Mapping and Predicting Urban Sprawl Using Remote Sensing and Geographic Information System Techniques: A Case Study of Eti-Osa Local Government Area, Lagos, Nigeria

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Key words: GIS, Remote sensing, Urban sprawl

SUMMARY

Monitoring urban sprawl is a vital part of assessing current trends with a view of improving urban quality of life in the future as sprawl affects man and his environment adversely. Despite the researches carried out on sprawl in Lagos state, very few have focused on mapping and predicting urban sprawl in Eti-Osa local government area (LGA) using remote sensing and GIS techniques. This paper focuses on mapping urban sprawl in Eti-Osa LGA from 1984 – 2000 and 2000 – 2006 respectively using remote sensing and GIS techniques. These results were used to perform future prediction analysis of likely urban sprawl scenario in the study area.

The remotely sensed data used for the study were Landsat Thematic Mapper satellite scenes for 1984, Landsat Enhanced Thematic Mapper scenes for 2000 and 2006, and 1 metre high resolution IKONOS imagery of the study area dated 2005 for ground truthing.

The results of the study indicated the spatial extent of urban sprawl was larger from 2000 – 2006 (net increase 1250 hectares) in comparison with that of 1984 – 2000 (net increase 929 hectares). The key findings of the study showed that urban sprawl in the study area occurred at a fast leapfrog pattern in the eastern area of Eti-Osa LGA and a slower polynucleated pattern in the former Maroko town, an area that was evacuated and demolished in 1990.

The future prediction analysis was performed using Idrisi Land Change Modeller algorithm which runs on the multi layer perception neural network and Markov chain modelling. The results of 10 years future prediction for the study area, based on urban sprawl trends between 2000 and 2006 indicated that the spatial extend of urban sprawl was 2,220 hectares. Given the current trends of urban sprawl and results of the future simulation, it's recommended that the Lagos State government take urgent measures to mitigate the occurrence of this trend in the study area.

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1. INTRODUCTION

Urban sprawl can be explained as the expansion of human settlements to accommodate a growing population while depleting natural resources. Pathan et al. (1989, 1991) and Kumar et al. (2007) described urbanization as the process through which the productive agricultural lands, forests, surface water bodies and groundwater prospects are being irretrievably lost. Urban sprawl is often uncoordinated and extends along the fringes of metropolitan areas with incredible speed. Commonly, sprawl invades upon prime agricultural and resource land in the process. Land is often developed in a fragmented and piecemeal fashion, with much of the intervening space left vacant or in uses with little functionality (Torrens and Alberti, 2002).

Jat et al. (2008) noted the importance of remote sensing and geographic information system (GIS) as tools for monitoring and planning purposes. Unlike conventional surveying and mapping techniques, remote sensing has proven to be a cost effective and technologically sound method of analysing urban sprawl (Jat et al., 2008, Ji et al., 2006, Martinuzzi et al., 2007, Yang and Liu, 2005, Haack and Rafter, 2006). Danson et al. (1995) noted effectiveness of environmental remote sensing as a tool in obtaining information on the nature and properties of objects on the earth surface and in the atmosphere through the use of data from sensors which record electromagnetic radiation reflected or emitted from those objects. Remote sensing data are especially important in the areas of rapid land use changes where the updating of information is tedious and time-consuming. The monitoring of urban development is mainly to find out the type, amount, and location of land conversion that has occurred (Yeh and Li, 1999b). Lin et al (2007) noted that monitoring and simulating urban sprawl and its effects on land-use patterns and hydrological processes in urbanized watersheds are essential in land-use and water resource planning and management. The Eti-Osa LGA is surrounded by water bodies, which has resulted in the occurrence of; make shift houses along the beaches, the lagoon, the natural water drainage channels, and sometimes extending as far as 50 – 100 meters beyond the shore into the water bodies. Most of structures built beyond the shore would only be obvious on high resolution imagery or pan sharpened medium resolution imagery. The amount and location of changes can assist in prioritizing infrastructure improvements such as schools, health facilities, roads and other infrastructure (Haack and Rafter, 2006).

One of the prerequisite for understanding urban sprawl is successful land use change detection (Jain, 2009), a process that can be achieved using remotely sensed data. With a wide range of techniques used for land use change detection to study urban sprawl, it’s only a matter of choosing the right technique based on the available data. According to Lin et al. (2007), composition, configuration and connectivity are primary descriptions of landscape or land-use pattern, when land use change resulting in land use/ cover pattern changes is being assessed.

2. STUDY AREA

Although Lagos state is the smallest state in Nigeria, with an area of 356,861 hectares of which 75,755 hectares are wetlands, it has the highest population, which is over five percent of the national estimate (Olujimi, 2009). Lagos state is situated on a coastal plain along Nigeria's south-western Atlantic seaboard. The study area, Eti-Osa LGA, is located within the southern area of Lagos state (6º26'34"N, 3º28'29"E), just below the Lagos lagoon. Figure 1 shows the study area.

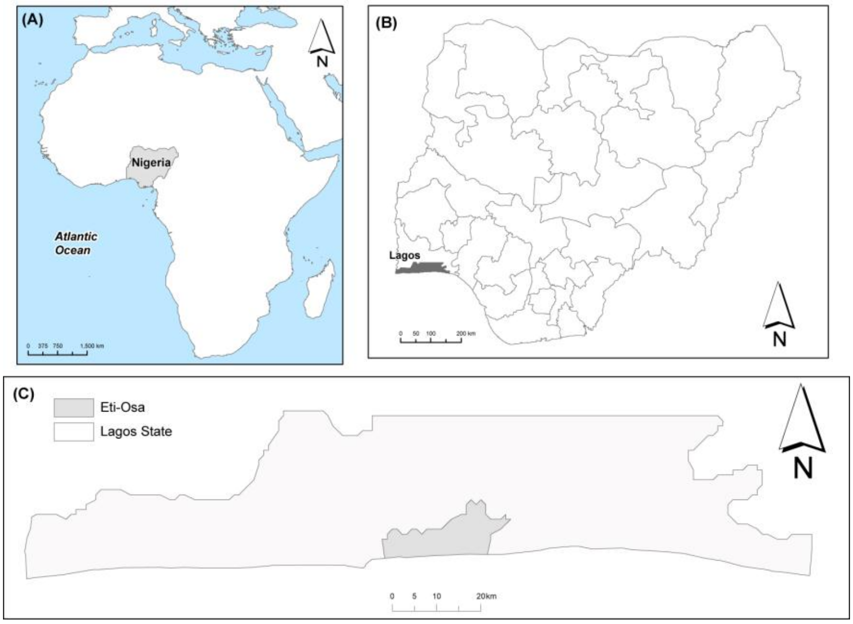

Figure 1 Map of study area showing: (a) location of Nigeria in Africa, (b) Lagos state in Nigeria, and (c) Eti-Osa LGA in Lagos state (Source: www.fews.net)

3. AIM AND OBJECTIVES

This paper aims to determine the spatial extent of urban sprawls around the shoreline of the Lagos coast facing the Gulf of Guinea using GIS and remote sensing methods.

The key objectives of this paper include:

1. Determine the spatial extent of urban sprawl using satellite data from 1984 to 2006.
2. Predict the future extent of urban sprawl in Eti-Osa LGA (2016).
3. Examine the causes and impacts of urban sprawl in the study area based on results generated.

4. Draw conclusions and make recommendations from results generated in the study.

4. DATA AND METHODS

4.1 Data used

Most of the data sourced and used for the study were secondary data sources. These are outlined and explained below:

a. GIS data from Lagos state government was not be readily available. Hence, the digital administrative maps of Nigeria, Lagos state and Eti-Osa LGA were sourced from the FEWS Net (Famine Early Warning Systems Network) as three level shapefiles.
b. Landsat satellite imageries downloaded for free from the GLCF (Global Land Cover Facility) and USGS (United States Geological Surveys). The Landsat path and row numbers of the study area are 191 and 55/56 respectively. For this study the images were for 3 years - 1984, 2000 and 2006. The data were processed to level 1 which means these had been radiometrically and geometrically corrected in GeoTiff format.
c. High resolution Ikonos imagery of the area for validation / accuracy assessment purposes.
d. Scanned topographic map of the Eti-Osa LGA from the Nigerian Federal Surveys.
e. Topographic map of Eti-Osa downloaded from Google maps (figure 2)
f. IKONOS satellite imagery of the study area acquired in 2005, used for accuracy assessment (figure 2).
g. Population/ census statistics for Eti-Osa LGA sourced from the National bureau of statistics, Nigeria.
h. A Digital elevation model (DEM) derived from a SRTM (Shuttle Radar Topography Mission) image over the study area downloaded from USGS using the Earth explorer.

The Landsat satellite data were available and downloaded from GLCF but the scenes with extreme cloud cover where abandoned. For maps, there is always some uncertainty as to the actual year of coverage as most maps are based on aerial photographs collected in one year, field work conducted in the following year or years and published perhaps in a third year (Haack and Rafter, 2006). The topographic sheet covering parts of Eti-Osa LGA was acquired as a scanned map and digitized giving rise to undershoot/ overshoot, misplaced points and dangle. These errors where corrected where possible, by careful post editing of the digitized map in comparison to the original map and the Google topographic map. All datasets were acquired in or georeferenced to the Universal Transverse Mercator (UTM) Zone 31 coordinate system with World Geodetic System (WGS) 84 datum.

4.2 Methods and techniques

4.2.1 <u>Image pre-processing</u>

Conversion of digital numbers to absolute radiance is important in data processing activity involving qualitative applications especially when reflectance of objects are measured over time using different sensors (Lillesand *et al*., 2008). This was done IDRISI using the RADIANCE function. Bands 1, 2, 3, 4, 5 and 7 where used in the classification process.

4.2.2 Classification of Landsat data

For this study, maximum likelihood classification (MLC) was used. It is preferred by most researchers as it’s a robust classifier that has been shown to be superior to other algorithms using medium and high resolution multispectral imagery (Baatuuwie and Leeuwen, 2011, Onojeghuo and Blackburn, 2011). Based on statistics (mean; variance/covariance), a (Bayesian) Probability Function is calculated from the inputs for classes established from training sites. Each pixel is then judged as to the class to which it most probably belongs (Eastman, 2006). The classes used and their definitions are shown in table 1.

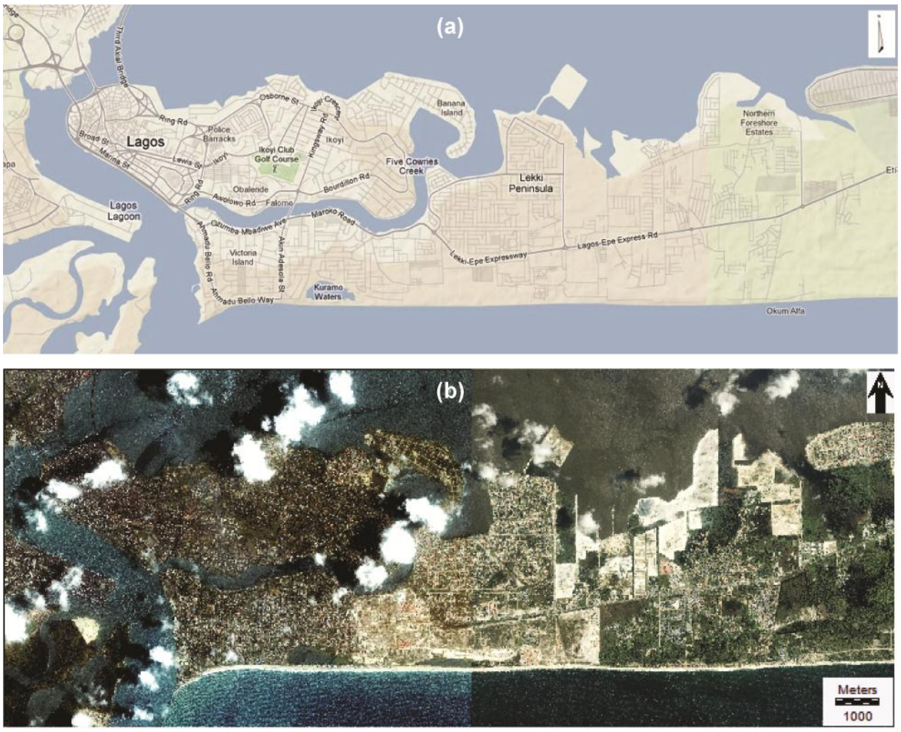

Figure 2 Image data sets used in study (a) A Google topographic map snapshot showing roads in Eti Osa LGA (Source: Google maps) and (b) IKONOS Satellite imagery showing Eti-Osa LGA in 2005

Table 1 Table showing the intended classes and their definitions

Urban	All built up structures including residential and commercial, roads, shanties, make shift buildings, freight containers and all other structures containing Aluminium, zinc or asbestos
Water	All water bodies including the ocean, lagoon, lakes creeks and rivers

Sand (bare)	All Sandy surfaces and deposits, Bare/ undeveloped surfaces which appear to be lightly vegetated
Vegetation	All forms of vegetation including those growing on land, in between urban structures and on water

4.2.3 Change detection and Urban Sprawl prediction

For this study, urban sprawl was investigated using the IDRISI Land Change Modeller (LCM). This integrated software is used for analyzing land cover change, projecting its course into the future, and assessing its implications for habitat and biodiversity change. LCM uses either a Multi-Layer Perceptron (MLP) neural network or Logistic regression while change detection is based on a series of empirically evaluated sub-models. A few site and driver variables were tested and those with the highest values used for predicting urban sprawl. Lower values could also be used if they are likely to influence final results. Using GIS operations buffers were created to the urban and sand (bare) reclassified maps for the years being assessed. A buffer was also created for the roads layer. The road basis layer was extracted as input for the prediction model and results from distance operations tested. Some of these were selected as static/ dynamic variables in the prediction model. Two land change models where created: 1984 to 2000 and 2000 to 2006. These results are presented in the results section of the paper.

4.2.4 Accuracy assessment

Accuracy assessment was conducted by selecting a sample of reference locations, and comparing the classifications at these reference locations to the classifications provided by the land cover map. The reference sample was selected independently of data used for training and /or developing the classification procedure (Stehman, 1997).

5. RESULTS

5.1 Image classification and accuracy assessment

Figure 3 shows the Landsat images (1986, 2000, and 2006) classified using MLC technique. The error matrix for the accuracy assessment was generated using the classified maps and a second signature map to produce kappa values. An IKONOS image and Google earth imageries were used as surrogate data to create a second training data set. The Google Earth imageries were dated 11/13/2000 (for the 2000 assessment) and 12/10/2006 (for the 2006 assessment). A second training data set was created to assess the accuracy of 1984 Landsat classified image. Table 2 presents the total number of pixels per class/ year used in the accuracy assessment matrix. The accuracy assessment was displayed as Kappa. The overall Kappa (k) coefficient was 0.9744 for the 1984 classification, 0.9514 for the 2000 classification and 0.9101 for the 2006 classification.

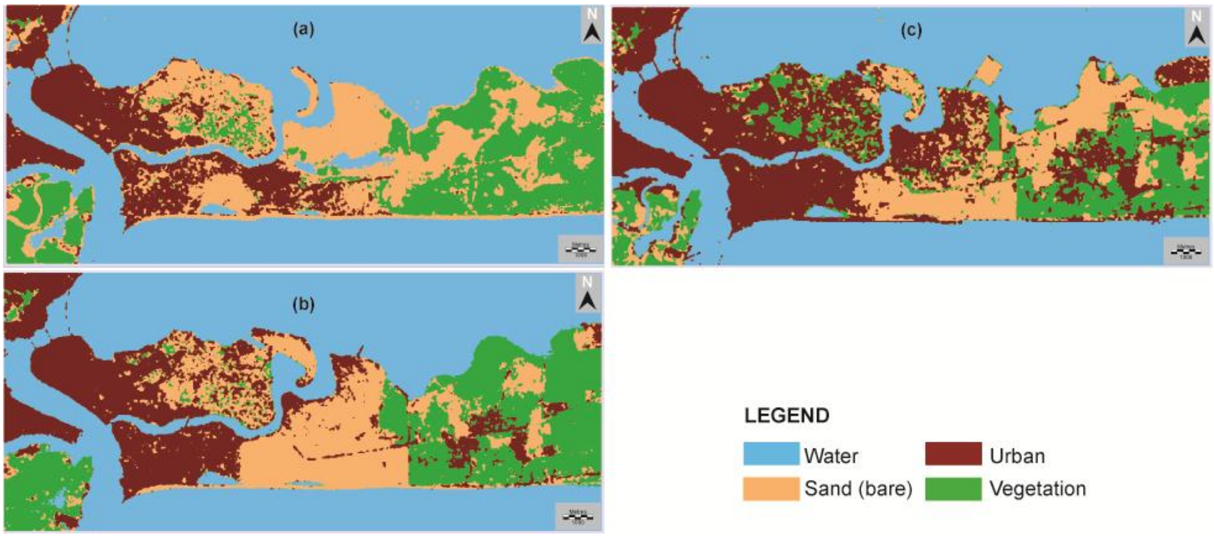

Figure 3 Results of Land Cover Classification of Eti-Osa LGA for (a) 1986, (b) 2000, and (c) 2006

Table 2 Total number of pixels used in ground truthing signature files per class and year.

	Water	Sand (bare)	Vegetation	Urban
1984	10899	1028	1129	1331
2000	3175	540	388	434
2006	6922	578	269	1025

5.2 Change detection and urban sprawl prediction

5.2.1 General land use change results

The results of analysis show that urban class had no net loss between 1984 and 2006. The urban area expanded by 929 hectares between 1984 and 2000 and 1250 hectares between 2000 and 2006, a shorter time interval. Figure 4 shows the gains and losses per class from 1984 – 2000 and 2000 – 2006. The highest net loss between 1984 and 2000 was in the Sand (bare) class (653 hectares), while it was the Vegetation class between 2000 and 2006 (706 hectares). Figure 5 shows the net changes per class from 1984 – 2000 and 2000 – 2006.

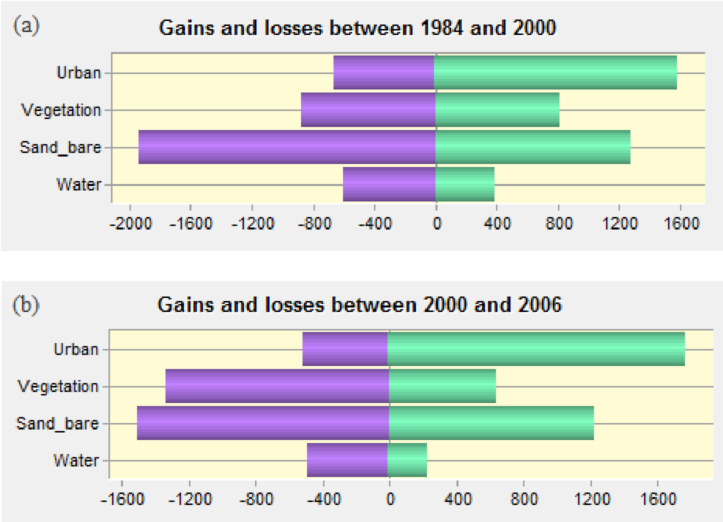

Figure 4 Graphs showing gains and losses in all classes from (a) 1984 to 2000 and (b) 2000 to 2006 in hectares

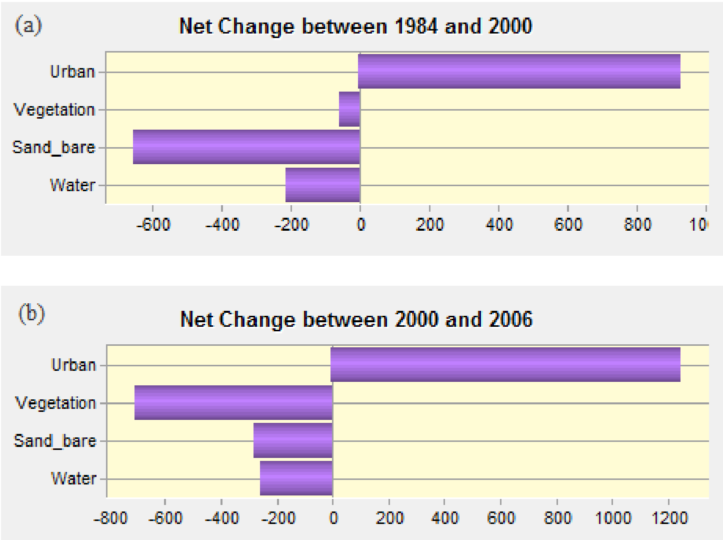

Figure 5 Graphs showing net changes in all classes from (a) 1984 to 2000 and (b) 2000 to 2006 in hectares

5.2.2 <u>Urban land use change results</u>

The urban class was used as an indication of the extent of urban sprawl. From the analysis, the highest contribution to the changes in the Urban class was from the Sand (bare) class with 559 hectares from 1984 – 2000 and 758 hectares from 2000 - 2006. Figure 6 shows the contributions to the net change in the urban class form other classes from 1984 to 2000 (a) and 2000 to 2006 (b). Map presentations of these contributions to the change in the urban class are shown in figure 7. Figure 8 shows the exchanges between the Sand (bare) and urban classes.

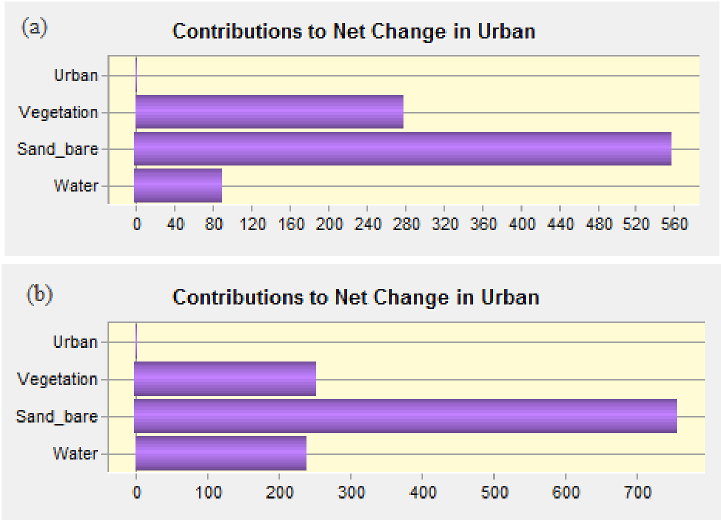

Figure 6 Graphs showing contributions to change in the urban class from other classes (a) 1984 to 2000 and (b) 2000 to 2006 in hectares.

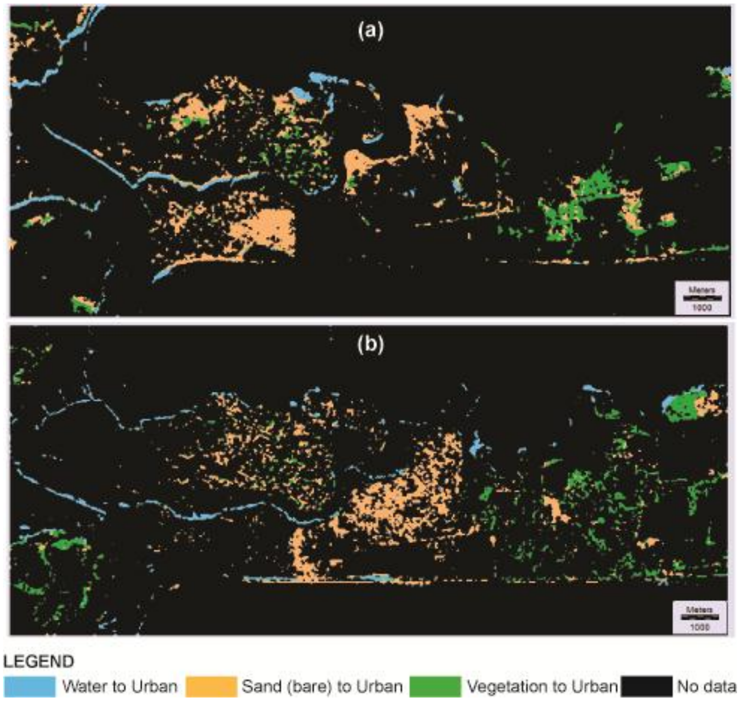

Figure 7 Maps showing the transitions to the urban class from other classes between (a) 1984 and 2000 (b) 2000 and 2006

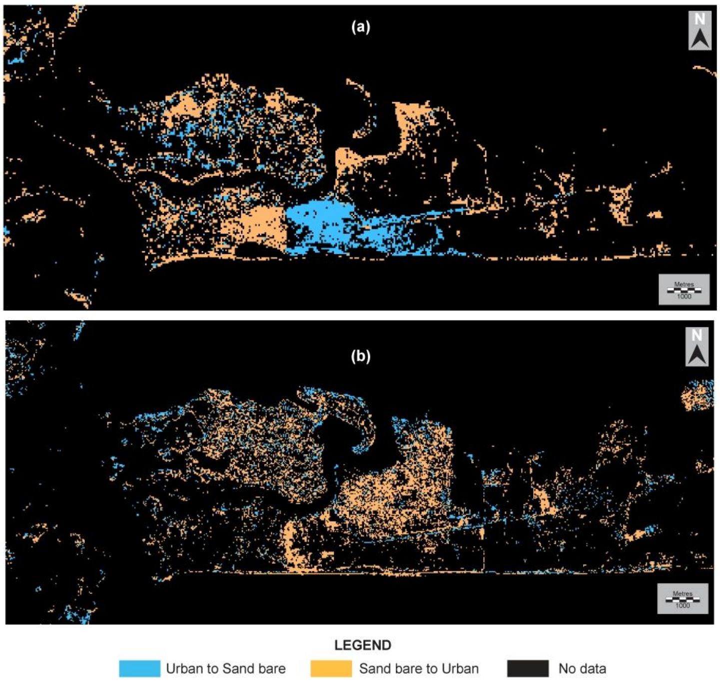

Figure 8 Map showing the exchanges between the Urban and Sand (bare) classes between (a) 1984 and 2000 (b) 2000 and 2006

5.2.3 Land Use Prediction

A prediction for urban sprawl in 2016 (10 years after the latest satellite scene acquired) was done to see what the LGA would look like with current trends. Two prediction methods where used with each one yielding a hard and soft prediction. The first included all the transition sub models while the second included none of the sub models. Figure 10 shows the results derived using and excluding the sub models. The results indicate that the impact of including or excluding the sub models was more visible with the soft prediction. The predictions performed assume that urban growth trend between 2000 and 2006 continued and there are no external forces driving change. This however is never the case as there could be natural disaster or changes in land use policies that could alter the trend of sprawl. Due to the low lying topography and close proximity to the Atlantic Ocean, the area is prone to flood disasters.

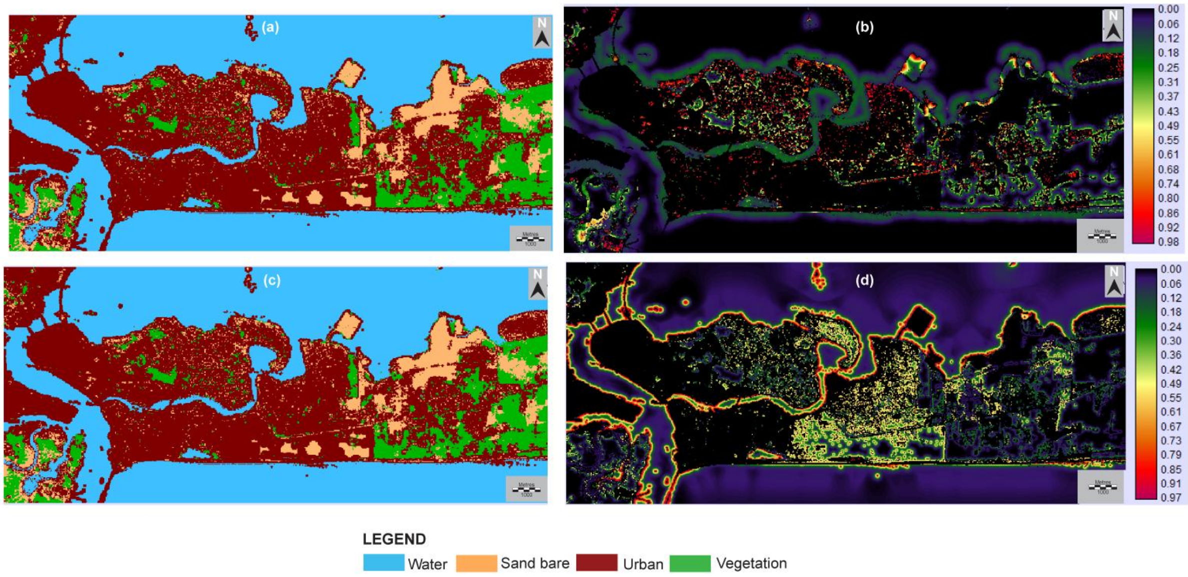

Figure 9 Possible land cover classes of the Eti-Osa LGA in 2016 (a) using a hard prediction (including all soft models), (b) using a soft prediction (including all soft models), (c) using a hard prediction (including no sub model) and (d) using a soft prediction (including no sub model)

The prediction revealed that by 2016, the Urban class would have increased by 2220 hectares with most of it as a result of a loss of 1192 hectares from the Sand (bare) class (see figure 10).

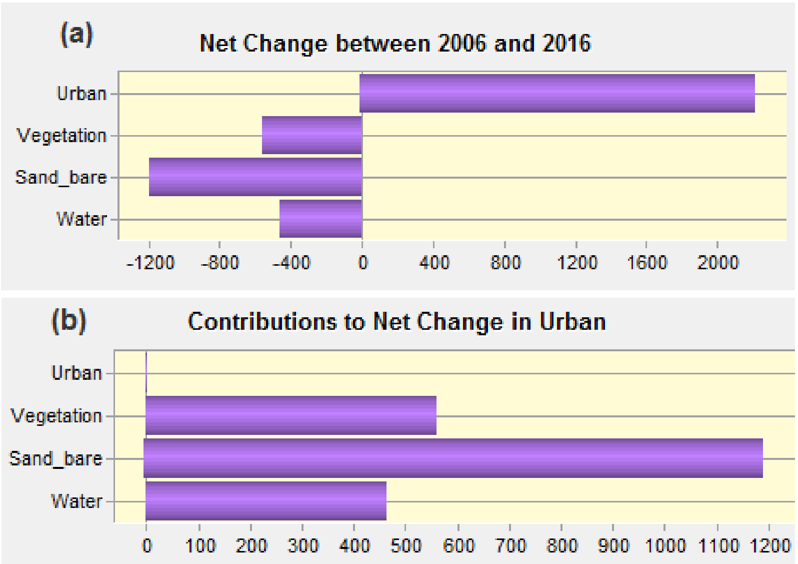

Figure 10 Graphs showing changes in classes from 2006 to 2016 and contributions to net change in the urban class

6. DISCUSSION

6.1 Causes and impacts of urban sprawl

The change analysis reveals that a lot of reclamation of swamps, vegetation and water bodies had taken place over time. Some of the areas reclaimed to sand (bare) in 2000 had urban infrastructure by 2006. Figure 11 shows a little area as it transitioned from water to urban. Adeaga (2009) lists increasing encroachment of urban facilities on urban planes, unprecedented land reclamation, and inadequate drainage paths and blocking of existing ones (some of the make shift drainage channels created in these reclaimed areas tend to be blocked due to poor refuse disposal attitudes) and poor management as causes of heavy flooding in Lagos in general.

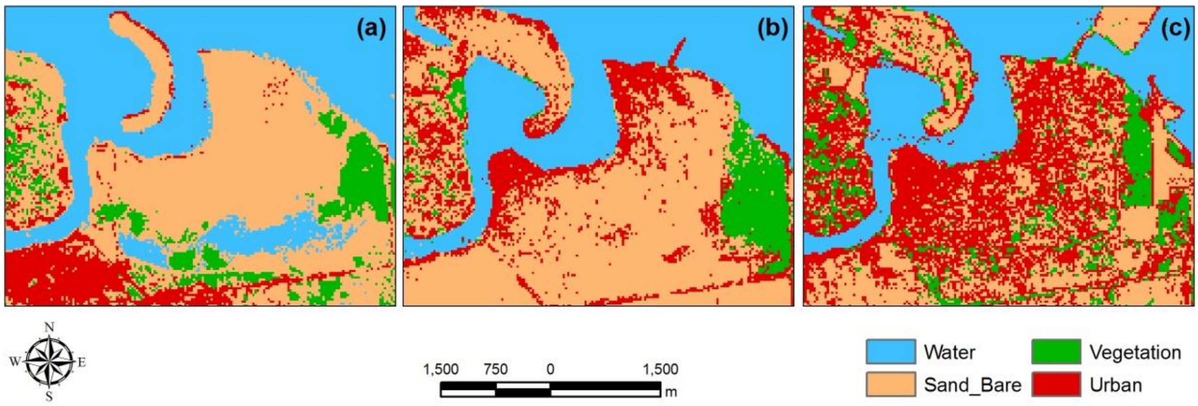

Figure 11 Snapshot of an area in Eti-Osa showing its transition from water to sand (bare) and then urban through 1984, 2000 and 2006

Poor urban planning or lack of planning as urban development increases is evident in not preventing new development on areas at risk of flooding, leaving unprotected areas that should be left undeveloped, for instance wetlands, because of their role as buffers against flooding risks and also not providing safer sites for the urban poor (Adelekan, 2009).
Kolawole (2011) noted that when torrential rainfall occurs in Eti-Osa, there is an influx of alligators and crocodiles into the urban area; putting residents at risk. These reptiles lived in those swamps before they were forced away due to urban encroachment. The study has demonstrates the effects of urban sprawl on changes to the flora/ fauna and wildlife.

7. CONCLUSION AND RECOMMENDATION

Communities worldwide need data to compensate for and adapt to current growth while planning for expected future change and its impacts on infrastructure, as well as the surrounding environment (Goetz et al., 2003).
This research set out to monitor urban sprawl along the Lagos shoreline with emphasis on the

Eti-Osa LGA, an area where urbanisation was concentrated on the western area. The main data source where the free and available medium resolution Landsat imageries. The research has found that indeed urban sprawl is occurring here and at an alarming speed putting lives at risk and ruining the beauty of the landscape.
Mapping urban sprawl in Lagos proved to be a nearly unattainable task due to the lack of a adequate spatial information. Mapping could be done better in future when data is more readily available to researchers. However, this paper has demonstrated the ability to map urban sprawl in the study area using remote sensing and GIS techniques, a cost effective means of data gathering.

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BIOGRAPHICAL NOTES

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