided information on the degradation of the land between the year 2000 to 2020. The result of this research reveals that the forest cover has reduced and converted into settlements and farmland over time. Initially, the forest area dominated the region, constituting the majority of the total land coverage. However, a clear trend of forest loss is observed, with forest coverage decreasing from 85.01 km^2 in 2000 to 72.26 km^2 in 2020. This decline highlights the ongoing challenges of deforestation and land degradation within the reserve. Conversely, the expansion of farmland and settlement areas indicates human-induced land-use changes and urbanization processes occurring within the vicinity of the forest reserve. Farmland coverage increased steadily from 10.74% in 2000 to 17.24% in 2020, reflecting agricultural expansion and encroachment into forested areas. Similarly, settlement areas expanded over the years, signaling anthropogenic activities in the region. These observations also corroborate with similar studies carried out in different study areas (Alo *et al*., 2022; Alo and Aturamu, 2014.; Bukoye *et al*., 2023; Duguma *et al*., 2019; Komolafe and Akintunde-Alo, 2023).

The accuracy assessment represents a critical aspect of our study, as it serves to validate the reliability of the land classification process conducted within the Ise Forest Reserve. By comparing the results of our classification with high-resolution data obtained from Google Earth Pro, we were able to gauge the accuracy of our findings. This verification step is essential in ensuring that the land cover classifications accurately represent the real-world conditions within the study area (Ye *et al*., 2018). The overall high accuracy observed across the different time periods studied underscores the robustness of our classification methodology. The consistently high levels of accuracy indicate that our classification process effectively captured the spatial distribution of land cover types within the Ise Forest Reserve over time. This suggests that the classification results are reliable and can be used with confidence in further analysis and decision-making processes. Furthermore, the calculation of kappa statistics provides a quantitative measure of agreement between the classified data and the ground truth obtained from Google Earth Pro (Nkomeje, 2017). The high kappa values obtained for each time period indicate strong agreement beyond chance, reinforcing the credibility of our classification results. This statistical validation adds another layer of confidence to our findings, enhancing the overall reliability of our study outcomes.

CONCLUSION AND RECOMMENDATIONS

The analysis of satellite imagery for the Ise forest reserve reveals a concerning trend of deforestation and land cover change due to human activities. This poses significant risks to biodiversity and ecosystem stability. Addressing these challenges requires a multifaceted approach involving policy interventions, education, community engagement, and regulatory measures. Policymakers must prioritize sustainable land management practices, including integrating land uses with existing ecosystems and implementing soil conservation measures. Education programs are vital for promoting environmental stewardship and inspiring collective action. Regulatory mechanisms are essential for protecting habitats and combating illegal activities. Establishing new protected areas can provide refuge for threatened species and support biodiversity conservation through ecotourism. Collaboration among policymakers, conservation organizations, and local communities is recommended to develop comprehensive conservation strategies. This includes research, monitoring, and evaluation to ensure the long-term health of natural ecosystems. Working together, we can safeguard biodiversity and ensure the resilience of ecosystems for future generations.

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