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# Trends in vegetation cover changes in Bonny area of the Niger Delta

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**ABSTRACT:** The main vegetation type in the area is the mangrove forest, which occupies most of the Niger Delta. The other vegetation type is the secondary (re-growth) vegetation that occupies a small area. The secondary vegetation is surrounded by the mangrove swamp forest; a two-layered vegetation. The one–layered forest has mangrove trees of 3-14 m high without undergrowth forming the only layer while the two-layered forest has a top layer made up of *Rhizophora* species (3-32 m high) depending on the height of trees at each site and a ground layer composed mainly of the fern *Acrostichum aureum* and seedlings of the tree species. There is a dearth of epiphytic bryophytes and lichens on the boles and branches of the trees. From satellite imageries of the area, it is evident that the landcover classes changed across the three epochs. The water class covered an area of 111.91km$^2$ in 1986, 108.90km$^2$ in 1998 and 103.41km$^2$ in 2007. Mature forest (Forest I) occupies a total area of 85.64km$^2$ in 1986; decreased significantly to 59.68km$^2$ in 1998 and 59.30km$^2$ in 2007. This could be attributed to man-made and industrial activities. Secondary Forest (Forest II) covered 11.18km$^2$ in 1986, but increased to 43.49km$^2$ in 1998 and decreased to 23.30km$^2$ in 2007. Urban/Industrial/Sand class had a steady increase across the epochs. This class which covered about 10.37km$^2$ in 1986 increased to 14.73km$^2$ in 1998, and 25.28km$^2$ in 2007. This increment is attributed to influx of humans into the area as a result of increase in Oil and Gas industry activities. Mangrove class covered 87.02km$^2$ in 1986 but increased to 95.86km$^2$ in 1998 and 106.79km$^2$ in 2007. Stressed Vegetation occupied 16.38km$^2$ in 1986; this class type was only evident during that period. Sparse vegetation which covered an area of 5.23km in 1986; decreased slightly to 5.07km$^2$ in 1998 but increased to 9.07 km$^2$ in 2007. Overall, the most dramatic change recorded is with respect to the areal extent of Urban/Industrial/Sand which increased by about 42% between 1986 and 1998 and about 144% between 1986 and 2007. The area covered by mangrove forest consistently declined over all the epochs while the reverse was the case with respect to the area covered by sparse vegetation. The area covered by stressed vegetation in 1986 disappeared during other epochs.


Many, many human actions tend to have indelible imprints on landscape in a short time (Briassoulis, 2000; Goldewijk and Ramankutty, 2004; Fabiyi, 2007). Throughout history, human activities have impacted on the natural ecosystem through the aggressive drive for development (Goldewijk and Ramankutty, 2004). It has been estimated that over the last three centuries, more than 1200 million ha of forests and wood lands have been cleared. Grassland and pastures have diminished by about 560 million ha and cropland areas have increased by about 1200 million ha (Richard and Flint, 1994). Human actions especially those involving biomass fuel consumption, land-use change, and agricultural activities have direct interaction with the land surface and negative consequences on vegetation and environmental qualities (Fabiyi, 2011). These interactions are rather complex and have attracted research interest in the last four decades (Goldewijk and Ramankutty, 2004).

The Niger Delta region in Nigeria had its share of negative influence of human activities on the natural landscape. The primary vegetation of the delta is fast changing to secondary and derived vegetation due to aggressive incursion of human activities into the seemingly undisturbed ecosystem that characterized the region about a century ago. Human activities including oil exploration and urban development are causing imbalances in the ecosystems of the region with resultant negative consequences on environmental quality and livability (Fabiyi, 2011). The extent of these environmental alterations has prompted different concerns including political agitations with respect to the social, economic and cultural consequences of the changes that are taking place. The oil multinational companies operating in the Niger Delta area have been fingered as the main change actors by especially the activist and environ-mentalists. The United Nations Development Programme reported that whereas the Niger Delta has an enormously rich natural

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endowment in the form of land, water, forests and fauna, these assets, however, have been subjected to extreme degradation due to oil prospecting. For many people, this loss has been a direct route into poverty, as natural resources have traditionally been primary sources of sustenance" (UNDP, Niger Delta Human Development Report, 2006).

Several forces are responsible for the changes in vegetation quality observed in the Niger Delta. Settlement developments, oil prospecting over the years imprint indelibly on the Niger Delta fragile canvas of the ecosystem. The main visible impact is the change in land use and vegetal cover. Human systems is a part of natural ecosystems but the activities that support human enterprises unfortunately damage the natural landscape of the Niger Delta is in the coastal belt of Nigeria, it is characterized by fragile ecosystems including mangrove, nypa palm, fresh water swamp, sheltered tidal flat and large expanse of vegetated bluff. Niger Delta is home to different fauna and flora species (some of which are in endangered list of IUCN) yet with about 31 million populations in an area of about – square kilometers. The Niger Delta combined the presence of oil rich hydrocarbon deposit with the rich alluvium and the abundance of aquatic life to make the place attractive to rapid expansion. The intense urbanization and industrialization that followed the discovery of oil at Oloibiri in the present day Bayelsa state in 1956, have many consequences on the landscape of the Niger Delta, for example enlargement of natural coastal inlets and dredging of waterways for navigation, port facilities, and oil and gas pipelines have direct impact on the fragile coastal ecosystems. The visible manifestations of these anthropogenic activities include loss of biodiversity and essentially deforestation, environmental degradation, loss in vegetal qualities and soil nutrient loss. A number of large scale and cottage industries sprang up in the last thirty years thereby contributing to environmental degradation of the Niger Delta (Fabiyi, 2011).

Other activities such as sand mining, hydrocarbon production like oil and gas, introduction of invasive species (nypa Palm) and engineering constructions such as jetty, seawalls and channelization are few among numerous activities taking place in the region. Apart from the various human induced changes in the ecosystems of the Niger Delta, the global climatic change is another significant change factor in the Delta. These drivers are responsible for long term modification of the coastal ecosystem including the Niger Delta. Though deforestation and apparent change in vegetal qualities are major land use/ land cover changes occurring in many coastal regions of African countries. The impacts of human activities within the coastal region, and the climate change effects are difficult to separate into different compartments (Fabiyi, 2011).

On a continental or global level, climatic fluctuations have been linked to the anthropogenic activities through the release of green house gas into the atmosphere, thus depleting the ozone layer. Effects of climate change have been measured in the continental or regional levels through sea level rise, melting of the icecap, increased rainfall and associated flooding in the low lying areas. In the sub local analyses context, the influence of human activities on the landscape can be directly measured through different approaches such as remote sensing and geographic information system (GIS) techniques (Fabiyi, 2011). Recent research discourse focuses on the ways to identify the extent of human influence on the global climate change from the normal perturbation associated with climatic cycle and to what extent will the global warming be reduced with the cutting down of carbon emission by industrialized nations. In the supra local context, it is necessary to separate the impact of the immediate anthropogenic actors on the ecosystems from the changes due to climate changes.

Several methods have been used to measure vegetation cover loss (DeFries et al., 1995). The methods require the definition of the thresholds and classification of the vegetation around the threshold based on some pre-determined schemes. This approach has been fraught with practical inefficiency, especially if there is a need to monitor changes over time. Other methods include the following authors" approaches (Copeland et al., 1996; Bonan, 1999; Houghton, 1999; Postel et al., 1996; Vitousek et al., 1997). Normalized difference of the vegetation index (NDVI) became popular in the last three decades to investigating the quality of vegetal cover. The normalized difference of the vegetation index (NDVI) is a non-linear transformation of the visible (red) and near-infrared bands of satellite information. It is an alternative measure of vegetation amount and condition. It is associated with vegetation canopy characteristics such as biomass, leaf area index and percentage of vegetation cover. NDVI is mathematically defined as: nir-red/ nir+red (Near infrared band – red band/ near infrared band +

red band) Previous studies have used Channels 1 (0.54 to 0.68 m) and 2 (0.73 to 1.10 mm) which are visible and near infrared of the advanced very high resolution radiometer (AVHRR) data (Groten, 1993; Loveland et al, 1991) other works on the use of NDVI to monitor vegetal changes include. Other studies linked NDVI to plant phenology (Defries et al., 1995; Read and Lam, 2002; Mora and Iverson, 1995). Apart from AVHRR NDVI have been calculated from LANDSAT-TM information using bands 3 (0.63 to 0.69 mm) and 4 (0.76 to 0.90 mm). NDVI values range from -1 to +1 for pixel values ranging between 0 to 255. NDVI, which is one of the most successful of many attempts to simply and quickly identify vegetated areas and their "condition" is utilized in this study.

## MATERIALS AND METHODS

This project examines the use of Remote Sensing and Geographic information Systems (GIS) in mapping and analyzing Land use/land cover changes within the Bonny area from 1986-2007. Land use /Land cover changes (LULC), which is recognized, as one of the most sensitive indicators of environmental change, reflects the impacts of human activities on the biophysical environment. The impact of activities relating to oil and gas exploration may generate some significant effects on the environment, such as loss of wildlife habitat, changes in surface and subsoil hydrology that may lead to accelerated soil erosion and land degradation, vegetation changes, air pollution and changes in coastline geomorphology.

The area of interest covers an area (see Figure 1) of approximately 322.04km$^2$ and it has bounding coordinates of 517899.355E- 540285.491E and 41432.386N-55817.979N in Transverse Mercator Nigerian Mid-belt projection and Minna datum The datasets used for this project were free of negative atmospheric influences such as cloud cover and atmospheric haze.

A number of processing algorithms were used to process the Natural Colour Composite Image, Land Cover Classification and Normalized Difference Vegetation Index. A short description is given of each of the processing method used and interpretation included. Further processing was carried out to delineate areas of vegetative growth and land cover type in the area of interest. This study is expected to reveal or depict the environmental performance of oil and gas facilities over the period in view through land cover change detection analysis.

The study is limited to baseline information generation from field data collection and remote sensing and GIS, based on change analysis of areas lying within the Bonny area. Spatial and satellite data were sourced from the Shell Petroleum Development Company (SPDC).

Landsat TM dataset of 1986, SPOT XI dataset of 1998 and Landsat ETM of 2007 datasets were used. These satellite images were processed and the different landcover types obtained for analysis.

## RESULTS AND DISCUSION

*Land cover Classification:* A Land cover classification was carried out over the Bonny area only, for three epochs using the Landsat TM 1986, SPOT XI 1998, and Land sat ETM of 2007. An unsupervised classification process, which uses an iterative ISO class algorithm to generate a number of classes pre-defined by the processor, was used. This unsupervised classification technique, groups similar pixels based on the spectral characteristics of the image datasets. This method does not require any prior knowledge of the land cover types in the area of interest. The following parameters were used for the unsupervised classification process; 98% unchanged, maximum standard deviation 4.5, minimum distance between class means 3.0. The iterative ISO class processes were carried out on the Landsat TM, SPOT XI, and Land sat ETM datasets. Six main classes were identified using an unsupervised classification technique.

*Aerial Environmental Baseline Study:* Baseline information was derived from the processing of satellite images and GIS datasets. There is presence of fourteen and nine Oil and Gas Pipelines respectively while there are and ten manifolds within the area of interest. Thirty-six wells are found with the area of interest and these are mainly from Bonny, Akikigha, Asaramatoru and Owuanga.Only one Flowstation is found within this area of interest and this is Bonny. Also, within this area could be found the following facalities SHELL Bonny terminal, Nigeria Liquefied Natural Gas (NLNG) and Mobil Terminal.

***Land-use :*** The land use pattern that pre-dominates the area of interest is shown in Figure 2. The Soku-Awoba-Bonny area measures approximately 121.5 x 64 km covering an area of 7782 km$^2$. Water and mangroves occupy 45% and 33% of the total area respectively. Undisturbed forest (Forest I) is present as freshwater swamp forest on the northern fringes of the mangrove swamps, riparian forest along major river channels and on palaeo-beaches along the coastline. Undisturbed forest occupies just over 8 % of the area. Human impact on these natural cover **types result in secondary or disturbed forest** (Forest II) covering 3% and Farmland 5%. Urban and industrial areas occupy just about 1% of the total area.

Landcover types within the pipeline corridor are dominated by mangrove at 75% of the total length. Rivers, creeks and wet mangrove constitute a further 20%. Urban-industrial areas traversed amount to 2.3% of the total length – this is mostly at the south-eastern end at Bonny Terminal but also includes oilfield industrial areas at Ekulama and Cawthorne Channel. The total area of pipeline corridor (given a 1 km width) is 91.00 $km^2$ or 1.7% of the total project area (7782 $km^2$).

*Vegetation:* The main vegetation type in the area is the mangrove forest, which occupies most of the Niger Delta. The other vegetation type is the secondary (re-growth) vegetation that occupies a small area. The secondary vegetation is surrounded by the mangrove swamp forest; a two-layered vegetation. The one–layered forest has mangrove trees of 3-14 m high without undergrowth forming the only layer while the two-layered forest has a top layer made up of *Rhizophora* species (3-32 m high) depending on the height of trees at each site and a ground layer composed mainly of the fern *Acrostichum aureum* and seedlings of the tree species. There is a dearth of epiphytic bryophytes and lichens on the boles and branches of the trees. The vegetation species composition within the area is shown in Table 1.

The detailed tree density per hectare is presented in Table 2. Various plant species make up the vegetation in this area. These include trees, shrubs, fern species, grasses and sedge. The indicator species of the vegetation types are *Rhizophora racemosa, Rhizophora harrisonii*, (for the mangrove swamp forest) *Alchornea cordifolia* and *Cocos nucifera* (for the secondary growth forest).

Farmlands with crops were also encountered among the vegetation. The common crops recorded include Cassava *(Manihot esculenta),* Coconut *(Cocos nucifera),* banana *(Musa* sp.*),* Cocoyam *(Colocasia esculenta),* groundnut *(Arachis hypogea),* Maize *(Zea mays),* Plantain *(Musa sapientum),* Pineapples *(Ananas comosus),* Pepper *(Capsicum* sp.*),* Okra *(Hibiscus esculentum),* Yam *(Dioscorea* sp.*)* and Water yam *(Dioscorea alata).*

*Mangrove:* It is found to be generally concentrated within the northern area, though spreads

*Forest II* It occurs towards the eastern and western fringes. Within it is found, pockets of forest I.

*Water***:** This comprises mainly the Bonny river flowing south wards in to the ocean and the Andoni River to the north and east of the image. There are quite a few creeks within the area.

*Forest* **I :**This type of vegetation is found mainly within the southern area spreading towards the east. The dominant vegetation is mature forest.

This is secondary forest which replaces the primary forest and is in the process of achieving maturity in the successional cycle.. This vegetation type is found in close proximity with the Urban/Industrial and Sparse Vegetation. Small portions of it are found within the mangrove area.

*Urban/Industrial/Sand***:** This is found around the shoreline as sand and also built up areas. Within the areas is a good network of roads connecting the communities.

*Sparse Vegetation***:** This cover the smallest portion of the area and it is found in close proximity with urban/industrial/sand and forest II.

*Stressed Vegetation:* This type of vegetation appeared near the mangrove in the eastern flange of the area of interest and as pockets around the northern axis. This is type of vegetation is only noticed in the Landsat TM of 1986.

The image representations could be seen in figures 3-5.

*Normalized Differential Vegetation Index* **(NDVI):** NDVI was used in highlighting areas showing the different levels of vegetation health. This objective was achieved by applying the vegetation formula to the image. A normalized difference vegetation index is a ratio of Near Infrared (NIR) and Red bands. The formula is presented below

**DN (out) = (band 1 – band 4)/ (band 1 + band 4)**

An NDVI lookup table was applied to the image. It was observed that

The areas with high NDVI values for the entire epochs are Mangrove, Matured forest (forest I), Secondary forests (forest II), Sparse Vegetation. These are shown in green, yellow and orange colours respectively.
The water, Stressed vegetation and Urban/Industrial are in blue and purple showing low NDVI.

*Time-Lapse Change Analysis:* Time-lapse analysis is for assessing changes in an area within a period of time. For the case of this study, it was carried out on Bonny Area using the Landsat ETM 2007, SPOT 4 of 1998 and Landsat TM of 1986. This was carried out on the landuse/landcover images (Figures 3 - 15). A breakdown of the various landcover types as a percentage of totals is shown in Tables 6 and 7.

*Conclusions:* The landcover change detection summary over the area of study between 1986 and 2007 is as follows:

The Time Lapse Analysis revealed that Water class decreased slightly over the years. Water class changed from 111.91km$^2$ in 1986 to 108.90km$^2$ in 1998, and 103.41 km$^2$ in 2007. Since the satellite images were acquired about the same period being dry season, the reason for the decline might be due to the increase in sand deposit along the shoreline.

There was a sharp decline in Mature forest (Forest I) from 85.64km$^2$ in 1986, to 59.86km$^2$ in 1998. By 2007, it decreased further to 59.30km$^2$. The decrease could be attributed to the construction work between 1986 and 1998 which was probably at its peak but reduced by the year 2007. The construction of Mobil facility is one of such activities.

Mangrove which was 87.02 km$^2$ in 1986 increased to 95.86 km$^2$ in 1998 and 106.79 km$^2$ in 2007. The increase might be due to the decline in the area covered by water. In the event of flooding, mangrove area covered by water will be shown as water body on the satellite image. When the water recedes, the vegetation signature can then be mapped from the image.

Stressed Vegetation was only seen in the year 1986 and it had a total coverage of 16.38km$^2$. The reason for this is due to the damage caused to the vegetation by flooding. This is part of the mangrove vegetation. It was separated from mangrove due to the classification done.

There was a sharp increase in secondary forest (Forest II) from 11.18km$^2$ in 1986, to 43.49km$^2$ in 1998. By 2007, it decreased to 23.30km$^2$. The increase between 1986 and 1998 was due to the re-growth that occurred where construction activities did not take place. The decrease between 1998 and 2007 should be due to the forest II being destroyed to make way for activities to go on.

There was a slight decrease in sparse vegetation from 5.23km$^2$ in 1986 to 5.07km$^2$ in 1998. Between 1998 and 2007, sparse vegetation increased to 9.67km$^2$. The decrease between 1986 and 1998 was due to regrowth vegetation while from 1998 to 2007, the increase occurred as a result of the decline in forest II due to construction and human activities.

Urban/Industrial/Sand class increased across the epochs. Urban/Industrial/Sand was 10.37km$^2$ in 1986, increased to 14.73km$^2$ in 1998, and 25.28km$^2$ in 2007. This was due to development and construction activities which brought about the influx of humans into the area.

Overall, the most dramatic change recorded is with respect to the areal extent of Urban/Industrial/Sand which increased by about 42% between 1986 and 1998 and about 144% between 1986 and 2007. The area covered by mangrove forest consistently declined over all the epochs while the reverse was the case with respect to the area covered by sparse vegetation.

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| Species | Common Names | Life Form Types | Uses/Economic Importance | Ecological Significance |
|---|---|---|---|---|
| *Acrostichum aureum* | Salt water fern | Palm | For making traps to catch fish | Could serve as indicator for deteriorating conditions for growth or *Rhizophora racemosa* and the rising level of land |
| *Afromomum septum* | - | Herb | Medicinal | - |
| *Alchornea cordifolia* | Christmas bush | Shrub | Could be used medicinally | Abundant in cleared and disturbed areas |
| *Alstonia booneri* | Pattern wood | Woody tree | For carving canoes, furniture<br>Sold as timber | Wetland species |
| *Anacardium occidentalis* | Cashew apple | Woody tree | Medicinal<br>Fruits edible | Grows in cleared and disturbed areas |
| *Ancisitrophyllum secondifolia* | Climbing palm | Palm | Stem used as binder in hut construction | Wetland species |
| *Anthocleista vogellii* | Gabbage tree | Woody tree | Leaves used for wrapping coconut<br>Root is medicinal | Wetland species |
| *Anthostema aubryanum* | Sapling wood | Woody tree | Sold as timber tree<br>For carving canoes and carpentry work | Wetland species |
| *Antidesma laciniatum* | - | Woody tree | - | - |
| *Anthonotha macrophylla* | - | Woody tree | - | - |
| *Avicenia germanis* | White Mangrove | Woody tree | Training/Dye from bark of the tree<br>Leaves, seeds are as curative ointment for ulcers or sores | Trees provide nesting sites for sea and shoreline birds and diverse animal life |
| *Axonopus compressus* | Carpet grass | Grass | For making lawns | Species of fallow lands |
| *Borreria ocymoides* | Fula's lesser necklace | Herb | Medicinal | Species of fallow lands |
| *Bridelia micranta* | - | Woody tree | - | - |
| *Calopognium mucunoides* | Mucuna (climber) | Climber | For Pasture or mulching | Grows in cleared and disturbed areas |
| *Carapa procera* | Crab wood | Woody tree | Gum resin<br>Medicinal | Wetland species |
| *Chromolaena odoratum* | Awolowo weed | Herb | Medicinal | Species of fallow lands, cleared and disturbed areas |
| *Chrysobalanus orbiculare* | Plum of the West Indies | Woody tree | Medicinal | - |
| *Cleistopholis paten* | Canoe wood | Woody tree | For canoe making<br>Medicinal<br>Cut and sold as timber | Wetland species |
| *Cocos nucifera* | Coconut Palm | Woody tree | Fruits edible/extraction of oil<br>Fibres processed for weaving<br>Coconut fronds for thatching etc. | - |
| *Costus afar* | - | Herb | - | Wetland |
| *Crotolaria retusa* | - | - | - | - |
| *Cyrtosperma senegalensis* | Swamp aerum | Under shrub | Medicinal | Wetland species<br>Grows in marshy lands |
| *Dichospelatum madagascariense* | - | Woody tree | - | - |
| *Dalbergia ecastaphyllum* | Indian timber | Woody tree | For carving e.g. walking sticks | - |
| *Dictyandra involucrates* | Timber | Woody tree | - | - |
| *Diadia serrulata* | Star of the ground | Herb | Medicinal | Species of fallow lands |
| *Daniella* sp. | - | - | - | - |
| *Dissotis rotundifolia* | Rockrose or sheep-eyes | Herb | Medicinal | Species of fallow lands |
| *Drepanocarpus Iunatus* | - | Tree | - | - |
| *Dracaenia arborea* | Mottled leaf | Tree sp. | Ornamental | - |
| *Elaeis guineensis* | Oil palm tree | Tree | Source of red palm oil<br>Fronds used for weaving baskets and for thatched houses | - |
| *Emelia praetermissa* | Bush bulk's ear | Herb | Medicinal and eating as salad | Species of fallow lands |
| *Erafrotis tenella* | Stink grass | Grass | Fodder for cattle | Species of fallow lands |
| *Ficus capensis* | Fig tree<br>(sand paper tree) | Woody tree | Plants have medicinal value | - |
| *Fimbristylis* sp. | Sedge | Sedge | Used for making mats | - |

| | | | | |
|---|---|---|---|---|
| | | | Medicinal | |
| *Fuirena ciliaris* | Sedge | Sedge | Burnt to make salt | Wetland species |
| *Gilbertiodetifron brachystegoides* | - | - | - | - |
| *Hibiscus suratensis* | Wild sour | Herb | Medicinal | Species of fallow lands |
| *Irvingia gabonensis* | Bush mango | - | Fruit edible | - |
| *Indigofera* sp. | Indigo sp. | Under shrub | Medicinal | - |
| *Killinga robusta* | Sedge | Sedge | Used for fumigant<br>Medicinal | - |
| *Klainedoxa gabonensis* | - | - | - | - |
| *Lagunculana racemosa* | Black Mangrove | Woody trees | Mangrove wood is a source of fuel, timber, electric poles and scaffolding materials in building construction | Stilt roofs bind the tidal mudflats together, hence ensuring the stabilization of coasts and protection of shoreline from erosional processes |
| *Lophora lanceolata* | - | Woody tree | - | - |
| *Lycopodium cerrum* | - | Woody tree | - | - |
| *Mariscus ligularis* | Sedge | Sedge | - | Abundant in cleared and disturbed areas |
| *Mangifera indica* | Mango tree | Woody tree | Leaf – medicinal<br>Fruit edible | - |
| *Mitragyna ciliata* | Abura (Timber) | Woody tree | Construction of light canoes<br>Making of household utensils (e.g. furniture)<br>Cut and sold for timber | Wetland species |
| *Milletia arboemis* | - | - | - | - |
| *Musanga cecropiodes* | Umbrella tree (corkwood) | Woody tree | Soft wood tree for household utensils and sold as timbers<br>Cut and used for buoyancy | Wetland species |
| *Nauclea diderrichii* | Opepe (sapling tree) | Woody tree | Valuable commercial/industrial wood<br>Transmission poles/piling timber | - |
| *Nephrolepis biserrata* | Climbing fern | Fern | - | Wetland species |
| *Nypa fruticans* | Salt water coconut (Nipa palm) | Palm | Palm for making thatch houses/basket weaving | Stabilization of coasts and protection of shoreline from erosional processes |
| *Newbouldia laevis* | - | - | - | Possess rapid colonizing potentials and can displace mangrove. |
| *Palisota* sp. | Break hoe or knee cap | Undershrub | Medicinal | Species of fallow lands |
| *Pandaus candelebranum* | Panadana luster (ornamental screw pine) | Palm | Leaves used for household uses | Wetland species |
| *Panicum* sp. | Elephant grass/guinea grass | Grass | For fodder and roofing thatch houses | Species of fallow lands |
| *Paspalm vaginatum* | Salt water sedge | Grass | Used as fodder | Grows in marshy areas<br>Can tolerate high degree of salinity and oil contamination |
| *Phoenix reclinata* | - | - | - | - |
| *Pennisetum hordeoides* | Shura grass | Grass | Used as fodder grass | Grows in cleared and disturbed areas |
| *Pentachletra macrophylla* | - | Woody tree | Timber tree | Wetland species |
| *Psychortria vogeliana* | Woodcock | Woody tree | Medicinal | - |
| *Raffia hookeri* | Raffia palm | Woody tree | Tree tapped for its wine<br>Fronds used as rooting sheets and woven into baskets<br>Fruits used as bait for animals | Wetland species |
| *Rubiaceae* | - | - | - | - |
| *Rhizophora harrisonii* | Red Mangrove | Woody trees | Mangrove wood is a source of fuel, timber, electric poles and scaffolding materials in building construction | Tidal mudflats, stilt roots/rootlets serve as critical nursery for fishes, prawn and habitat for crabs and molluses |
| *Rhizophora racemosa* | Red Mangrove | Woody trees | Mangrove wood is a source of fuel, timber, electric poles and scaffolding materials in building construction | Tidal mudflats, stilt roots/rootlets serve as critical nursery for fishes, prawn and habitat for crabs and molluses |

| | | | | |
|---|---|---|---|---|
| *Selaginella myosnus* | Club plant | Twining climber | Medicinal | Wetland species |
| *Setana* sp. | Foxtail grass | Grass | For pasture | - |
| *Sida acuta* | Hornbeam leaf | Herb | Medicinal | Species of fallow lands |
| *Sporobolus pyramidalis* | Rat's tail grass | Grass | For fodder | Species of fallow lands |
| *Symphonia globulifera* | Hog Gum tree | Woody tree | For making canoes<br>Household utensils<br>Sold as timber/planks | Wetland species |
| *Syzygium guineensis* | Berry of Kizza | Shrub | Medicinal | Species of fallow lands |
| *Tridax procumbens* | Snail's salia | Herb | Medicinal | Species of fallow lands |
| *Vernomia cinera* | - | Herb | Medicinal | - |
| *Zanthoxylum giletii* | - | - | - | - |

**Table 1:** Species Composition of vegetation in the Soku/Awoba-Bonny Area
**Key: - not known**

**Table 2:** Tree Density per hectare within the Soku/Awoba-Bonny Area.

| Plant species | Mean Density/Hectare |
|---|---|
| *Achrosticum aureum* | 850 |
| *Alchornea cordifolia* | 600 |
| *Anthocleista vogelli* | 450 |
| *Anthonotha macrophylla* | 300 |
| *Antidesma laciniatum* | 100 |
| *Avicennia germinans* | 500 |
| *Bridelia micrantha* | 200 |
| *Cocos nucifera* | 330 |
| *Dalbergia ecastaphyllum* | 300 |
| *Daniella* sp | 200 |
| *Dichopetalum madagascriense* | 200 |
| *Dictyandra involucrata* | 600 |
| *Drepanocarpus lunatus* | 300 |
| *Elaeis guineensis* | 400 |
| *Ficus capensis* | 600 |
| *Gilbertiodetifron brachystegoides* | 160 |
| *Irvingia gabonensis* | 100 |
| *Klainedoxa gabonensis* | 100 |
| *Laguncularia racemosa* | 530 |
| *Mangifera indica* | 500 |
| *Milletia arboensis* | 100 |
| *Musanga cecropiodes* | 100 |
| *Newbouldia laevis* | 100 |
| *Nypa fruticans* | 550 |
| *Pandanus candelabrum* | 100 |
| *Phoenix reclinata* | 1300 |
| *Rhizophora harrisonii* | 1386 |
| *Rhizophora racemosa* | 1389 |
| *Zanthoxylum gilletii* | 200 |

**Table 3**:. Landcover summary for 2007

| Landcover Types | sq km | % |
|---|---|---|
| Water | 103.41 | 31.55 |
| Mangrove | 106.79 | 32.58 |
| Forest I | 59.30 | 18.09 |
| Forest II | 23.30 | 7.11 |
| Sparse Vegetation | 9.67 | 2.95 |
| Urban/Industrial/Sand | 25.28 | 7.71 |
| **Total** | **327.74** | **100** |

**Table 4:** Landcover summary for 1998

| Landcover Types | sq km | % |
|---|---|---|
| Water | 108.90 | 33.23 |
| Mangrove | 95.86 | 29.25 |
| Forest I | 59.68 | 18.21 |
| Forest II | 43.49 | 13.27 |
| Sparse Vegetation | 5.07 | 1.55 |
| Urban/Industrial/Sand | 14.73 | 4.50 |
| **Total** | **327.74** | **100** |

**Table 5**: Landcover summary for 1986

| Landcover Types | sq km | % |
|---|---|---|
| Water | 111.91 | 34.15 |
| Mangrove | 87.02 | 26.55 |
| Forest I | 85.64 | 26.13 |
| Forest II | 11.18 | 3.41 |
| Sparse Vegetation | 5.23 | 1.60 |
| Stressed Vegetation | 16.38 | 5.00 |
| Urban/Industrial/Sand | 10.37 | 3.16 |
| **Total** | **327.74** | **100** |

**Table 6:** Land cover summary for the three Epochs

| Landcover Types | 1986 (%) | 1998 (%) | 2007 (%) | 1986 (sq km) | 1998 (sq km) | 2007 (sq km) |
|---|---|---|---|---|---|---|
| Water | 34.15 | 33.23 | 31.55 | 111.91 | 108.90 | 103.41 |
| Mangrove | 26.55 | 29.25 | 32.58 | 87.02 | 95.86 | 106.79 |
| Forest I | 26.13 | 18.21 | 18.09 | 85.64 | 59.68 | 59.30 |
| Forest II | 3.41 | 13.27 | 7.11 | 11.18 | 43.49 | 23.30 |
| Sparse Vegetation | 1.60 | 1.55 | 2.95 | 5.23 | 5.07 | 9.67 |
| Stressed Vegetation | 5.00 | 0.00 | 0.00 | 16.38 | 0.00 | 0.00 |
| Urban/Industrial/Sand | 3.16 | 4.50 | 7.71 | 10.37 | 14.73 | 25.28 |

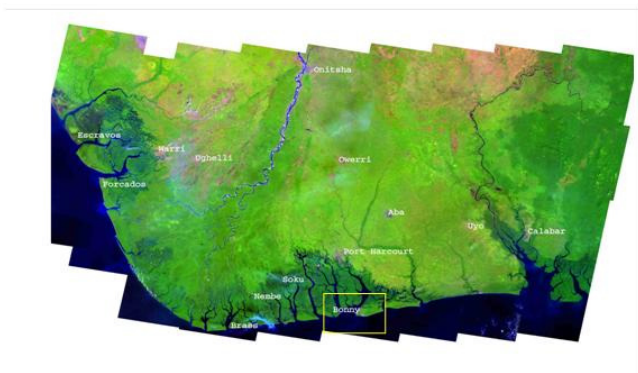



**Fig 1:** Satellite image of Niger delta major towns and study area

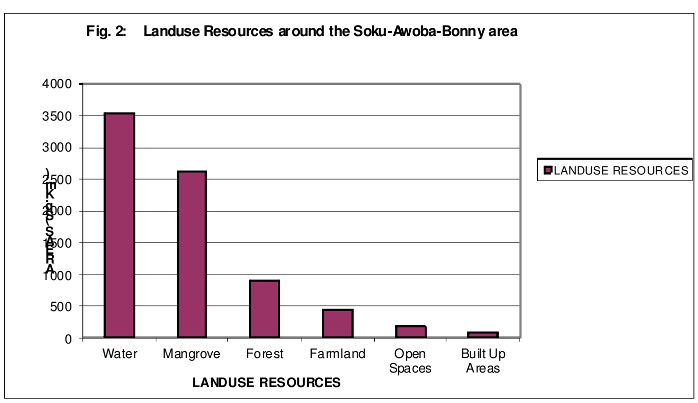



Fig. 2: Landuse Resources around the Soku-Awoba-Bonny area

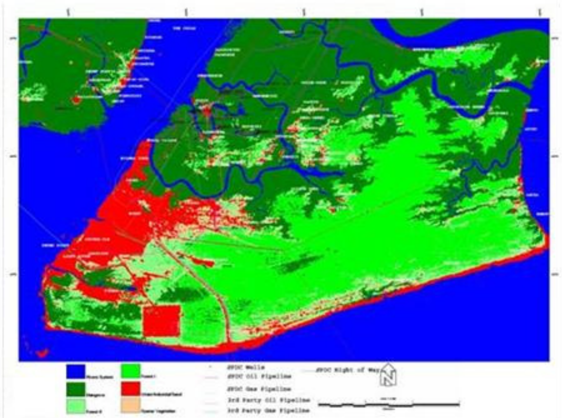


**Fig 3**: Landcover map of Bonny Area derived from Landsat ETM 2007

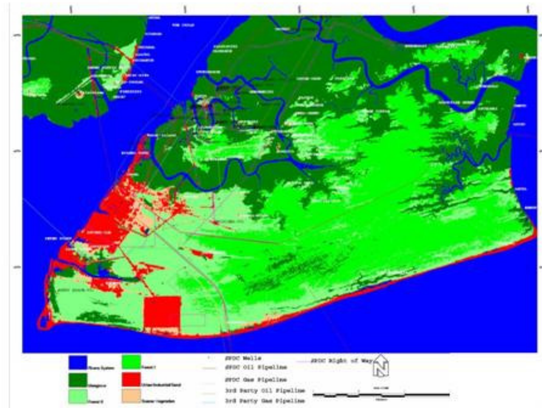


**Fig 4:** Landcover map of Bonny Area derived from SPOT 4 1998

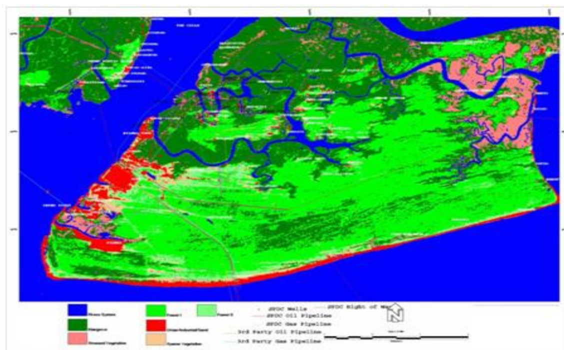


**Fig 5**: Landcover map of Bonny Area derived from Landsat TM 1986

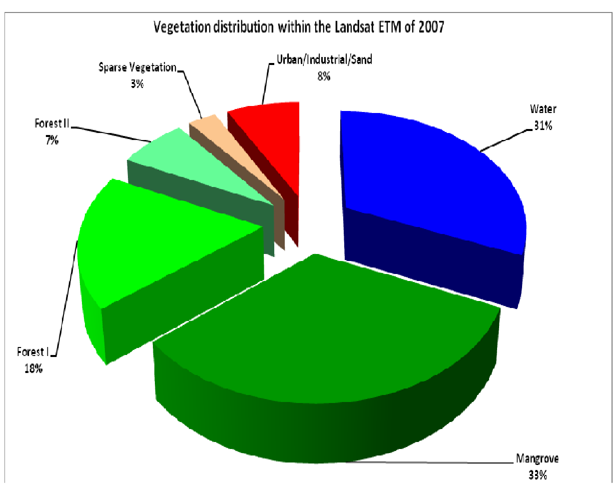



**Fig: 6:** Pictorial representation of the landcover types in 2007 Landcover types

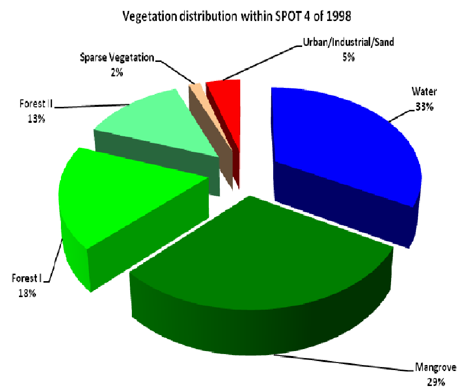



**Fig: 7:** Pictorial representation of the Land cover types in 1998

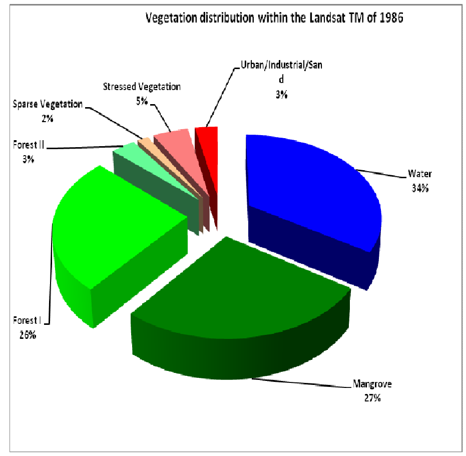



**Fig: 8**: Pictorial representation of the Land cover types in 1986

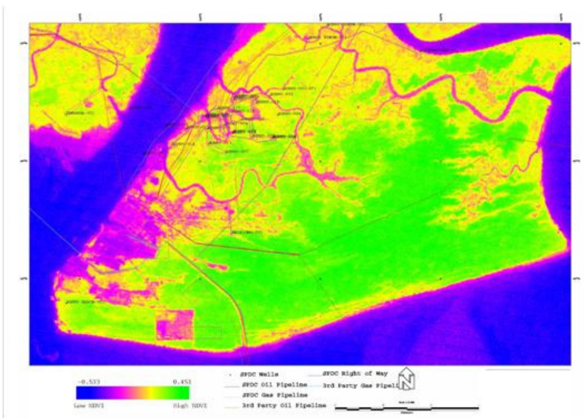


Fig 9: Normalized Difference Vegetation Index Map of Landsat ETM for 2007

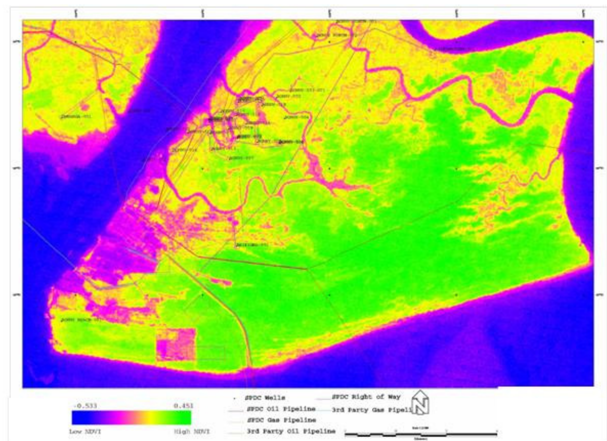


**Fig 10**: Normalized Difference Vegetation Index Map of SPOT 4 for 1998

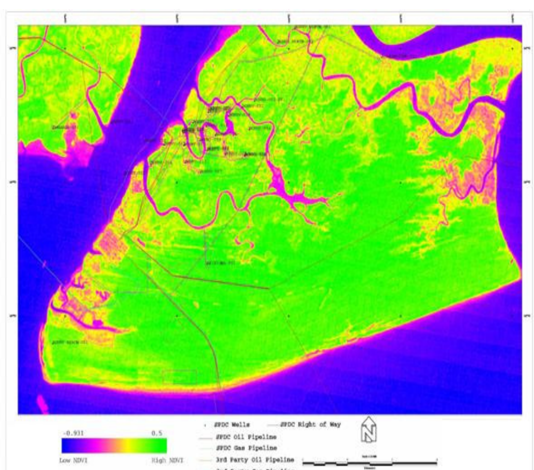
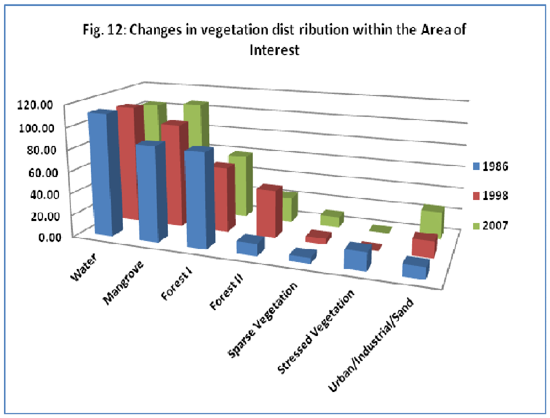


**Fig 11**: Normalized Difference Vegetation Index Map of Landsat TM for 1986



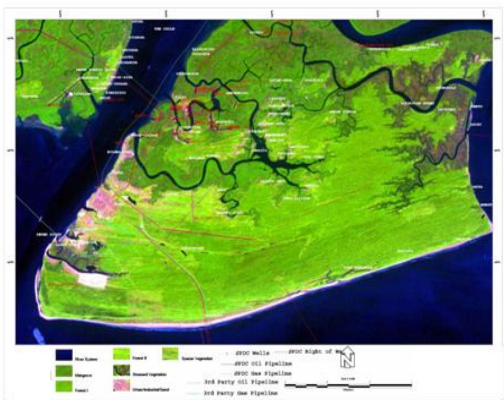



**Fig 13**: Landsat ETM of 2007

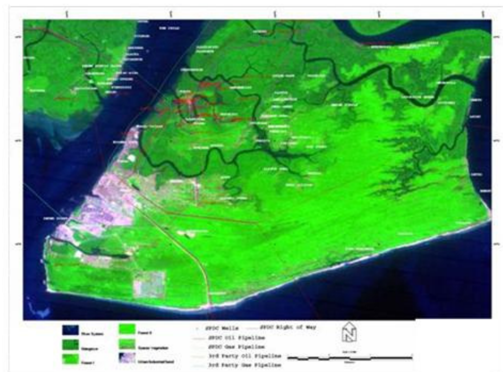


**Fig 14**: SPOT 4 of 1998

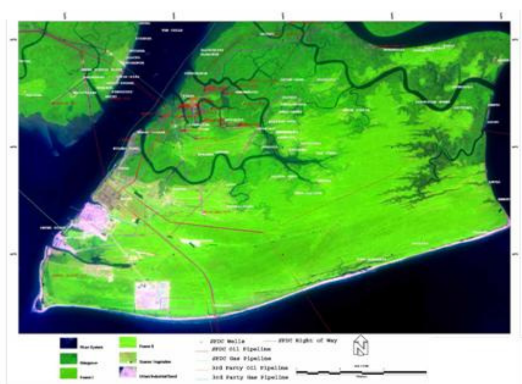
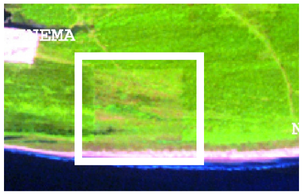
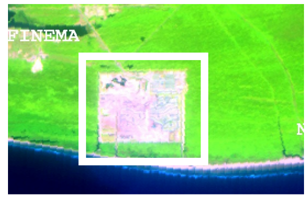
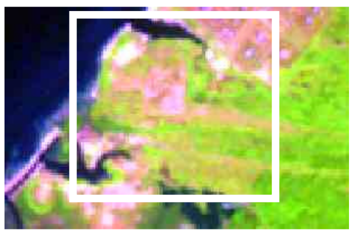
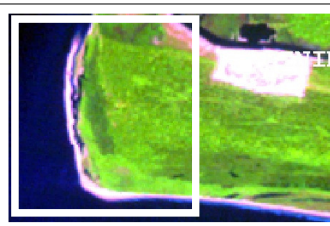
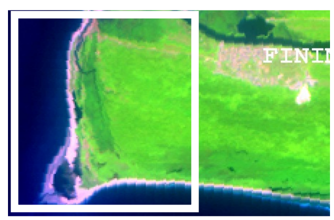
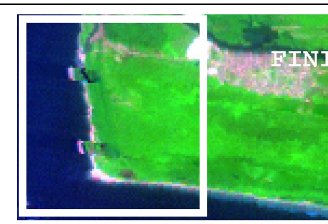


**Fig 15**: Landsat TM of 1986

**Table 7:** Land use and Land cover Profile changes

| Changes | Date 1 1986 | Date 2 1998 | Date 3 2007 |
|---|---|---|---|
| Change 1 | <br>Absence of LNG Staff Quarters near Finima | <br>LNG Staff Quarters in existence | <br>Completion of the LNG Staff Quarters |
| Change 2 | <br>Construction at the LNG site had just begun | <br>Construction reaches advanced stage | <br>Construction completed and activities in full throttle |
| Change 3 | <br>Presence of appreciable Sand deposition along the Shoreline | <br>Presence of Spit at the entrance of Bonny river | <br>Spit disappears from the entrance of Bonny river due to erosion |

| | | | |
|---|---|---|---|
| Change 4 |   Absence of Oil facility near Finima |   Construction of the Oil Facility site reaches advanced stage |   Construction probably completed |
| Change 5 |  Presence of Sand deposit |  Presence of Settlement |   Settlement grows due human influx |
| Change 6 |  Stressed Vegetation within the Mangrove vegetation |  Absence of Stressed Vegetation within the Mangrove vegetation |  Absence of Stressed Vegetation within the Mangrove vegetation |