

# **Temporal Deforestation Assessment Survey of wetlands in Port Harcourt, Nigeria**

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**Key words:** Change detection, Classification, Conversion, Wetlands.

Spatial planning and Development

## **SUMMARY**

The Niger-Delta is one of Nigeria's four Geo-morphological zones (Nwilo, 2003; Uzoka, 2007) which have Port Harcourt as its major city. This region is rich in flora and is also a good habitat for fauna, bounded by her adjoining zones; the mud coast to its north-west and strand coast to the east. The availability of this quality of land cover tends towards extinction as a result of urban drift from metropolitan areas to coastal landforms for about a century. Prior to wetlands conversion, activities along coastal fringes caused by increased land need of inhabitants, accounted for the huge loss of 9209.05 hectares over the Niger Delta (Godstime et al, 2011). To effectively represent the loss of this particular land-use, an updated land-use map was created using the Geo-information technology framework (Fazal, 2008) as an application tool adopting the layer concept for each feature in a geographical perspective. This study accounts for "Wetlands Monitoring and Mapping in coastal cities: Historical and Local evidence of changes in the land use and sprawl of Port Harcourt City Local Government Area, Niger-Delta, Nigeria". The methodology of land-use classification and change detection mapping was employed using multi-sourced datasets (Lui and Mason, 2009; Bhatta, 2010). Population growth prior to rapid urbanization was identified as a catalyst for most deforestation activities while *Nypa* palm invasion has also resulted in a huge loss of mangrove plant at regions of lower salinity. Using the 2003 ETM<sup>+</sup> dataset two index extraction images were produced using the NDVI algorithm to extract *Nypa* palm and mangrove vegetation while water ratio was used to extract water. These features were converted from raster to polygon, which were later used in creating an index classification map. Hence the computed wetland (*Nypa* Palm, Mangrove and Water body) 2003 was 4.696 hectares which is equivalent to 39% of the survey compared to the estimated 60% obtained from digitizing and that of the study area (LSB, 2005). However, for the forty (40) years under review a loss of 4350.109 hectares as a result of deforestation of Urban forestry at annual change rate of 108.753 hectare per year. Therefore, the utilization of geo-information technique is crucial for addressing regional environmental studies (i.e. wetland inventory and management) as the most valuable approach (Pepple, 2012).

## **RINGKASAN**

Niger -Delta adalah salah satu Nigeria empat zon Geo- morfologi (Nwilo, 2003; Uzoka, 2007) yang mempunyai Port Harcourt sebagai bandar utamanya. Kawasan ini kaya dengan hidupan liar dan habitat baik untuk Juga hidupan liar, dikelilingi oleh zon bersebelahan beliaiu, pantai lumpur ke utara - barat dan kepada sehelai pantai timur. Ketersediaan kualiti ini daripada

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tanah cenderung ke arah kepupusan akibat daripada hanyut bandar dari kawasan metropolitan ke pantai secara bentuk bumi selama satu abad. Sebelum tanah lembap penukaran, aktiviti di pinggir pantai tanah disebabkan oleh keperluan peningkatan penduduk, menyumbang kerugian besar 9.209,05 hektar dalam Niger - Delta (Godstime et al, 2011). Berkesan mewakili kehilangan khas penggunaan tanah ini, tanah - menggunakan peta dikemaskini telah dicipta menggunakan rangka kerja Geo- teknologi maklumat (Fazal, 2008) sebagai alat lapisan permohonan mengamalkan konsep bagi setiap ciri dalam perspektif geografi. Kajian ini merangkumi "Pemantauan dan Pemetaan Tanah Bencah di bandar-bandar pantai : Bukti sejarah dan Tempatan perubahan guna tanah dan terkapar Port Harcourt City Kerajaan Tempatan, Niger - Delta, Nigeria". Metodologi penggunaan tanah klasifikasi dan perubahan pemetaan pengesanan diambil bekerja menggunakan set data multi -sumber (Lui dan Mason, 2009; Bhatta, 2010). Pertumbuhan penduduk sebelum perbandaran yang pesat telah dikenal pasti sebagai pemangkin kepada aktiviti-aktiviti penebangan hutan. Kebanyakan manakala sawit Nypa juga serangan telah mengakibatkan kerugian besar tumbuhan paya bakau di kawasan kemasinan yang lebih rendah. Menggunakan 2003 ETM<sup>+</sup> dataset pengekstrakan indeks dua imej dihasilkan menggunakan algoritma NDVI untuk mengekstrak Nypa sawit dan hutan bakau yang sementara nisbah air digunakan untuk mengeluarkan air. Ciri-ciri ini adakah ditukar dari raster kepada poligon, yang kemudiannya digunakan dalam mewujudkan klasifikasi indeks peta. Oleh itu paya tomografi berkomputer (Nypa Palm, Bakau dan badan Air) 2003 adalah 4,696 hektar yang bersamaan dengan 39% daripada kajian berbanding dengan Anggaran 60% Mendapat dari pendigitan dan Bahawa kawasan kajian (BSA, 2005). Walau bagaimanapun, selama empat puluh (40) tahun di bawah kajian semula kerugian akibat daripada penebangan hutan 4350.109ha perubahan perhutanan Bandar pada kadar tahunan sebanyak 108.753 hektar setahun. OLEH YANG DEMIKIAN, penggunaan teknik geo-maklumat adalah penting bagi menangani kajian alam sekitar serantau (iaitu inventori dan pengurusan tanah lembap) sebagai pendekatan yang paling berharga (Pepple, 2012).

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## **1. BACKGROUND OF STUDY**

Wetlands are a vital ecological component and core element in resource management initiative ranging from local to global ecosystems. Wetlands perform a variety of functions beneficial to society. Wetlands help to control flooding, ameliorate droughts, provide habitat for a myriad of flora and fauna, maintain and improve water quality, provide storage for water, stabilize water supply, mitigate erosion, reduce hurricane-related damage and offer recreation possibilities (Novitzki *et al*, 1996). Globally, wetlands, as methane generators and carbon sinks, are recognized as important contributors to weather modification. MEA's (2005) study identified more specific contributions made by wetlands include: being the principle supply of renewable fresh drinking water for an estimated 1.5 – 3 billion people; reducing nitrate concentrations by up to 80%; contributing some US\$34 billion to the gross world product annually through wetland-related fisheries; and significantly exceeding the economic value of converted or altered wetlands.

Coastal wetlands constitute unique ecosystem which are important interfaces between the dry land and adjacent ocean in which the land ecology and use directly affect the ocean space ecology and vice versa (Nwilo, 2003). Lagos and Port Harcourt have been experiencing high pace of urbanization for about a hundred years. Between 1900 till date, the pace of growth has been on the increase due to the development of the north-west and north-south railway route which permitted rapid expansion of cash crop farming and profited the extractive industries (Specialist Consult, 1975). The single but most important component of urbanization in Port Harcourt is that of route network (Pepple, 2008). This has brought about a high turnover of people to these areas; this was induced by the concentration of commercial infrastructure and the creation of administrative offices. Imperatively, an outward flow of settlements occurs due to the present need for land by the local residents of this coastal city.

In retrospect, the first ever recorded change in the land use in terms of wetland loss was in 1912 prior to the construction of a Railway terminus and Port along Bonny River, Port Harcourt within the ancestral agricultural land of Rebisi community by the British visitors (Isiehie, 1976). Inventory and mapping has attained global recognition in different international projects and awareness conferences whose foci are strategic planning for fragile ecosystems in conserving, re-constructing and integrating them into urban forestry systems. Finally, for a good understanding of this study a wetland inventory mapping is highly required. This will not only help in effective planning but also help in calculating population distribution using known variables and also forecasting population. Since growing urban centre fails to fulfill the expected service to those who depend on them, it could be inferred that Port Harcourt like most cities is un-urbanized despite its rate of expansion.

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### 1.1 Statement of the Problem

City growth is a major indicator of industrialization which has a negative impact on the environmental health of a locality. Port Harcourt city is of economic importance to Nigeria with a concentration of multi-national oil industries in it, now being associated with unplanned and nature threatening activities. This had resulted in high amounts of commercial and industrial activities as well as an ever-increasing multi-cultural population and also the most populous Niger Delta city governed by natural land constraints (Specialist Consult, 1975).



Figures 1. 1: Shows co-habitation of two vegetation species (Nypa palm & mangrove) and permanent structures obstructing a natural drainage at Borikiri sand-field, Port Harcourt.

Only lately accurate localized wetland mapping has been utilized as an important tool for understanding wetland functions and monitoring their response to natural and anthropogenic actions (Mclean *et al*, 2005; Baker *et al*, 2006). Godstime *et al's* (2011) identified different human induced activities for the wetland loss in demand for more urban space. Thus, issue of wetland loss/ urban gain (WL/UG) is an indicator to an extinction of this ecosystem; since physical construction within these wetlands exceeds Low Water Mark at most areas.

### 1.2 Research Aims

- 1.To extract past and recent environmental situation using spatial data processing techniques that will identify vegetation amongst other features.
- 2.To use the GIS to show local relationships within the study area into the framework in an intuitive and explicit manner producing a synthesized map for all datasets and extract varying land-use trends to accurately identify areas affected using multi sourced datasets.
- 3.To extract and update wetland locations and propose a planned wetland mapping approach for future inventory mapping utilizing periodic remotely sensed datasets.

### 1.3 Research Objectives

- 1.To identify and extract wetlands area from all acquired datasets.
- 2.To identify the inventory system practiced in this region.
- 3.To identify the benefits of the methods used by other researchers and adopt such for this study.

## 1.4 Research Questions

1. Are wetlands the most important natural of this area?
2. Is there a wetland inventory system practiced in Nigeria?
3. How can change detection analysis be improved for this study?

## 1.5 Research Hypothesis

The following research hypotheses were postulated for data analysis of this study.

H<sub>0</sub>1: Wetlands are not Niger delta's most important natural resource.

H<sub>1</sub>1: Wetlands are Niger delta's most important natural resource.

H<sub>0</sub>2: There is no significant relationship between wetland deforestation and ever increasing urban encroachment.

H<sub>1</sub>2: There is a significant relationship between wetland deforestation and ever increasing urban encroachment.

## 1.6 Study Area

Port Harcourt thus lies on a peninsula, its urban form being governed by natural land constraints which also have strong bearing and directions of future development and communications. The northern terrace consists of dry land while the southern terrace consists of small isolated islands of firm ground in the vast lower Deltaic area which is continuously being rearranged by strong tidal flood currents (Specialist Consult, 1975).

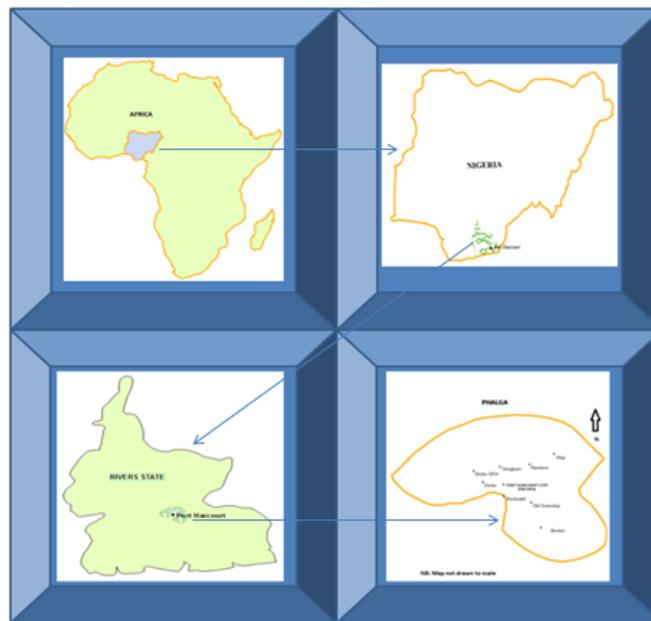


Figure 1. 2: A descriptive array of the study area from continental to local view not drawn to scale.

Table 1. 1: Showing geographic conditions cited in Specialist consult (1975) Master Plan.

S/No	Conditions	Description
1	Climatic	Heavy rainfall and tropical climate with a mean yearly temperature of 30°C.
2	Ecological	Bonny River and the vast deltaic swamp restraints planned southern city growth.
3	Geological	Low ground water despite rainfall and homogenous soil.
4	Topography	Responsible for the northwards growth rather than cyclic; only recently physical construction was made at the southern direction.

The study area typically lies between 275000 - 287000 (meters) **East** and 533000 - 523000 (meters) **North**; in zone 32 on the WGS 84 Universal Traverse Mercator (UTM) projection system. Situated along the Bonny River which possesses a small but adequate deep river-port (i.e. the major River in the south west part of figure 1.2 below), contributing to the earning power of the state. The study area is bounded by neighbouring coastal communities and has access to potential energy from oil and natural gas, in addition to good communications, has created favourable conditions for this city becoming one of Nigeria's most important cities, (Specialist Consult, 1975).

## 2. LITERATURE REVIEW

Wetlands as defined by the U.S. Army Corps of Engineers and U.S. Environmental Protection Agency "as those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturation soil conditions" (Lawrence *et al*, 2005). Nwilo (2007) also defined "wetlands as areas wholly or partly covered by water they are regions where trees such as Nypa palm and Mangrove plants co-habit". The aforesaid trees contribute directly to the livelihood of most local communities provided products such as wood fuel thatch materials, timber logs and as well breeding ground for sea food nutrients. Mangrove plants have tangled roots that grow above the deltaic swamp common to the Niger Delta.

Today, wetlands are incredibly sensitive ecosystems and because of human activities, they have been degraded considerably. Development along waterways and even draining of wetlands has caused increased pollution a decrease in available water and water quality. In addition, the introduction of non-native species has changed the natural species composition and sometimes crowded out native species. Recently, the importance of wetlands for their economic and biological benefits has been accepted in many countries. As a result, efforts are now being made to protect existing wetlands, restore damaged ones, and even develop new, artificial wetlands in viable areas. Wetland ecosystems have attained increasing recognition of the importance in mapping its distribution around the world for economic and environmental purposes (Darras *et al*, 1999; Finlayson and Rea, 1999) basis for which the world's wetland inventory project was commissioned (Lillesand, and Kiefer, 2008).

The Nypa palm plant is an ornamental vegetation specie which was introduced as a coastal defence plant along the south-eastern shore-line (Strand coast) in 1906, utilizes sea dispersal process to dominate neighbouring coastal landforms for about a century (Nwilo, 2007). Hence, the faster growth of these riparian plants also contributed to the reduction in population of mangrove vegetation across of the Niger Delta (Godstime *et al*, 2011). Urban sprawl emerged as a contentious national policy issue in United States since alteration of hydrology affects the abundance of California's functioning wetlands (Hanham and Spiker, 2005), most Nigerian coastal cities are experiencing wetland loss in form of urban expansion, which has been a subject of concern to planners and policy makers (McLean *et al.*, 2005; Specialist Consult, 1975).

This document provides a simplified worked example of the application of the PPDAC methodology discussed in Chapter 3 of Smith's (2009). The acronym PPDCA means P for problem, P for plan, D for data, A for Analysis and C for Conclusions. This approach has not only for illustrative use but has been utilized for specific local projects that have been concluded. The PPDAC approach is intended to provide guidance on how one might approach such a project, for example how one might undertake the preparation of a proposal that seeks to address the task specified. Also, it should be noted that PPDAC is intended to provide a flexible and dynamic methodology, not a rigid set of procedures or forms and may be applied at several stages or levels of a project (Smith, 2009). For this study, PPDAC approach shown below was also adopted.

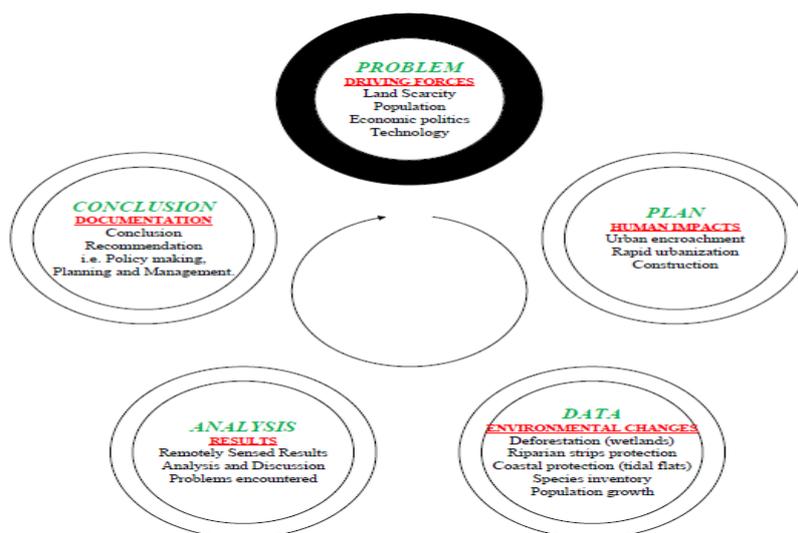


Figure 2. 1: Shows PPDAC approach adopted for this study.

### 3. METHODOLOGY

This is the data processing techniques for effective visualization utilizing remotely sensed data in multi-spectral, multi-temporal and multi-scaled to make judgment of what a feature is and its significance. The steps below were adopted for effective planning and producing best achievable results and a flow chart has been created to illustrate the procedures thereof. Therefore, the various datasets acquired from diverse sources would be harmonized to achieve the desired results. In this study, 8 Landsat datasets, 110 Ortho-photos and Master Plan (spatial data) while population datasets (aspatial data) to provide an information of the study area using the geo-information technique and softwares (i.e. ER Mapper, ENVI 5.0 and ArcGIS 9.3) as application tools.

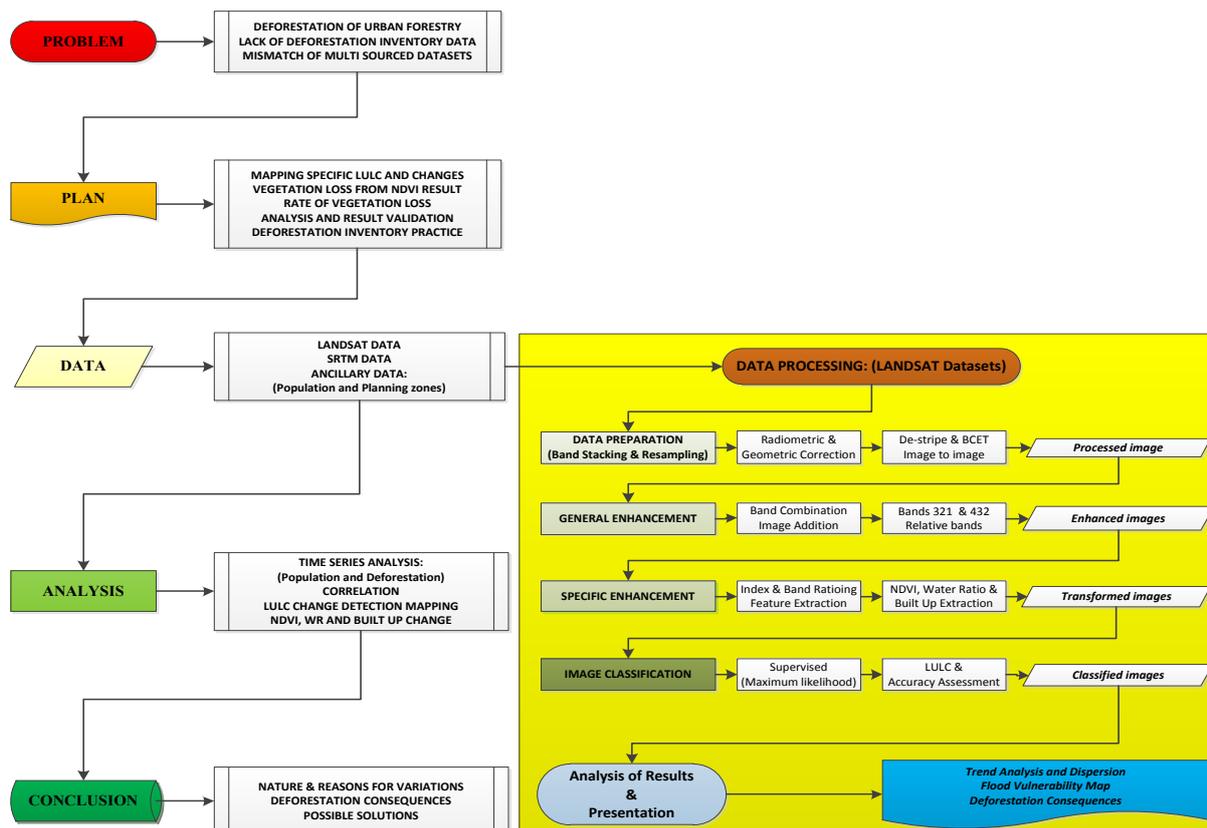


Figure 3. 1: Flowchart of Port Harcourt Wetland Deforestation assessment project.

### 3.1 Data and Data Sources

Data and data sources involves all available relevant acquisition of data; as a prerequisite for studies of this nature the utilization of multi-source dataset is essential part of any functional mapping or inventory project since it requires data description documentation and quality assessment. Therefore, data source is divided in two parts namely; the office and field study.

#### 3.1.1 Desk Study

This conceptual stage of the project solely involves the observation of existing secondary information of the Port Harcourt Local Government Area. Existing dataset were prepared for visual image interpretation; essential to the proposed mapping and field planning exercise.

#### 3.1.2 Field Study

This could also be called a field study since it actually deals with the data obtained by the researcher from the study area. For this study field reconnaissance was conducted to obtain photographs and ground control coordinates of vantage point of photographic data capture.

### 3.2 Data Pre-Processing

Acquired datasets were sorted and collated according to their types and they are listed below in tables stating technical specification of all spatial datasets.

#### 3.2.1 Analogue Pre-Processing

In practice since visual analysis can reveal significant features within imagery, it is necessary for such data to be effectively processed. Scanning is usually done to convert analogue maps or photographs to digital raster image (Bhatta, 2010). This approach was adopted to ensure that the results correspond to average ground resolution (Konency, 2003). The Master plan 1975 was digitized to delineate planning zones and extract such information, to effectively aid feature extraction. The aforementioned processes were to convert all analogue datasets to digital format for accurate data processing and analysis.

### **3.2.2 Digital Image Processing**

Digital image processing is not only a step in the remote sensing process, but is itself a process consisting of several steps. However, as discrete data types they merged well together and proved integral to the effective discrimination of wetland cover. For this survey the LANDSAT datasets were used to obtain temporal vegetation analysis. Regardless of the remotely sensed data available for use three basic steps need to be adopted: preprocessing, enhancement and classification (Jensen, 1996). In practice all acquired datasets requires preprocessing as such this process involves arranging and organizing the data for analysis. ERDAS ER Mapper 2011, ENVI 5.0 and ArcGIS 9.3 were used for data processing and analysis.

#### **3.2.1.1 De-stripping**

The eight (8) Landsat datasets acquired for this study were obtained from the earth explorer website. Four of the aforesaid datasets were of Landsat MSS, One Landsat TM and three Landsat ETM<sup>+</sup> sensors. One ETM<sup>+</sup> dataset was of Scan Line Collector (SLC) on mode. Scenes from June 2003 were not used for study because of the failure of the (SLC) on May 31st, 2003 which is used to remove the "zigzag" motion of the imaging field of view. The consequence of this is that the SLC-off mode results in scenes with gaps (Bhatta, 2010). The last two ETM<sup>+</sup> datasets (2007 and 2012) were corrected using the gap masks of corresponding bands (i.e. B1 for GM1 where B implies band and GM implies Gap Mask) using the ETM<sup>+</sup> the de-stripe function of ENVI 5.0 software.

#### **3.2.1.2 Band Stalking, Projection and Resampling**

All bands for each datasets (MSS, TM and ETM<sup>+</sup>) were stalked together in a single file to produce an image with four for MSS seven for TM and nine for ETM<sup>+</sup> datasets. All datasets were projected to World Geodetic System (WGS) 1984. The spatial resolution of an image can be improved by utilizing the pan chromatic band of ETM<sup>+</sup> datasets to resample the image to 15 x 15 meter pixel size while saving the stalked image using the ERDAS ER Mapper software.

#### **3.2.2.4 Mosaicking**

Before individual images of same source can be mosaic, they must be of same map projection i.e. but cover different adjoining areas the area of interest. A seamless mosaic precise geo-registration was executed for the acquired 110 scenes each covering 1km by 1km ground distance the 2004 colour aerial photograph of 1:1000 resolution acquired by Akom Survey. These images were merged to produce coverage of the study area, since the images have header information of same projection, datum and scale; which was necessary for a reference

image. Photos are simply zipped and matched together by dissolving the edges having continuous feature match over (Fazal, 2008; Lui and Mason, 2009).

### 3.2.2.5 Geo-Rectification

Geometric rectification is a process by which points in an image are registered to corresponding points on a map or another image that has already been rectified. It is a very common approach prior to any image analysis; if measurements such as area, direction or distance are to be made, that image should be rectified for those measurements to be accurate. Since the goal of geometric rectification is to modify the spatial relationships between pixels in an image, hence putting image elements in their proper “x and y” positions (Bhatta, 2010). The mosaic was used as a reference image for the geo-rectification of all other datasets. The first step was an image to image rectification to ensure positional conformity in all corresponding images. All datasets (LANDSAT datasets and Master Plan 1975) were projected to the zone 32 of the Universal Transverse Mercator (UTM) map projection system. Common features such as planned roads intersections were used and an average of nine (9) ground control points (GCP’s) were used for the rectification of each image; with a root mean square error (RSM) of less than 1 applying linear transformation.

### 3.2.2.6 Radiometric Correction

This is a process of improving the fidelity of the brightness value of a remotely sensed data. Using this approach the influence of brightness value errors or inconsistencies caused by environmental factors during acquisition of imagery are “balanced or normalized” on all image coverage and spectral bands having the potential of limiting image interpretability and analysis (Lui and Mason, 2009; Bhatta, 2010). Having observed the spectral profiles of the balanced contrast enhancement technique (BCET) and dark pixel subtraction (DPS) images this research has chosen the BCET technique as the preferred radiometric correction.

## 3.3 Data acquisition and preparation

a prerequisite for studies of this nature the utilization of multi-source dataset is the essential part of any functional mapping or inventory project since it requires data description documentation and quality assessment.

Table 3. 1: Shows LANDSAT datasets of Path 188/ Row 57 for the study area.

S/N o	Satellit e	Sensor	Acquisition Date	Spacing (days)	Bands Used
1	Landsat 1	MSS	December 29, 1972	-	1 - 4
2	Landsat 2	MSS	May 15, 1976	1233	1 - 4
3	Landsat 5	MSS	December 12, 1984	3133	1 - 4
4	Landsat 5	MSS	February 21, 1987	801	1 - 4
5	Landsat	TM	November 29, 1999	4664	1 – 5, and 7

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	7				
6	Landsat 7	ETM <sup>+</sup>	January 8, 2003	1136	1 – 5, 7 and 8
7	Landsat 7	ETM <sup>+</sup>	January 19, 2007	1136	1 – 5, 7 and 8
8	Landsat 7	ETM <sup>+</sup>	January 1, 2012	1136	1 – 5, 7 and 8

Source: Meta-data (USGS, 2012).

The balanced contrast enhancement technique (BCET) was adopted for this study. Before use, it was compared with the dark pixel subtraction (DPS) that gave a good visual output.

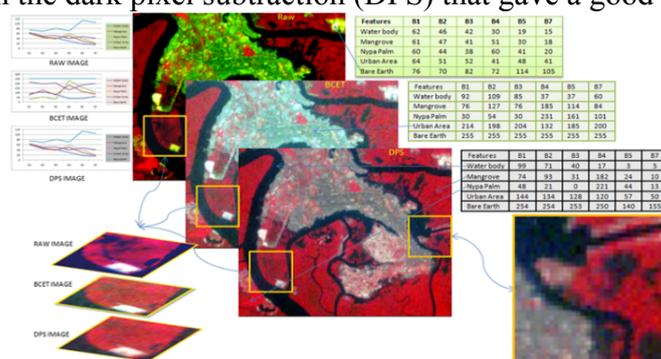


Figure 3. 2: Raw image, BCET and DPS array comparison.

Considering the spectral profile of the three sets of images showing normalization effect on respective images, the BCET image was preferred.

### 3.4 Image Processing

#### 3.4.1 Image Enhancement

There are many mathematical operations that can be used to enhance an image. Generally, they fall into two major categories: point operations and local operations. Point operations change the value of each individual pixel independent of all other pixels, while local operations change the value of individual pixels in the context of the values of neighboring pixels (Jensen, 1996). The band ratio enhancement technique was adopted for vegetation assessment which primarily involves the use of LANDSAT data to compose vegetation indices such as NDVI. The aim of this exercise is to show wetland loss which this research intends to extract vegetation utilizing the (NDVI) arithmetic operation. For this singular reason vegetation indices can be grouped as image enhancement and therefore making an image more interpretable for wetland studies.

#### 3.4.2 Index/ Ratio Operation

##### 3.4.2.1 Normalized Difference Vegetation Index (NDVI)

$$NDVI = (DN_{NIR} - DN_R) / (DN_{NIR} + DN_R)$$

$DN_{NIR}$  = Brightness value of pixel in NIR band and  $DN_R$  = Brightness value of pixel in Red band

The result of this approach is a very high positive value for healthy vegetation is obtained from NDVI and on the other hand very low negative value is obtained from features like water cloud. For the separation between the three classes of vegetation were obtained using upper and lower bound threshold algorithms.

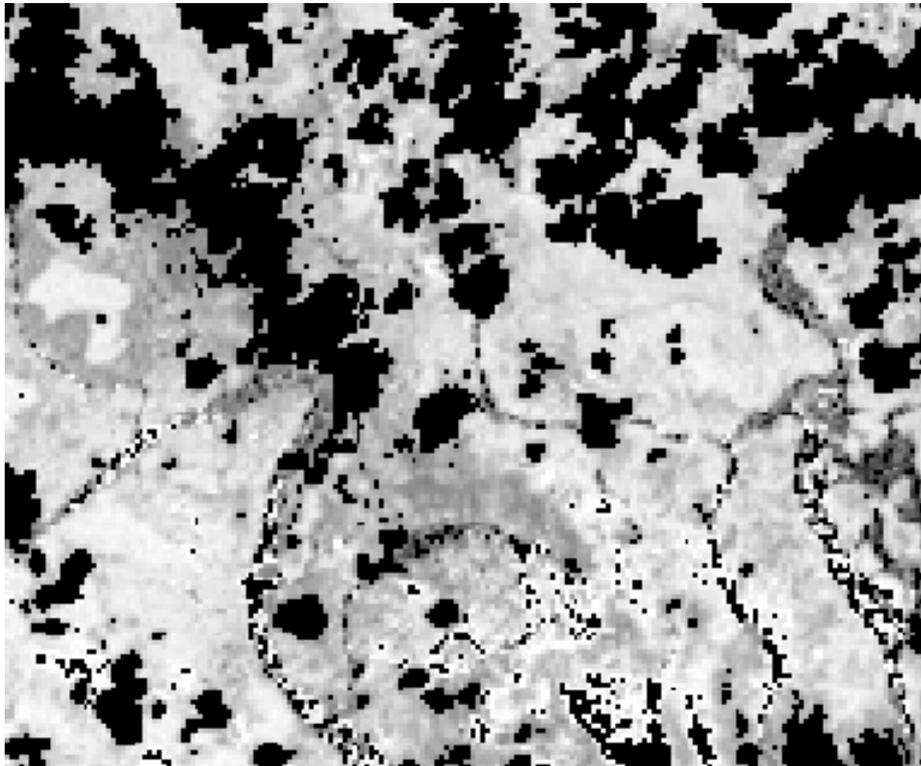


Figure 3. 3: Shows cloud removal while before NDVI operation for LANDSAT MSS 1972.

The above result was obtained after the process of cloud removal while performing the NDVI operation by masking the algorithm below. For the 1972 image, this operation was also done for all the data sets with cloud, mathematically expressed as: If  $I1 < 70$  then  $(I3 - I2) / (I3 + I2)$  else null, where  $I = \text{Input}$ .

#### 3.4.2.2 Water Ratio (WR)

$$WR = DN_{SWIR} / DN_G$$

$DN_{SWIR}$  = Brightness value of pixel in SWIR band and  $DN_G$  = Brightness value of pixel in Green band

A very high positive value for surface water terrain is obtained from this ratio operation and on the other hand very low negative value is obtained from features like vegetation, soil etc.

#### 3.5 Accuracy Assessment

This is a feedback system for checking and evaluating the objectives and results of a classified product. In principle such products are compared with reference image that was created based on human generalization. The scale of the reference map used is very important, since all linear and polygonal features allows for a buffer zone. The classified pixel of the ETM<sup>+</sup> 2003 image were cross referenced with the 1:1000 composite (mosaic) since ground truth option was not possible to achieve for this study, this approach conforms to Jensen *et al's* (2005)

study. Finally comparison of the both datasets was image using the error matrix. Hence the produced result was used to validate the accuracy of the classification.

### 3.6 Research Instrument and Analytic Technique

The questionnaire consists of 15 items related to the importance of wetland conservation and the likelihood of the inclusion of inventory information in Environmental Impact Assessment (EIA) reports for effective decision-making. The items will be based on a feedback using a five point scale (1 = strongly agreed to 5 = strongly disagree). Similarly, statistical measures such as frequencies and percentages were used in addition to the chi-square statistical test. In principle cited that if your design involves three or more groups with the results summarized in proportion or percentages, you should use the chi-square test to weigh the reliability of the result. The Chi-square statistical technique will be used to test the hypotheses at 5% level of significance. The chi-square formula is mathematically defined below as:  $x^2 = \sum (f_0 - f_e)^2 / f_e$  Where  $f_0$  = Frequency observed;  $f_e$  = Frequency expected and  $x^2$  = Output of the chi-square.

## 4. ANALYSIS OF RESULTS

### 4.1 Data Interpretation, Analysis and Presentation

This in section results generated and analysis of these results were obtained from the research questionnaire. Out of the 70 questionnaires administered, 68 pieces were returned and used for analysis, which represents 97.1% response rate. This chapter is divided into 2 parts; the first treats analyses of the personal characteristics of respondents while second treats the research questions of the study and tests of hypotheses will also be carried out.

### 4.2 Population Analysis

From the temporal population result rapid growth was found to be the cause of frequent deforestation with the study from 1963 i.e. 79,634 to 179,653. Population projection and estimates were therefore made to meet this need in the absence of census information for the year(s) under consideration. Considering the cost and planning required to conduct evenly spaced census within the region.

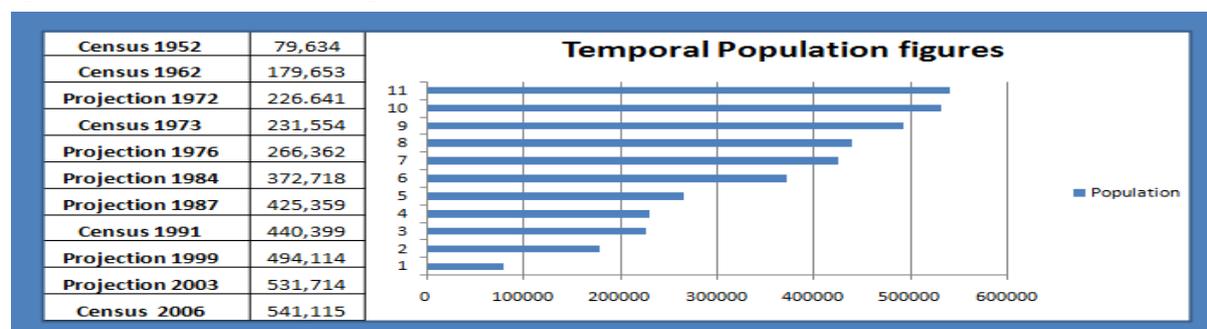


Figure 4. 1: Shows population chart of the study area.

Table 4. 1: Shows census data and its parameters of the study.

Dates	Po	Pn	n	d	x	k	R
1963 – 1973	179,563	221,000	10	41,437	0.231	0.10	0.864
1973 - 1991	221,000	440,399	18	219,399	0.993	0.18	0.999
1991 - 2006	440,399	541,115	15	100,716	0.229	0.15	0.802

Source: Geo-database (Author, 2012)

### 4.3 Geospatial Analysis

#### 4.3.1 Area Calculation

This operation was done to extract area of particular features taking account of different threshold ranges while performing the ratio or index operation. The areas for vegetation and water body for respective LANDSAT datasets were computed from the NDVI and water ratio shown in the table below.

Table 4. 2: Shows coverage of planning zones of the study in hectares.

S/No	Zone	Zonal_ID	Area (Sq.km)
1	Borikiri	1	8.6289
2	Dockyard	2	5.6733
3	Town	3	4.0615
4	Old GRA	4	3.3948
5	Orogbum	5	4.9710
6	Diobu	6	6.2782
7	Orominike	7	2.5110
8	Diobu GRA	8	1.3373
9	Rainbow Town	9	20.8836
10	Trans Amadi	10	3.0616
11	Elekeohia	11	2.1737
12	Rumuogba	12	0.3072
13	Eagle Island	13	6.7366
14	Rumueme	14	2.4200
15	Rumuolumeni	15	0.6089
16	Iwofe	21	3.2108
17	Woji	22	4.5848
18	Okrika	26	2.8977
Total		83.7409	

Source: Geo-database (Author, 2012)

This tailored classification approach was adopted at a threshold value range between 0.6497 – 0.465. The aforesaid feature tends to be brighter than the other features because plant have an invasive growth (grows in clusters) even at elevated surfaces above water table. This foreign plant thrives at regions of salt and fresh water mixture this occurrence allows for it becoming Niger Delta's most invasive species.

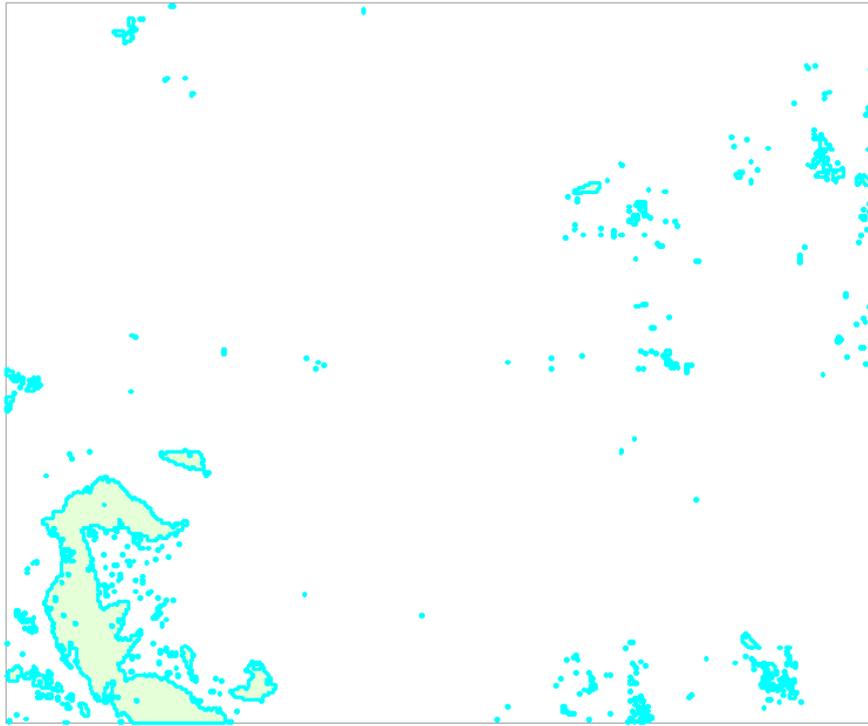


Figure 4. 2: Shows a sample Nypa Palm extraction form NDVI 2003 using original image.

#### 4.3.2 Change Calculation

The area for respective LANDSAT datasets were computed and shown in the table below. The normalized difference vegetation index (NDVI) result had varying results, caused by cloud effect and deforestation.

Table 4. 3: Shows area and change calculation from NDVI statistics for all dates.

Interval	Before Impact	After Impact	Change	Change	Annual change Rate	Inference	Spacing in years
	Area (ha)	Area (ha)	Area (ha)	Area (%)	Area (ha/yr)		
1972 - 1976	5984.02	6229.12	245.100	4.096	61.275	Gain	4
1976 - 1984	6229.12	5060.44	-1168.680	-18.762	-146.085	Loss	8
1984 - 1987	5060.44	7219.52	2159.080	42.666	539.770	Gain	3
1987 - 1999	7219.52	5347.09	-1872.430	-25.936	-156.036	Loss	12
1999 - 2003	5347.09	5791.42	444.330	8.310	111.083	Gain	4
2003 - 2007	5791.42	2920.27	-2871.155	-49.576	-717.789	Loss	4
2007 - 2012	2920.27	1633.91	-1286.355	-44.049	-257.271	Loss	5

Source: Geo-database (Author, 2012).

From Table 4. 3 above vegetation recorded a gain of 245 hectares with an annual change rate of 61.275 hectares per year (ha/yr) between 1972 and 1976; this was as a result of the cloud cover on the 1976 dataset. Between 1976 and 1984 a huge vegetation loss of 1168.680 hectares was recorded with an annual change rate of -146.085 ha/yr due to deforestation of the lowland areas for Borikiri Garden City. Similarly, between 1984 and 1987 a gain of 2159.080 hectares was recorded and an annual change rate of 539.770 ha/yr as a result of rejuvenation of the reclamation site. The study area also experienced a huge loss of 1872.430 hectares between 1987 and 1999 with an annual change rate of -156.036 ha/yr. Between 1999 and 2003 a gain of 444.330 hectares was recorded with an annual change rate of 111.083 ha/yr. The last two intervals between (2003 – 2007 and 2007 – 2012) recorded losses of 2871.155 and 1286.355 hectares with an annual change rate of -717.789 and -257 ha/yr respectively.

Table 4. 4: Shows area and change calculation from NDVI statistics for first and last dates.

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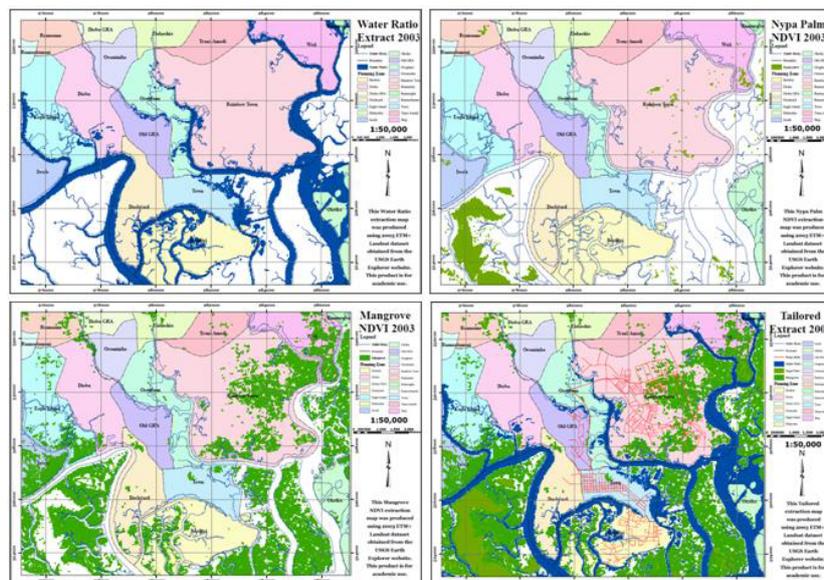
Interval	Before Impact	After Impact	Change	Change	Annual change Rate	Inference	Spacing in years
	Area (ha)	Area (ha)	Area (ha)	Area (%)	Area (ha)		
1972 - 2012	5984.02	1633.91	-4350.109	-72.695	-108.753	Loss	40

Source: Geo-database (Author, 2012).

For the forty (40) years under review a loss of 4350.109 hectares as a result of deforestation of urban forestry at annual change rate of 108.753 hectares. Similarly, a translation of these variables in relation to wetland loss in Port Harcourt city forecasts the need for more lands comparing the present and future population density, employment opportunities and birth rate.

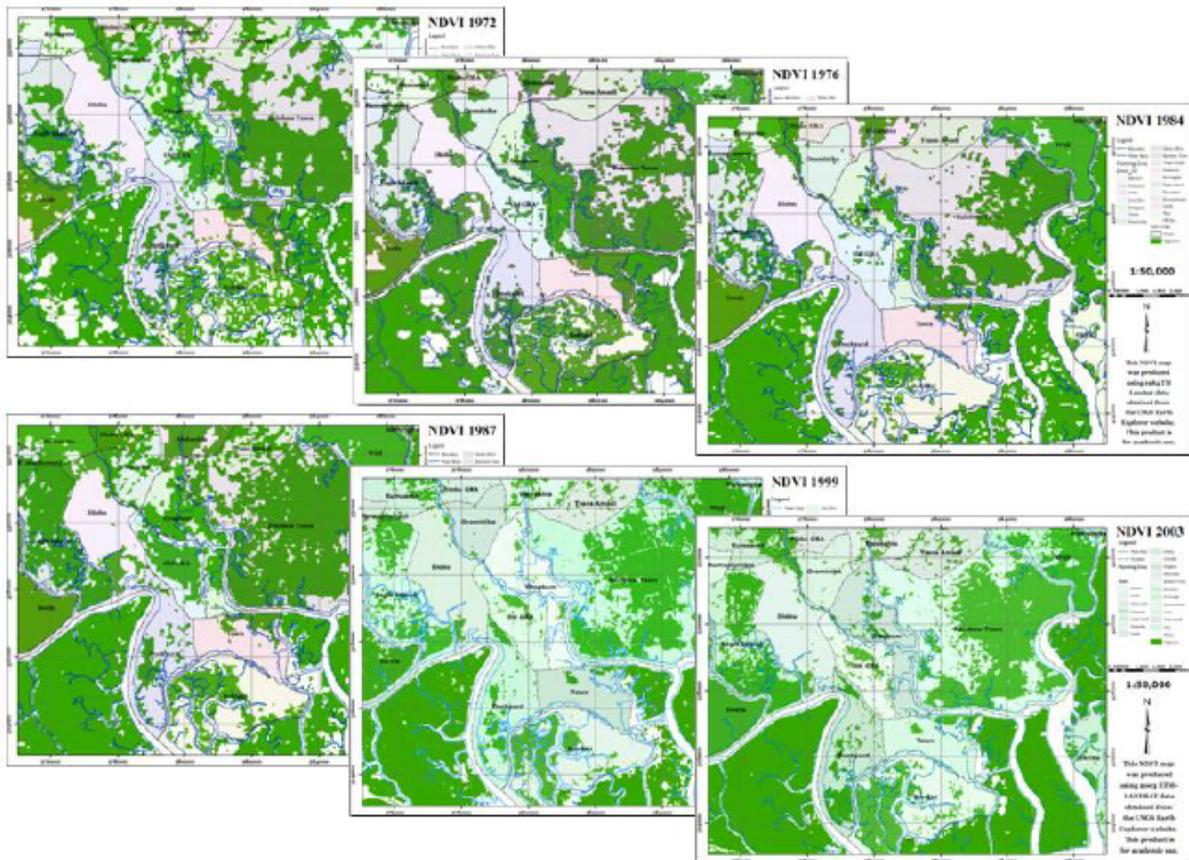
#### 4.4 Deliverables

The 2003 LANDSAT dataset was effectively utilized to extract three main land cover extractions and a composite map for all three extractions was produced.

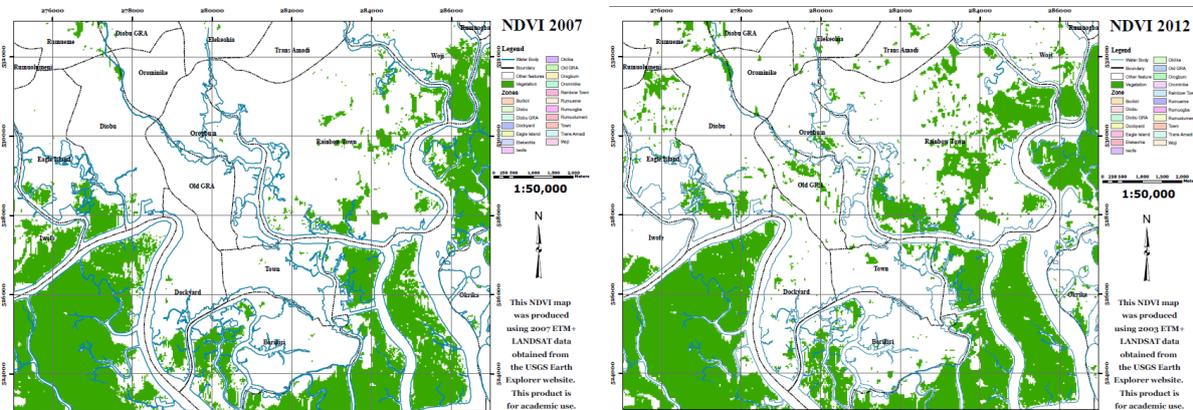


Figures 4. 3: Shows individual and combined feature extraction maps.

The image was the most analysed of all acquired datasets which shows account for individual feature extraction, see Figures 4. 3 below. The aforesaid extractions are Water Ratio (WR) and Normalized Difference Vegetation Index (NDVI). Using the NDVI approach two index images were produced to extract Nypa palm and mangrove vegetation effectively.



Figures 4. 4: Showing temporal NDVI maps for all LANSAT datasets of SLC on mode.



Figures 4. 5: Showing temporal NDVI maps for LANSAT 2007 and 2012 datasets of SLC off mode.

Using the Shuttle Radar Topographic Mission (SRTM) 2000 DEM dataset a vulnerability map was produced. The map revealed that the drainage pattern of the study area is the constraint to coordinated city growth. Similarly, after map production, a quality assessment of the output was compared with the tailored extraction map below. The deep water on the map flood map was omitted in the acquired DEM dataset. The deep water on the map flood map was omitted in the acquired DEM dataset. Therefore, the aforesaid omissions were observed to be of 5 meters below mean sea level, see Figure 4. 6 below.

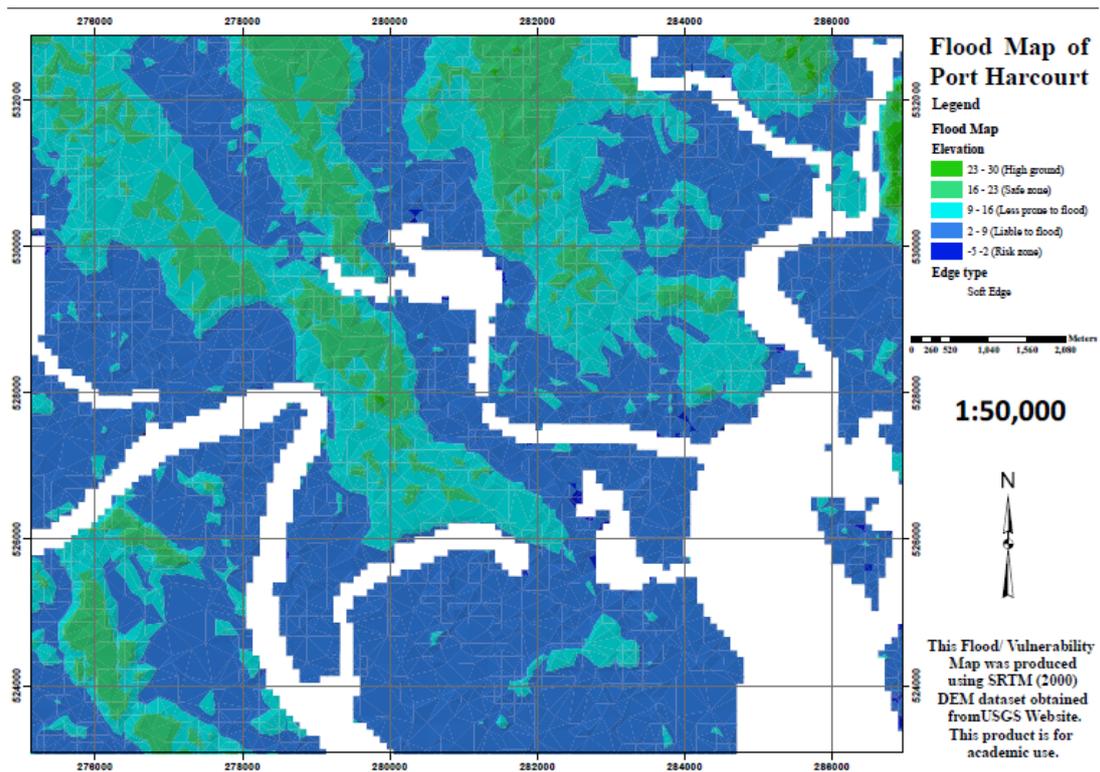


Figure 4. 6: Shows flood map of the study area using SRTM Digital Elevation Model.

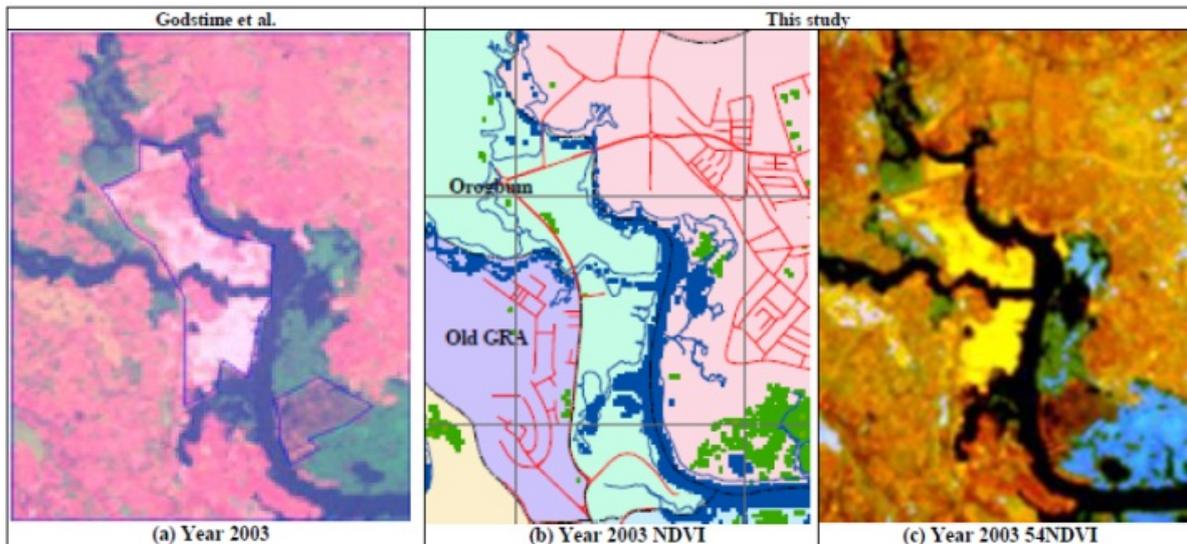


Figure 4. 7: Shows visual outputs for classification and tailored feature extraction.

From the three visualized output for the study, with emphasis on the Amadi Creek stretch as region of interest (ROI) sector A using LANDSAT 2003 ETM+ data. The classified (column 1) and tailored classified (column 2) were compared using the enhanced image (column 3) image as reference image.

## 4.5 Change Analysis

Change detection ability does not terminate at identifying land cover changes but the analytic capability of measurements utilizing geo-information application tool. Therefore, the difference between images and maps is very important in change detection analysis, utilizing statistical testing can show significant difference the type of index or classifier used. The change analysis was necessary to obtain the percentage of change over the period of 40 years for the entire study area.

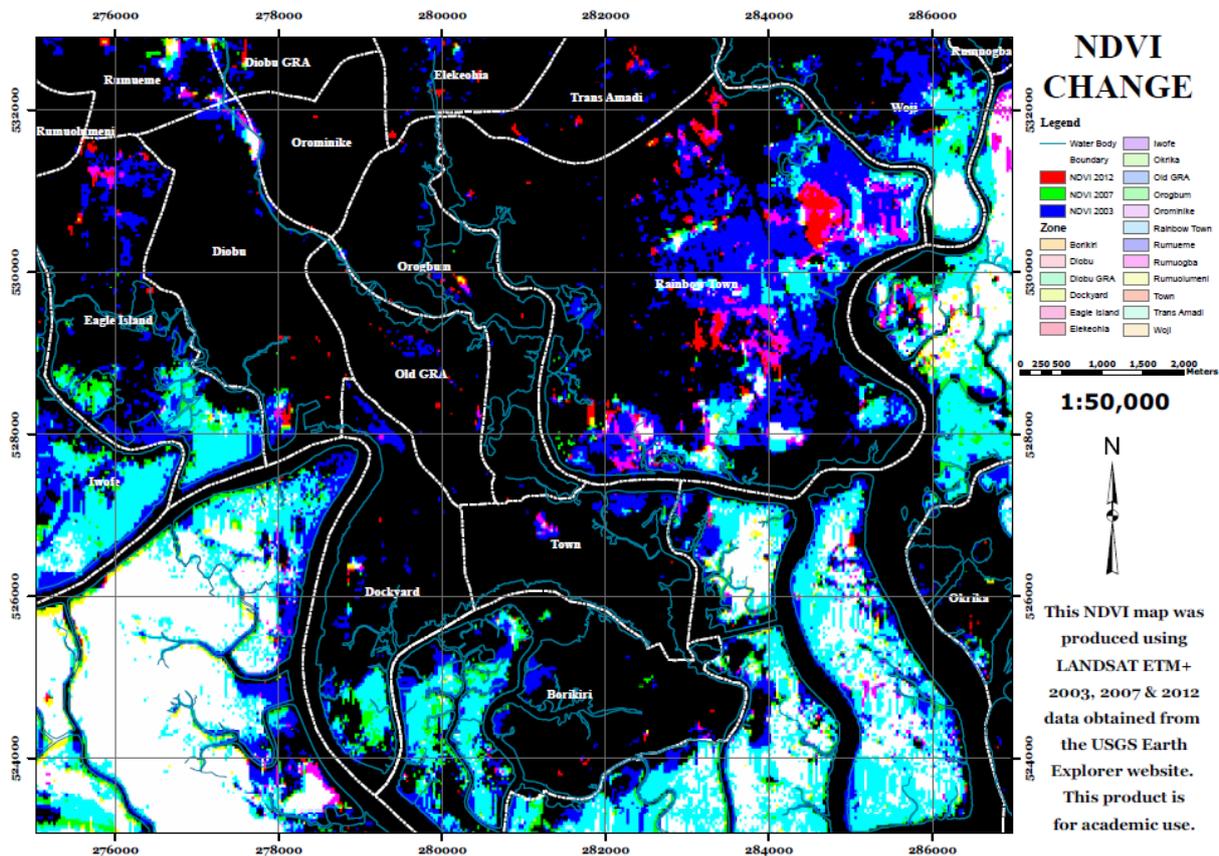


Figure 4. 8: NDVI map for LANDSAT ETM for 2003 in blue, 2007 in green and 2012 in red.

From Table 4. 5 below the transformed index image in Figure 4. 8 above could be effectively analysed using the tri-stimulus theory for addition and subtraction of colours.

Table 4. 5: Binary image interpretation for the last three epochs in RGB composite (2003, 2007 and 2012).

S/No	Colour	Combination	Interpretation
1	Black	R - G - B	No vegetation in all images (does not exist 2003, 2007 & 2012 images).
2	White	R + G + B	Vegetation before 2003 (exist in all images).
3	Magenta	B + R	Vegetation before 2003 and after 2007 (exist in 2003 & 2012 images).
4	Green (G)	Green only	Vegetation after 2003 and before 2012 (only in 2007 image).
5	Yellow	R + G	Vegetation after 2003 (exist in 2007 and 2012 images).
6	Blue (B)	Blue only	Vegetation before 2007 (only in 2003 image).
7	Red (R)	Red only	Vegetation after 2007 (only in 2012).
8	Cyan	G + B	Vegetation before 2012 (exist in 2003 and 2007 images).

## 4.6 Swat Analysis

### 4.6.1 Strengths

1. The researchers in depth knowledge of the study area
2. Ability to utilize the PPDAC approach in solving real life problems.

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#### 4.6.2 Weaknesses

1. Limited previous academic studies on this area
2. Availability of required datasets

#### 4.6.3 Opportunities

1. It will encourage wetland conservation in this area and creates opening for further studies by other researchers.
2. Could be utilized as a reference material to guide legislation in the future.

#### 4.6.4 Threats

1. Time constraint in image pre-processing and processing.
2. Demands high techniques in handling multi sourced datasets.

### 5. CONCLUSION AND RECOMMENDATION

#### 5.1 Conclusion

The completion of this study has demonstrated the relevance of spatial planning employing image processing analysis and geo-information in revealing urban wetland loss within the coastal suburbs. Since the intended goal is effective wetland monitoring and mapping along coastal fringes of Port Harcourt city. It is important to restate the overall objectives of this study are as follows; firstly “to identify and extract wetlands area from all acquired datasets”. Secondly, to identify the inventory system practiced in this region and thirdly, to identify the benefits of the methods used by other researchers and adopt such approach for this study”. Therefore to achieve these objectives, relevant research works were reviewed and validation of research hypothesis shows that wetland monitoring and mapping of coastal cities was largely underscored.

The aforesaid findings were collated from views of environmentalists. The test hypothesis confirmed the following; “are wetlands the most natural resource of the study area” ( $\chi^2_{computed} = 19.030$  and  $\chi^2_{tabulated} = 5.991$  at 2 degree of freedom), to this occurrence when  $\chi^2_{tabulated} > \chi^2_{computed}$   $H_0$  is accepted while  $H_1$  is rejected. (i.e.  $H_1$  was accepted: Wetlands are Niger delta’s most important natural resource). Likewise, “the incorporation of wetland inventory deliverables in managing urban growth is essential” ( $\chi^2 = 3.376$  and  $\chi^2_{tabulated} = 5.991$  at 2 degree of freedom)  $H_{02}$  is rejected while accepting  $H_{12}$  ( $H_{12}$  There is a significant relationship between wetland deforestation and urban encroachment).

In monitoring estuarine ecosystem such as the Port Harcourt wetlands for its preservation management medium scale vegetation maps were produced using the temporal vegetation index extract. Hence for the forty (40) years under review a loss of 4350.109 hectares was recorded as a result of deforestation of urban forestry at annual change rate of 108.753 hectares. Remotely sensed data offers an alternative measurement of vegetative characteristics that provides a more synoptic view to remote terrain. Since multispectral data serves to retain good spectral resolution the pan chromatic band 8 provides improved spatial resolution. The use of co-registered multispectral data was essential for creating colour composite, index/ratio and classification images. Therefore, monitoring wetland loss or urban growth requires temporal images for which the satellite datasets to be useful for monitoring temporal changes.

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With over 60% of the study area population are living close to the water bodies, the coastal zone is a region subject to increasing stress on existing wetlands induced by human activities. These riparian zone serves as a major transportation routes and also important in the hydrological balance of the study area. Therefore, these sensitive riparian environments within the study are protected by mangrove vegetation which are been destroyed in an effort to clear potentially peri-urban settlements. It should be noted that monitoring the health of this forest is a step towards protecting the coastline from erosion and flooding of nearby inland water. Vegetation indices generally can be employed as a monitoring tool; using spectral bands as input and yielding different reflecting vegetation characteristics while controlling the influence of spectral variance from other features.

An important application utilized in this study is the integration of NDVI change map with population data. This approach gave an account of how population growth a particular settlement can be expressed as a catalyst for vegetation loss at zonal level. Therefore, the extents of vegetation loss within zones where population increased have been experienced were obtained. The classified map 2003 had an overall accuracy of 86.36% from a ratio of (9854/11410) pixels with a kappa coefficient of 0.7779. The derived statistics from the confusion matrix shows that the result for such mapping exercise was acceptable. Since the non-contact mapping approach using coarse datasets has achieved the expected qualitative results. Potential users of this technology should note that computer aided analysis is data driven, rather understanding the limitations and capabilities of results obtained from these systems. Therefore, such data dependent results can be no better than the quality of the form which it was derived without assumptions.

The present environmental situation of this local area is rapidly changing as a result of induce human activities. This region has lost huge amount of mangrove vegetation which Godstime *et al.* (2011) stated as causes of wetland vegetation. Nypa palm is now a major contributor which accounts for 15% the total wetland loss of this area. This foreign specie is a dominate wetland plant which flourishes on elevated heights slightly above mean tidal level where salt water intrusion of high water mark of ordinary tide (H.W.M.O.T.) mixes with fresh water. Finally, the acquired LANDSAT datasets were effectively utilized to obtain measurements and map the aforesaid temporal vegetation loss. Therefore, the identification, delineation and mapping of wetlands are crucial for regional studies, resource management and planning. Analyzing such wetland characteristics as compared to urban land use ensures controlled development within valuable wetland and likewise the health of such vegetation not been compromised due to improper adjacent developments. Consequently, monitoring the rate and extent of deforestation and regeneration are key parameters measured if remote sensing methods are adopted.

## **5.2 Recommendations**

Further study on this area is recommended to validate the results obtained from this study. Hence the data processing techniques to be used should be done taken account of the problems encountered in this study. The Geographic Information System, Remote Sensing approach and image processing approach should be employed for yearly map updating as a means of monitoring construction activities on or along low-lying elevated land forms. Higher

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resolution datasets are therefore recommended for effective discrimination amongst the two wetland vegetation of interest.

A detailed land use/ land classification system should be designed for effective monitoring, mapping and management of land-use activities within the city. This will reveal wetlands loss necessitated by urban encroachment into these fragile land forms. Encouraged conservation practices through public participation in government policies and such principles as part of basic science curriculum in foundation education. Having evaluated the desirability of the inclusion of remotely sensed data in mapping wetlands, it important to research on and develop measurement models for reporting purposes in Niger Delta. This model should leverage on works in other researchers and incorporate the indigenous views on the subject matter.

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