ASSESSMENT OF TWO DECADE MANGROVE FOREST DYNAMICS IN RIO DEL-RAY, CAMEROON. USING MULTI TEMPORAL SATELLITE DATA AND GIS

Longonje .N. Simon[1] Lysinge M. N. Ivanna [2]

1. Department of Environmental Science, University of Buea, P.O. Box 63 Buea, Cameroon Tel +237(0) 674905963. E-Mail: nlongonje@yahoo.com
2. Department of Environmental Science, University of Buea, P.O. Box 63 Buea,

ABSTRACT

Rio del-ray mangrove forest is found in South West Region, Cameroon. The extent of land use and mangrove forest cover changes in area was investigated using remote sensing and GIS techniques. Land use and mangrove forest changes over the past 24years were analyzed, which revealed the occurrence of significant land use and mangrove forest transformation from one land use class to another. During the studied period of 24 years (1992-2016), cultivated lands increased by 39.24%, settlements increased by 57.34% and mangrove forests decreased by 8.25%. The study concludes that, there have been significant changes in land use pattern and mangrove forest cover in Rio del-ray mangrove Forest in Cameroon which require concerted actions to reverse the changes. The establishment and enforcement of different laws and regulations relating to natural resources and land use planning could improve land tenure and resource use in villages bordering the forest.

Key words: Land use, mangrove vegetation, cover change, Rio del ray, Cameroon.

Introduction

Mangrove forests are undergoing constant changes due to its dynamic nature itself and to greater extents through natural and anthropogenic activities. One of the most important concern on land use changes is that the world's forests have declined, while the cropped land areas have expanded by a similar magnitude (Slayback, 2003). Understanding of mangrove dynamics in a particular area is a prerequisite to conservation and management directives, such as the establishment, protection and management of reforestation plots in the framework of regeneration projects (Lee et al., 1996; Caloz and Collet, 1997).

Remote sensing is an indispensable tool for assessing and monitoring mangrove forests, primarily because many mangrove swamps are inaccessible or difficult for field survey. Remote sensing provides synoptic coverage, and historical satellite data dating back to the 1960s are available. Global mapping initiatives have failed to map the extent and rate of deforestation with sufficient detail because these studies have been based on satellite data with coarse spatial resolution. For example, only extensive mangrove areas were mapped as part of the Global Land Cover 2000 survey (Stibig et al., 2007). At local scales, several studies have used moderate-resolution satellite data [e.g. Landsat, SPOT and the India Remote Sensing Linear Imaging Self-scanning Sensor (IRS LISS III)] to characterize and map mangrove forests (Silapong & Blasco, 1992; Ramsey & Jansen, 1996; Blasco et al., 2001; Selvam et al., 2003; Ramasubramanian et al., 2006; Vaiphasa et al., 2006). Synergistic use of optical and radar data has been particularly useful in cloud-covered tropical mangrove areas (Aschbacher et al., 1994; Giri & Delsol, 1995).

The mangrove ecosystem in Cameroon is degrading, despite increasing awareness in education and sensitization regarding its importance and values. Lack of proper management strategies are some of the leading causes of its depletion (Longonje, 2008).

Mangrove forests serve various purposes. In Cameroon, local communities located in, or around mangrove areas depend almost entirely on them for their livelihood. Firewood harvesting, charcoal productions, commercial activities, fishing are some of the ways in which they are being exploited (Longonje ,2002). In some areas of the world rapid urbanization, aquacultures are also activities which exert pressure on this ecosystem (Longonje, 2008)

This present study aims at determining the extent and distribution of mangrove forests and identified rates and causes of change using multi-temporal satellite data and field observations.

Our analysis sought to answer the following research questions: how much mangrove forest remains; what is the rate of change; what are the main reasons for the change?

Study area

The mangrove area investigated is located in Southwest region Cameroon, Ndian division, with geographical coordinates latitude 4° 45 ' - 4° 50 ' North and longitude 8° 30 ' - 9° 00 ' East (Figure 1). It is situated in the wet climate zone of Cameroon, characterized by two seasons with a long rainy season (from March to November) and dry season from December to February; it is always interspersed with rains.

The Rio-del-Ray area has a population of about 72,425 people and is home to 9 ethnic groups which include; Batanga, Ngolo, Bima, Bakoko, Balondo Badiko, Korup, Bateke, Ejaghams and Efiks (Longonje, 2008). The mangrove area is dominated by Rhizophora species. (Hanneke Van lavieren et al., 2012).

Materials and Methods

Image acquisition and classification

This study made use of satellite images obtained from the United States Geological Survey (USGS) and the Global Land Cover Facility (www.Glcf.umiacs. und.edu) websites. These images were processed using the remote sensing software ENVI and maps were produced using the ArcGIS software. ENVI 4.4 (2004) was the remote sensing software used for pre-processing; NDVI analysis, change detection, visual interpretation and the production of land use and land cover maps. ArcGis 9.3 (1999) was the GIS software used for image displays and final map productions.

Satellite Image acquisition and procession

The primary data used is optical multispectral satellite images that were acquired and processed. Satellite data was acquired from the Landsat sensor (MSS, ETM+ and TM) only.

In this study a total of 4 Landsat images were used: MSS 1992 which was acquired on the twelfth of December, 1992; MSS 2000 obtained on the eighth of December, 2000; TM 2008 acquired on the twelfth of December, 2008; ETM+ 2016 which was obtained on the twenty eighth of May, 2016, Their selection was based on the following criteria: **1)** availability of images within the geographic coordinates defined, **2)** reduced cloud cover (which is a common phenomenon observed for images obtained in the tropics) which is tied to the seasonality of the imageries, **3)** time interval of at least 8 years which is relevant to be able to assess any visible changes on land use and landcover patterns and lastly **4)** spatial resolution (which is determined by the satellite sensor used). From the dates of acquisition of the images, all the images were taken in the dry season . These images were used as base maps during land use and vegetation cover analyses. The spatial resolution for Landsat TM and ETM+ images varied slightly between 28.5 m to 30 m

Field Ground truthing

Vegetation types identified from the 1992-2016 images were counterchecked by carrying out fieldwork for primary and secondary data in the study area in order to update data interpreted from the image. A GPS was used to record ground coordinates for different vegetation types on the map in order to increase the accuracy reference points. A GPS-guided field investigation was conducted in April and July 2016. The fieldwork supported interpretation of TM and ETM+ images and delineation of the general land cover types and mangrove/marsh areas. The field observations provided independent reference data for the accuracy assessment. The obtained coordinates were later used to validate the observed landuse and vegetation cover types on the satellite images before classifying the land use and vegetation cover changes over time.

Pre-processing of Landsat multispectral satellite data

False colour composite and layer stacking

False colour composite (which is a combination of different bands that highlights features differently) was made to be able to get the best-fit case needed for a proper land use classification. From this, the band combination of 342 was chosen for all the images.

For land use classification, different pairs of images were used based on their time interval and similarity. The different image pairs were later stacked together and resized spatially (size) and spectrally (resolution) to bring them to the same size and resolution. After the spatial and spectral processing, these images were separated to begin the classification process proper.

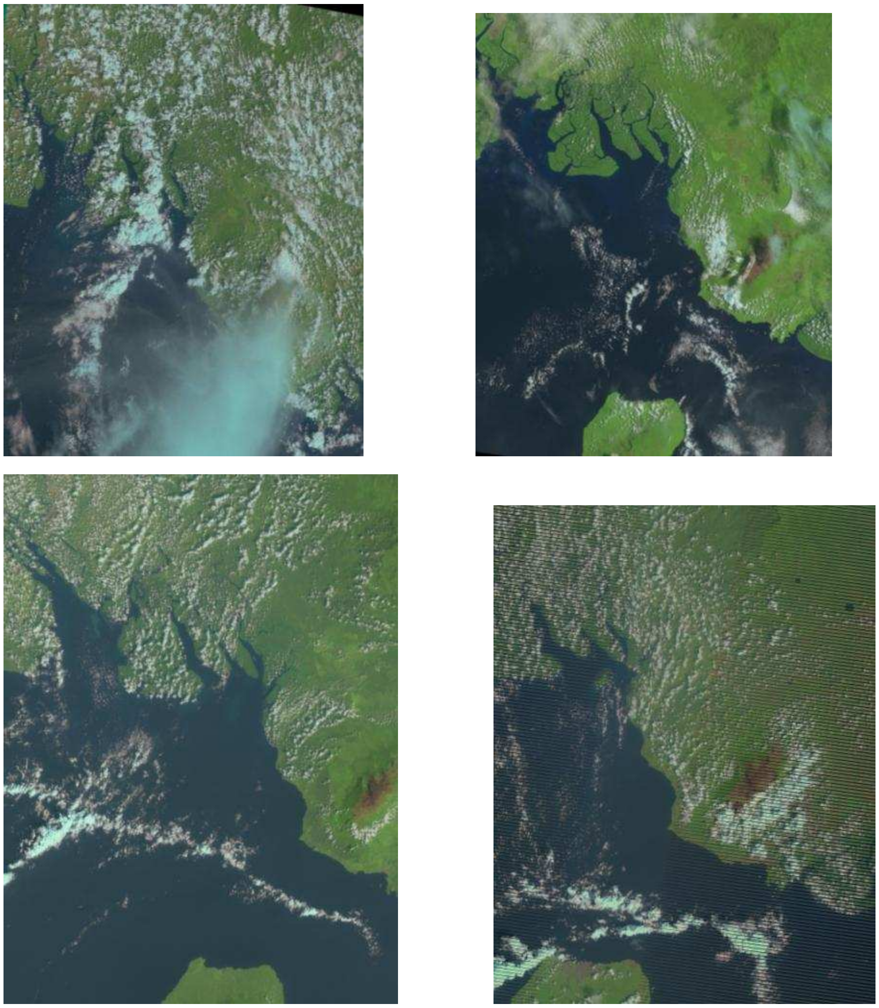

Figure 1: False colour composite of satellite images of Rio De Ray Mangrove.

NDVI Analyses

Training sites (i.e. identification of landcover classes) are most often defined by both field groundtruthing in combination with the spectral signatures of the images used. This was the procedure used for this study that started with a preliminary field investigation to assess the different land covers in the study area. Additional information was obtained from the Normalized Differential Vegetation Index (NDVI) tool in ENVI. Even in studies with prior field knowledge, NDVI is a required prerequisite in land cover assessment needed for a quality supervised classification.

ENVI 4.4 which was the remote sensing software used for these analyses, provides 27 vegetation indices needed to detect the presence and relative abundance of pigments, water, and carbon as expressed in the solar-reflected optical spectrum (400 nm to 2500 nm). NDVI is one of the oldest, most well known, and most frequently used VIs (Rouse et al., 1973). The combination of its normalized difference formulation and use of the highest absorption and reflectance regions of chlorophyll make it robust over a wide range of conditions. NDVI calculation is defined by the following equation:

$$NDVI = \frac{4-3}{4+3}$$ -------------------------- Equation 1

Where:

3 and 4 refered to bands 3 and 4 of the satellite images used.

The value of the NDVI index ranges from -1 to 1 and the common range for green vegetation was 0.2 to 0.8. In this study, NDVI was obtained from all the Landsat images analysed using the transform function of ENVI. The higher the NDVI value the more the vegetation .

Supervised classification

ENVI 4.4 software was used in carrying out supervised classification. This classification was carried out after these images had been resized both spatially and spectrally and NDVI classification carried to define training sites. From the NDVI classification and field assessment, 4 training sites (landcover classes) were defined and classified as: mangrove forest, settlement, agricultural land, and water bodies (Table 1).

Table 1: Training sites classification and description

Training site	Description land cover classes
Mangrove forest	Characterized by mostly dense mangrove forest, mangrove shrubs and swamp
Settlement	This constitute built-up areas (roads, houses) and bare soil
Agricultural land	Small hectares of land cultivated by individuals for subsistence agriculture (agricultural land)
Water bodies	springs, streams, and rivers

Land use and vegetation cover change detection

Change detection analysis entails finding the type, amount and location of land use changes that are taking place (Yeh et al., 1996). Change detection often involves comparing satellite imageries of an area taken at different times. Thus, change detection can only be assessed from more than one image and it is mostly visible over a period of 8 to 10 years.

In this study, change detection was performed through the overlay method based on generated vector themes of different years. Change detection was done between supervised classified images of 1992-2000 (8 years difference), 2000-2008 (8 years difference) and 2008-2016 (8years difference) using the first year as a common baseline data year for the periods. The overlay was performed by intersecting feature themes so that the boundaries and attributes of themes were combined to form the derivative output theme.

Assessment of the rate of cover change

The estimation for the rate of change for the different covers was computed based on the following formulae (Kashaigili, 2006):

$$\% \text{ cover change} = \frac{Area_{iyearx} - Area_{iyearx+1}}{\sum_{i=1}^{n} Area_{i\ yearx}} \times 100 \text{------------------ (1)}$$

$$\text{Annual rate of change} = \frac{Area_{iyearx} - Area_{iyearx+1}}{t_{years}} \text{-- (2)}$$

$$\% \text{ annual rate of change} = \frac{Area_{iyearx} - Area_{iyearx+1}}{Area_{iyearx} \times t_{years}} \text{X100----------------- (3)}$$

Where: $Area_{i\ year\ x}$= area of cover i at the first date,

$Area_{i\ year\ x+1}$= area of cover i at the second date,

$\sum_{i=1}^{n} Area\ iyearx$= total cover area at the first date and

t years = period in years between the first and second scene acquisition data

GIS analysis

The classified and enhanced images processed in the ENVI 4.4 software were saved in geotiff format and exported to ArcGIS 9.3 and 10.2 (GIS software) for further analyses and the production of the maps. The image analysis extension in ArcGIS helped to sharpen more features for better visualisation for the features of interest in the study area

Results and Discussion

Mangrove dynamics and land cover class distribution 1992-2016

The land cover maps for 1992, 2000, 2008 and 2016 are presented in Figures 2, 3 4 5 and 6 respectively. Generally, the maps show the variation in mangrove forest cover within the three time periods under consideration. It was estimated that mangrove vegetation cover was decreasing at the rate of 0.34% per year and there have been significant changes in land use pattern and land cover in the Rio del- Ray mangrove forest. Figure 2 is the based map in 1992. Figure 3 shows that in 2000, mangrove forest reduced by 3.39% (34.54 km^2), due to agricultural activities and settlement. Settlement area changed by 2.03% (34.08 km^2), agricultural land changed by 7.40% (141.70 km^2) .

In 2008, mangrove forest changed by 2.06% (20.97 km^2), while agricultural land and settlement area changed by 28.62% (12.21 km^2) and 12.9%(4.41 km^2) respectively as shown in Figure 4. Figure 5 shows that in 2016, mangrove forest changed by 2.80% (28.49 km^2), Settlement area changed by 38.44% (13.10 km^2), agricultural land changed by 25.41% (26.00 km^2) .

During this period (1992-2016), the results showed a substantial decrease in mangrove vegetation cover from 1018.19 km^2 to 934.19 km^2 that is a decreased of 8.25%. The results also show that the settlement increased by 57.34 % and agricultural land increased by 39.24**%**. Figure 7. Land use/ Mangrove forest change for the studied area between 1992 and 2018 is presented in Figure 8.

The results clearly indicated that agricultural land and settlement areas increased in these temporal periods. This implies that agricultural activities increased in these periods due to population increase through immigration and increased wealth resulting from small trading. Agricultural expansion is among the reported activities, which have significant effect on natural vegetation (Ngalande, 2002). The continuous increase in cultivated land is also reflected in an increased area under settlements (Figure 6). Increase in population size leads to demand for more resources and area for cultivation which has an implication on settlements expansion.

As revealed in Table 2, agricultural land and settlement increased by 39.24 km^2 and 57.34 km^2 , respectively over the period of 24 years (1992 and 2016) assuming a linear increase per year.. The mangrove forest decreased by 8.25 km^2 over the period of 24 years (1992 to 2016) assuming a linear decrease. It is possible that the decrease in mangrove forest and increase in settlement cover is attributed to increased demand for suitable land for cultivation. This rapid increase might be due to clear felling of trees for firewood, poles, timber and increased settlement and agricultural activities (mostly subsistence farming).

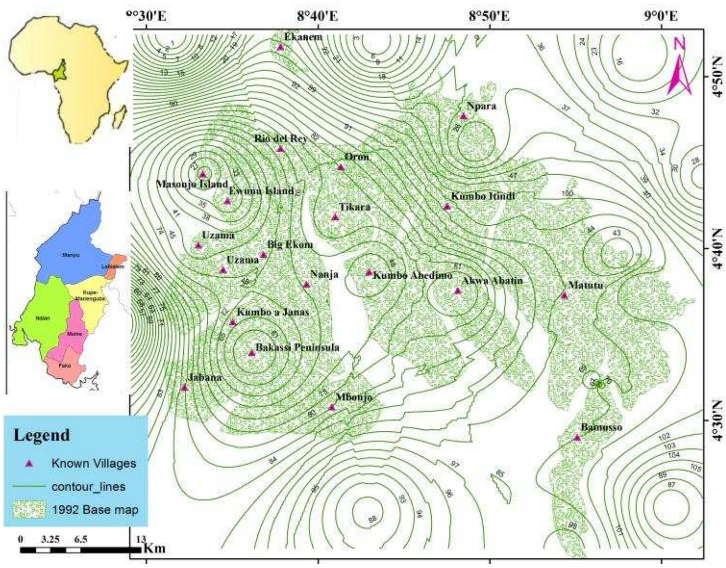

Figure 2. Mangrove vegetation base map, 1992

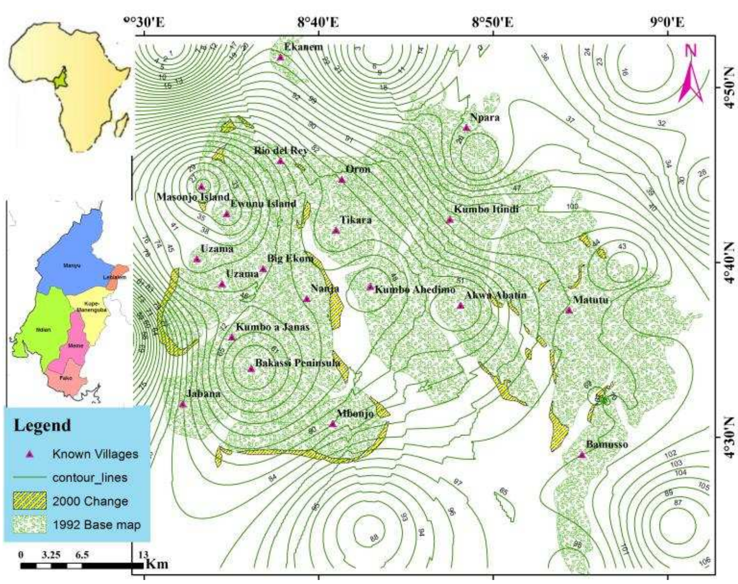

Figure 3. Mangrove Vegetation change . 2000.

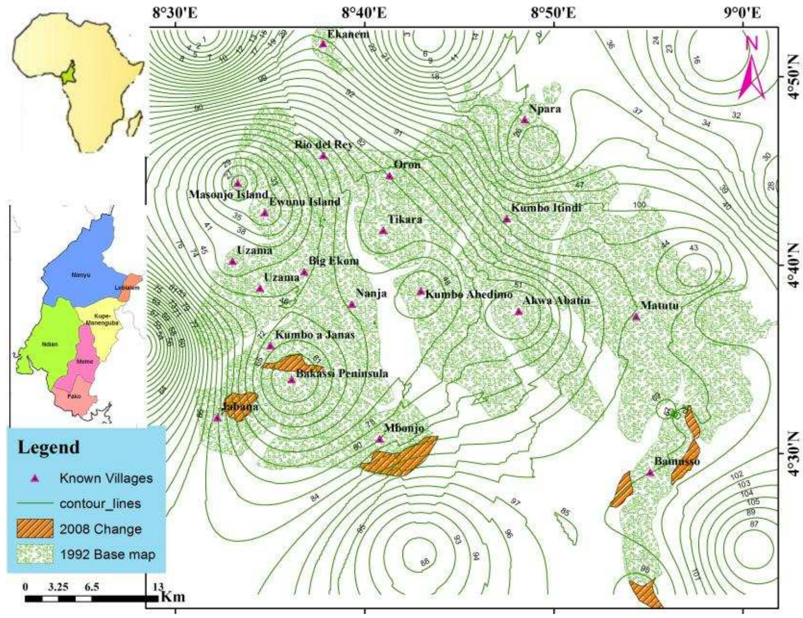

Figure 4. Mangrove Vegetation change . 2008.

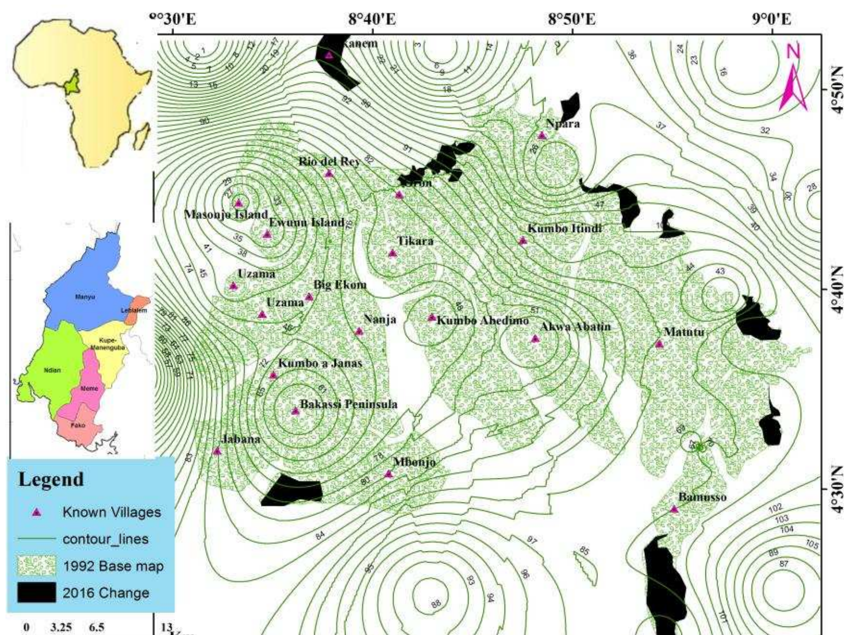

Figure 5. Mangrove Vegetation change . 2016.

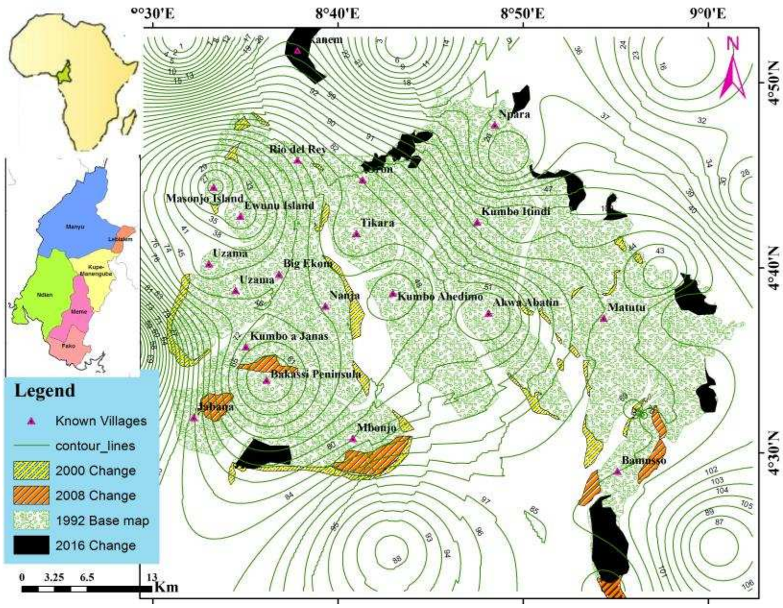

Figure 6. Mangrove Vegetation change 1992, 2000, 2008 and 2016.

Table 2: Class type, changed area and the rate of change between 1992 and 2016

Class type	1992 (based map) (km^2)	2000 Change		2008 change		2016 change		Class change		Present State (km^2)
		(km^2)	%	(km^2)	%	(km^2)	%	(km^2)	%	
Mangrove Forest	1018.19	34.54	3.39	20.97	2.06	28.49	2.80	84.0	**8.25**	934.19
Agricultural land	141.70	7.40	5.22	12.21	8.62	36.00	25.41	55.61	**39.24**	86.09
Water bodies	58.01	5.04	8.69	4.20	7.24	9.61	16.57	18.85	**32.49**	39.16
Settlement	34.08	2.03	5.96	4.41	12.94	13.10	38.44	19.54	**57.34**	14.54
Total	**1251.98**	**49.01**	3.91	**41.79**	3.34	**87.2**	6.96%	**178.00**	**14.22**	**1073.98**

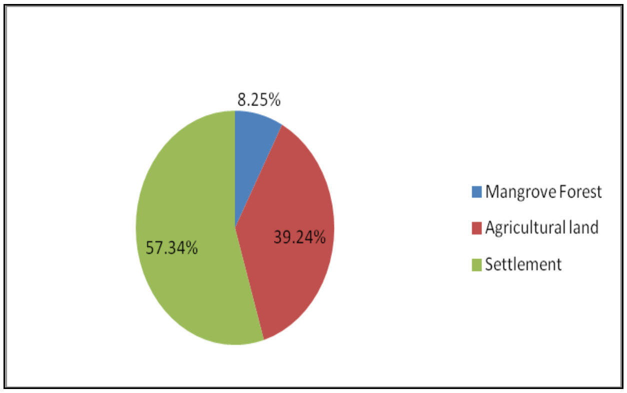

Figure 7. % class change for Rio Del Ray mangrove between 1992 and 2018.

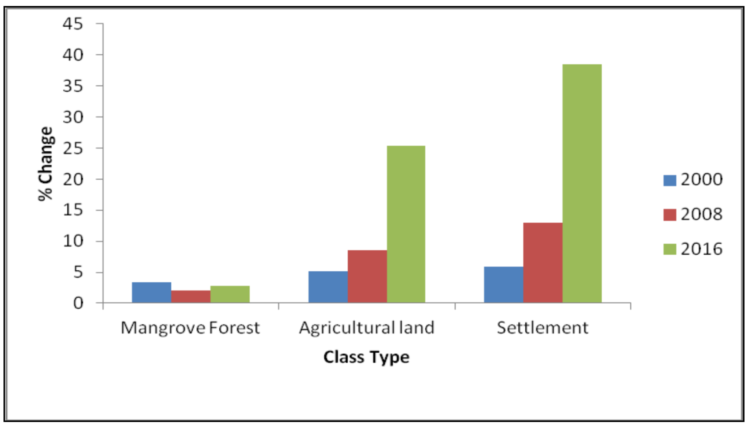

Figure 8 . Land use/ Mangrove forest change for Rio Del Ray between 1992 and 2018.

Conclusions

The findings revealed that the study area had undergone notable changes in terms of land use and land cover for the period 1992-2016. The results revealed that cultivated land and settlement areas have increased in the last twenty four years, where mangrove forest decreased linearly during the same period. The study concludes that there have been significant changes in land use and cover in the forest and concerted actions are required to reverse the changes. This situation is likely to reduce wildlife habitat and may also result in forest extinction in future if the situation is left unattended to. The results revealed changes in land use and vegetation cover hence environmental education of local communities at village level is needed to maintain the existing natural vegetation in areas such as this in the country where hu-man activities have seriously affected the resources. The study suggests the establishment and enforcement of different laws and regulations to protect the natural vegetation. It is also suggested the establishment of land use planning could help to improve land tenure and resource use in villages bordering the forest and could substan-tially reduce the problem of land degradation.

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