

ASSESSING THE CHANGES IN THE MANGROVE ECOSYSTEM OF ORON AND EASTERN OBOLO ESTUARIES BETWEEN 1986 AND 2018

ABSTRACT

Studies were carried out to assess the impact of nipa palm (*Nypafruticans*) population and the sustainability of the mangrove forest of Oron and Eastern Obolo estuaries in Akwa Ibom state for a period of 30 years. Assessment of the land use change of Oron and Eastern obolo mangrove forests revealed a progressive succession of the nipa palms over the mangroves within a period of three decades (1986- 2018). The result showed a significant reduction ($P > 0.05$) in the population of mangroves and an increase in the of nipa palm, from 7610 in 2000 to 5540 in 2018, while nipa palm increased from 3411 to 6229. Satellite imageries obtained for both Oron and Eastern Obolo showed a decrease ($P > 0.05$) in the land area covered by mangroves while there was an increase ($P > 0.05$) in the area of land covered by nipa palms. These changes observed resulted in the loss of 1.9km² and 4.8km² of mangroves in Oron and Eastern Obolo respectively as well as an increase of 2.5km² and 7.4km² increase ($P > 0.05$) in nipa palms. In summary, the outcome of the research shows a progressive succession of nipa palm over the mangroves. This calls for urgent action to mitigate the impact caused by the alarming succession that is currently on-going in the mangrove forest of Oron and Eastern Obolo, and by extension other mangrove forests across Nigeria and the world at large, if the ecosystem services performed by these mangroves will have to be sustained.

INTRODUCTION

A mangrove is a shrub or tree that primarily thrives in brackish or salty coastal waters. Mangroves often grow along coasts and tidal rivers in an equatorial climate. They have unique characteristics that allow them to absorb more oxygen and expel salt, allowing them to withstand conditions that would kill most plants. The phrase is also applied to such species-rich tropical coastal vegetation. As a result of convergent evolution in multiple plant groups, mangroves are taxonomically diverse. The largest mangrove area is found within 5° of the equator, and they are found all over the world in the tropics and subtropics as well as some temperate coastal areas, primarily between latitudes 30° N and 30° S (Giri *et al.*, 2011; Fries *et al.*, 2019).

10 of the 17 West African nations, from Senegal to Nigeria, have mangroves. Nigeria has the greatest mangrove area in Africa, with an estimated 10,515 km², or 5.8% of the world's total mangrove area; the majority of this area is in the Niger delta. Along with Indonesia, Brazil, and Australia, Nigeria is among the eight nations with extensive mangrove reserves that are still in existence. All nine of the coastal states—Lagos, Ogun, Ondo, Edo, Delta, Bayelsa, Rivers, Akwa Ibom, and Cross River—have forests. Mangroves make up around 18% of the land area,

and these regions are protected by national and international laws but only a few of the declared protected sites are actively managed, (Corcoran *et al.*, 2007). In Akwa Ibom State, according to BDCP, (2010), the left overs of some healthy mangrove stands are found in Oron, Udunguko, Mbo, Urue-offongOruko, Opobo, Uruan, IkotAbasi, EsitEket, Ibeno, Eastern Obolo, and Parrot Island.

Mangroves provide a wide range of benefits including the provision of food and fisheries; biodiversity preservation (Mazda *et al.*, 2005); medicinal values (Bandaranayake 1998); coastal/shoreline protection (Danielsen *et al.*, 2005); soil formation (Sherman *et al.*, 1998); carbon sink (UNEP, 2011; Donato *et al.*, 2011), improvement of water quality (Alongi 1989), as well as nutrient cycling. Mangrove restoration is an issue of concern for a number of reasons. Mangroves help maintain healthy marine and coastal environments. They shield the surrounding areas from weather extremes and tsunamis. Mangrove forests are also good in storing and sequestering carbon, which helps to slow down global warming (Friess *et al.*, 2019).

Mangrove ecosystems have an outstanding relevance ecologically and economically, for this reason there is an urgent demand for conservation and restoration measures. Therefore, retrieving up-to-date information with regard to the extent and condition of mangrove ecosystems is an essential aid to management and policy- and decision-making processes. Typical mangrove habitats are temporarily inundated and often located in inaccessible regions; consequently, traditional field observation and survey methods are extremely time-consuming and cost intensive. To address these issues, large-scale, long-term, cost-effective monitoring and mapping tools are required, which are available by means of remote-sensing technology (Aschbacher *et al.*, 1995; Blasco *et al.*, 1998; Dahdouh-Guebas, 2002; Wang and Sousa, 2009).

Remote sensing has been widely proven to be essential in monitoring and mapping highly threatened mangrove ecosystems (Blasco *et al.*, 2001; Vaiphasa *et al.*, 2006). Many research studies on this subject have been carried out around the globe. Tropical and subtropical coastal mangroves are among the most threatened and vulnerable ecosystems worldwide (Valiela *et al.*, 2001). The habitat area loss during the last two decades is estimated to be about 36% of the total global mangrove area. Although the rate of decrease has slowed since the 1980s, the average annual loss rate of mangroves of 0.66% during the years 2000–2005 is still alarming (FAO, 2007).

1.1 Objectives

- i. assess the changes in the formation of the mangrove ecosystem of Oron and Eastern Obolo over time,
- ii. determine the changes in the population of mangrove species in relation to the nipa palm in the 2 estuaries over a period of time,

2 MATERIALS AND METHOD

2.1 STUDY AREA AND DESCRIPTION OF SAMPLING SITES

The study was undertaken in 2 estuaries, Eastern Obolo and Oron. Eastern Obolo is located in the Niger Delta fringe between Imo and Qua Iboe Rivers estuaries and lies between latitudes 4°33'N - 4° 50'N and longitudes 7° 45' - 7° 55' E; and about 650m above sea level in the tropical mangrove forest belt, east of the Niger Delta.. It is bounded to the north by Mkpate Enin Local Government Area, northeast by Onna, west by Ikot Abasi, southeast by Ibeno Local Government Area all in Akwa Ibom state, and in the south by the Atlantic Ocean. It has a total landmass of 117,008 square kilometers with an estimated shoreline of about 184 km long and a population of 60,543 people, according to 2006 population census. The tidal range in the area is about 0.8m at neap tides and 2.20m during spring tides with little fresh water input joined by numerous tributaries as they empty into the Atlantic Ocean (NEDECO, 1961). The climate of the area is tropical with distinct rainy (April to October) and dry seasons (November to March) with a high annual rainfall averaging about 2500mm (AKUTEC Report 2005).

Eastern Obolo estuary is a unique aquatic environment in the tropical belt with marked maritime influence characterized with riverine inflow, vertical mixing, coastal nutrient enrichment, oil pollution and other anthropogenic sources. It is also one of the ecologically and economically rich transitory marine ecosystems in the Niger Delta region of Nigeria with mangrove and saline water providing breeding grounds for a variety of fish and shrimp species. The area is characterized by an extensive mangrove swamp with inter-tidal mud flats influenced by the semi- diurnal tidal regime of the estuary. Numerous activities such as oil exploitation and exploration, laundry, fuel wood exploitation, boat transportation and capture fisheries take place along the estuary/watershed (James *et al.*, 2013). Fishing and farming are the main economic activities in this study area.

A study by Fimsco Surveys (2002) reported that Eastern Obolo ecosystem was rich in biodiversity and wildlife population before oil exploration. According to history, the Eastern Obolo people, migrated into the area from Western Obolo over 300 years ago and enjoyed a functional environment of unpolluted air, water and land (Enemugwem, 2000).

Oron is located between 4°50' 0" latitude 5° North and longitude 9° East at the right bank of the lower estuary of the Cross River. It is the third largest city in Akwa Ibom State with an area of 70 km² and a population of 156,461 according to 2006 population census. The region is extremely fertile and is known for its topographical Oil Palm Belt, tropical rainforest, swamps, and beaches. There are also deposits of solid minerals such as iron, free silica or glass sand and gravel. Seafoods such as crayfish, snipers, oyster and periwinkle abound richly in Oron as in all coastal areas. The tidal range in Esuk Oron is between 2.01m (6.6ft) and 2.06m (6.8ft), by which time it brings high saline water and adds nutrients to the estuary, flushing away waste products, impurities, or even pollution. As the high tide gradually falls to its lowest point, it becomes the low tide, and the cycle starts over again (Godwin, 2012). Oron is in the tropical region and has a uniformly high temperature all the year round. The two main seasons are the dry- which spans between October and April and wet- season which starts around May and ends in September. The people of Oron are predominantly fishermen, farmers and traders who trade across the Gulf of Guinea frontiers.

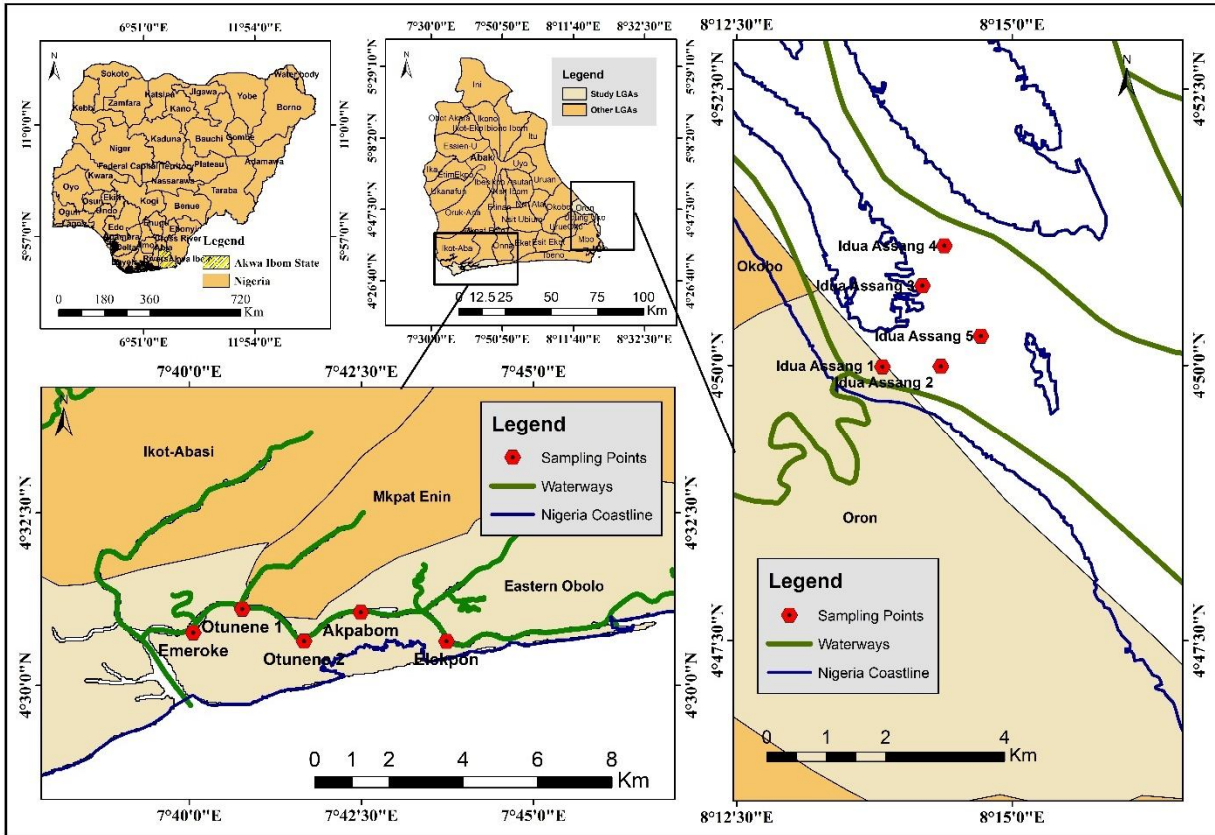


Fig. 1: Map of Akwa Ibom State showing the study areas, Oron and Eastern Obolo Local Government Areas.

2.2 METHODOLOGY

The raw spatial images were acquired from United States Geological Survey (USGS), on www.earthexplorer.usgs.gov for Landsat 5TM, Landsat 7ETM and Landsat 8 OLI for 1986 to 2018. Three images of the study area were acquired within a time frame of 30years. The final process employed the use of the empirical radiometric calibration coefficients to transform the data into reflectance values. A set of control points were acquired as training sites for classification and validation to cover the study area. A GPS unit was used to get coordinates for the sampling points (transects). Appropriate enhancement techniques were applied to the images to make the mangroves appear better on the images as described by Green *et al.*, (1996). In addition to the individual spectral bands of Landsat images, vegetation indices such as Normalized Difference Vegetation Index (NDVI), Green Atmospherically Resistant Index (GARI), and Normalized Difference Infrared Index (NDII) were also derived from the images to improve quality of classification.

ANALYTICAL TECHNIQUES

Data collected were subjected to descriptive statistics such percentages, frequency distribution and proportions of responses from which some inferences were drawn. ANOVA and SPSS were also used to carry out a wide range of data manipulation to achieve desired results. Bar chart and least significant difference (LSD) were used to determine changes in mangrove size as well as the land use change.

3 RESULTS

A critical examination of the result of analysis for Oron estuary as presented in **Table 2** shows that in 1986 mangroves occupied the largest area of 6.8km^2 with a pixel count of 7610, representing 12.7% of the entire forest, while nipa palm covered an area of 3.1km^2 with a pixel count of 3411 (5.7%). Other features in the forest were as follows: built up 5442 (4.9km^2), water body 1752 (1.6km^2), shrubs 14168 (12.8km^2) while forest and farmland occupied 9279 (8.4km^2) and 17954 (16.2km^2) respectively. However, in 2000, mangrove forest reduced from its initial of $7610(6.8\text{km}^2)$ to $6682(6.0\text{km}^2)$ and later $5540(4.9\text{km}^2)$ in 2018 while nipa palm increased from $3411(3.1\text{km}^2)$ in 1986 to $4624 (4.2\text{km}^2)$ in 2000 and then $6229 (5.6\text{km}^2)$ in 2018.

The results for remote count of features and land use in the mangrove forests of Oron are shown on Tables 1a, b and Figures 2 a,b.

Table 1a: Pixel counts of features of land use and land cover of Oron in Akwa Ibom State

Features	1986	2000	2018	LSD _(0.05)
Built Up	5442.0 ^c	5831.0 ^b	5844.0 ^a	3.6056
Water Body	1752.0 ^c	5114.0 ^b	9554.0 ^a	57.9828
Mangrove	7610.0 ^a	6682.0 ^b	5540.0 ^c	30.4631
NIPA	3411.0 ^c	4624.0 ^b	6229.0 ^a	34.8281
Shrub	14168.0 ^a	11541.0 ^c	13048.0 ^b	33.4664
Forest	9279.0 ^c	10673.0 ^b	11324.0 ^a	25.5147
Farmland	17954.0 ^a	15151.0 ^b	8077.0 ^c	52.9434

The mean value in each row followed by different superscripts is statistically different at ($P < 0.05$). Mean separation was done using Least Square Difference (LSD) without replicates derived from QI Macros 2018 excel add in statistical package.

Table 1b: Pixel counts of features of land use and land cover of Oron in Akwa Ibom State

Features	1986	2000	2018	LSD _(0.05)
Built Up	1658.0 ^c	4232.0 ^b	8904.0 ^a	50.7346
Water Body	14422.0 ^c	14904.0 ^b	15272.0 ^a	19.1833
Mangrove	54197.0 ^a	51888.0 ^b	48870.0 ^c	48.0521
Nipa	13231.0 ^c	18395.0 ^b	21432.0 ^a	55.1090
Shrub	6888.0 ^c	8924.0 ^b	14492.0 ^a	45.1221
Forest	34903.0 ^a	23970.0 ^b	15411.0 ^c	92.5149
Farmland	8594.0 ^c	11580.0 ^a	9512.0 ^b	30.2985

The mean value in each row followed by different superscripts is statistically different at ($P < 0.05$). Mean separation was done using Least Square Difference (LSD) without replicates derived from QI Macros 2018 excel add in statistical package.

Similarly, analysis of Eastern Obolo estuary shows a consistent decrease in land area covered by the mangrove forest from 48.78km² in 1986 to 43.98 km² in 2018 while the land area cover for nipa palm increased from 11.91 in 1986 to 19.29 in 2018, implying a loss of 4.8 km² of mangrove forest and an increase of 7.38 km² of nipa forest.

The results for remote count of features in the mangrove forests of Eastern Obolo are shown on Tables 2a,b and figures 2. Satellite imageries for Oron and Eastern Obolo LGA for the period between 1986 and 2018 (30years) are shown in figures 2 a-c and 3 a-c.

Table 2a: Area (km²) of land use and land cover of Oron in Akwa Ibom State.

Features	1986	% of total Area covered	2000	% of total Area covered	2018	% of total Area covered	LSD _(0.05)
Built up	4.9 ^b	9.13	5.25	9.78	5.26	9.80	0.1082
Water body	1.58 ^c	2.94	4.60	8.57	8.60	16.03	1.7395
Mangrove	6.85 ^a	12.76	6.01	11.20	4.99	9.29	0.9139
Nipa	3.07 ^c	5.72	4.16	7.75	5.61	10.45	1.0448
Shrub	12.75 ^a	23.76	10.39	19.36	11.74	21.88	1.0040
Forest	8.35 ^c	15.56	9.61	17.90	10.19	18.99	0.7654
Farmland	16.16 ^a	30.12	13.64	25.42	7.27	13.55	1.5883

Total area covered 53.66km². The mean value in each row followed by different superscripts is statistically different at (P < 0.05). Mean separation was done using Least Square Difference (LSD) without replicates derived from QI Macros 2018 excel add in statistical package.

Table 2b: Area (km²) of land use and land cover of Eastern Obolo in Akwa Ibom State

Features	1986	% of total Area covered	2000	% of total Area covered	2018	% of total Area covered	LSD _(0.05)
Built up	1.49 ^c	1.24	3.81 ^b	3.16	8.01 ^a	6.65	1.5232
Water body	12.98 ^c	10.77	13.41 ^b	11.13	13.74 ^a	11.40	0.5745
Mangrove	48.78 ^a	40.48	46.70 ^b	38.76	43.98 ^c	36.49	1.4422
Nipa	11.91 ^c	9.88	16.56 ^b	13.74	19.29 ^a	16.01	1.6523
Shrub	6.20 ^c	5.14	8.03 ^b	6.66	13.04 ^a	10.82	1.3528
Forest	31.41 ^a	26.07	21.57 ^b	17.90	13.87 ^c	11.51	2.7749
Farmland	7.73 ^c	6.41	10.42 ^a	8.65	8.56 ^b	7.10	0.9110

Total area covered 120.5km². The mean value in each row followed by different superscripts is statistically different at (P < 0.05). Mean separation was done using Least Square Difference (LSD) without replicates derived from QI Macros 2018 excel add in statistical package.

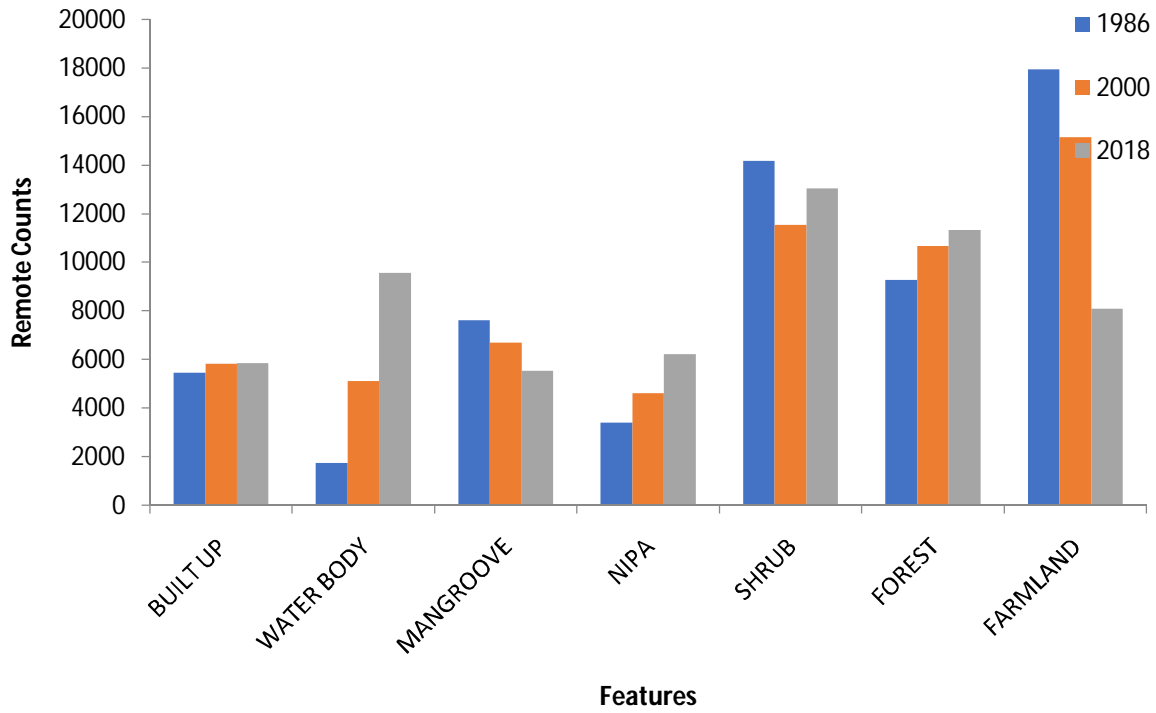


Figure 2a: Pixel counts of land use and land cover in Oron - Akwa Ibom State

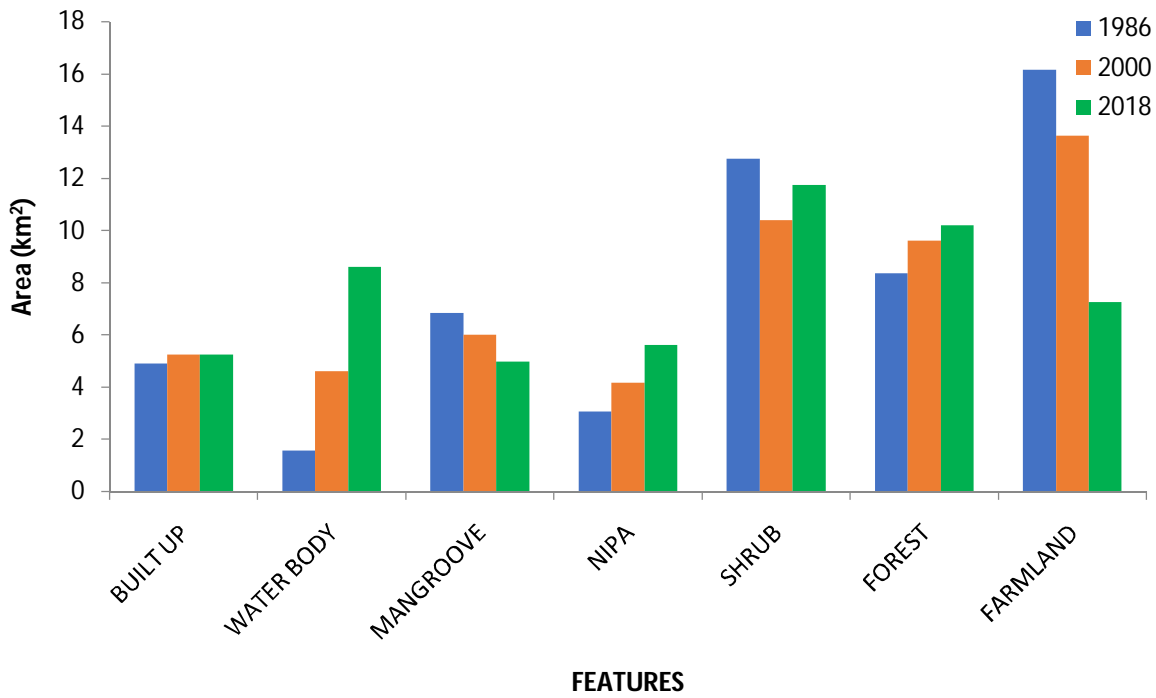


Figure 2b: Area (km²) of land use and land cover of Oron - Akwa Ibom State

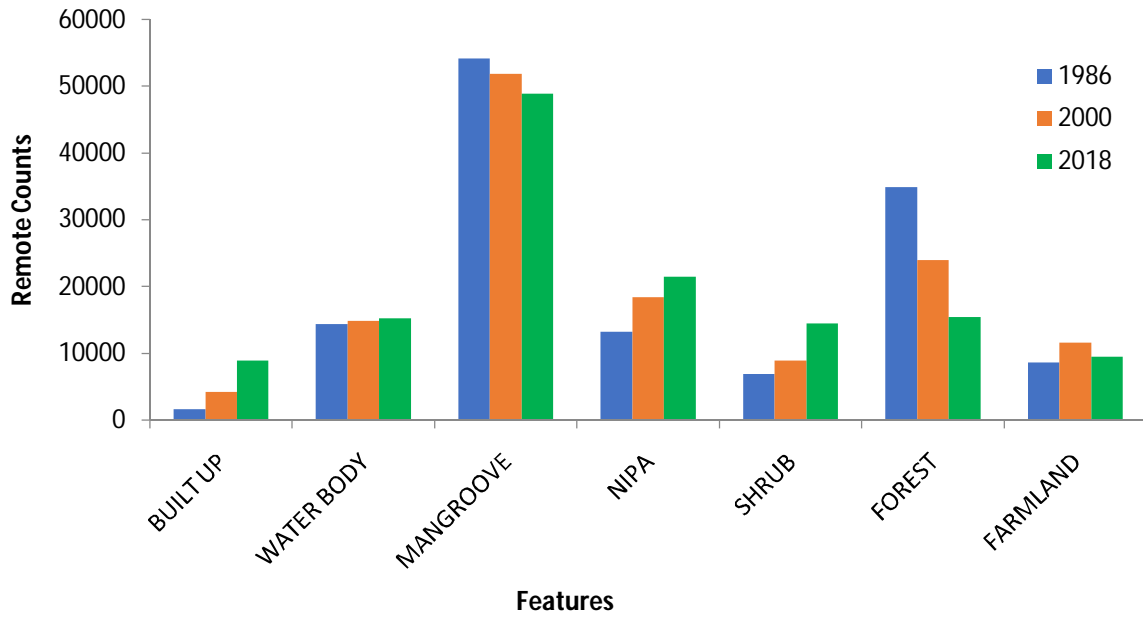


Figure 3a: Pixel counts of land use and land cover in Eastern Obolo - Akwa Ibom State

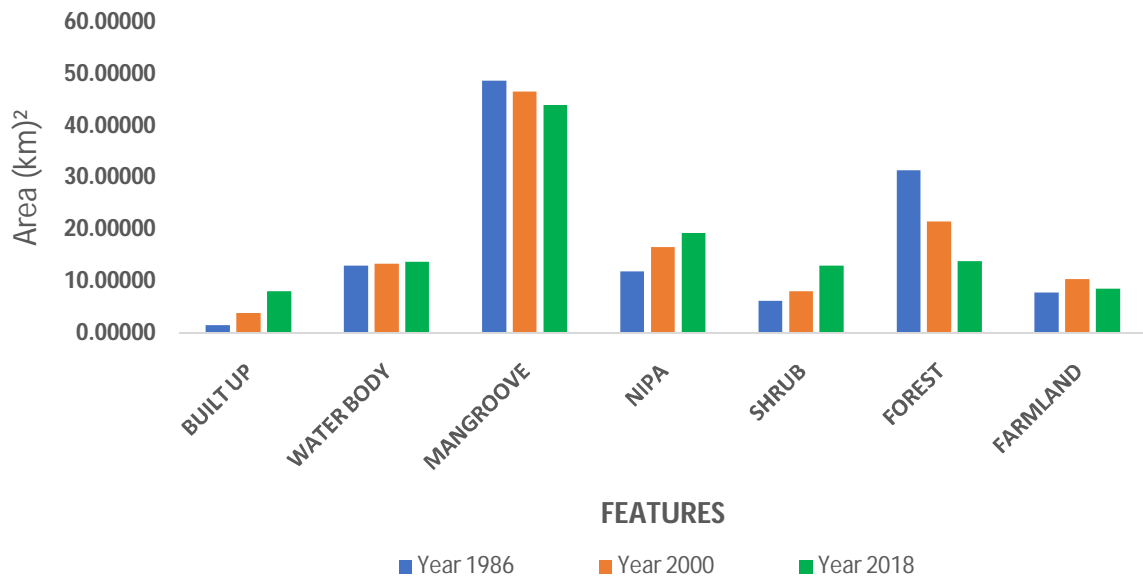


Figure 3b: Area (km²) of land use and land cover of Eastern Obolo - Akwa Ibom State

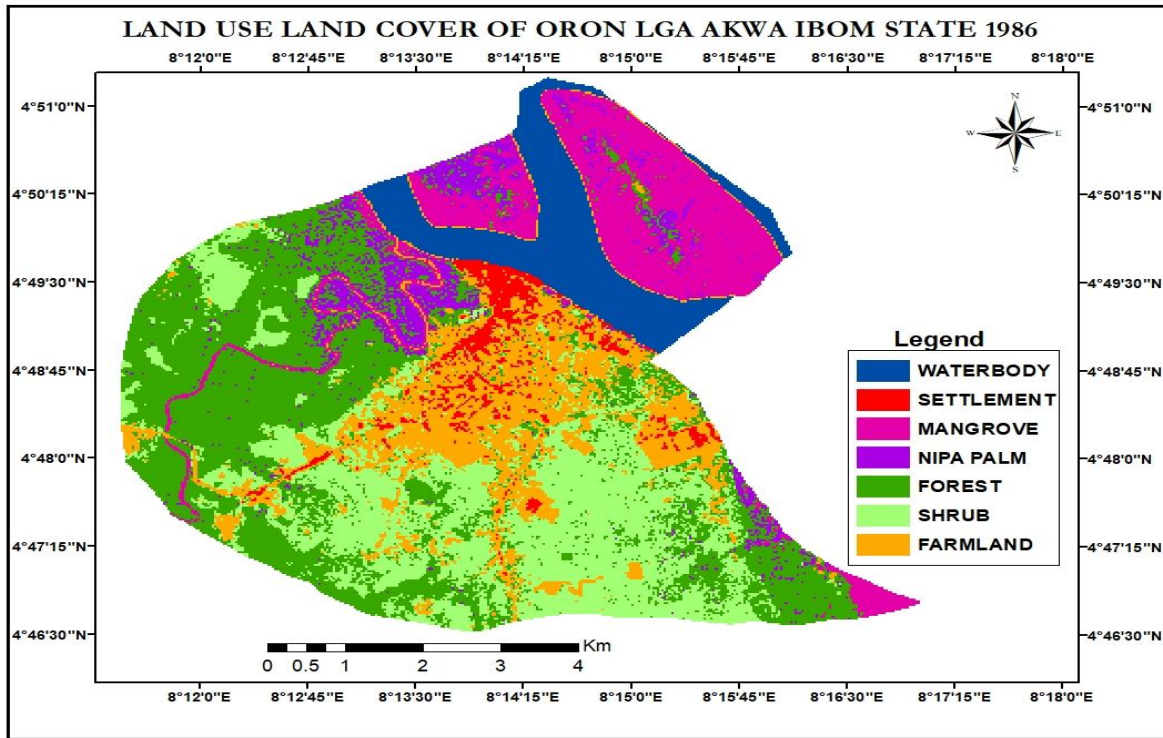


Fig.4a Satellite Image showing Land use cover of Oron LGA in 1986

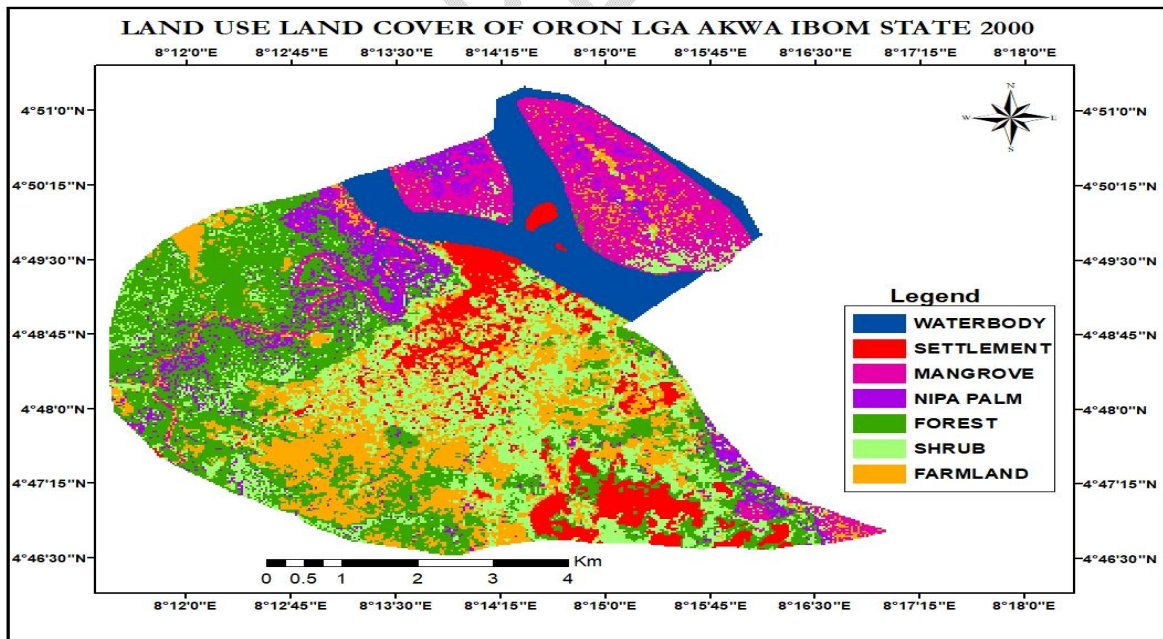


Fig. 4b Satellite Image showing Land use cover of Oron LGA in 2000

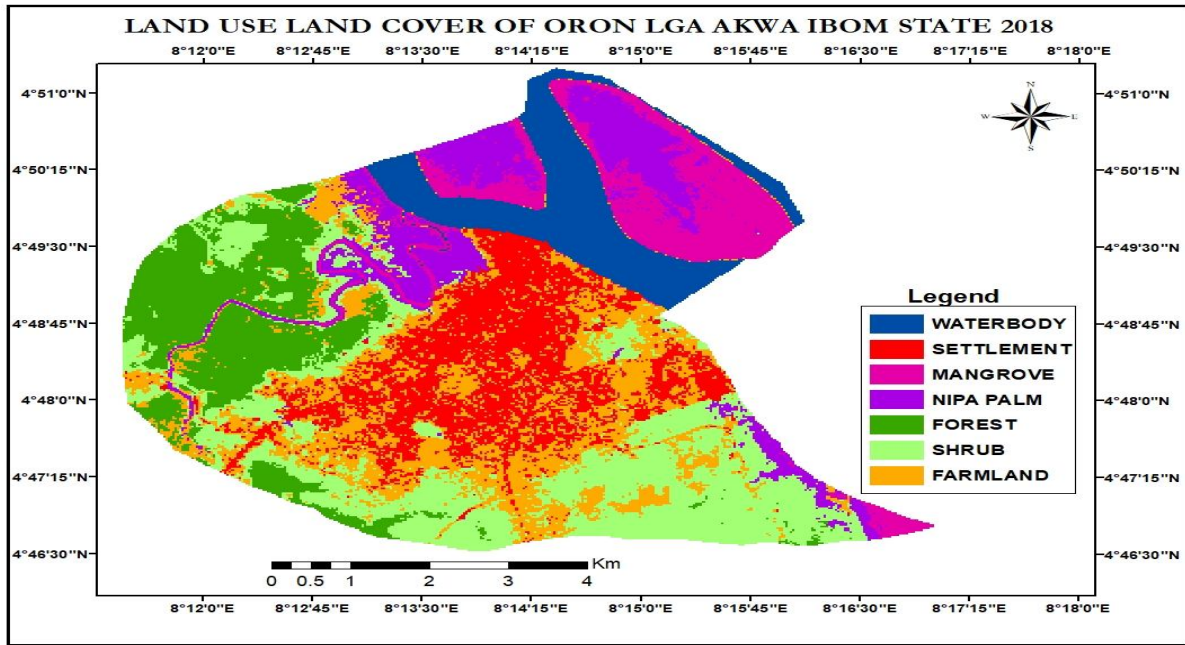


Fig. 4c Satellite Image showing Land use cover of Oron LGA in 2018

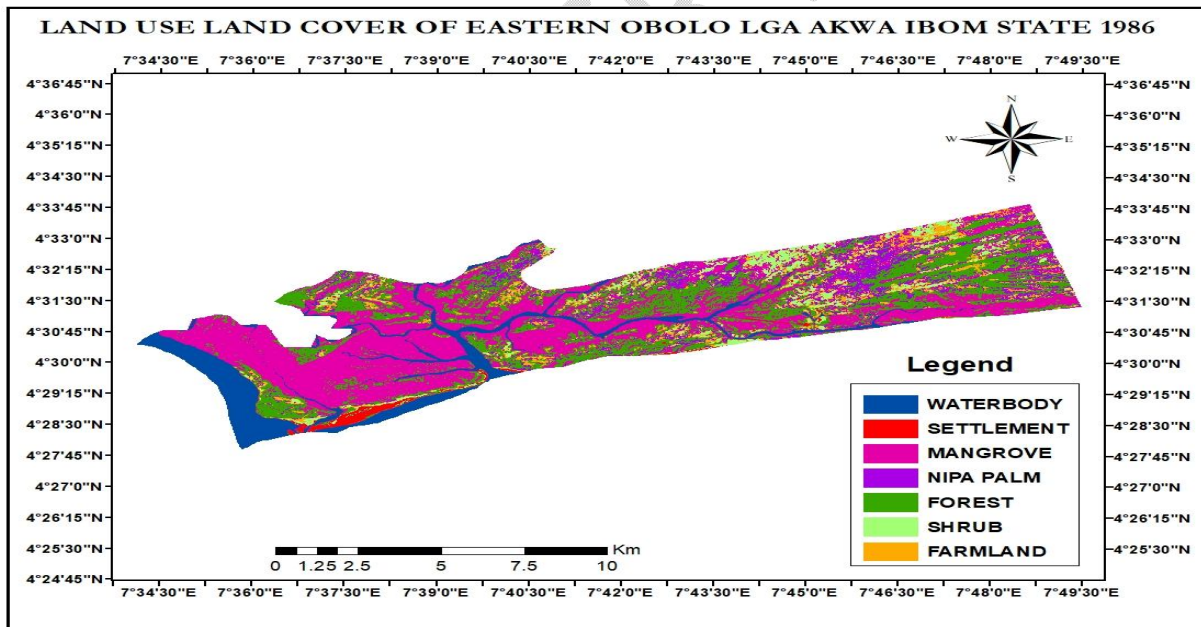


Fig. 5a Satellite Image showing Land use cover of Eastern Obolo LGA in 1986

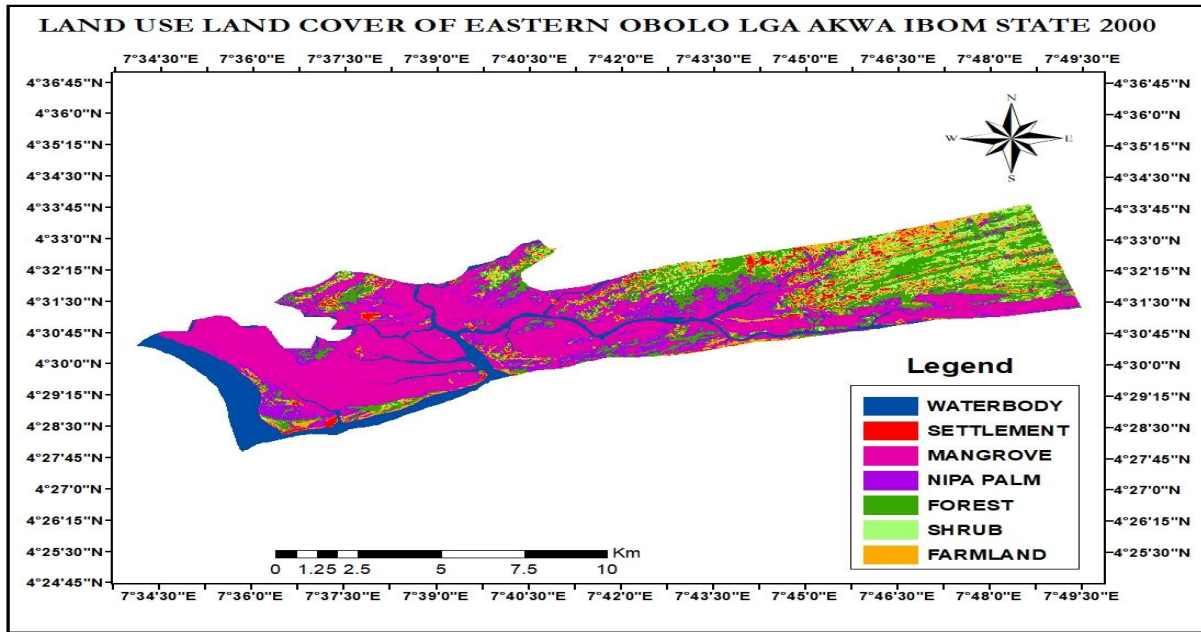


Fig. 5b Satellite Image showing Land use cover of Eastern Obolo LGA in 2000

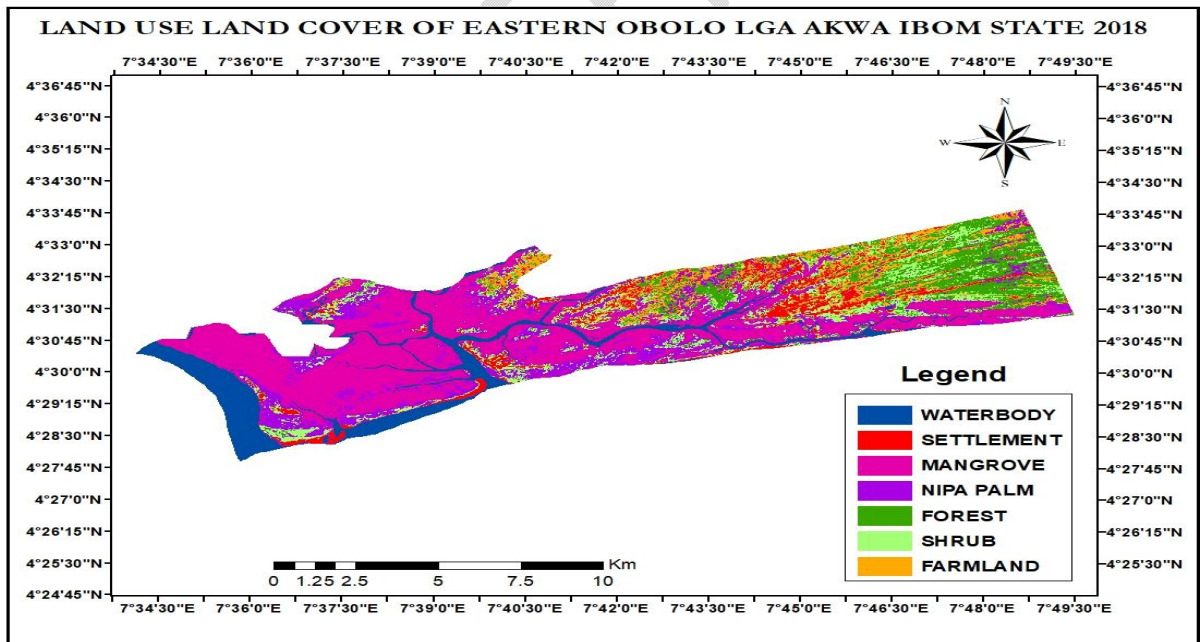


Fig. 5c Satellite Image showing Land use cover of Eastern Obolo LGA in 2018

DISCUSSION

A number of authors have noted that mangrove habitat inventories, change detection and monitoring, success in conservation and reforestation, silviculture, and the development of aquaculture all benefit from the knowledge that may be obtained via mangrove remote sensing, including Green *et al.* (1998), Aschbacher *et al.* (1995), Manson *et al.* (2001), Giri *et al.* (1996), and Wang *et al.* (2004). According to them, support for ecosystem evaluation, productivity assessment (biomass estimation), estimation of regeneration capacity, multiple management requests (fisheries, aquaculture activities, conservation management, management guidelines and strategies), field survey planning, water-quality assessment, prompt information supply for disaster management, and delivery are all ways to better understand ecological and biological relations and processes, functions, and relationships.

The changes observed in the mangrove forests from 1986 to 2018 (30year period) resulted in the loss of 2070 stands of mangrove, representing 1.9km² of the mangrove forest to other land use/cover types, while nipa palm increased by 2818 stands equivalent to a land area of 2.5km².

The result shows that the percentage and land area covered by mangrove forest kept decreasing while that of nipa palm increased over the period under review. In 1986 for instance, the mangrove count was 12.7% but decreased to 11.2% in year 2000 and subsequently to 9.3% in 2018; while nipa palm had a 5.7% in 1986 but increased to 7.7 % in 2000 and 10.4% in 2018. Similarly, the land area covered by mangrove forest decreased from 6.8km² in 1986 to 4.9km² in 2018 while that of nipa palm increased from 3.1km² in 1986 to 5.6km² in 2018.

This remote sensing result agrees with various authors such as Dahdouh-Guebaset *al.*, (2002) and Cunha-Lignonet *al.*, (2009) who noted that the use of aerial photographs and other remote sensing technologies Pin combination with geographic information systems (GIS) offers a useful tool for monitoring changes in mangrove forests and assessing anthropogenic impacts on them. Aerial photographs have been widely used in the mapping and assessment of mangrove forests (Heuman, 2011), allowing long-term decadal retrospection on the basis of spatio-temporal imagery analyses (Dahdouh-Guebaset *al.*, 2006). The outcome shows clearly a gradual succession of the nipa palm over the mangrove forest.

CONCLUSION

Evidence from remote sensing suggest a decline in the mangrove forests of Oron and Eastern Obolo and a concomitant increase in nipa palm population. The use of remotely sensed data and application of Geographic Information System to determine the change in mangrove forest distribution was carried out for a period of 30 years (2000 and 2018). Based on the findings of the study, it was concluded that there has been a significant decrease in the mangrove forest area in Oron and Eastern estuaries Akwa Ibom State. In Oron for instance, the area had changed from 6.85km² in 1986 to 4.99 km² in 2018; while nipa palm area had increased from 3.07km² to 5.61km² within the same period. This change resulted in a loss of 1.86km² of mangrove forest and an increase of 2.54km² of nipa palm. Thus, the study concludes that the rate of mangrove forest destruction over the years has been alarming and thus requires urgent attention to recover these environments if the ecosystem functions performed by mangroves are to be sustained.

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