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Assessment of Forest Cover Changes of Sakponba Forest Reserve in Benin City, Nigeria over a 32 year period (1987-2019)

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ABSTRACT: Nigeria has been experiencing a surge in population growth affecting her forest over the last decades. Despite the establishment of forest reserves and national parks all over the nation as a way to protect her forest ecosystem, these forests continue to be tremendously degraded due to human population growth and development at the expense of our natural resources. Hence, this study was initiated to evaluate the extent of forest cover changes of Sakponba forest reserve e in Benin City, Nigeria over a 32 year period (1987-2019) using remote sensing and GIS techniques. Landsat data was acquired for the area, pre-processed and exported into a GIS platform for analysis. Findings from this study shows that within 32years (1987 to 2019), Sakponba forest which in 1897 occupied a geographical area of 285. 4971 km^2, has lost 190.4481 km^2 of its dense forest area and gained 115.2198 km^2 in moderate forest, 74.0934 km^2 in open forest and 1.1349 km^2 to water. The annual rate of forest deforestation between various year intervals was calculated. The major activities taking place in this forest reserve includes agricultural practises and overexploitation of timber and fuel wood. The degradation of this forest has led to adverse effects in ecological services as well as loss in biodiversity. Therefore, it is suggested that the Edo state government should enact stringent laws protecting this forest reserve, establish sustainable reforestation programs, enlighten and create awareness amongst the people and encourage the planting of ornamental trees to restore more carbon sequestration and thus reduce global warming.

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The tropical forest is home to a diverse range of plant and animal species that provide a wealth of commodities and services used all over the world, resulting in a rapid increase in anthropogenic activities over time, forest degradation, and reduced restoration capacity of forest ecosystems, all of which have serious environmental consequences. (Chapin *et al.*, 2000; Lewis, 2006; Barlow *et al.*, 2016; Betts *et al.*, 2022). Forest ecosystems, including tropical deciduous forests and savannas, cover approximately 14% of the Earth's terrestrial area ($18.6106\ km^2$). They store approximately 861 gigatonnes of carbon, which is distributed across soil (44%), live biomass (42%), dead wood (8%) and litter (5%) (Pan *et al.*, 2011). Africa is estimated to have the largest rate of forest loss (Barnsley, 2008), although there is a lack of reliable data on the rates and causes of such losses, particularly in developing countries, including Nigeria. Nigeria's forest estates span roughly 10 million hectares, or nearly 10% of total land area (92,377km²) (Usman and Adefalu, 2010). Over the past few decades, there have been major changes in land use and

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forest cover in the country's forest ecosystems. The total forest cover consists of approximately 445 protected areas spread across five major ecological zones namely freshwater/mangrove, lowland rainforest, derived savanna, and Sahel/Sudan savanna (Umar *et al*., 2018, Saka-Rasaq, 2019). Nigeria is estimated to have the world's highest rate of primary forest destruction, losing 55.7% of its primary forests between 2000 and 2005 (FAO, 2006). These changes are attributed to the ongoing expansion in human population, agricultural growth, and societal changes that have resulted in the unsustainable exploitation of natural resources. Rising human population and global climate change have also been highlighted as important drivers of plant cover loss and growth in seasonally dry tropical ecosystems around the world (Lepers *et al*., 2005). Among other anthropogenic causes that contribute to this, the impact of the local communities around these forest reserves cannot be overemphasized because they are increasingly engaged in activities such as poaching and illicit logging. (Mohan *et al*, 2021). Nigeria's national parks are among the few remaining natural ecosystems capable of enhancing biological processes and life support systems. It is a tropical protected area strategy to conservation that has been widely embraced in West African countries due to differing perspectives on natural resource utilization. However, the bulk of these parks and reserves have degraded beyond the point of regeneration (USAID/Nigeria, 2008).

This study is focused on Sakponba forest reserve located in Orhionmwon local government area, Edo state, in order to quantify the magnitude of forest degradation. Sakponba forest reserve is known to have the highest percentage of tree species in Edo state (Ihenye *et al*., 2011) and has led to anthropogenic induced degradation such as logging, illegal entry, collection of non-timber forest products and farm practices, where logging and farming are seen as the major treat to the destruction of this forest reserve (Azeez *et al*., 2010; Balogun and Iyekekpolor, 2020). To quantify the extent of forest loss or degradation, several methods which include tracking of secondary forest dynamics, canopy height change, identification of canopy gaps and clearings, and forest disturbance mapping which is the use of GIS and remote sensing in land use and land cover change analysis. Landuse/Landcover provides the fundamental details of the geographical distribution and position of both natural and human resources, both qualitatively and quantitatively. Hence, the application of land use/cover change is vital for forest loss monitoring. Therefore, the objective of this paper is to evaluate the extent of forest cover changes of Sakponba forest reserve in Benin City, Nigeria over a 32 year period (1987-2019) using remote sensing and GIS techniques.

MATERIAL AND METHODS

Study Area: Sakponba forest reserve is a tropical rainforest located in Orhionmwon local government area about 30 kilometers south-east of Benin City. The reserve was constituted in 1912, covering an area of 504.1368 sq km. The forest is located between latitude 6 04' N and longitude 5 32' E. Sakponba forest reserve is divided into two main areas by River Jamieson, Area BC 29 and BC 32/4. The forest reserve has 175 compartments, out of which 101 are located within BC 29 and 75 in BC 32/4. The reserve is rich in economic valuable tress such as Opepe, Afara, Mahogany, Albizia and several others, with villages located within and around the forest area. The mean annual rainfall is 2162mm, the wettest period is between July and September while the driest is between December and January; the relative humidity is generally high averaging 71% in the afternoon. The minimum and maximum temperatures are generally low from 16 – 26^{0}C. The forests serve as source of income generation to the government, communities and individuals through activities such as lumbering, logging and farming taking place in the forest.

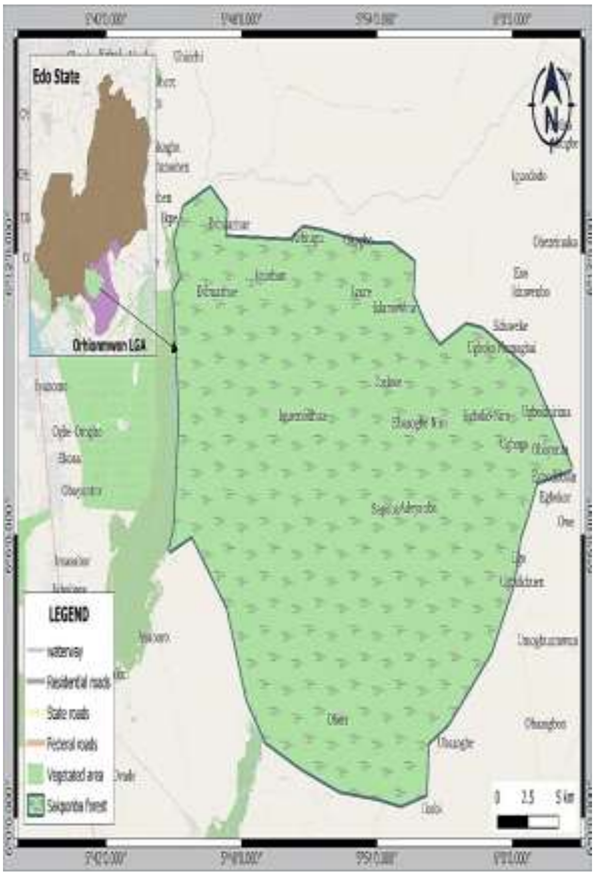

Figure 1: Map of Sakponba forest reserve

Data acquisition: This study utilized satellite imagery of the study area, specifically path and row 189/56, which were obtained from the website of the United States Geological Survey (USGS). The temporal resolution of the study spanned ten years, from 1987 to 2019. The Landsat 5-TM image was obtained for the year 1987, while the Landsat 7 ETM+ images were obtained for the years 2012, 2002, and 2019. To ensure high quality imagery, images with less than 10% land and scene cloud cover were collected for each year. However, due to the unavailability of quality images with less than 10% land and scene cover, images from different days within the same week were used, resulting in some inconsistency in collecting images for the same date across the years.

Experimental design: The experimental design is as illustrated in figure 2

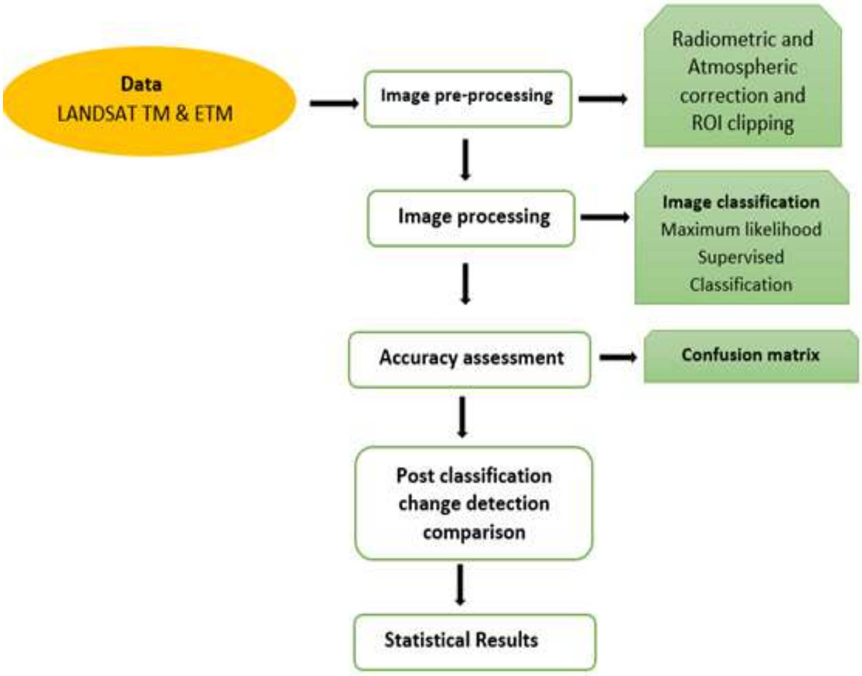

Fig 2: Experimental design

Image pre-processing and processing: As depicted in Figure 2, following the collection of the images, atmospheric and radiometric correction techniques were applied in ENVI 5.3 to enhance the image classification process. The classification of forests was achieved through the use of a supervised classification method known as the maximum likelihood supervised classification technique in ENVI 5.3. The images for each selected year were classified into four categories, including surface water and three vegetation categories, namely dense vegetation, moderate vegetation, and open vegetation. Careful selection of training samples for each category was conducted and is presented in Table 2.

Table 1: Vegetation classification names, description and number of trained samples for each of Landsat datasets.

Class	Description	Number of samples (1987)	Number of samples (2002)	Number of samples (2012)	Number of samples (2019)
Dense vegetation	>70% trees	43	45	37	41
Moderate vegetation	>50% trees	42	35	41	39
Open vegetation	Agriculture, grassland and crop land	40	42	41	43
Water	Reservoirs and rivers	23	26	27	21

Accuracy assessment: Conducting an accuracy assessment or validation is an essential step in processing remote sensing data, as it determines the usefulness of the resulting information to a user. In this study, the accuracy assessment of the classified images was performed using the confusion matrix technique and the ground truth image tool in ENVI 5.3 software. The confusion matrix provides a relationship between the known reference data, which is the ground truth data obtained from the high-resolution image, and the corresponding land use/cover classification map. The values in the confusion matrix represent the count of pixels of each class that were correctly classified in the right category. The result of an accuracy test typically provides users with an overall accuracy of the classification image and the accuracy for each class in the classification image and it is presented in Table 3.

Table 2: Accuracy table

Class	User's accuracy	Producer's accuracy 1987	User's accuracy	Producer's accuracy 2002	User's accuracy	Producer's accuracy 2012	User's accuracy	Producer's accuracy 2019
Dense WL	94.99	90.44	89.84	92.62	89.99	94.60	85.99	87.65
Moderate WL	84.74	82.82	86.00	90.20	88.20	94.74	86.12	90.60
Open WL	87.99	90.62	95.65	88.82	85.34	90.95	83.44	87.63
Water	95.99	89.93	86.88	87.54	87.22	99.29	89.62	86.94
Overall accuracy (%)	89.91		88.87		89.80		87.76	
Kappa Coefficient	0.85		0.84		0.86		0.85	

Annual rate of deforestation: According to Puyravaud (2003), the annual rate of deforestation gives information on the average rate at which the forest changes over the years. In other to calculate the annual rate of deforestation of dense vegetation also known as annual change, the formula below was used.

$$R = \frac{A_2 - A_1}{t_2 - t_1} \quad (1)$$

Where; (the Si unit is unit area per year); R = annual deforestation; A_1= area of forest at a earlier time frame t_1, A_2= area of forest at a later time frame t_2.

RESULTS AND DISCUSSION

Findings from this study show that within 32years (1987 to 2019), Sakponba forest has lost 190.45 km^2 of its dense forest area and gained 115.2198 km^2 in the moderate forest, 74.0934 km^2 in open forest. Figure 3 shows images of the forest cover classified into four distinct groups based on the aerial extent of the vegetation cover; dense vegetation, moderate vegetation, open vegetation and water for 1987, 2002, 2012 and 2019 respectively. The moderate vegetation includes fragmented areas of the dense forest and it can be deduced that with increase in the moderate vegetation, more trees are been cleared out to create farm lands and exploitation of timber as shown in table 3. Open vegetation covers areas of the forest burnt or cleared out for farming. The forest lands in the Sakponba forest reserve have greatly been degraded as a result of excessive exploitation consequent upon poor management of the forest reserve. It is therefore evident that deforestation is a major problem in this study area. Forest loss is as a result of increased pressure on forest resources such as fuel wood, medicinal plants, farm practices and illegal hunting of animals (Azeez *et al*., 2010; Suleiman *et al*., 2017; Olayode, 2019; Balogun and Iyekekpolor, 2020).

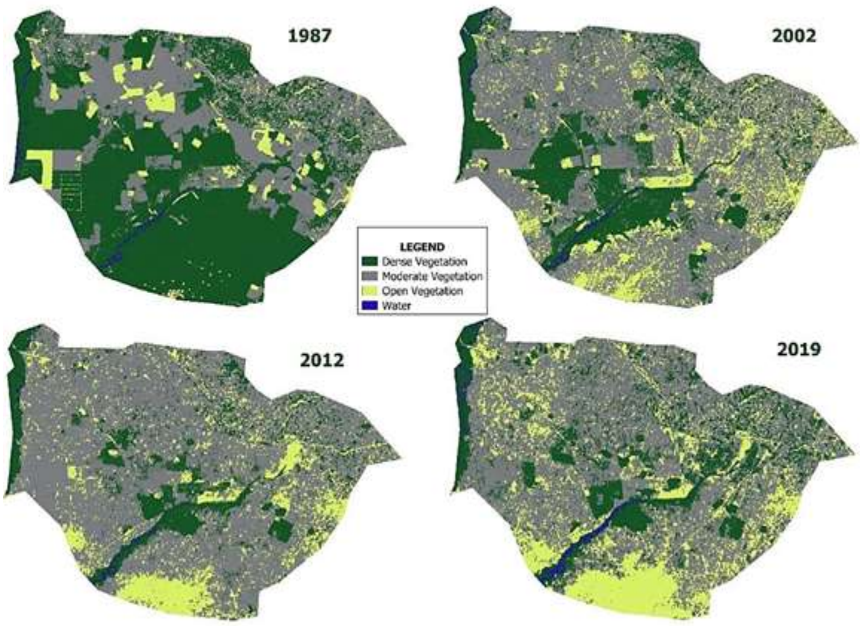

Fig 3: Satellite imagery of Sakponba Forest Reserve

Extent of forest cover changes between 1987 and 2002: Sakponba forest saw a drastic decline in its forest, the dense vegetation had reduced from 56.63% of the spatial area of Sakponba forest to 22.63% respectively and moderate vegetation had increased from 35.88% to 61.03% while the open forest increased from 6.97% to 15.78%, the dense forest occupied an area of 285.4971 km^2 decreased to an area size of 114.0966km^2 in 2002 as shown in table 3. Population growth, increased farm activities, exploitation of resources are vices which has led to decline in the dense vegetation. Information obtained by a study carried out by Azeez *et al* (2010) revealed that the most land use activity within Sakponba forest reserve was farming. A majority of the farmers practice mixed cropping with numerous choices of crops through the taungya system. The Sakponba forest reserve comprises of 175 compartments with seventy-six tree species and five shrub species making the forest reserve the reserve with highest percentage of tree species in Edo state (Ihenyen *et al*., 2011). These compartments as permitted by the state government have been allocated to timber contractors, indigenes and people leaving outside the forest area for exploitation of timber and farming within the reserve with a fee paid to the government annually (Balogun and Iyekekpolor, 2020) and is a driving factor that contributes to the deforestation of Sakponba forest reserve as timber is continuously lumbered and trees felled for more land space for farming activities and charcoal making.

Table 3: Vegetation cover distribution

Vegetation cover	1987 (Sq km)	Percentage (%)	2002 (Sq km)	Percentage (%)	2012 (Sq km)	Percentage (%)	2019 (Sq km)	Percentage (%)
Dense	285. 4971	56.63	114.0966	22.63	71.4366	14.17	95.039	18.85
Moderate	180.8613	35.88	307.6992	61.03	355.0788	70.43	296.0811	58.73
Open	35.1405	6.97	79.5348	15.78	76.2471	15.12	109.2339	21.67
Water	2.6397	0.52	2.808	0.56	1.3761	0.27	3.7746	0.75
Total	504.1386	100%	504.1386	100%	504.1386	100%	504.1386	100%

Table 4: Annual rate of forest change

Area change per year/percentage change	Dense		Moderate		Open	
Between 1987-2002	11.4267km^2 Decrease	**60.04%**	8.4559km^2 Increase	**70.13%**	2.9596km^2 Increase	**126.33%**
Between 2002-2012	4.2660km^2 Decrease	**37.39%**	4.7410km^2 Increase	**15.40%**	0.3288km^2 Decrease	**4.13%**
Between 2012-2019	3.3762km^2 Increase	**34.44%**	6.4282km^2 Decrease	**16.62%**	4.7124km^2 Increase	**43.26%**

Extent of forest cover changes between 2002 and 2012: The dense cover had further decreased to 14.17% (71.4366 km^2) of the forest area and moderate vegetation increased to 70.43% (335.0788km^2) with a decline in open vegetation 15.12% (76.2471km^2). This further indicates the extent of community and timber companies' dependence on the forest resource in the Sakponba forest. Over the past years, about 66% of these farmers have been farming in the reserve despite the fact that it is a protected area under Category II of IUCN (International Union for conservation of Nature and National Resource) categories of protected areas. The result can be clearly seen in the continuous decline of forest extent and expansion of farmland and these findings corroborate those of Suleiman *et al*. (2017) who reported its biggest deforestation and forest cover transitions between 1985 and 2015 resulting from agricultural expansion, excessive fuel wood collection , overgrazing and forest fire. Similarly the Niger Delta region suffered the same fate within these years, due to uncontrolled timber logging, fuel wood extraction and oil exploration in the region (Onojeghuo and Blackburn, 2011).

Extent of forest cover changes between 2012 and 2019: The dense cover had an increase of 4.68% resulting in a total of 18.85%, it increased from 71.4366 km^2 to 95.049 km^2. While the moderate cover meet a decrease from 355.0788 km^2 to 296.0811 km^2 , while the open cover saw an increase as well from 76.2471km^2 to 109.2339 km^2 . Attempts have been made by the Edo state government efforts to fight illegal activities and halting of farm activities over the years, resulting in the gradual increase in the dense cover vegetation between 2012 and 2019, nonetheless the dense vegetation cover is not as the primary forest in 1987.

Extent of forest cover changes between 1987 and 2019: In 32 years, Sakponba forest reserve has lost 190.4481 km^2 of its dense cover area and gained 115.2198km^2 in moderate cover and 74.0934km^2 in open cover. From the images, it is evident that

Sakponba forest reserve is seriously degraded implying that deforestation is evident and remains a major problem in the study area. The reason for the increase in deforestation increased farming activities resulting from population growth leading to high demand in food supply, therefore the need for more land space for farming as well as the wide practice of shifting cultivation among farmers. A similar situation can be observed in Kainji Lake national park, where bare land increased progressively between the years 1988 to 2018 as a result of anthropogenic activities (Adeyemi and Ibrahim, 2020). This can be explained by the nature of the tree species found in the reserve which favours exploitation by local people and loggers to generate income. The government plays a major role in the deforestation of this reserve by allocating plots of lands for farming and logging, and inefficiency in management strategies employed in the reserve, inadequate trained staff, lack of equipment, and corruption. The instability in the trends of forest cover loss or gain displayed reflects the physical and bio-physical processes going on in the forest, affecting the ecosystem services as shown in table 4, where the annual rate of forest cover change between the various years describes all changes (increase and decrease in size) experienced by the various vegetation covers (dense, moderate and open), within various time periods. These transitions reflect the forest cover dynamics in the reserve. Forests play an important ecosystem service role in maintaining the earth's carbon balance both storing (carbon sequestration) and releasing CO^2 into the environment. Today, the world's forest store over a trillon tonnes of carbon dioxide in its biomass with 300 to 400 tonnes of CO^2 per hectare in mature tropical forest (Mendelsohn *et al*., 2012) and deforestation reduces the carbon storage releasing these tons of CO^2 in to the environment. Farooqui *et al*. (2021), explained the importance of forest in carbon sequestration and conservation of water. It is known today that carbon is stored in forest living biomass (trunk, leaves, branches, roots), debris, litter and soil (Tang *et al*., 2018; Zhou *et al*., 2019; Sun and Liu, 2020).

Conclusion: This study revealed rapid degradation of the forest reserve over 32 years due to anthropogenic activities linked to human population growth. Although there was an improvement in vegetation cover from 2012-2019, complete restoration to the 1987 state without disturbance would take over 150 years. Sustainable reforestation programs and mitigating measures are necessary in light of the invaluable ecological services the forest provides. There is need for government to enforce protective laws, support reforestation, create jobs for indigenous people, promote alternative fuel sources, fund forest protection agencies, equip forest officials, and engage experts in sustainable forest management.

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