Nigerian Research Journal of Engineering and Environmental Sciences 3(1) 2018 pp. 39-47

Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

RJEES

Original Research Article

A SYSTEMATIC ASSESSMENT OF PLANTATION EXPANSION IN OKOMU FOREST RESERVE, EDO STATE, SOUTHERN NIGERIA

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ARTICLE INFORMATION

Article history:
Received 28 May, 2018
Revised 02 June, 2018
Accepted 04 June, 2018
Available online 30 June, 2018

Keywords:
Tropical rainforest
Okomu oil palm plantation
Agriculture
Remote sensing and GIS
Nigeria

ABSTRACT

Agriculture is the mainstay and a major source of foreign exchange earning for many tropical countries. Studies have examined the pattern and consequences of agricultural plantation on tropical rainforest ecosystems. However, systematic assessment of the processes that result in the observed pattern of land use is limited. This study examined the pattern and processes of oil palm and rubber plantations expansion in Okomu forest reserve, Edo State, Nigeria. Segmented Landsat images of 1987 and 2015 were classified using support vector machine algorithm into three categories: plantation, forest and others, cross tabulated and analysed using intensity analysis approach. The results show that plantation increased by 12%, others 14% and forest loss 15% during the period of this study. Forest loss was primarily caused by plantation expansion prior to the creation of Okomu National Park. Plantation's gain targets others while others' gain also targets plantation. Both gains however avoid forest while forest's gain targets plantation but avoids others. However, plantation expansion increases the pressure on the rainforest and depletes natural habitat. The integration of environmental protection and conservation policies into economic and land use planning, administration and governance is recommended.

1. INTRODUCTION

The tropical rainforest is facing increasing pressure because of high demand for urban space, food production and industrial raw materials driven by a rapidly rising global population (Geist and Lambin, 2002; Hobinger *et al.,* 2011; Koh *et al.,* 2011; Akinyemi, 2013; Enaruvbe and Atedhor, 2015; Torbick *et al.,* 2016).Though a large proportion of agricultural land is under peasant farming in many tropical countries, plantation agriculture and agroforestry are now popular (Aweto, 2001; Villamor *et al.,* 2014; Zhang *et al.,* 2015; Tonks *et al.,* 2017). The expansion of plantation agriculture is accelerating tropical deforestation in many countries and is now a major contributor to changes in environmental components, including water quality, soil fertility status, habitat and biodiversity loss in these countries (Soares-Filho *et al.,* 2006; Koh and Wilcove, 2008; Koh *et al.,* 2011; Silva *et al.,* 2016).

In many West African countries, population increase, economic development and the growing demand for food and industrial raw materials were key factors that influenced the formulation of policies aimed at the expansion and increase in the productivity of tree crops such as oil palm (*Eliase guineesis*), cocoa (*Theobroma cacao*) and rubber (*Hevea brasiliensis*) (Udo, 1965; Asubonteng *et al.,* 2018). Oil palm, rubber and cocoa plantations are now common in the rainforest ecological zone of many countries in the region, including Nigeria. The expansion of plantations therefore increases the pressure on the rainforest leading to degradation and depletion of environmental components such as habitat and biodiversity loss, carbon storage, water and soil preservation capacity (Kassa *et al.,* 2017; Lobora *et al.,* 2017; Tran and Fischer, 2017; Velázquez *et al.,* 2017; Wakhid *et al.,* 2017; Oliver *et al.,* 2018).

Okomu Forest Reserve is described as one of the most densely forested areas in southern Nigeria, with a high biodiversity value and was therefore one of the earliest reserves gazetted in 1935 with a land area of about 1200km^2 (von Hellermann, 2011). Post-independent agricultural boom and the policy of tree crops expansion emphasized in the 1962 – 1968 National Development Plan of Nigeria, however led to the allocation of de-reserved parts of the forest reserve to monoculture plantations of rubber and oil palm (Udo, 1965; von Hellermann, 2011). The presence of rare and endangered animal species such as the White-throated monkey (*Cercopithecus albogularis*) and African forest elephant (*Loxodonta cyclotis*) led to the creation of a wildlife sanctuary within the reserve in 1986 to protect these and other endangered and vulnerable species (Akinsorotan *et al.,* 2011).

Tree crops such as oil palm, cocoa and rubber remain important sources of raw materials. However, the expansion of these plantations, coupled with timber extraction and smallholders farming activities, pose a threat to ecological conservation and diversity. Earlier studies in Okomu forest reserve examined the fauna and floristic composition of the forest (Jones, 1955, 1956; Ejidike and Okosodo, 2007; Idu and Osemwegie, 2007). In addition, the impact of plantation and agroforestry systems on soil fertility status and vegetation diversity in tropical rainforest ecosystems have been extensively studied (Ekanade, 1985; Aweto and Moleele, 2005; Ogunkunle and Awotoye, 2011; Tonks *et al.,* 2017; Wakhid *et al.,* 2017; Wartenberg *et al.,* 2017) however, there is limited information on the linkage between observed pattern of land use change and the processes driving the conversion of tropical rainforest to plantation agriculture. Though recent studies (Asubonteng *et al.,* 2018; Minaei *et al.,* 2018) examined the pattern and processes of land changes, studies linking these patterns to processes are few in a protected landscape such as Okomu Forest reserve. Ayanlade (2016) noted the increasing deforestation in Okomu and Gilli Gilli Forest reserves while Ayanlade and Drake (2015) discussed the spatial pattern of deforestation in Okomu and Gilli Gilli forest reserves as part of their study of deforestation in the Niger Delta using remote sensing approach. They reported that there was plantation expansion in the reserves but did not determine the processes that brought about the observed patterns even though large expanse of land is required for plantation agriculture to be viable (Aweto, 2001; Hartemink, 2005).

This study therefore intends to examine the processes that resulted in the pattern of plantation expansion in Okomu forest reserve between 1987 and 2015. This is important because successfully achieving the goal of biodiversity conservation, highlighted in the United Nations Sustainable Development Goal number 15 (United Nations, 2016), requires an understanding of both the factors and the processes driving deforestation in biodiversity hotspots such as Okomu forest.

2. METHODOLOGY

2.1. Study Area

This study was conducted in Okomu Forest Reserve, Edo State, southern Nigeria (Figure 1). The area is bounded approximately by latitudes 6.08° and 6.30°N and longitudes 5.01° and 5.27°E. The reserve now consists largely of Okomu National Park, Okomu oil palm plantation and Osse rubber plantation. Okomu National Park has an area of approximately 202 km^2. While the oil palm and rubber plantations occupy a large part of the reserve. There are also small-scale cocoa plantations, subsistence farms and settlements scattered in the reserve which have led to widespread forest degradation. The forest is characterized by a relatively flat to very gently undulating plains developed on sedimentary rocks and littoral deposits with most parts lying below 200 m above mean sea level (Ojanuga, 2006). The climate of the region is characterized by a double maximal year-round rainfall pattern with a mean monthly rainfall of about 2000 mm which peaks between May and October and a mean monthly temperature of 27°C. Vegetation in the reserve is composed of a close stand of three layers of trees consisting of lower and middle storeys and a discontinuous layer of tall emergent trees. Some tree species in the area include African mahogany (*Khaya ivorensis*) and African walnut (*Lovoa trichilioides*).

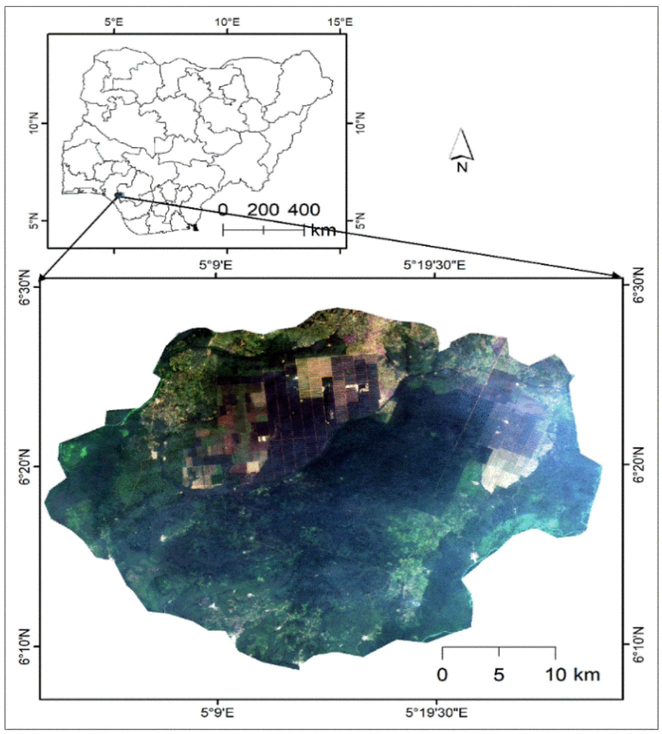

Figure 1: Location of Okomu forest reserve in Edo State, Nigeria

2.2. Data Sources and Image Classification

This study was based on field observations and analysis of Landsat satellite image data obtained from the achieves of the United States Geological Surveys (USGS). These 30 m resolution images are suitable for monitoring and analysis of forestry and other environmental resources (Minaei *et al.,* 2018). Two cloud-free images of the study area, acquired in January 2, 1987 and February 17, 2015, were obtained and used for this study. These images were selected because they were acquired at the same season of the year and therefore eliminates seasonal variation in vegetation signature. The data for the study area were extracted from the scenes with Path 190 and Row 056. Radiometric corrections and dark object subtraction processes were performed on the images to reduce possible errors caused by atmospheric distortions. Image pre-processed was followed by segmentation which makes it possible to use object-based image analysis which has been reported to produce more accurate maps from satellite image data than pixel-based methods (Ye *et al.,* 2018). The segmented images were gridded at 50 m interval and a minimum of twenty grids were randomly selected from areas under plantation, forest and other land use and land cover types for field visit. Fieldwork was conducted between December, 2014 and February 2015 which was close to the acquisition date of the 2015 image.

Using seventy percent of the information obtained from field visit, the images were classified into three categories: plantation, forest and others, using the support vector machine classification algorithm. Image processing and analysis were carried out using ENVI 5.1 software environment. The category classified as others include farmlands, open and degraded forest, water, swampy area, areas cleared for farming or plantation expansion and settlements. Plantations include oil palm, rubber and smallholder cocoa plantations while forest category is the relatively undisturbed forest area.

Square contingency matrix of the two images was obtained by overlaying the images using cross tabulation process in Idrisi Selva software. This matrix is the only input required for the analysis of land change processes using the method of Intensity Analysis developed by Aldwaik and Pontius (2012). The percent gain and loss were computed using Equations (1) and (2) respectively.

$$\% \text{ Gain} = \sum_{i=1}^{n} c_{ij} - c_{ii} \quad (1)$$

$$\% \text{ Loss} = \sum_{j=1}^{n} c_{ij} - c_{ii} \quad (2)$$

Where c_{ij} are the non-diagonal values on row *i,* column *j* and c_{ii} are values along the diagonal of the matrix.

Intensity Analysis compares the size of land use change in a category to the size of the losing category in the earlier year or the size of the gaining category in the later year. In this way, it can determine whether the categorical change is random or systematic. The intensity of a systematic change will be higher than uniform rate of land change given the size of the category while a random change will be less than the average rate of change of the category. Though intensity analysis is carried out at three levels - Interval, Category and Transition levels - the analysis in this study is limited to the transition level because the interest here is to determine the rate of transition from one category to another at two points in time (1987 and 2015). In addition, the transition level of analysis provides more information about the processes of land use conversion than the others two levels of intensity analysis. Accuracy assessment was carried out on the maps derived from image analysis using the thirty percent of the field information (Enaruvbe and Pontius Jr., 2015).

3. RESULTS AND DISCUSSION

The square contingency table of the 1987 and 2015 maps is shown in Table 1. The table indicates that the total area occupied by oil palm and rubber plantations increased by 12% of the total area of the reserve. However, plantation also reduced by 4% during the period of this study. In contrast, forest gained over 3% but loss 15% and others gained 14% while it loss 10% between 1987 and 2015. Table 1 also indicates that 5% each of plantation and forest and 61% of others was unchanged between 1987 and 2015. Plantation agriculture increased by over 8% in Okomu Forest Reserve between 1987 and 2015. The increase in plantation agriculture is a direct response to government policy to enhance the cultivation and productivity of tree crops such as oil palm, rubber and cocoa as sources of raw materials and avenue for employment creation as was also the case in many tropical countries, such as Indonesia, Ghana and Cote d'Iviore (Asubonteng *et al.,* 2018; Gatto *et al.,* 2015; Widner, 1993; Zhai *et al.,* 2012). This policy led to widespread clearing and replacement of the rainforest with oil palm, rubber and cocoa plantations (Akinyemi, 2013; Aweto and Enaruvbe, 2010) in many parts of the rainforest. Asubonteng *et al.* (2018) also reported similar policy impacts in the eastern region of Ghana while Ayanlade and Drake (2015) noted that agricultural land use has been on the rise, to the detriment of the rainforest, in the Niger Delta region of Nigeria.

Table 1: Square contingency matrix (%) of land use and land cover categories in Okomu Forest Reserve, 1987 - 2015

		1987			2015	1987-2015
		Plantation	Forest	Others	Total	Gain
2015	Plantation	4.89	5.11	6.90	16.90	12.01
2015	Forest	0.17	4.93	3.33	8.44	3.49
2015	Others	4.25	9.68	60.73	74.66	13.93
1987	Total	9.30	19.74	70.96	100.00	29.44
1987-2015	Loss	4.42	14.79	10.23	29.44	

Figure 2 shows the spatial distribution of land use and land cover in Okomu forest reserve in 1987 and in 2015. The figure also shows maps of areas of persistence, gain and loss during the period of the study. Overall, plantation agriculture increased by more than 8% in Okomu Forest Reserve between 1987 and 2015.

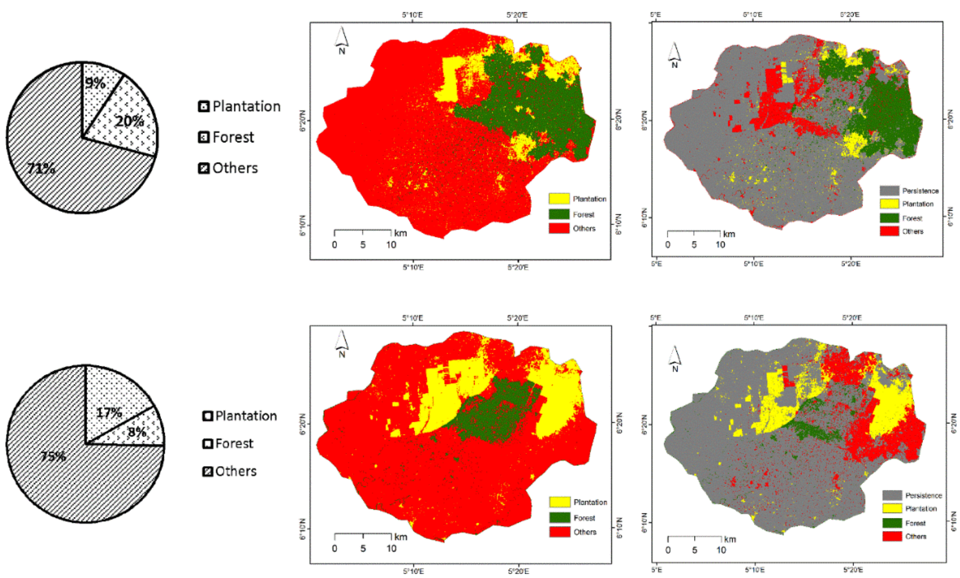

Figure 2: Percentage of land cover categories, distribution of land use in 1987 (middle-top) and 2015 (middle-bottom), persistence and loss (top-left) and persistence and gain (bottom-left) in Okomu Forest Reserve, 1987-2015

The intensity of land use and land cover transition in Okomu Forest Reserve is depicted in Figure 3. The figure shows the processes of land use transition in the reserve. The uniform intensity line indicates the average percentage at which each category will loss or gain if they gain or loss in proportion to their area extent. A category is therefore systematically targeted if the average percentage loss is higher than the uniform intensity and random if the average is less than uniform intensity. Figure 3 shows that plantation systematically losses to others but avoids losing to forest. In the same vein, forest loss to plantation but avoids others while others loss to plantation and avoids forest.

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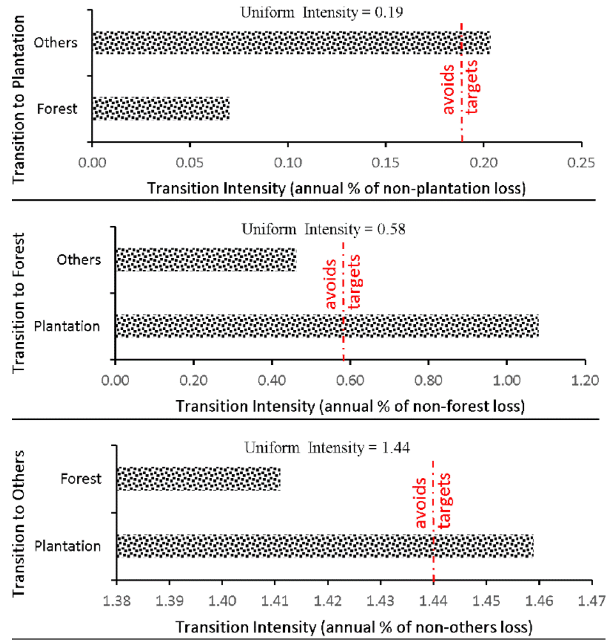

Figure 3: Transition intensity of land cover categories in Okomu Forest Reserve, 1987-2015

The allocation of de-reserved parts of Okomu forest reserve to large-scale, labour intensive plantation companies attracted labourers to the area. This led to the establishment of settlements, such as AT & P in Okomu, which were designed for plantation workers and their families. These settlements however, attracted other service providers such as mechanics, traders and other artisans leading to an increase in the population of such settlements. This increasing population results in the demand of land for subsistence farming activities. Traditionally, subsistence farming practices employ little or no modern agricultural inputs such as fertilizers or mechanized farming tools. These smallholder farmers practice shifting cultivation which is characterized by the clearing of a few hectares of land with slash-and-burn clearing system. The cleared land is cultivated for two or more farming seasons and allowed to regenerate for a few years depending on the availability of land (Schneibel *et al.,* 2017). In addition, uncontrolled timber extraction, sometimes within Okomu National Park, is also causing increasing forest degradation and loss. Illegal logging within the National Park was reported by forest officers during the field visit. The extraction of timber from the forest is an important factor in forest degradation. This is because though the loggers extract timber selectively, there is no deliberate effort to replace extracted trees. These practices lead to the degradation of the forest which explains the 14% gain in the others category and the 15% loss in forest during the period of this study. The continued expansion of plantation agriculture in Okomu forest reserve also implies increased pressure on the rainforest which further exposes the animal and plant species in the forest to danger.

The overall image classification accuracy of the maps is shown in Table 2. The table shows that the accuracy of the maps is 80.56% in 1987 and 92.97% in 2015. The overall accuracy of the maps derived from the analysis of Landsat is greater than 80% at each time point (Table 2). However, the high loss recorded by forest between 1987 and 2015 (Table 1) implies that much of the areas that were forest in 1987 have been converted to plantation or others categories. Also, the reflectance of matured plantations is similar to that of the rainforest in Landsat images and can therefore be easily confused and misclassified. This explains the low producer's and user's accuracy observed in plantation and forest categories especially in the 1987 map. The lower accuracy values of the 1987 image is because the data used for accuracy assessment were collected in 2015 (Akinyemi *et al.,* 2017; Enaruvbe and Pontius Jr., 2015). The overall accuracy is however comparable with other studies conducted in the study area (Ayanlade and Drake, 2015).

Table 2: Classification accuracy of land use maps of Okomu Forest Reserve derived from Landsat images based on area proportion

	Producer's Accuracy (%)	User's Accuracy (%)	Producer's Accuracy (%)	User's Accuracy (%)
Class	2015		1987	
Plantation	84.41	97.43	36.34	79.69
Forest	69.45	92.16	58.50	42.38
Others	98.58	92.33	93.14	88.92

Note: Overall classification accuracy in 1987 = 80.56%; 2015 = 92.97%; Producer's accuracy is equivalent to commission error (e.g. erroneously classifying forest as plantation category); User's accuracy is equivalent to omission error (e.g. erroneously excluding bare surface from others category).

4. CONCLUSION

This study has highlighted the pattern and processes of oil palm and rubber plantation expansion in Okomu forest reserve. The conversion of the rainforest to plantation agriculture leads to substantial loss of biodiversity in the reserve. The creation of Okomu National Park has however, set a boundary for the prevention of further encroachment of plantations into the forest. It however, has not eliminated the activities of poachers and illegal loggers. The proximity of settlements to the National Park and the increasing population of such settlements implies that the chances of human interference with the natural habitat of these species is on the rise. Environmental protection and conservation policies should therefore be integrated into economic and land use planning, administration and governance so as not to jeopardize scare environmental services and resources on the altar of economic prosperity.

5. ACKNOWLEDGMENT

The author is very grateful to the Management and Staff of Okomu National Park Services, Osse Rubber Estate Limited and Okomu Oil Palm PLC for their assistance during the field data collection.

6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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