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***Research paper***

# Land use/land cover change detection along the coastline of Nigeria and its probable causes

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**Abstract**

The Nigerian coastline has been subjected to studies on land use/land cover changes, using satellite images, for three decades. This paper is borne out of the need to understand the dynamics of coastal management. The study aims at assessing land use-land cover changes along coastline in Nigeria from 1986 to 2016 using multi-day satellite imageries. The satellite data were used to extract land use/cover changes and to map the physical extent of the coastal areas of Nigeria for the three-time series during the same season. Urban/built up areas, water and vegetation are the three land use/cover classes of interest along the Nigerian coastline. The urban/built up area class increased from 8.9% in 1986 to 13.7% in 2000, and then 23% in 2016. On the other hand, vegetation decreased from 55% in 1986 to 49% in 2000 and then 43% in 2016. In contrast, water class increased from 36% in 1986 to 37% in 2000, and then decreased to 32.7% in 2016. Considering observations made from this study, it is therefore recommended that the appropriate government agencies, coastal managers and urban planners should promote afforestation along with other mitigation measures, to reduce the adverse effects of human development on the ecosystem.

***Keywords***: *Coastline; Coastal Management; Ecosystem; Land Use/Cover; Satellite Data.*

## 1. Introduction

Land use-land cover change analysis enable planners and policy makers to have adequate knowledge on what should be done to have equitable development that will be sustainable and eco-friendly (Abbas and Fasona, 2012). Land cover refers to the physical cover on the land including both the natural and modified vegetation and artificial constructions (Campbell, 1996). Land use describes the use of the land by the people usually with emphasis on the functional role of land in economic activities (Anderson et al., 1976); and man's activities which are directly related to the land (Abdukadir, 1993). When land use and land cover are treated jointly, they represent both the physical cover and human imprints on the land. Land use/land cover change represents the changes that are occurring over the cover as a result of human modification of its uses. It can also result from human driven natural processes such as climate change. Land use/land cover change can alter the terrestrial ecosystem and its ability to perform its provisioning and support services (Fischlin, et al, 2007). When unchecked, change in land use/land cover can lead to land degradation with potential to significantly exacerbate disasters.

The coastline is generally considered to be the edge or margin of land next to the sea or ocean. Various technical definitions of coastline are used by different coastal management and regulatory agencies but most coastal zone researchers describe the coastline as the interface between land and water (Dolan et al., 1980). Coastlines are dynamic and are therefore areas of constant change (Boak and Turner, 2005). The changes in the coastline largely depend on its geology and geomorphology; the nature of tidal waves impacting the coastline; changes in sea-level; and sediment transport by longshore currents (Carter and Woodroffe, 1994; Cowell and Thorn, 1994; Pidwirny, 2006a). Coastline changes often result in erosion of coastal areas or accretion of sediments, depending on the dominant processes acting on the coastline (Pidwirny, 2006b). Moreover, human activities that impact coastlines include dredging, construction of breakwater infrastructure and physical development; mineral exploration, ports construction, removal of backshore vegetation, construction of barrages and coastal control works (Fanos et al, 1995; Berger and Lams, 1996; Ibe, 1998; Pandian et al., 2004). The coastline is the bridge between aquatic life and terrestrial life, and it is usually a fragile ecozone. As a result, the study of coastline changes can be of immense benefit to the understanding of complex coastal ecosystems.

Land use/land cover changes detection or delineation along the coastline can help in monitoring the coastline. The Mahin transgressive coast in the western Niger Delta of Nigeria coastline is associated with a high intensity of both oil mineral exploration and subsistence farming activities which is leading to changes in the pattern of land use/land cover of the area (Fasona M.J, 2003).The processes involved in oil exploration and transportation in the swamp and mangrove ecosystems degrade the land cover and deplete aquatic fauna in a number of localities thereby bringing about land use/land cover change (LULCC).

Several methods have been employed to study and monitor coastlines, including traditional methods that incorporate local observations and basic surveying techniques. Survey maps, historical coastline mapping and comparison of beach profile over a period of time can also be used to analyse coastline changes. Other more recent methods include simulation of coastline changes using numerical models (e.g., El-Serafy, 1984); combination of coastline survey using Global Positioning System (GPS) receivers; long-shore sediment transport using numerical modelling packages such as MIKE21 and LITPACK (Pandian et al., 2004); and airborne Light Detection and Ranging

(LIDAR) survey methods. All these methods can be used with varying accuracy to determine the position of the coastline at specific time periods and to detect coastline changes over time. The use of satellite remote sensing techniques and geographic information systems (GIS) for the identification, mapping and analyses of coastline changes have gained prominence in recent years as high resolution satellite data have become more readily available.

The aim of the study is to assess land use-land cover changes along the entire coast of Nigeria from 1986 to 2016 using multi-date satellite imageries. This will aid in attaining the following objectives; establishment of land use/land cover patterns of the study area for 1986, 2000 and 2016, and description of the changes that have occurred within the selected years.

There has been a worldwide increasing awareness and studies on land use and land cover change analysis in the last four to five decades. The importance of such studies to sustainable development plan of nations has also been universally recognized. Paradoxically, there is still an extremely low level of recognition and research attention on land use and land cover change studies in Nigeria (Okude, 2006). Some of the few prominent land use and land cover analysis and change detection attempts which are being reviewed here include NIRAD Project (1976/78), Areola (1977), FORMECU (1996): and Omojola (1997).

The NIRAD Project was commissioned in 1976 and completed in 1978. It was based on imagery acquired through the Side Looking Airborne Radar (SLAR) to produce the first vegetation and land-use maps covering the whole landmass of Nigeria. According to FORMECU (1976), the NIRAD Project constitutes the first and only nation-wide database on the Nigeria environment as at 1976. The primary thematic purpose of the project was the inventory and mapping of vegetation types in Nigeria as well as the demarcation of forest reserves boundaries (Adeniyi, 1984). Thus employing a visual image interpretation method, the NIRAD Project provided the first national land use/land cover information of any appreciable consistency.

However, some shortcomings of the study have been identified by Adeniyi (1984) and FORMECU (1996). First, the classification scheme developed in the study is largely related to vegetation (a land cover). Thus the vegetation and land use classes as shown on the 1976/78 produced maps do not discriminate between land use and natural vegetation cover. So it was found that many polygons contain inclusions of other classes to varying degrees. Secondly, the NIRAD classification scheme did not include human settlements' as a cover category. Hence the interpreters must have treated the interpretation and delineation of settlement boundaries as residual matters. Also, the scheme is also besetted with obvious errors associated with the calculated area of the Country and States and consequent variations among land use, land cover categories. Again, the polygon boundary on the 1976/78 vegetation and land use maps appears to have been derived in part from observations (that is, Fieldwork) despite what the imagery suggested that the boundary classes should be. And lastly, the NIRAD Project may be regarded as suitable for its ad hoc purpose but not suitable for a national land use classification scheme. However, despite the identified shortcomings, the NIRAD Project provided the first national land use/land cover information of any appreciable consistency (Adeniyi, 1984).

Areola (1977) carried out a study on land types and terrain conditions in Lagos, in which he demonstrated the usefulness of aerial photo interpretation in the identification or mapping of land types. The study which is localized was undertaken in 1977 at about the same time with the NIRAD National Project. The study used Visual interpretation of infrared black and white photography which was flown at about 1970 over the coastal areas of Lagos between the west of Ikorodu and the Yewa River on the border with Republic of Benin. In the study, the major land types were morphologically determined, while the sub-divisions within each unit were based on differences in vegetation.

The second national and the most current nation-wide database on Nigeria land use and vegetation was provided by the study carried out by Forestry Management and Coordinating Unit (FORMECU) in 1996. It was part of the Environmental Management Project (EMP). The objective of the Project was to assess and evaluate the available data; identify data gaps; develop programs for the production of current and reliable information on vegetation changes and degradation over time; develop and implement a GIS database for the country of Nigeria. The project involved an establishment of historical statistical record on the status of vegetation and land use. Trends were also analysed, that is the extent and intensity of the changes in vegetation and land use, over an 18-year period.

## 2. The study area

The Nigerian coastal region is located in the southern part of the country and bounded to the south by the Atlantic Ocean (Figure 1). The region is endowed with immense natural resources, especially hydrocarbon deposits. Crude oil production and export from the region, in the range of two million barrels a day, dominates the Nigerian economy, accounting for over 90% of the Nation's total export earnings. The region is also home to the largest contiguous Mangrove forest in Africa and third largest in the world, following Indonesia and Brazil (Nwilo, 2003; Areola, 1977). Ibe (1988) identifies the swamps of the Niger delta as covering an area of about 9,000 sq. km., with the mangrove mainly vegetated, tidal flat and are flood plains, lying between mean low and high tides. The Niger River bifurcates to form deltas through which the river drains into the Atlantic Ocean. The area encompasses several ecological zones including coastal barrier islands, mangroves, freshwater swamp forest and lowland rainforests. The beaches of the region receive sand from the coastal rivers and these are re-distributed by longshore currents (Ibe, 1988). The region is endowed with hydrocarbon resources, which are the mainstay of Nigeria's economy. Since the discovery of crude oil in commercial quantities in the area in the late 1950s, the region has witnessed major infrastructural development resulting from oil and gas exploration, upstream damming of the Niger River, and construction of ports for crude oil and gas export.

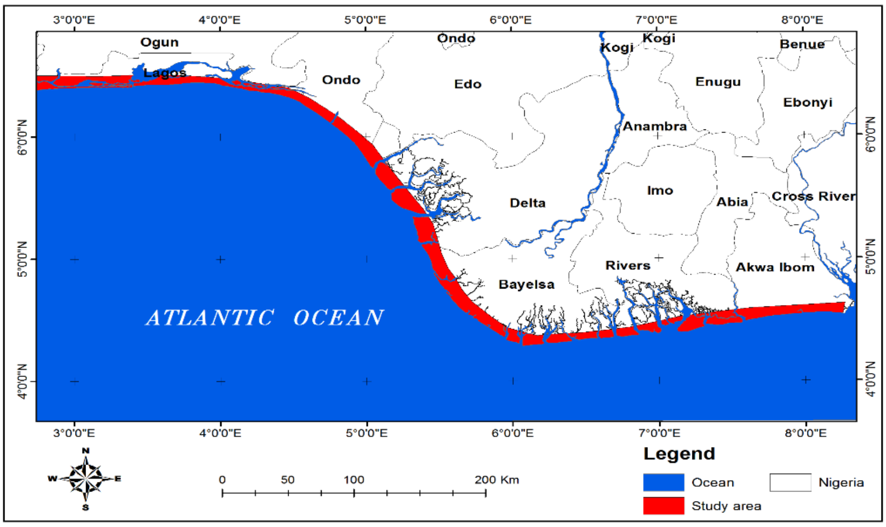

**Fig. 1:** Study Area Map.

## 3. Materials and methods

A Landsat TM image (1986), a Landsat ETM+ image (2000) and a Landsat OLI/TIRS (2016) were used to extract land use/cover change and to map the physical extent of the coastal areas of Nigeria for three-time series during the same season. Table 1 shows the information related to the satellite images used in this study.

**Table 1:** Information of Satellite Data Used in This Study

| Satellite data | Date | Spatial resolution (m) | Source of data |
|---|---|---|---|
| Landsat TM | 1986 | 28.5 | United States Geological Survey (USGS) |
| Landsat ETM+ | 2000 | 28.5 | United States Geological Survey (USGS) |
| Landsat OLI/TIR | 2016 | 28.5 | United States Universals Survey (USGS) |

### 3.1. Image pre-processing

Geometric rectification is critical for producing spatially corrected maps of land use/cover changes through time. The Landsat TM and ETM+ images were projected to Geographic coordinate system WGS84. The Landsat TM image was used as a reference to register the other Landsat images. Using the image-to-image registration, the first-degree polynomial equation was used in image transformation. The nearest neighbor resampling method was used to avoid altering the original pixel values of the image data.
The color composites for the three images were generated from Landsat TM and ETM+ bands 3, 2, 1 and Landsat OLI/TIR bands 4, 3 and 2. These color composites were selected to assist the selection of the training sites of each class and analysis purposes.

### 3.2. Classification system

Supervised classification has been widely used in remote sensing applications. A supervised classification system using maximum likelihood algorithm was consequently applied for land use/cover mapping from the three images. To map changes that had occurred the entire coast of Nigeria from 1986 to 2016, six non-thermal bands of both Landsat TM and ETM+ images were individually used as input for maximum likelihood classification system.
After land use/cover classification system has been chosen, training sites were carefully selected in sufficient homogeneity to maximize the accuracy of classification in the image. This step is probably the most important part of supervised classification, for it is the spectral signatures extracted from these sites that will determine the overall classification accuracy, and thus the utility of the final thematic map. Therefore, care should be taken in selecting training sites that represent typical examples of each land cover class and avoiding heterogeneous areas.

**Table 2:** Land Use/Cover Classes Used in This Study and Their Definitions

| Classes | Definition |
|---|---|
| Urban/ built up areas | Residential, industrial and commercial complexes, transportation, communication and utilities. |
| Water | All areas of open water, including streams, lakes and reservoirs. |
| Vegetation | Herbaceous, shrub and brush rangeland and areas of sparse vegetation cover. |

## 4. Results and discussions

### 4.1. Post classification comparison

The post-classification comparison approach is very advantageous when using data from different sensors with different spatial and spectral resolutions (Alboody, 2008). It was employed for detection of land use/cover changes, by comparing independently produced classified land use/cover maps. The main advantage of this method is its capability to provide descriptive information on the nature of changes that occurs (Mundia and Aniya, 2005). It is important to note that this method depends on the results of the classification of all images and data stored in GIS database. The GIS capabilities allowed the post-classification comparisons, and facilitated qualitative assessment of the factors influencing urban expansion. There are three land use/cover classes of interest along the Nigeria coast: Urban/ built up areas, Water and vegetation.

The spatial distributions of these classes were extracted from each of the land use/cover maps by using of GIS spatial analysis. The statistic land use/ cover distribution for the three-time series (1986, 2000 and 2016) as derived from the maps are presented in table 3. The urban/built-up area class increased from 8.9% in 1986 to 13.7% in 2000, and then to 23% in 2016. On the other hand, vegetation decreased from 55% in 1986 to 49% in 2000 and then to 43% in 2016.In contrast water class increased from 36% in 1986 to 37% in 2000 and then decreased to 32.9% in 2016.The spatial distributions of the three classes were extracted from each land use/cover maps of 1986, 2000 and 2016 as shown in Figures 2, 3, 4. The results indicated that the urban/built up areas increased from 977 $km^2$in 1986 to 1,503.8 $km^2$ in 2000, and then to 2615.9 $km^2$ in 2016, showing an expansion of urban/built up areas of 1,638 $km^2$ from 1987 to 2016.

**Table 3:** Results of Land Use/Cover Classification Statistics for 1986, 2000 and 2016

| Class name | 1986 Km$^2$ | % | 2000 Km$^2$ | % | 2016 Km$^2$ | % |
|---|---|---|---|---|---|---|
| Water | 3954.9969 | 36.025382 | 4069.7235 | 37.146139 | 3605.3136 | 32.905359 |
| Natural vegetation | 6046.2783 | 55.074503 | 5382.405 | 49.127555 | 4735.4202 | 43.219736 |
| Urban/ Built up areas | 977.0868 | 8.900115 | 1503.8514 | 13.726307 | 2615.8815 | 23.874905 |
| Total | 10978.362 | 100 | 10955.9799 | 100 | 10956.6153 | 100 |

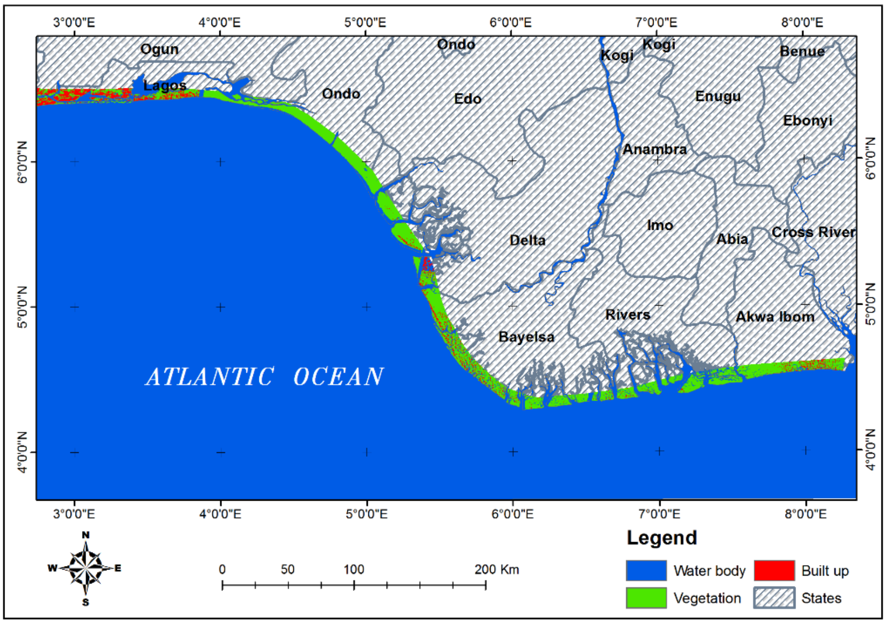


**Fig. 2:** Land Use/Cover Classification Map of the Coastal Region of Nigeria for the 1986.

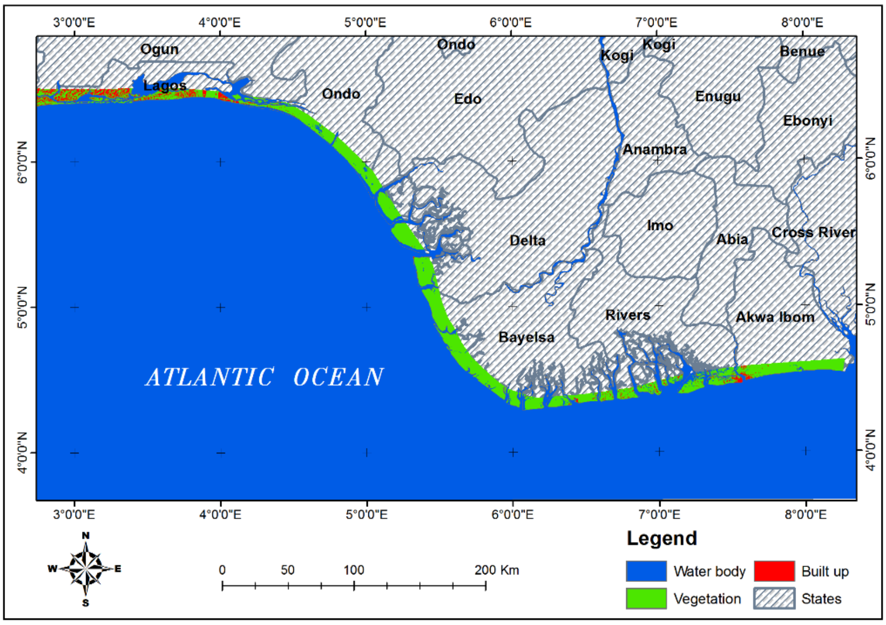


**Fig. 3:** Land Use/Cover Classification Map of the Coastal Region of Nigeria for the 2006.

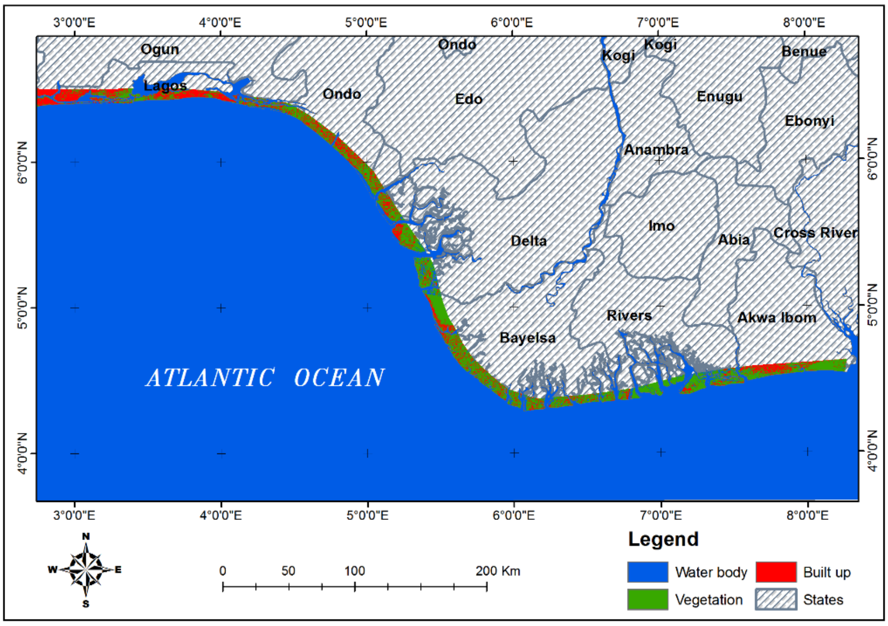


**Fig. 4:** Land Use/Cover Classification Map of the Coastal Region of Nigeria for the 2016.

## 5. Conclusion

Information about land use/cover patterns change over time is necessary not only for urban planning purposes, but also to improve the management of the use of land resources. This study has demonstrated the importance of using satellite remote sensing and digital image processing together with GIS technique in studying coastal land use/ land cover change, which is valuable in the management of regional coast effectively over a period of time.

The change detection results of the study area show that urban/built-up areas covered 977 km$^2$ (8.9%) in 1986 to 1,503.8 km$^2$ (13.7%) in 2000, and then to 2615.9 km$^2$ (23%) in2016. This represents a net increase of 1,638 km$^2$, which is mainly attributed to the fast increase population maybe due to large rural urban migration or increase in commercial activities along the coast or as a result of the coast lands being seen as a site for high class resident.

The study took the advantage of remote sensing and GIS techniques that are indispensable for dealing with the dynamics of land use/cover change along the entire coast of Nigeria over the last 30 years of the study period. Therefore, it is highly recommended that governments, coastal managers, urban planners and decision makers can use remote sensing and GIS techniques for effective monitoring of coastal land use/land cover change trends. Thus, it will improve their predictions toward the amount of coastal land use/ land cover changes and the location of future built-up areas along the coast, and enhance the existing urban strategies for better sustainable coastal management.

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