Dynamics of Forest Landscape Transition across Protected Areas in the Niger Delta from 1986 to 2014

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Abstract

The overall aim of this study was to conduct a spatially explicit study of forest cover changes across 13 selected protected areas (PAs) across the study area using a combination of satellite remote sensing and ground data. The objectives of the study included: determine the spatial extent of forest landscape for selected PAs using three epochs of satellite imagery (1986, 2000 and 2014); determine the spatial extent and rates of forest transition over two 14-year periods (1986 to 2000 and 2000 to 2014); and provide a comprehensive summary of current forest landscape status in the study area. The results indicated that the spatial extent of forest landscape for the 13 FRs was 522,164, 481,870 and 457,651 hectares in 1986, 2000 and 2014 respectively. The forest cover transition for the two 14-year periods investigation showed a larger percentage of forest landscape across the 13 FRs were more affected by deforestation in comparison to afforestation. The overall annual deforestation rates for the PAs were 0.82% and 0.68% for 1986 to 2000 and 2000 to 2014 time periods. The annual afforestation rates for both 14-year periods were 0.38% and 0.39% respectively. Based on the results being obtained there was an urgent need to review the ways forest reserves and national parks in Cross River state were managed. The promotion of forest conservation was vital to the preservation of existing forest landscapes and endangered wildlife, such as the Cross River *Gorilla gorilla* and Nigeria-Cameroon chimpanzees. The role of community participation with the assistance of government and conservation organizations would prove effective in forest monitoring activities across the state. In conclusion, results of this study showed the potential of incorporating satellite remote sensing and ground truth data for better understanding the spatial dynamics of forest cover in PAs across the Niger Delta region.

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Keywords

Remote Sensing, Forest Reserves, Change Detection, Protected Area

1. Introduction

The Niger delta region is an ecological fragile region with high levels of biodiversity and is known to be a repository of biologically diverse plants that offers opportunities for food and pharmaceuticals [1]. Plants such as *Thaumatococcus danielii* (Marantaceae), *Synsephalaum dulciferum* (Sapotaccae) and *Dioscroreophyllum cumminsii* (Menispermatacae) grow naturally in the Niger delta region and are potential sources of high calibre or potent natural sweeteners [2] [3]. Other medicinal plants that grow naturally in the region include Fagara sp. for sickle cell anaemia treatment and *Rauvolfia vomiforia* for high blood pressure relief [2]. In addition to providing plants for medicinal purpose, the forest ecosystem offers the following products: fuel wood for cooking, heating, drying of rice and charcoal production; timber for use in the road/railroad construction, building industry or boat construction; paper production and edible wildlife plants in forms of leafy vegetables, fruits and seeds, spices, food wrappers and starchy tubers. However, due to problems like rise in population density; urbanisation; activities relating to exploration of crude oil (e.g. indiscriminate felling of trees and land clearing for sesmic surveys, drilling for crude etc.); deforestation [4]; and poor farming practice all have negative impacts on the preservation of forests and the produce derivable therein. Therefore, the conservation of the tropical forest ecosystem in the region is a critical issue needing urgent attention.

A major approach to conserving the diverse forest landscape across this fragile region is through the establishment and effective management of conservation sites across the states in this region. The conservation of forest landscapes and its derivable resources in the region is directly linked to the peculiarity of human activities not evenly distributed on the land surface owing to variations in climatic, geological, demographic, and cultural, factors in different areas of Nigeria [5]. Consequently, land uses are not influenced by capabilities of existing resources or effective landuse polices but rather the resources that are directly derivable. As is the case of the Niger delta region, derivable resources (such as oil and timber) are exploited without consideration for future development and conservation of the environment. The Niger Delta region has been termed as a biodiversity hotspot and classed as the second most sensitive environment in Africa [6]. With over 70 protected areas (PAs) being designated and gazetted as national parks, game reserves, forest reserves (FR) and strict natural reserves [7] across the region, there are still challenges facing forest and wildlife conservation [8] [9]. The distribution of PAs in the Niger Delta region comprise of 1 strict Nature Reserve of IUCN (International Union for Conservation of Nature) category Ia in Edo state; 2 national parks, IUCN category II in Edo and Cross River State (CRS); 4 game reserves of category IV in Edo and CRS; and 63 FRs all across the state [7] [10]. Phil-Eze and Okoro [10] note that there has been a substantial decline in biodiversity around the Niger Delta due to immense loss in forest cover. The study further emphasizes on the need to select suitable PA sites based on the ecological zones of the region, as such an approach will prove to better sustain biodiversity conservation. A key requirement for selecting new or managing existing PAs is first understanding the spatial transition pattern of forest landscapes across the region, information that's currently lacking for the region.

Studies have demonstrated the potential of combining satellite remote sensing and ground data [11] to effectively determine the spatial extent of deforestation across PAs in tropical forest regions of the world [12] [13]. In a study conducted by DeFries *et al.* [12], multiple satellite imagery was used to examine the extent of forest cover loss over a period of two decades throughout the world's moist and dry tropical forests. In order to answer the existing gap in literature on spatial information of forest landscape dynamics across PAs in the Niger Delta region, this paper presents results on the current status of tropical forests in CRS (a state with over 50 percent of tropical forests in the Niger Delta region).

The overall aim of this study was to conduct a spatially explicit study of forest cover changes across 13 selected PAs (FRs and national parks in CRS) using satellite remote sensing and ground data. The objectives of the study were: 1) determine the spatial extent of forest landscape of selected PAs using three epochs of satellite imagery (1986, 2000 and 2014); 2) determine the spatial extent and rates of forest transition over two 14-year periods (1986 to 2000 and 2000 to 2014); and 3) to provide a comprehensive summary of current forest land-

scape status in the study area.

2. Materials and Methods

2.1. Study Area

The study area comprises of 13 forest reserves (FRs) spread across the state and is known to have over 50% of the country's remaining tropical forest (**Figure 1**). The ecological zone of Cross River state is characterized by lowland rain forest, freshwater swamp forest, mangrove vegetation, coastal wetland vegetation, Montane Forests and savannah vegetation [14]. The FRs across the state are managed by either local communities, government representation (in form of the Cross River State Forestry Commission—CRSFC), conservation organizations or a combination of the afore-mentioned. The FRs investigated in the study includes the following: Afi River (FR1), Agoi (FR2), Boshi (FR3), Boshi extension (FR4), Cross River North (FR5), Cross River South (FR6), Ekinta
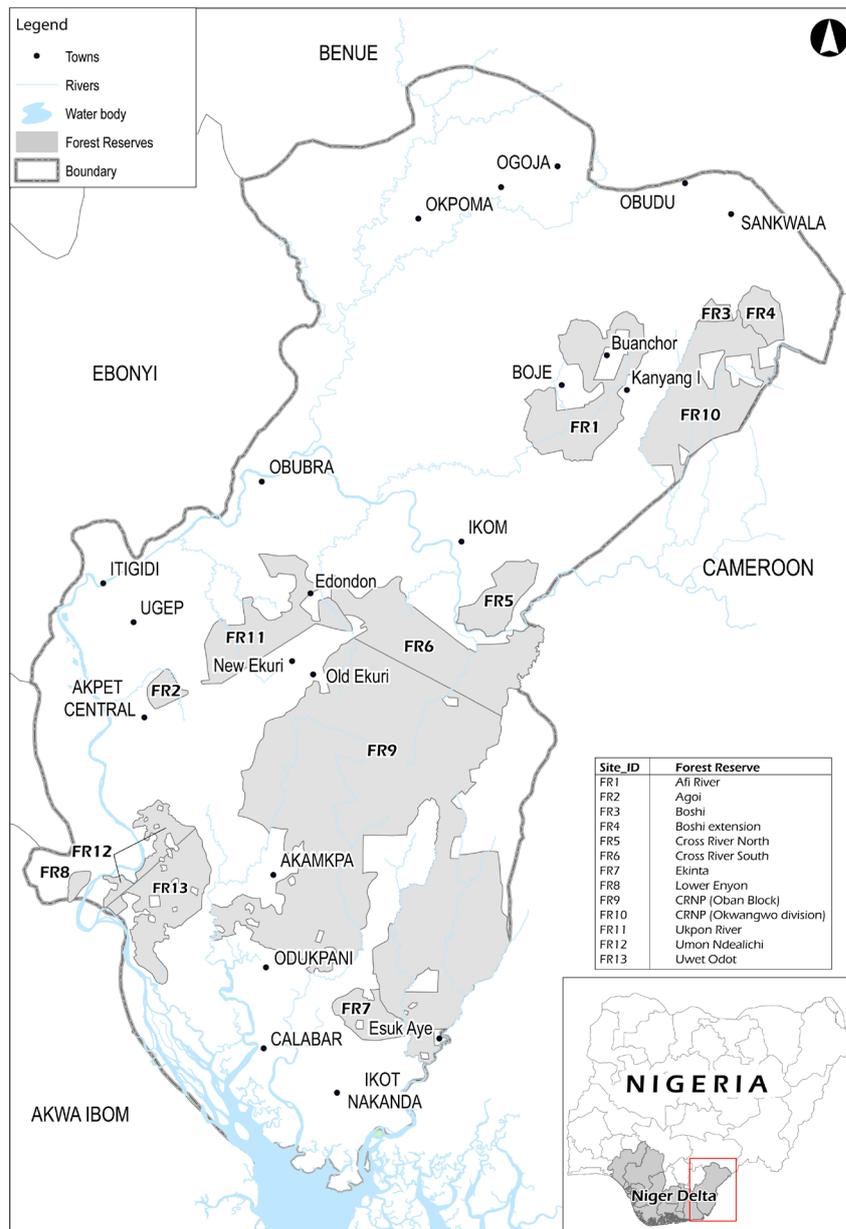
Figure 1. Map of study area showing 13 forest reserves across cross river state.

(FR7), Lower Enyon (FR8), Cross River National Park (Oban Block) (FR9), Cross River National Park (Ok-wangwo division) (FR10), Ukpon River (FR11), Umon Ndealichi (FR12) and Uwet Odot (FR13).

2.2. Remotely Sensed Data

For this study the satellite imagery used for forest classification and change detection analysis were for three epochs (1986, 2000 and 2014) included Landsat and UK-DMC sensor data. The Landsat images used were Landsat Thematic Mapper (dated December 1986), Landsat Enhanced Thematic Mapper—ETM (January 2000) and UK-DMC (January 2014) all acquired in the dry season in order to minimize seasonality variations [15]. Both Landsat images were downloaded from the Global Landcover Facility website while the UK-DMC image was provided by the Nigeria Space Agency (NASRDA—National Space Research and Development Agency). The supplied satellite imageries were radiometrically and geometrically corrected thereby allowing for direct image-to-image comparison.

2.3. Image Classification and Change Detection Analysis

The satellite images were classified using the unsupervised ISODATA (Iterative Self Organising Data Analysis) classification technique [16]. This procedure was performed using the ISODATA classifier algorithm in ERDAS Imagine software [17]. Using independent training and testing data, a total of six broad classes based on the IPCC (Intergovernmental Panel on Climate Change) land use classification scheme [18] were delineated to show forestland, cropland, grassland, wetlands, settlements and other land classes. Following the confirmation that the classified images were within tolerance, the classified outputs for each year were further reclassified to reflect two major classes needed for the is study: forest and non-forest classes respectively. The training and validation ground truth data were obtained from the following sources: Google Earth, high resolution satellite imageries, historic aerial photographs, global positioning system (GPS) ground data and manual interpretation of the satellite imageries used in the study.

The process of change detection analysis was performed using the Land Cover Modeler of IDRISI 17.0 Selva Edition [19]. Using the LCM transitions in forest cover landscape across the study area was performed to identify the extent of deforestation, unchanged forest cover and afforested parts of the FRs. The two time intervals investigated in this study were 1986 to 2000 and 2000 to 2014 respectively. The annual deforestation rates of the classified outputs were calculated using Equation (1) below:

$$\frac{\log F_b - \log (F_a - B)}{(t_a - t_b)} \times 100 \tag{1}$$

where $F_{b/a}$ = forested area for baseline (earlier) and assessment (later) in hectares, B = deforested area in hectares and "t_a and t_b" indicate time-1 and time-2 respectively.

3. Results and Discussion

### 3.1. Accuracy Assessment of Classified Images

The classification accuracy results of the classified images for 1986, 2000 and 2014 are presented in **Table 1** below. The results indicated that the overall classification accuracy for the 1986, 2000 and 2014 images were 91%, 89% and 91% respectively.

3.2. Pattern of Forest Cover Transition

Table 2 presents the results of forest cover and change detection analysis for all FRs in the study area. The spatial extent of forest landscape for the 13 FRs were 522,164 hectares (1986), 481,870 hectares (2000) and 457,652 hectares (2014) respectively (**Table 2**). **Figure 2(a)** shows the percentages of forest landscape cover for 1986, 2000 and 2014. The results show that forest landscape in FR1, FR2, FR3, FR6, FR7, FR9, FR10 and FR11 decline from 1986 to 2014. The second pattern of forest cover transition shown in FR4 was a rise between 1986 and 2000 with subsequent decline in 2014. In FR5, FR8 and FR13, the third pattern of forest transition was a decline from 1986 to 2000 and rise in 2014. The final pattern of transition observed in the study was a rise in forest landscape from 1986 to 2014 observed in FR12.

Table 1. Accuracy assessment results showing user accuracy (UA), producer accuracy (PA) and overall accuracy (OA) generated for classified images.

Land use	1986 (TM)		2000 (ETM+)		2014 (UK-DMC)	
	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)
Settlement	89.8	97.0	87.1	95.7	91.8	88.2
Farmland	89.4	94.7	88.6	87.8	90.9	86.2
Grassland	94.4	85.0	93.6	96.7	91.7	94.3
Wetland	87.5	75.0	86.4	88.4	90.0	87.8
Settlement	100	57.1	100	54.6	93.3	96.6
Other land	100	88.2	100	100	86.7	100
OA (%)	**90.7**		**89.4**		**90.8**	
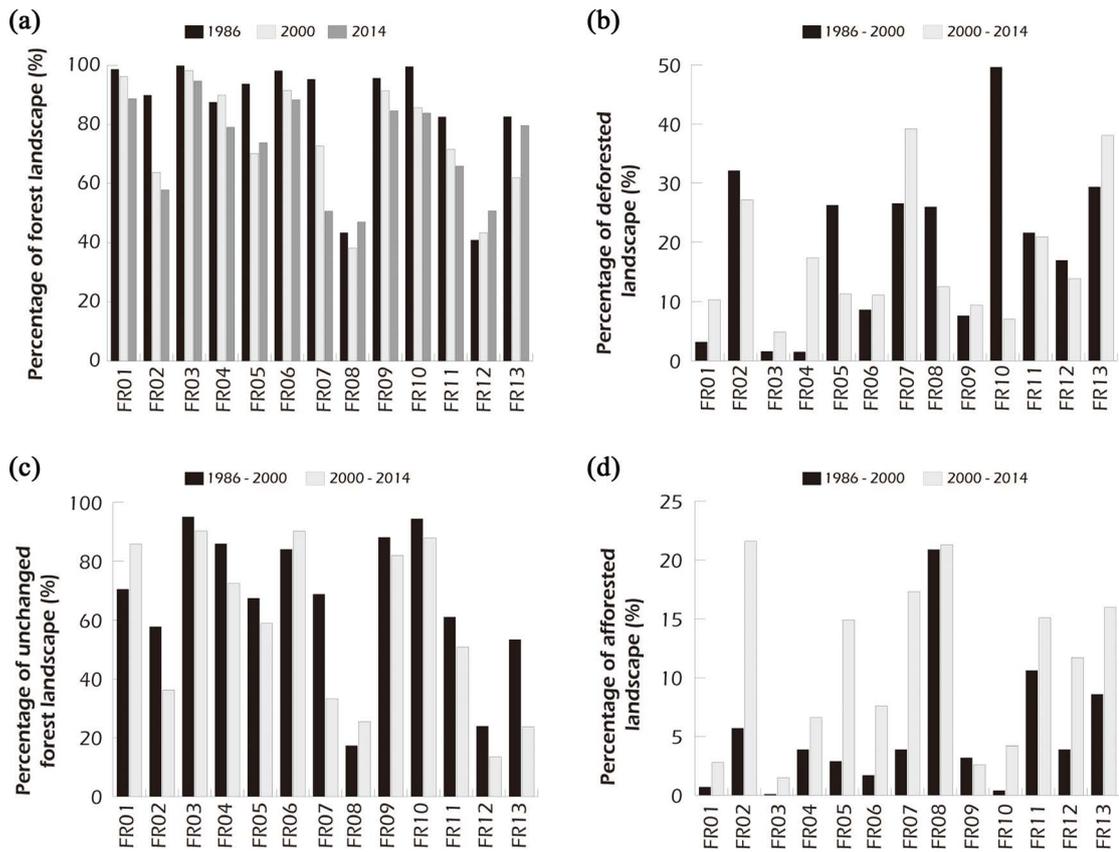
Figure 2. Results of study showing percentage cover of (a) forest landscape cover; (b) deforested landscape; (c) unchanged forest landscape; and (d) afforested landscape from 1986 to 2014 for forest reserves in CRS.

Results of forest cover transition for the two 14-year periods investigated showed that overall a larger percentage of forest landscape across the 13 FRs were more affected by deforestation in comparison to afforestation (**Figure 2(b)** and **Figure 2(d)**). With regards to the unchanged forest landscape, the results showed a general decline over the two 14-year periods with the exception of FR6 which was approximately the same. The forest landscape across the study area affected by deforestation declined from 81,143 hectares (between 1986 and 2000) to 70,624 hectares (between 2000 and 2014). The afforested and unchanged forest landscape over the 14-year periods investigated increased by 33,582 hectares and declined by 13,131 hectares respectively (**Table 2**). The overall annual deforestation rates for the PAs were 0.82% and 0.68% for 1986 to 2000 and 2000 to 2014 time periods. The annual afforestation rate for both 14-year periods was 0.38% and 0.39% respectively. **Figure 3** shows the forest cover maps for the 13 FRs across Cross River state. **Figure 4** shows the forest cover transition map indicating forest landscapes across the FRs that were deforested, unchanged and afforested.

Table 2. Results of forest cover and change detection analysis for forest reserves (FRs) across the study area from 1986 to 2014.

| Protected Areas	1986-FR (ha.)	2000-FR (ha.)	2014-FR (ha.)	Deforested-86-00 (ha)	Deforested-00-14 (ha)	Unchanged 86-00 (ha)	Unchanged 00-14 (ha)	Afforested 86-00 (ha)	Afforested - 00-14 (ha)
Afi River (FR1)	39,606.5	38,602.4	35,610.0	1297.9	4133.8	28,308.6	34,468.8	293.9	1141.4
Agoi (FR2)	3899.4	2761.8	2513.3	1390.7	1181.7	2508.8	1573.4	249.2	935.4
Boshi (FR3)	2479.1	2440.7	2351.9	39.2	121.1	2360.79	2242.62	2.88	37.89
Boshi extension (FR4)	7136.3	7330.9	6452.9	121.1	1415.8	7015.2	5915.1	315.7	537.8
Cross River North (FR5)	13,484.5	10,112.9	10,621.3	3783.0	1631.6	9701.6	8478.8	419.0	2145.5
Cross River South (FR6)	48,703.9	45,369.9	43,771.1	4250.8	5497.4	41,695.2	44,720.4	848.0	3754.9
Ekinta (FR7)	10,569.5	8063.7	5622.2	2945.6	4347.0	7623.9	3697.7	437.0	1917.8
Lower Enyon (FR8)	878.8	772.0	952.2	527.6	253.3	351.2	516.8	422.6	430.7
CRNP (Oban Block) (FR9)	286,099.0	273,160.0	252,709.0	22,572.9	28,184.5	263,524.0	244,983.0	9658.1	7752.0
CRNP (Okwangwo) (FR10)	51,429.9	44,274.1	43,259.7	25,591.8	3601.2	48747.2	45456	198.72	2192.94
Ukpon River (FR11)	25,866.5	22,425.6	20,621.5	6746.0	6531.0	19,120.5	15,912.1	3322.4	4728.2
Umon Ndealichi (FR12)	8378.6	8867.3	10,393.2	3487.1	2843.7	4891.6	2770.2	791.6	2395.7
Uwet Odot (FR13)	23,632.0	17,688.9	22,773.2	8389.5	10,882.4	15,242.5	6774.2	2458.8	4578.6
Total area (ha)	**522,164.0**	**481,870.1**	**457,651.5**	**81,143.0**	**70,624.4**	**451,090.9**	**417,509.2**	**19,417.8**	**32,548.8**
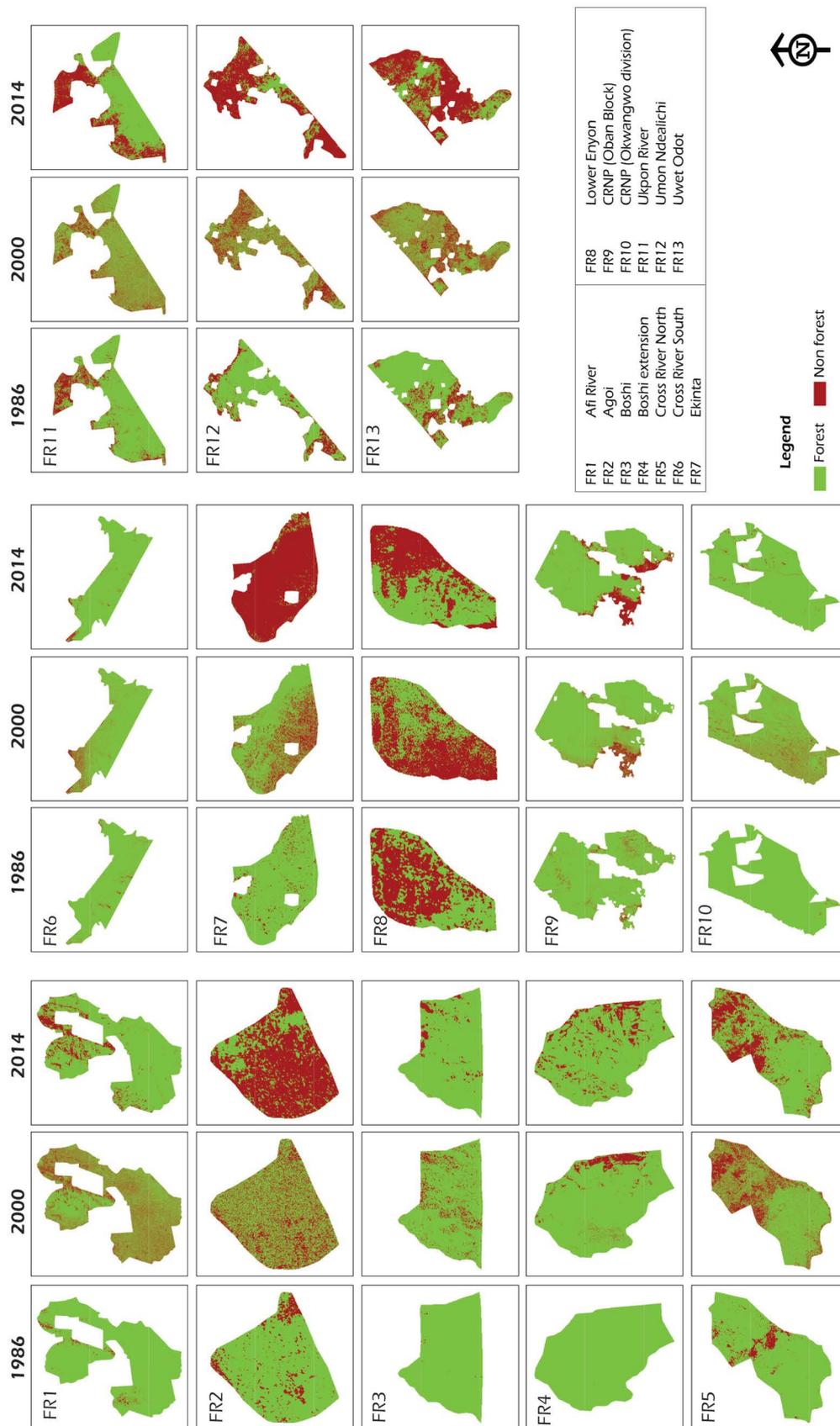
Figure 3. Forest cover maps of forest reserves across cross river state for 1986, 2000 and 2014.
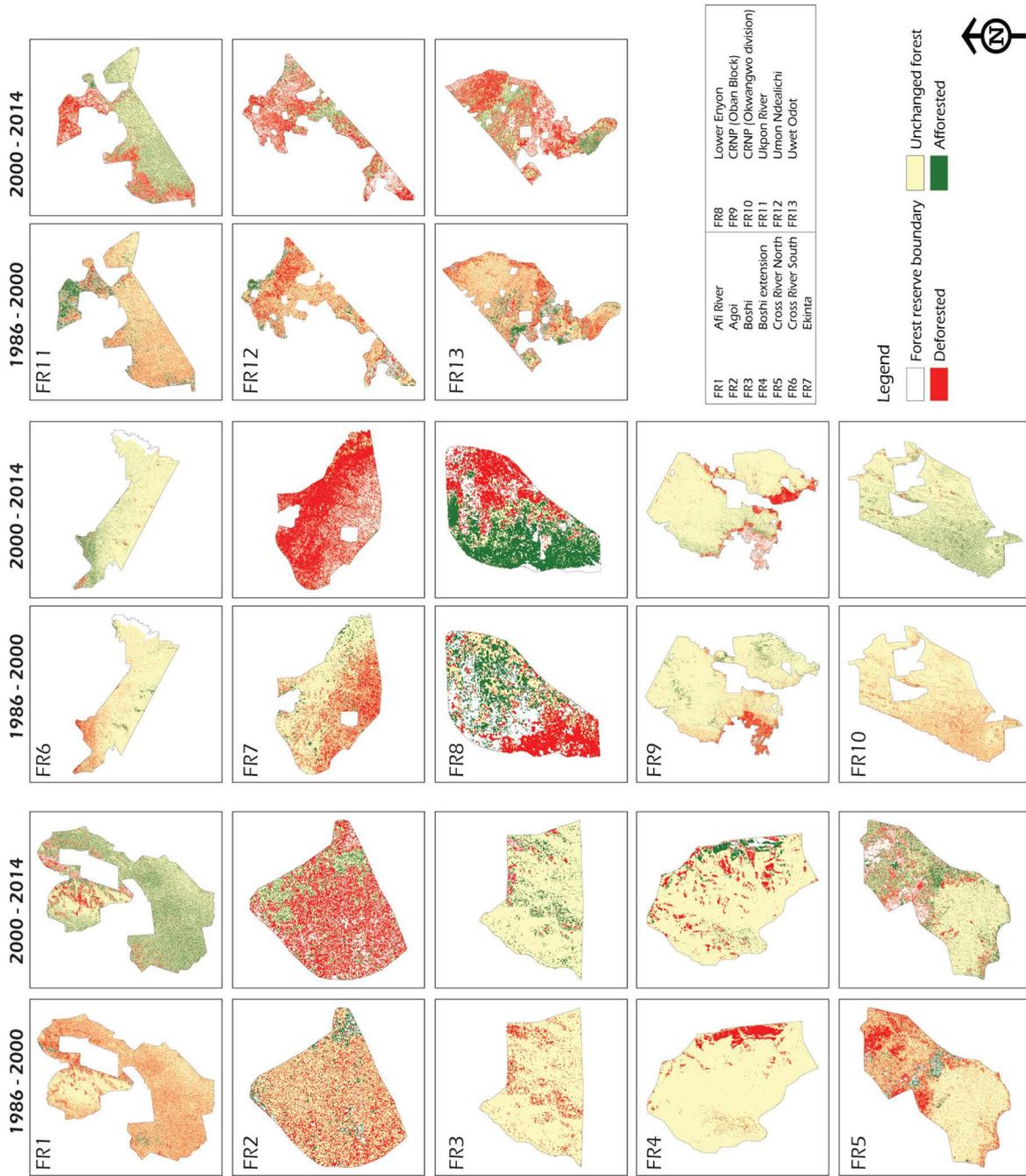
Figure 4. Forest transition maps of forest reserves across the study area for two 14-year periods (1986-2000 & 2000-2014).

4. Conclusions

This study has demonstrated the effectiveness of utilising satellite remote sensing and ground based measurements to determine the spatial extent and changes of forest landscape across protected areas in CRS. The results indicate that spatial extent of forest landscape for the 13 FRs is 522,164, 481,870 and 457,651 hectares in 1986, 2000 and 2014 respectively. Results of forest cover transition for the two 14-year periods investigation show a larger percentage of forest landscape across the 13 FRs are more affected by deforestation in comparison to afforestation. The overall annual deforestation rates for the PAs are 0.82% and 0.68% for 1986 to 2000 and 2000 to 2014 time periods. The annual afforestation rates for both 14-year periods are 0.38% and 0.39% respectively.

From the results it's obvious that the 13 PAs are under threats of deforestation. Hence, there's an urgent need to review the ways FRs and NPs in CRS are managed. The promotion of forest conservation is vital to the preservation of existing forest landscapes and endangered wildlife, such as the Cross River *Gorilla gorilla* and Nigeria-Cameroon chimpanzees. The role of community participation with the assistance of government and conservation organizations will prove effectively in forest monitoring activities across the state. In addition, further research as to the effects of forest change in protected areas across the Niger Delta suggests that as such information is currently lacking. In conclusion, results of this study show the potential of incorporating satellite remote sensing and ground truth data for better understanding the spatial dynamics of forest cover in PAs across the Niger Delta region.

Acknowledgements

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