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## **Spatio-Temporal Assessment of Degraded Marine Wetlands and its Remediation Measures in Southern Akwa Ibom State, Nigeria**

by

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### **Abstract**

*This study was based on the assessed degraded marine wetlands as well as remediation measures in Southern Akwa Ibom State, Nigeria. It also assessed the strategies used for sustainable management of wetlands within the area. Geographic Information Systems (GIS) was employed for the collection and processing of geographic data along with Remote Sensing (RS) which provided information on geographic objects using satellite space-borne platforms. Global Positioning System (GPS) receiver was used in the study to provided information on spatial data positions in order to collect ground truth sample points. Thematic Land Use/Land Cover data of the study area as well as other relevant reference materials were also acquired. Erdas Imagine and ArcMap were used in processing and mapping the wetland changes caused by petroleum activities and the consequent effects of these actions, by assessing the pattern of distribution of the affected wetland. On the assessment of remediation methods, personal observation and reports from relevant MOCs, Government Ministries, Departments, Agencies and interviews were conducted across the different stakeholders within the study. The result showed that there was a significant change in the wetland area of Southern Akwa Ibom State though more than 68% of the wetland mapped had remained unchanged. While wetland was increasing in some areas others experienced a decrease. A total of 5758.14 hectares of different land cover classes in 2003 were now wetland cover in 2016. A total of 8735.06 hectares of wetland cover in 2003 were now covered with different land cover in 2016 while a total of 12629.11 hectares remain unchanged. It was observed that management of the wetland was majorly based on traditional methods of total and periodic restrictions to some community preserved areas as well as periodic fallowing. The traditional management strategies of seasonal restrictions and buffers is not sustainable enough to protect and preserve the wetlands from complete degradation and as such measures should be taken to sensitize all stakeholders in the study area to adhere to the government laid down laws and regulations in order to protect, preserve and ensure a sustainable wetland for future generations.*

**Key Words:** Marine wetland, Degradation, Petroleum, Remote Sensing, Land Cover Change, Remediation Measures, Sustainable management



## 1. Introduction

Over the last 10,000 years, about half of the earth surface has witnessed tremendous change largely due to the result of alteration of land cover by humans (Lambin and Meyfroidt 2008). Foley, et.al. (2005) stressed that land use and cover change is a major cause of global environmental change. In the opinion of Skokanová, Falt'an and Havlíček (2016), the structure of a cultural landscape is largely determined by human decisions – by direct or indirect impacts of human activities. FAO (1997) remarked that Nigeria has the world's highest deforestation rate of primary forests and has lost half of its primary forests in the last twenty years through logging, subsistence agriculture and collection of fuel woods. In a related study, Balogun and Salami (2016) stressed the need for an early monitoring of the biofuel production activities in Nigeria so that the country can maximize the benefits and perhaps control land cover change resulting from such activities. This is basically as a result of increase in human activities over the surface of the earth. Such changes must therefore be understood and tracked in order to check the negative effects of the change on other components of the environment.

Wetland is not left out of these adverse effects. Activities supported by wetland such as agricultural practices which forms the main means of livelihood within the local communities are on the decline, thus triggering a decreasing multiplier effects to the alternative livelihood opportunities at the local level. According to (Best, Verhoeven and Wolff 1993) wetland covers about 6% of the total surface of the Earth and is found on every latitude. The Millennium Ecosystem Assessment (MEA) examined the importance and value of ecosystem services provided by wetlands to the livelihood and wellbeing of the inhabitants (Duraiappah and Naeem, 2005), but in spite of these valued services, wetlands were amongst the endangered ecosystem globally, from the perspective of agriculture and water management (Falkenmark, Finlayson and Gordon 2007).

Southern Akwa Ibom State, Nigeria is known as one of the wetlands rich in biodiversity in the country. Its wetland ecosystem is noted for its primary support for the people living in the area. According to Adekola and Mitchell (2011), the wetlands' ecosystem services are being eroded through petroleum activities, dredging, invasive plant infestation and wetland reclamation. The Nigerian government, realizing the environmental problems associated with these activities in the Niger Delta wetland, set up Ministries and Commissions to partner with other stakeholders such as (oil multi-nationals, research institutions, resident communities, etc.) to look into the conservation, management and development of this wetland region.

Land cover could be seen as the physical, chemical or biological characterization of the terrestrial surface, e.g. grassland, forest or concrete, whereas land use refers to the human purposes that are associated with that cover e.g. raising cattle, recreation, or urban living (Meyer and Turner, 1994). Land use change is likely to cause land cover change, but land cover may change even if the land use remains unaltered (Turner and Meyer, 1994). Meyer (1995) added that, changes in land cover by land use do not necessarily imply a degradation of the land.

The biophysical drivers of land use change are therefore the characteristics and processes of the natural environment including landforms, topography, weather and

climate variations, geomorphic processes, volcanic eruptions, and plant succession. The socio-economic drivers on the other hand, consist of demographic, social, economic, political and institutional factors and processes such as population and population change, industrial structure and change, technology and technological change, the family, policies and rules, values, community organization and norms, property regime. It is noteworthy that the biophysical drivers usually do not induce land use change directly, rather they do cause land cover change, which, in turn, may influence the land use decisions of land owners/managers. Land use changes may result in land cover changes which, then feedback on land use decisions causing perhaps new rounds of land use change.

Anthropogenic activities, such as agriculture, have been in practice since the time of earliest cultivation (Ambujam and Anuradha, 2013). Right from inception, food production from cultivation and human settlements was developing primarily along fertile riverine wetlands and floodplains in the early beginning of agricultural practices. This was largely due to depositions of sediments on the flood plains creating a fertile area for agricultural practices to thrive, in addition to easy accessibility due to the present of waterway transportation (Verhoeven and Setter, 2010).

As technology increased and agricultural practices became sophisticated, wetlands have been reclaimed, causing the loss of natural ecosystems, leading to a loss of performance to functions other than crop productivity (Hassan, Scholes and Ash, 2005).

According to the Millennium Ecosystem Assessment (2005), an estimation of more than 50% of the total wetland areas quantified so far from several regions of North America, Europe and Australia shows a reduction of area, mostly due to conversion to intensive agriculture, population change, industrial structure and change, technology and technological change, the family, policies and rules, values, community organization and norms, property regime.

Hassan, Scholes and Ash (2005) also stated that although the protection of wetland has been made priority by 159 countries as at 2009 after the Ramsar Convention in Iran, wetlands have continued to be threatened by reclamation. He projected that population increase will also add more pressure to the wetlands as food production is expected to increase by 50% more by the end of 2030.

FAO (2003) report, reported that there was a shortage of plant food supply, forcing a change of trend to more animal-based food. A reversal will mean more demand for cultivated land, which will lead to more land reclamations by which wetlands will be affected.

According to Smeets et.al. (2007), that there has been an initiative to reduce carbon emissions with growing energy crops for biofuel use as well as climate neutral economic activities, hence the planting of trees and forest even on the non-forested wetlands. Additives such as fertilizers caused disturbances to its natural ecosystem by interfering with the natural characteristics of the wetland.

In Nigeria, the Niger Delta wetland region is endowed with abundant mineral and organic matter, with a huge deposit of fossil fuel in an area that also supports plant cultivation and other socio-economic activities (Imogie *et.al.*, 2012). But these activities

have gradually changed the wetland physical and chemical properties, making it a threat to the natural biodiversity and human livelihood (Ndidi *et.al.*, 2015).

It has obviously become necessary to protect our wetlands from all human activities that are not sustainable, while optimizing measures to regenerate the already damaged wetlands, for a more efficient, effective and environmental friendly ecosystem services.

This research uses a remote sensing based approach to mapping and monitoring petroleum degraded marine wetlands of the southern Akwa Ibom State. Therefore, this study addressed the characteristic changes brought about by the impact of human activities on wetlands and the resultant land cover within the wetland from 2003-2016, as well as the current wetland management practices in the study area.

## 2. Study Area

Three coastal Local Government Areas (LGA) of Akwa Ibom State were used as the study area. These include; Eastern Obolo, Ibeno and Esit Eket LGAs were randomly selected for study. The area is situated at the Southern part of Akwa Ibom State and lies between latitudes 4°15' and 4°45' N and longitudes 7°30' and 8°20' E, (Figure 1) with a total land area of 528.807 kilometre square and a population of 198,168 people (National Population Commission, 2010). The area experiences a mean annual rainfall that decreases northwards from the coast with the figures ranging from about 2100mm to about 4050mm. (Udoh and Udofia, 2014). It is noted for its abundant wetlands, saline mangroves, fresh and salt-water swampy forests, sandy coastal ridge barriers, as well as low land rain forest. Large number of rivers, streams, canals and creek are many prominent features of the area with a history of frequent flooding, erosion both gully and coastal and crude oil spillages and gas flaring since the discovery of oil and gas in the area. Apart from crude oil, the area is also rich in many other natural resources, such as natural gas, forest and marine resources, etc.

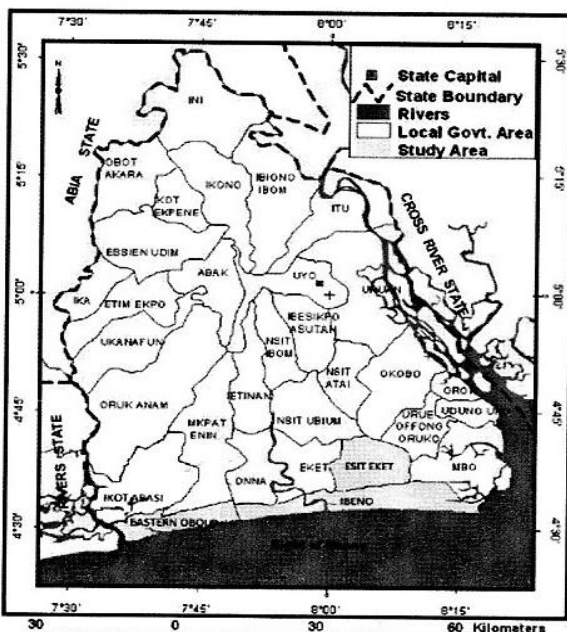


Figure 1: Map of Akwa Ibom State showing study area.

### EXTRACTED STUDY AREA MAP ON LGA BASIS

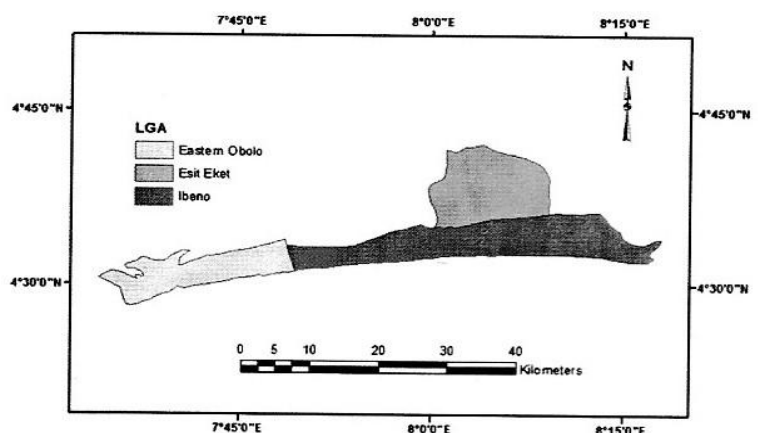


Figure 2: Extracted study area map on LGA basis

### 3. Materials and Methods

#### 3.1. Data

The study made use of Landsat 7 ETM+ of 2003 and Landsat 8 OLI (Operational Land Imager) and TIRS (Thermal Infrared Sensor) of 2016. These images were 100% cloud free and were obtained from the United States Geological Survey (USGS). The choice of Landsat data was as a result of availability, and that their data is multispectral to support a land-use/land cover change analysis for the purpose of the study. The Landsat images of 2003 and 2016 were of the same month of different years (January of each of the years). This made it reasonable and therefore possible to carry out change detection considering the similarity in environmental conditions. All the images and maps used were projected into Universal Transverse Mercator (UTM) map coordinates, a coordinate system that matched the GPS settings (projection name and parameters) used as stated below;

Projected Coordinate System:	WGS_1984_UTM_Zone_32N
Projection:	Transverse_Mercator
Projection Parameters	
- false_easting:	500000.
- false_northing:	0.
- central_meridian:	9.
- scale_factor:	0.9996
- latitude_of_origin:	0.
- Linear Unit:	Meter
Geographic Coordinate System:	GCS_WGS_1984
Datum:	D_WGS_1984
Prime Meridian:	Greenwich
Angular Unit:	Degree

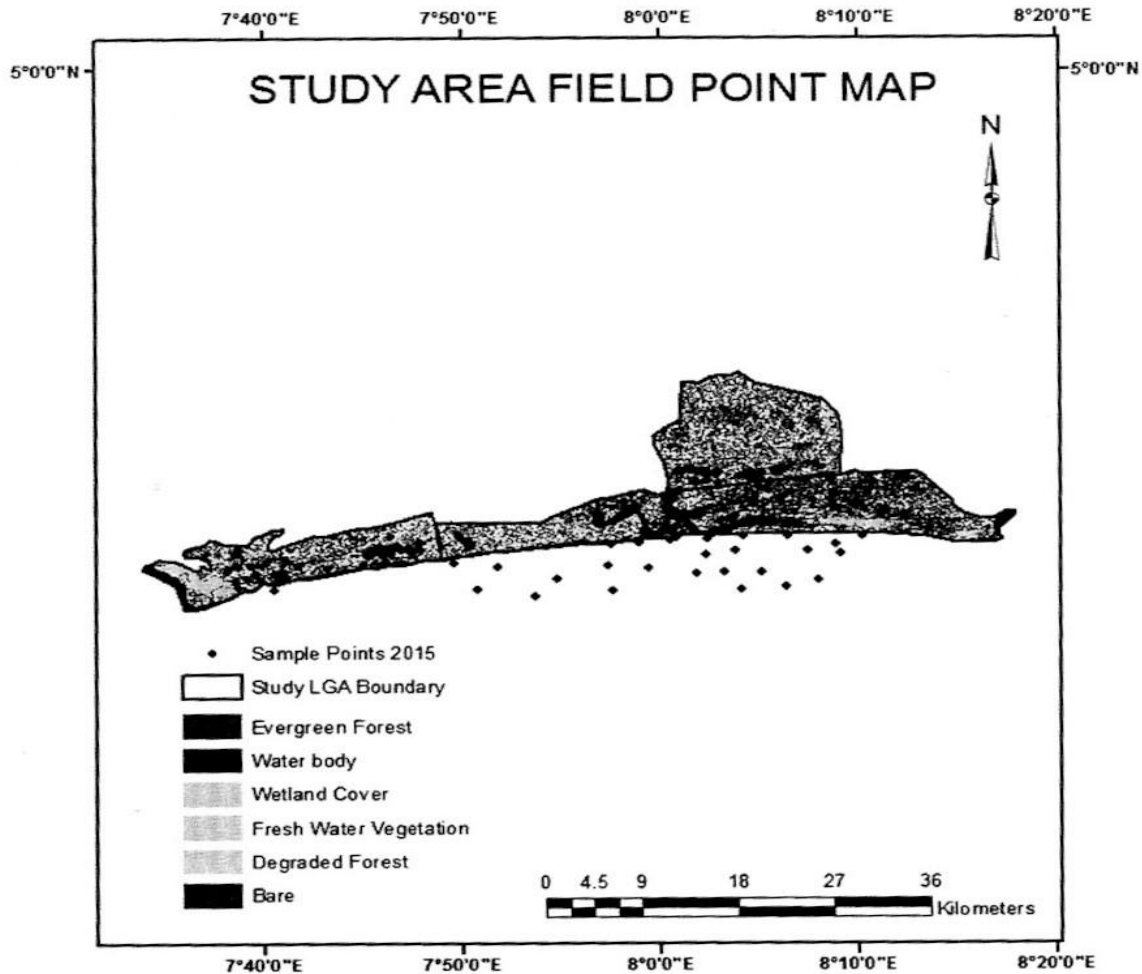
**Table 1: Attributes of the Landsat 7 ETM+ and Landsat 8 OLI and TIRS Imagery used in the Study**

Acquisition	Sensor	Spatial Resolution(30m)	Path/Row
2003-01-08	7 ETM+	30	188/057
2016-01-17	OLI_TIRS	30	188/057

#### 3.1.2 Ground Truth Data:

Within each land cover class, more ground points were sampled using a GPS receiver. Garmin GPS map 76CSx was used in the field for marking and recording of all the 241 coordinate points mapped. A stratified sampling method was adopted based on the six homogenous spectral characteristic classes identified using the 2015 Landsat image and ground sample points were collected. As expected, some of the areas mapped were inaccessible, and as such, a linear transect method was adopted in taking several points. 5 identified land cover classes were on land while one was on water.





**Figure 3: Study Area Field Point Map**

**Table 2: Description and Definitions of Land Use/Land Covers Classes.**

	<b>IGBP DISCover classes</b>	<b>Definitions</b>	<b>Equivalent of UN land cover classification system (LCCS) classes</b>
1	Dense Forest	Evergreen Forest, Mixed Forest and Deciduous Forest	Evergreen Forest
2	Water	Canals, Streams, Bays and Estuaries, Lakes and Reservoirs	Water Body
3	Wetland	Forested and Non-forested Wetland.	Wetland
4	Freshwater Swamp Forest	Forests which are inundated with freshwater, either permanently or seasonally(Ayuba 2012).	Fresh Water Vegetation
5	Agricultural Land	Cropland, Rangeland, Orchards, Pasture, Vineyards, Confined Feeding Operations, Ornamental Horticultural Areas, Herbaceous Rangeland, Groves, Nurseries, Shrub, Brush Rangeland, Mixed Rangeland and Other Agricultural Land.	Degraded Forest
6	Built-up and	Mixed Urban or Built-up Land, Dry and Salt	Bare

	Barren Land	flats, Beaches, other Sandy Areas, Residential, Commercial, Industrial, Transportation, Communications, Utilities, Urban, Bare Exposed Rock, Strip Mines, Quarries, Gravel Pits, Transitional Areas, Mixed Barren Land.	
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**Source:** (Anderson et al. 1976), (Hansen & Reed 2000).

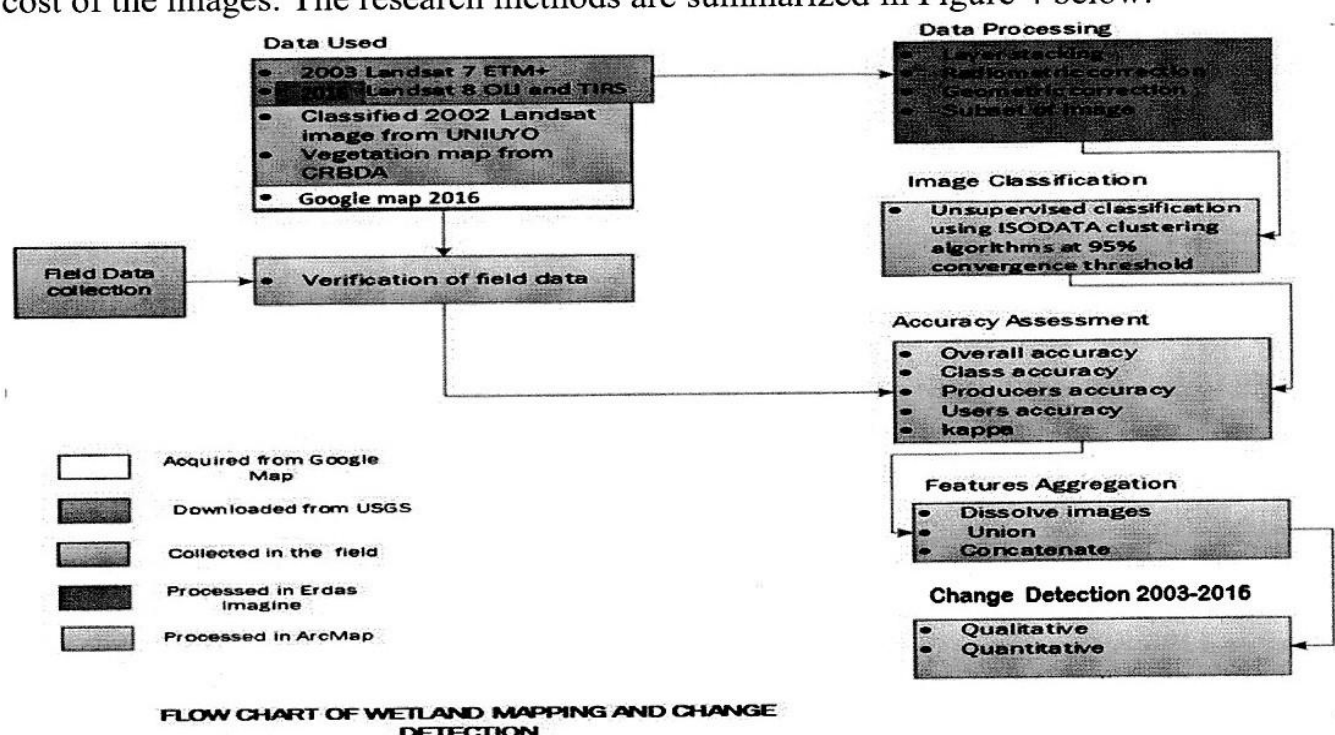
### 3.1.3 Land Cover Classification

The study adapted the Food and Agriculture Organization and United Nations Environment Programme (FAO/UNEP) land cover classification system (LCCS), which is widely accepted as a standard for LUCC studies. (Anderson et al., 1976; Loveland et al., 1997). (Table 4)

## 3.2 Methods

### 3.2.1 Image Classification

The two-time series Landsat images of January 2003 and 2016 were processed with the use of Erdas Imagine 2014 image processing software. While the 2016 Landsat image was post classified, that of January 2003 was classified and validated with the classified November 2002 land cover image. The choice of November 2002 classified image for validation was due to its similar weather conditions and the fact that it was the only available and most pertinent classified image available for a date close to the January 2003 chosen Landsat image used for the study. The selection of these two images (January 2003 and 2016) was based largely on the favorable atmospheric (100% cloud free) and radiometric (stripping line free) conditions, the availability of the same month in different years, similarity of preceding monthly weather conditions and the low cost of the images. The research methods are summarized in Figure 4 below.



**Figure 4: Flow Chart of the Research Methods**



According to Bakx et al. (2012), there are five major stages for an image to be processed for a change detection to be achieved; these are data selection, the preparation stage, the classification stage, the accuracy assessment stage, and then the process of identification and detection of the changes. This study was conducted according to these stages.

Land cover image for Southern Akwa Ibom State was produced from these. The downloaded images were a seven band TIFF file for 2003 image and an eight band TIFF file for 2016 image, with an extent larger than the actual study area. The separate bands were layer stacked using Erdas Imagine 2014. After layer stacking, the images were subset using the bounding box from the geometric group of Erdas Imagine. Unsupervised classification was employed to classify the images using the ISODATA clustering algorithms with a maximum number of classes of 15 and an iteration count of 10 with a 95% convergence threshold. Each of the resultant clusters were classified as a land cover according to the knowledge of the researcher of the area. The classified raster was later reclassified to six classes by aggregating the 15 clusters to these classes, namely Evergreen Forest, Water Body, Wetland Cover, Fresh Water Vegetation, Degraded Forest and Bare. The actual boundary of the study area was determined by clipping the digitized polygon shape file of the study area from the study area map obtained from the University of Uyo with the subset classified raster, producing the resultant image that covered the 3 local government areas of the southern part of Akwa Ibom State, namely Esit Eket, Ibeno and Eastern Obolo. Classification was quite challenging, but ancillary data, knowledge of the study area and a Google Earth 2016 image were also used to aid in classification decisions.

In the field, 341 training points were obtained from the named classes of the 2016 image with a GPS receiver, and due to the difficulty of traveling in the terrain, most of the points were collected linearly. These points were spatially joined with the 2016 classified raster image. 31 randomly sampled points were selected from each of the five classes of the classified January 2003 images of Evergreen Forest, Water Body, and Fresh Water Vegetation, Degraded Forest as well as Bare Cover and 151 random sample points from Wetland Cover class. These points were chosen across the thematic 2003 classified Landsat image based on the nearest neighboring pixel. These points were spatially compared with the reference map of classified November 2002 Landsat image.

Spectral and land cover features as well as pixel changes with a recognized pattern in the 2003 reference map provided a degree of confidence in the classification of the 2003 image. Jiang et al. (2012) also proposed a similar method. A classification accuracy of 2003 and 2016 images were calculated. Table 3 (below) shows how the error matrix tables were calculated. The producer's, user and kappa accuracies were produced both for the individual and the overall land cover (Yang et al., 2002).

For the 2003 Landsat image, the sample of random points of not less than 31 per class and the reference map was used for the calculation of the accuracy level. Features of the two-time series images were aggregated separately at this time by dissolve before a geometric union of the two images was conducted. The class name as described by each GRIDCODE was concatenated to create a combined attribute field where the

change detection can be visibly viewed on the map attributes, both qualitatively and quantitatively.

**Table 3: Error matrix table for accuracy assessment**

Field Class	Map Class							User accuracy
		1	2	3	4	5	6	
	1	A <sub>1</sub>	E <sub>12</sub>	E <sub>13</sub>	E <sub>14</sub>	E <sub>15</sub>	E <sub>16</sub>	C <sub>1</sub>
	2	E <sub>21</sub>	A <sub>2</sub>	E <sub>23</sub>	E <sub>24</sub>	E <sub>25</sub>	E <sub>26</sub>	C <sub>2</sub>
	3	E <sub>31</sub>	E <sub>32</sub>	A <sub>3</sub>	E <sub>34</sub>	E <sub>35</sub>	E <sub>36</sub>	C <sub>3</sub>
	4	E <sub>41</sub>	E <sub>42</sub>	E <sub>43</sub>	A <sub>4</sub>	E <sub>45</sub>	E <sub>46</sub>	C <sub>4</sub>
	5	E <sub>51</sub>	E <sub>52</sub>	E <sub>53</sub>	E <sub>54</sub>	A <sub>5</sub>	E <sub>56</sub>	C <sub>5</sub>
	6	E <sub>61</sub>	E <sub>62</sub>	E <sub>63</sub>	E <sub>64</sub>	E <sub>65</sub>	A <sub>6</sub>	C <sub>6</sub>
Producer accuracy		B <sub>1</sub>	B <sub>2</sub>	B <sub>3</sub>	B <sub>4</sub>	B <sub>5</sub>	B <sub>6</sub>	N

### 3.2.2 Accuracy Assessment

A classified November 2002 Landsat image from Geographic Information System (GIS) Unit of the University of Uyo and a vegetation map from the Cross River Basin Development Authority (CRBDA) were obtained and used as ancillary data to the January 2003 Landsat 7 ETM+

After classification of the January 2003 Landsat image, its accuracy was assessed using the November 2002 Landsat classified images as the reference data. This approach was selected due to the fact that the November 2002 Landsat image was a processed and classified image with ground truth points accurately verified by the University of Uyo GIS Unit. Furthermore, it was the only available classified image with a date close to that of the January 2003 image, and had similar weather conditions between November 2002 and January 2003. The following accuracy assessment results were obtained, the overall accuracy was 68%, with an overall kappa at 60%. The user class accuracy for Evergreen Forest was 100%, Water 95%, Wetland Cover 44%, Fresh Water Vegetation 95%, Degraded Forest 70%, and Bare 100%. The producer accuracy for Evergreen Forest was 55%, Water 50%, Wetland Cover 95%, Fresh Water Vegetation 81%, Degraded Forest 41%, and Bare 73%.

The overall accuracy assessment of 2016 was 88%, with an overall kappa coefficient was 85%. The user class accuracy for Evergreen Forest was 64%, Water 93%, Wetland Cover 87%, Fresh Water Vegetation 95%, Degraded Forest 80%, and Bare 93%. The producer accuracy for Evergreen Forest was 86%, Water 100%, Wetland Cover 92%, Fresh Water Vegetation 74%, Degraded Forest 85%, and Bare 92%. Thus the producer's and user's accuracy had higher values, and these results indicated that the accuracy level of the 2016 image classification with selected ground points was sufficient.

### 3.2.3 Monitoring the remediation measures adopted for degraded Marine Wetlands in the study area.

The only method of remediation adopted by the residents of the study area is the seasonal restrictions on the use of wetlands. Monitoring of the effect of this remediation measure on the marine wetland was done by assessing within the period under consideration (2003-2016) the level of total yield of harvested crops per year in kg from farmers, the rate of regeneration and recovery of the degraded wetland ecosystem, the rate of depletion of wetland per year, the abundance of available biodiversity and wetland management strategies that has been in practice from various Multinationals, relevant Ministries, Agencies and Departments. Information on the listed indicators for wetland remediation monitoring was obtained from personal observation, interviews with selected individuals, and existing records available with relevant Ministry, Departments and Agencies (MDAs) like the Ministry of Environment and Ministry of Petroleum Resources who is tasked with obtaining reports from the yearly operations of the oil multinationals (i.e. Exxon Mobil, Total E & P Nigeria Limited etc.,). The information collected from the period under consideration tells more of how effective the following method was, as a remediation measure to the degraded wetland in the study area.

## 4. Results and Discussion

The results of the wetland cover extent presented in Table 8, show the amount of change in this land cover classes in 2016 from 2003. But for the purpose of this study, the highlighted brown part of the table shows where Wetland Cover had changed to other land covers. It was observed that Wetland Cover was gradually being overtaken by species of trees that are canopy covering in about 2,806.42 hectares of the total wetland area of 21364.18 hectares in the study location. Also, 4154.04 hectares of land had been inundated by water. Such modification to canopy covering trees implied a greater propensity for the vegetation to absorb excess carbon dioxide from anthropogenic activities for photosynthesis. It also implied a reduction in the rate of evaporation from the wetlands. Generally, this has the effect of reducing the rate of climate variability and change.

**Table 1: Showing observable changes in Wetland Cover per hectare for the two time periods**

FID	X	y	FID_2003_D	GRID-CODE	ClsName03	FID_2015_D	GRID-CODE_1	ClsName16	Concatenate	Change_Ha
0	355272	499545	0	1	Evergreen Forest	0	1	Evergreen Forest	Evergreen Forest - Evergreen Forest	54112.6
1	355272	499545	0	1	Evergreen Forest	1	2	Water Body	Evergreen Forest - Water Body	439.1
2	355272	499545	0	1	Evergreen Forest	2	3	Wetland Cover	Evergreen Forest - Wetland Cover	2438.6



3	355272	499545	0	1	Evergreen Forest	3	4	Fresh Water Vegetation	Evergreen Forest - Fresh Water Vegetation	13517.2
4	355272	499545	0	1	Evergreen Forest	4	5	Degraded Forest	Evergreen Forest - Degraded Forest	43269.0
5	355272	499545	0	1	Evergreen Forest	5	6	Bare	Evergreen Forest - Bare	13116.9
6	355272	499545	1	2	Water Body	0	1	Evergreen Forest	Water Body - Evergreen Forest	472.0
7	355272	499545	1	2	Water Body	1	2	Water Body	Water Body - Water Body	61064.5
8	355272	499545	1	2	Water Body	2	3	Wetland Cover	Water Body - Wetland Cover	1418.7
9	355272	499545	1	2	Water Body	3	4	Fresh Water Vegetation	Water Body - Fresh Water Vegetation	246.2
10	355272	499545	1	2	Water Body	4	5	Degraded Forest	Water Body - Degraded Forest	56.6
11	355272	499545	1	2	Water Body	5	6	Bare	Water Body - Bare	224.4
12	355272	499545	2	3	Wetland Cover	0	1	Evergreen Forest	Wetland Cover - Evergreen Forest	2806.4
13	355272	499545	2	3	Wetland Cover	1	2	Water Body	Wetland Cover - Water Body	4154.0
14	355272	499545	2	3	Wetland Cover	2	3	Wetland Cover	Wetland Cover - Wetland Cover	12629.1
15	355272	499545	2	3	Wetland Cover	3	4	Fresh Water Vegetation	Wetland Cover - Fresh Water Vegetation	1231.4
16	355272	499545	2	3	Wetland Cover	4	5	Degraded Forest	Wetland Cover - Degraded Forest	102.8
17	355272	499545	2	3	Wetland Cover	5	6	Bare	Wetland Cover - Bare	240.4
18	355272	499545	3	4	Fresh Water Vegetation	0	1	Evergreen Forest	Fresh Water Vegetation - Evergreen Forest	14481.1
19	355272	499545	3	4	Fresh Water Vegetation	1	2	Water Body	Fresh Water Vegetation - Water Body	511.2
20	355272	499545	3	4	Fresh Water Vegetation	2	3	Wetland Cover	Fresh Water Vegetation - Wetland Cover	1809.3
21	355272	499545	3	4	Fresh Water Vegetation	3	4	Fresh Water Vegetation	Fresh Water Vegetation - Fresh Water Vegetation	10824.7
22	355272	499545	3	4	Fresh Water Vegetation	4	5	Degraded Forest	Fresh Water Vegetation - Degraded Forest	3620.4
23	355272	499545	3	4	Fresh Water Vegetation	5	6	Bare	Fresh Water Vegetation - Bare	421.0
24	355272	499545	4	5	Degraded Forest	0	1	Evergreen Forest	Degraded Forest - Evergreen Forest	10368.0
25	355272	499545	4	5	Degraded Forest	1	2	Water Body	Degraded Forest - Water Body	96.6
26	355272	499545	4	5	Degraded Forest	2	3	Wetland Cover	Degraded Forest - Wetland Cover	61.3
27	355272	499545	4	5	Degraded Forest	3	4	Fresh Water Vegetation	Degraded Forest - Fresh Water Vegetation	970.6
28	355272	499545	4	5	Degraded Forest	4	5	Degraded Forest	Degraded Forest - Degraded Forest	9148.7
29	355272	499545	4	5	Degraded Forest	5	6	Bare	Degraded Forest - Bare	8033.9

30	355272	499545	5	6	Bare	0	1	Evergreen Forest	Bare - Evergreen Forest	1878.6
31	355272	499545	5	6	Bare	1	2	Water Body	Bare - Water Body	110.3
32	355272	499545	5	6	Bare	2	3	Wetland Cover	Bare - Wetland Cover	30.2
33	355272	499545	5	6	Bare	3	4	Fresh Water Vegetation	Bare - Fresh Water Vegetation	176.3
34	355272	499545	5	6	Bare	4	5	Degraded Forest	Bare - Degraded Forest	1626.8
35	355272	499545	5	6	Bare	5	6	Bare	Bare - Bare	4254.8
						Total	5758.14	Other land covers in 2003, now Wetland Cover in 2016		
						Total	8735.06	Wetland Cover in 2003, now other land covers in 2016		
						Total	12629.11	No change		

Fresh Water Vegetation had gradually grown to cover about 1231.38 hectares, Degraded Forest and Bare Covers occupied 302.85 and 240.39 hectares respectively. Similarly, the highlighted green part of the table shows where other land covers have changed into wetland area. As observed, 2438.55 hectares have changed from Evergreen Forest to Wetland Cover, 1418.68 hectares have changed from Water Body to Wetland Cover, while Fresh Water Vegetation has changed to Wetland Cover with about 1809.38 hectares. Wetland area also took over 61.38 hectares of Degraded Forest and 30.24 hectares from areas that were bare in 2003. Notwithstanding all the changes, the blue color strip of the table shows where there were no changes, which included 12,629.11 hectares or nearly 60% of wetland on the study location in 2016.

Table 9 shows the amount of change of Wetland Cover to other land covers from 2003 to 2015. It has been observed that there was a conversion of about 8735.06 hectares or 40.88% of the wetland area present in 2003 to other classes in 2016.

Table 10, on the other hand, shows the areas in 2015 which were classified as Wetland Cover which were other land covers in 2003, an area of 5758.14 hectares or a 31.31% increase of Wetland cover in 2016 from 2003.

Thus, from the above findings, 8735.06 hectares that was Wetland Cover in 2003 were now Other Land Covers in 2016 and 5758.14 hectares that were not Wetland Cover in 2003 were Wetland Cover in 2016.

Table 11 shows the difference in Wetland Cover between 2003 and 2015 within the study area. About 8735.06 hectares of decreasing Wetland Cover was subtracted from about 5758.14 hectares of increasing Wetland Cover and a net decrease of about 2976.92 hectares of Wetland Cover have been lost within the period of consideration.

**Table 9: Showing observable decrease in total wetland area from 2003 to 2016**

Area (Ha)	2003 Wetland Cover to 2016 other feature classes	Wetland Cover to Evergreen Forest
Decrease	8735.06 (40.88%)	Wetland Cover to Water Body
No Change	12629.10 (59.11%)	Wetland Cover to Fresh Water Vegetation
Total	21364.17 (100%)	Wetland Cover to Degraded Forest
		Wetland Cover to Bare

**Table 10: Showing observable increase in total wetland area over the last 12 years**

Area (Ha)	2003 other feature classes to 2016 Wetland Cover	Evergreen Forest to Wetland Cover
increase	5758.14 (31.31%)	Water Body to Wetland Cover
No Change	12629.10 (68.68%)	Fresh Water Vegetation to Wetland Cover
total	18387.25 (100%)	Degraded Forest to Wetland Cover
		Bare to Wetland Cover

**Table 11: Showing net change in area per hectare of Wetland Cover between 2003 and 2016**

Area (Ha)	2003 Wetland Cover to 2016 other feature classes	Area (Ha)	2003 other feature classes to 2015 Wetland Cover	Net Change (Ha)
Decrease	8735.06	Increase	5758.14	2976.92



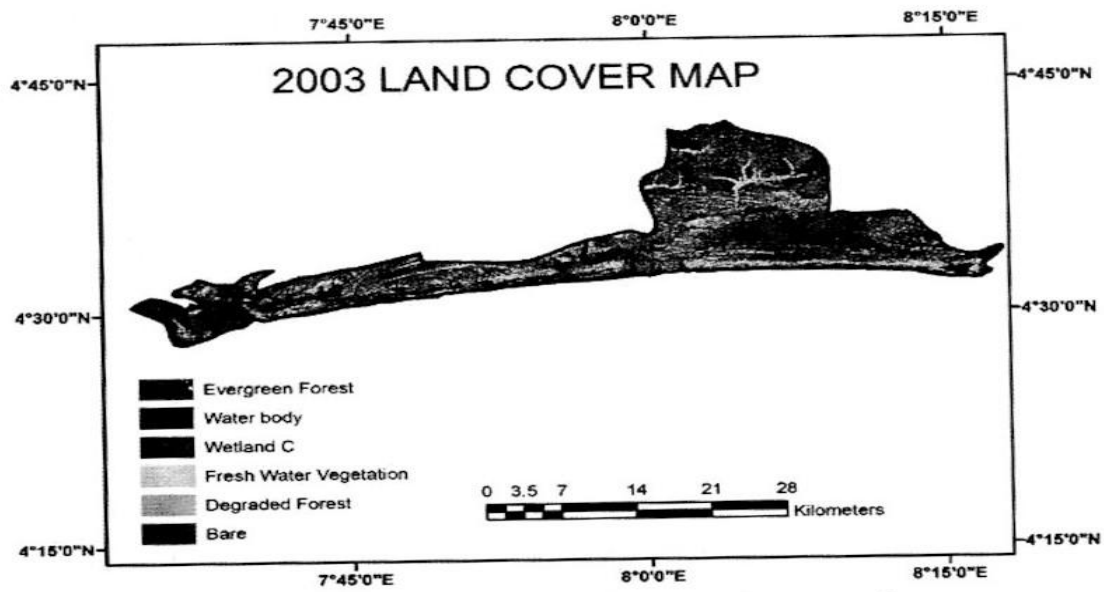


Figure 5: Map showing 2003 land cover classes

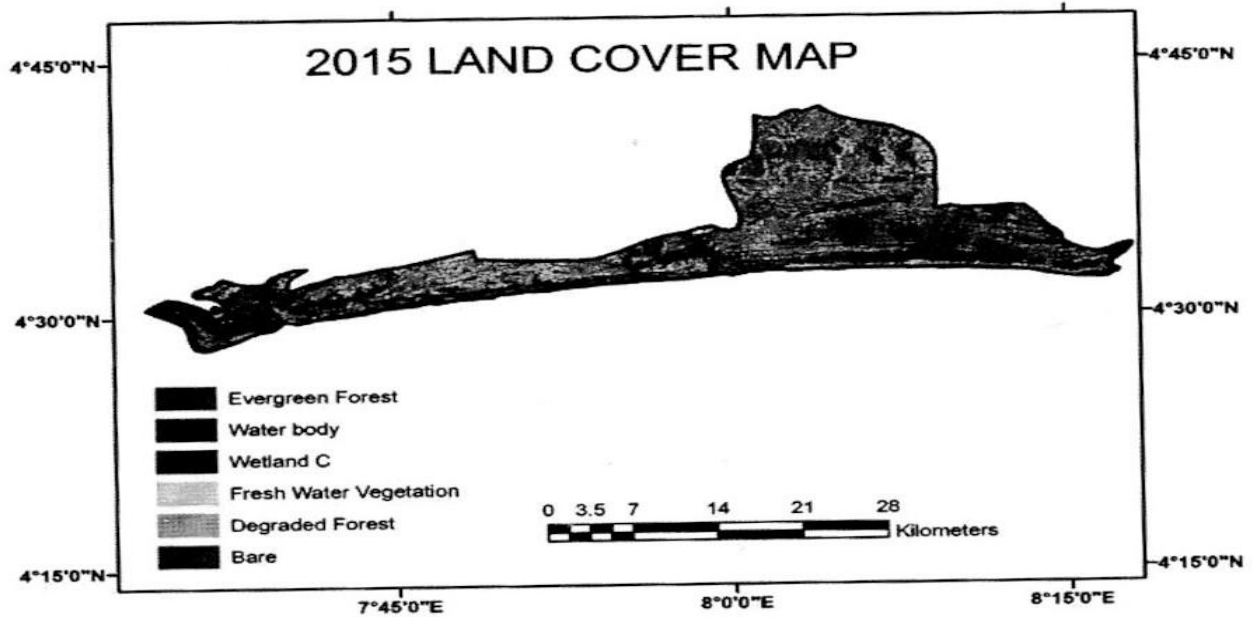
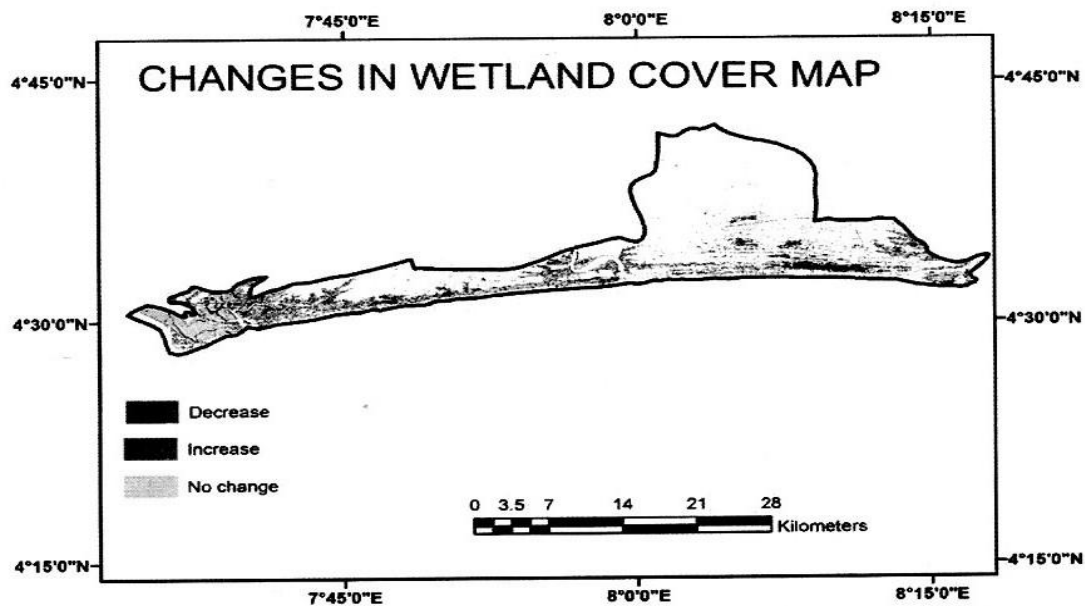


Figure 6: Map showing 2015 land cover classes.



**Figure 7: Map showing area of changes**

The results clearly showed that there were changes in the wetland cover in the study area as some have been converted to other land cover within the period of consideration. About 8735 hectares of land was converted from wetland to other land cover types. Such changes have effects on biodiversity and agricultural activities in the region was noted. For instance, the conversion of wetlands into water bodies occurred mostly because of dredging of the fringe areas of the wetlands for oilfield infrastructure along what is known as right of way (ROW) on the facility sites, thereby transforming the wetland at those locations into water bodies. On the other hand, wetlands were reduced to bare cover as the heaps of dredged materials were most often deposited on the adjoining wetlands and sometimes were abandoned, thereby converting the affected wetland area to bare cover., This also occurs during the laying of pipelines that requires a lot of sand filling for pathways that cross the wetlands. Other wetland converted into bare cover may have been caused as a result of migration of people (population expansion) due to the perceived potential of opportunities in the oil operation areas. Consequently, the conversion effects are seen in the reduction of wetlands, the destruction of fauna and flora, the reduction in wetland agricultural areas, the contamination of water and damage to aquatic life.

Wetland management has been one of the critical parts of the activities in the study area. It was noted that some of the communities have been in the business of regulating the pressure on wetlands by their seasonal restrictions of the use of the wetlands. It was also noted that the government has laws and regulations on conserving and preserving the wetlands across the country for ecological and tourism purposes.

## **5. Conclusion and Recommendations**

Changes recorded in the wetland cover of the study area were caused by anthropogenic activities such as the slash and burn method of agriculture, activities of the Oil Multinational Companies (MOCs). Others include population expansion from

migration towards the region due to perceived opportunities. These have caused the degradation of biodiversity, the conversion of wetland into bare cover for residential purposes as well as the reduction of suitable areas available for cultivation. Repeated practices of these unsustainable activities leads to the failure of the ecosystem to recover and regenerate faster, although communities under consideration, have been practicing seasonal restriction and fallowing. Implementation of government laws and regulations on preservation and conservation of these wetlands should be taken seriously.

Finally, it is necessary that the wetlands be protected from all degrading human activities and that sustainable practices should be encouraged, especially those measures that will rescue the already degenerating wetlands for sustainable and environmental friendly ecosystem services.

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