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Land Cover Dynamics Associated with the Spatial Changes in the Wetlands of Lagos/Lekki Lagoon System of Lagos, Nigeria

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ABSTRACT

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Urban sprawl is one of the severe land use/land cover (LULC) change agents, especially in rapidly urbanizing developing countries such as Nigeria. Land use/land cover is among the key drivers of environmental change as it leads to dramatic changes in both landscape patterns and ecosystem functions. Lagos metropolis, the nation's economic nerve center, is on a low-lying coastal landscape endowed with lagoons, wetlands, and other ecological assets. The Lagos/Lekki Lagoon system, with its catchments and wetlands, constitute about 71% of the state. With rapid urbanization and intense development pressure, some of the fringing wetlands and other land cover in the area have been converted to urban landscape. Just like the wetlands, the precise nature of these land cover changes is comprehensively unknown. In this ongoing study, land cover dynamics linked to the spatial changes in the wetlands fringing these lagoons are also comprehensively assessed. With low topography, high energy, and erosive coastlines, the extent of coastal erosion (1985–2009) in the area is assessed with remote sensing data and geographic information system (GIS) using topographic maps as baseline data. ENVI software is deployed for the processing of Landsat imageries, and unsupervised classification is used for image classification. The objective is to establish the locations and magnitude of the land cover dynamics between 1984 and 2006, ultimately leading to implications for flood risk on affected areas. Results show that as swamps decreased from 344.75 km^2 to 165.37 km^2 and mangroves decreased from 88.51 km^2 to 19.95 km^2, both between 1984 and 2006, built-up areas increased from 48.97 km^2 to 282.78 km^2 at 10.61 km^2/y; water body decreased from 685.58 km^2 to 654.98 km^2 at –0.16 km^2/y; bare land increased from 24.32 km^2 to 72.73 km^2 at 2.2 km^2/y; and vegetation decreased marginally from 1369.15 km^2 to 1361.08 km^2 at –0.37 km^2/y all between 1984 and 2006. Evidently most of the growth in built-up areas occurred in previous wetland areas and some vegetated areas. Most of the increase in built-up area occurred in the Eti-osa Local Government Area (LGA) and then in the Kosofe LGA. The decrease in the water body is attributable to anthropogenic action of reclamation and accretion arising from island formation on the Lekki Lagoon. Some of the consequences of the land cover (LC) dynamics are briefly highlighted.

ADDITIONAL INDEX WORDS: *Urbanization, land cover change, coastal landscape, lagoons, remote sensing, wetlands, built up.*

INTRODUCTION

Urbanization has been known to be an important human activity that influences the environment. Urbanization, which is the conversion of land to uses associated with human habitations and economy, has shown an increasing trend worldwide as humanity experiences a shift to urban living (Pauleit, Ennos, and Golding, 2005; Weng, 2001; Xiao *et al.,* 2007; Zhang *et al.,* 2008). Of this shift, over 95% of the net increase in global population is in the cities of the developing world (Zhang *et al.,* 2008). As a consequence, rapid urbanization or urban sprawl is one of the severe land use/land cover (LULC) change agents, especially in developing countries such as Nigeria. Increasingly, LULC is recognized as one of the key drivers of environmental change (Shi *et al.,* 2009). This is because it leads to dramatic changes in both landscape patterns and ecosystem functions (He and Yin, 2010; Herold, Goldstein, and Clarke, 2003; Luck *et al.,* 2001; Turner, 1989). The capacity of ecosystems and environmental systems to perform functions that support human systems can be upset when rapid and haphazard urban growth occur in areas of highly vulnerable environmental assets (Flores, Olivas, and Chavez, 2008). The conversion of large natural areas or agricultural areas to built-up areas can lead to biodive rsity loss, an increase in impervious surfaces, flooding, impairing of air quality, and influence erosion and sediment yield (CEO-NCSU, 2005). Reflectivity of the land surface is altered, and the hydrological cycle and exchange including aquifer recharge may be similarly affected (Odunuga and Oyebande, 2007; Xiao *et al.,* 2007). To understand the interactions between spatial patterns and processes in landscapes requires accurate quantification of

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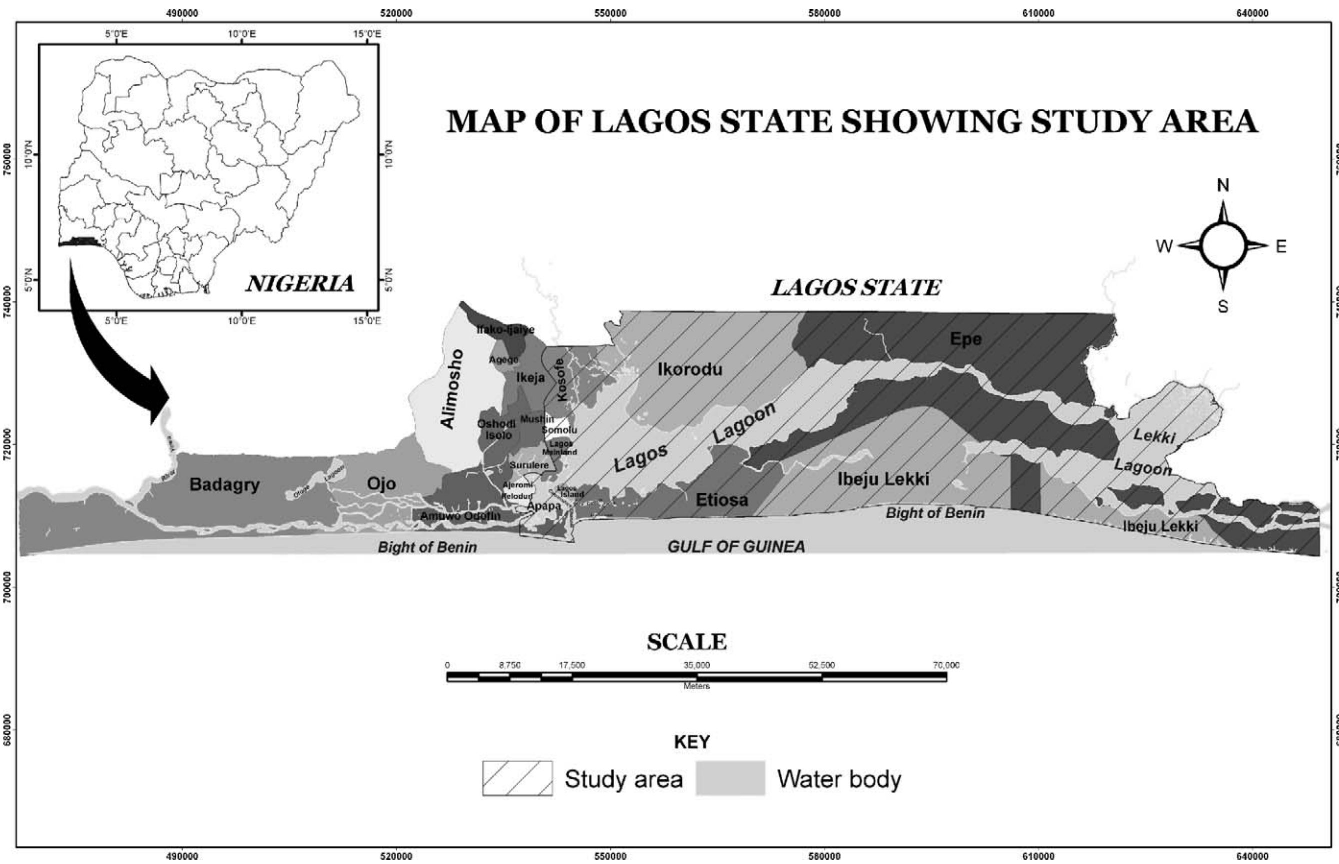


Figure 1. Map of the study area (Source: Federal Surveys 7.5′ Topographic Series, 1984).

those spatial patterns and their temporal changes (Weng, Liu, and Lu, 2007; Wu *et al.,* 2000). In other words, quantifying these changes is potentially useful in tracking the capacity of natural ecosystems to perform intrinsic functions in support of human systems (Flores, Olivas, and Chavez, 2008). For instance, quantified estimates of LULC change can be important for estimating impervious surface and bare/disturbed soils as inputs to watershed water quality and hydrologic assessment (CEO-NCSU, 2005). Therefore, analyzing and quantifying the landscape/land cover patterns and their dynamics are important in assessing the effects of the changes and for sustainable development. This is particularly essential as Pauleit, Ennos, and Golding (2005) suggested that little data is widely available to regularly assess the extent of past and current urban development and to predict their environmental consequences. Fortunately, in recent years, satellite imagery and remote sensing data along with geographic information system (GIS) have provided accurate and timely means for tracking and monitoring land cover spatiotemporal trends in order to assess critical ecological processes at various scales (Flores, Olivas, and Chavez, 2008; Lu *et al.,* 2004; Olaleye, Abiodun, and Igbokwe, 2009).

Lagos metropolis, the current economic capital of the nation, and many of its districts were developed on a coastal landscape of low-lying tidal flats, estuaries, wetlands, and other ecological assets. Rapid and *ad hoc* urbanization has led to extensive reclamation of wetlands and encroachment on these ecological assets (Abegunde, 1988; Adeniyi, 1980). The Lagos/Lekki Lagoon system, which is the largest of the coastal barrier–lagoon complex (Ibe, 1988) with their fringing wetlands and catchments, occupies about 71% of the total area of the state. Parts of this area have and are still undergoing intense development pressure as some of the fringing wetlands have been converted in recent decades. Some recent studies have examined land cover changes (Odunuga and Oyebande, 2007; Olaleye, Abiodun, and Igbokwe, 2009) and wetland conversion (Taiwo and Areola, 2009) in parts of this area. A change detection of the NW portion of Lagos Lagoon occupied by the Lower Ogun River estuary revealed a rapid increase in built-up area from 1965 to 2005 (Odunuga and Oyebande, 2007). A similar study in the Lekki Peninsula portion equally showed a phenomenal increase in built-up area from about 41 ha in1964 to 7271 ha in 2003 (Olaleye, Abiodun, and Igbokwe, 2009). Despite these studies, critical gaps at the local council planning level still exist in the availability of comprehensive data on magnitudes and precise locations of the resulting land cover for the entire study area.

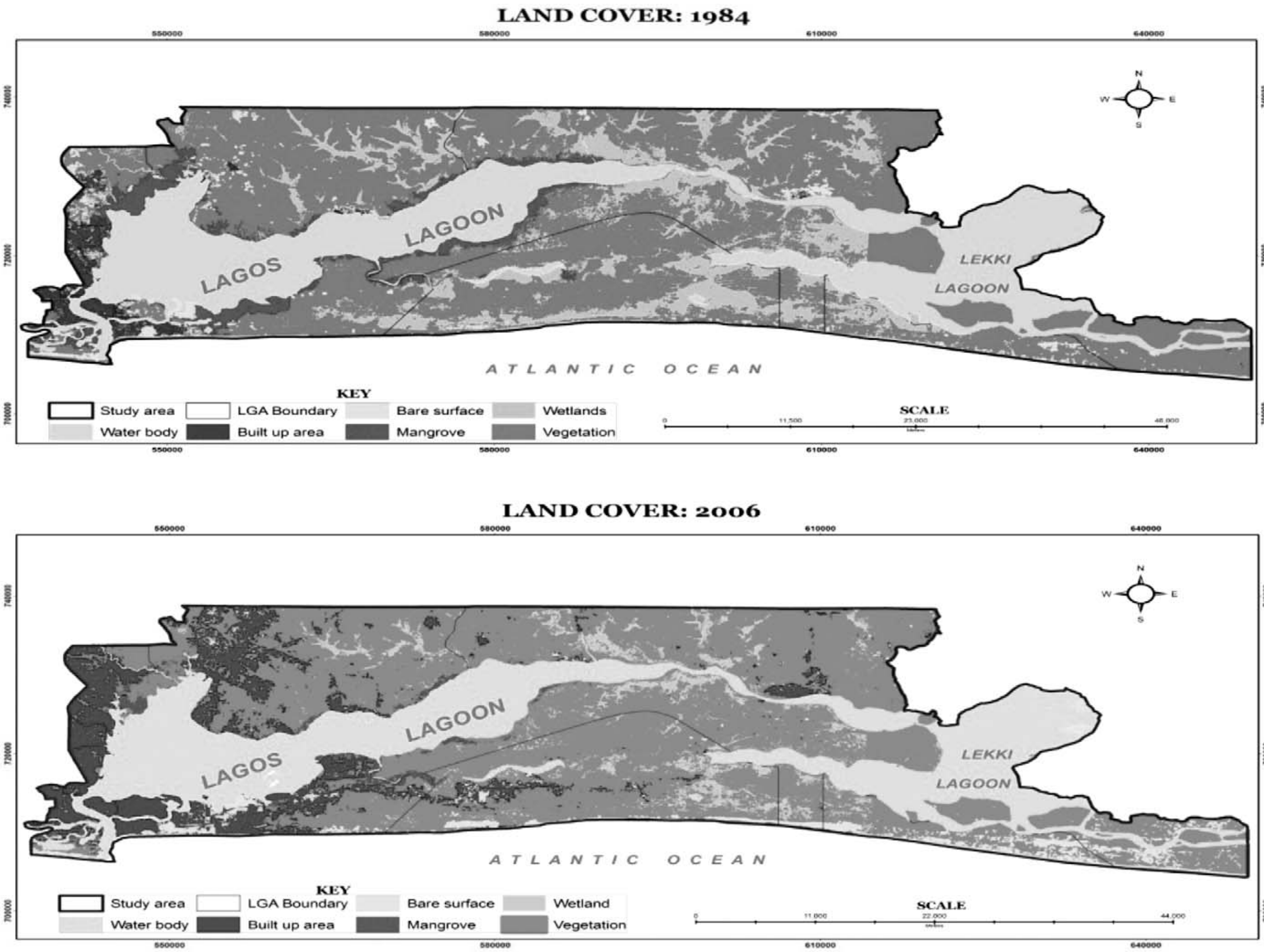


Figure 2. Land cover for 1984 and 2006.

Having assessed the spatial changes in the wetlands fringing these lagoons, it becomes imperative to identify the land cover types that succeeded and constituted the resulting landscape of the area. Part of this on-going study, therefore, is to assess the land cover dynamics associated with urbanization and wetland conversion in this area. With low topography, high energy, and high turbulence generated by breaking waves on the barrier coastlines of this area, beach profiles are characteristically steep, and the beaches are erosive; Ibe (1988) had earlier recorded erosion rates of 25–30m/y at Victoria Beach east of the east mole. The extent of coastline changes occasioned by erosion on the coastlines of the area (1985–2009) is thus also assessed. The objective is to establish locations and magnitude of these land cover and coastal landscape changes between 1984 and 2006. The study seeks to fill this information gap by addressing the following questions. (1) What are the land cover types in the area at the earlier static year and what have they changed to in recent times? (2) What are the implications of these changes with increasing imperviousness and wetland conversion in terms of flood risk to the resulting coastal landscape? The former question is addressed in this report.

Table 1. *Land cover change between 1984 and 2006.*

Class	1984	%	2006	%
Bare land	24.32	0.95	72.73	2.84
Built-up area	48.97	1.91	282.78	11.04
Mangrove	88.51	3.46	19.95	0.78
Vegetation	1369.15	53.46	1361.08	53.14
Water body	685.58	26.77	654.98	25.57
Swamps	344.75	13.46	165.37	6.46
Cloud cover/ mixed pixels	0	0	4.38	0.17
TOTAL	2561.26	100	2561.26	100

METHODS

Baseline data for the study was obtained from 1 : 25,000 topographic maps, which were scanned, georeferenced, digi-

Table 2. *Land cover distribution across LGAs in 1984.*

S/N	LGA	Swamp	%	Water	%	Vegetation	%	Man-grove	%	Built-up	%	Bare land	%
1	Amuwo odofin	0.06	0.02	4.24	0.84	10.53	0.77	3.16	3.57	NIL	NIL	1.74	7.17
2	Apapa	0.01	0	7.45	1.48	7.45	0.54	2.3	2.6	8.58	17.52	0.65	2.67
3	Epe	163.38	47.39	398.85	79.36	586.85	42.87	24.76	27.98	0.71	1.45	3.62	14.9
4	Etiosa	12.69	3.68	30.41	6.05	109.24	7.98	22.65	25.59	9.06	18.51	6.85	28.19
5	Ibeju Lekki	125.78	36.48	14.14	2.81	308.04	22.5	1.55	1.75	NIL	NIL	2.29	9.43
6	Ikorodu	41.23	11.96	26.82	5.34	299.56	21.88	17.2	19.43	2.27	4.64	3.91	16.09
7	Kosofe	1.58	0.46	10.87	2.16	40.19	2.94	15.87	17.94	8.34	17.02	3.91	16.07
8	Lagos Island	NIL	NIL	3.15	0.63	0.84	0.06	NIL	NIL	4.55	9.29	0.05	0.23
9	Main	NIL	NIL	5.72	1.14	4.76	0.35	0.73	0.83	7.52	15.36	0.58	2.37
10	Somolu	NIL	NIL	0.94	0.19	1.6	0.12	0.29	0.32	7.93	16.2	0.7	2.89
	TOTAL	344.74	100	502.58	100	1369.04	100	88.51	100	48.97	100	24.32	100

tized, and input into ArcGIS 9.3. Then two scenes of Landsat TM of December 1984 and ETM$^+$ of 2006 with relevant ancillary data and field reconnaissance were processed with bands three, four, and five for color composite. Using ENVI 4.8 software and unsupervised classification, six information classes of static land cover for the two dates were extracted. An overlay of the resulting land cover maps of the two dates produced the land cover change, which was vectorized and exported to ArcMap as shapefiles for editing and area calculations.

To assess the extent of coastal erosion in the area in recent years prior to the commencement of the Eko Atlantic City project on Victoria Beach, Google Earth high resolution imageries of 2000, 2004, 2006, and 2008/2009 were used to extract coastline locations for those years. These were then projected on to the baseline topographic map of 1984–85 to evaluate shoreline changes in segments of Etiosa and Ibeju/Lekki Local Government Areas (LGAs). It is noteworthy that a discrepancy or displacement of ±13–18 m was observed between two overlaid Google Earth imageries.

THE STUDY AREA

The study area covers the eastern half of Lagos State (Figure 1). The location is at about 3°20′ E and 4°20′ E and 6°23′ N and 6°42′ N, while covering an area of about 2561.26 km^2 of land and water. On the north and east, it is bounded by Ogun State; on the south, it is bounded by Bight of Benin/Atlantic Ocean. This constitutes about 71% of the total area of the state, about 3632 km^2. The Lagos/Lekki Lagoons are part of the barrier–lagoon complex, which spans the entire coastline of Lagos State from the Nigeria/Benin Republic border in the west to the Ogun State border in the east (Ibe, 1988). Lekki Lagoon has four arms. Two of these connect the Niger Delta in the east: one connects Lagos Lagoon and the other to the west ends in a swampy dead end in the middle of Lekki Peninsula. Lagos Lagoon has two arms: the eastern arm links Lekki Lagoon, while the western arm is the only direct connection to the sea. This only direct outlet links Lagos Lagoon through Commodore Channel to Bight of Benin/Atlantic Ocean. With direct connection to the sea, salinity is generally higher in the Lagos Lagoon, while both lagoons have shallow depths of 1.5–3.0 m with negligible bottom relief (Ibe, 1988). Of the 20 LGAs in the state, 10 are coterminous with these lagoons and their only direct outlet to the Atlantic Ocean. These include Apapa, part of Amuwo–Odofin, Epe, Etiosa, Ibeju/Lekki, Ikorodu, Kosofe, Lagos Island, Mainland, and Shomolu LGAs.

The climate of the area is controlled namely by two air masses: the tropical maritime and tropical continental air masses. The former is wet and originates from the Atlantic Ocean, while the latter, which is warm, dry, and dusty, originates from the Sahara Desert. Two seasons are generally experienced in the area: the rainy season (April–October) and the dry season (November–March).

RESULTS

Results show that just as swamps decreased from 344.75 km^2 to 165.37 km^2 and mangroves decreased from 88.51 km^2 to 19.95 km^2, both between 1984 and 2006, built-up areas increased from 48.97 km^2 to 282.78 km^2 at 10.61 km^2/y; water body decreased from 685.58 km^2 to 654.98 km^2 at –0.16 km^2/y; bare land increased from 24.32 km^2 to 72.73 km^2 at 2.2 km^2/y; and vegetation decreased marginally from 1369.15 km^2 to

Table 3. *Land cover distribution across LGAs in 2006.*

S/N	LGA	Swamp	%	Water	%	Vegetation	%	Man-grove	%	Built-up	%	Bare land	%
1	Amuwo–Odofin	NIL	NIL	6.01	1.27	7.21	0.53	0.88	4.41	1.54	0.55	1.33	1.84
2	Apapa	NIL	NIL	7.32	1.54	3.51	0.26	0.95	4.79	14.53	5.14	0.23	0.32
3	Epe	91.37	55.25	377.02	79.48	665.31	48.88	3.93	19.7	19.63	6.95	19.02	26.15
4	Etiosa	1.12	0.68	24.85	5.24	56.3	4.14	4.52	22.68	77.97	27.61	23.06	31.71
5	Ibeju Lekki	53.94	32.62	13.8	2.91	344.34	25.3	0.46	2.31	18.03	6.38	19	26.13
6	Ikorodu	18.87	11.41	26.54	5.6	255.41	18.77	4.7	23.57	81.1	28.72	8.93	12.28
7	Kosofe	0.07	0.04	10.21	2.15	26.74	1.96	4.35	21.82	41.66	14.75	0.65	0.89
8	Lagos Island	NIL	NIL	3.04	0.64	0.35	0.03	NIL	NIL	5.19	1.84	0.02	0.03
9	Main	NIL	NIL	4.88	1.03	1.45	0.11	0.14	0.7	12.66	4.48	0.23	0.31
10	Somolu	NIL	NIL	0.67	0.14	0.42	0.03	NIL	NIL	10.13	3.59	0.25	0.35
	TOTAL	165.37	100	474.35	100	1361.05	100	19.92	100	282.4	100	72.72	100

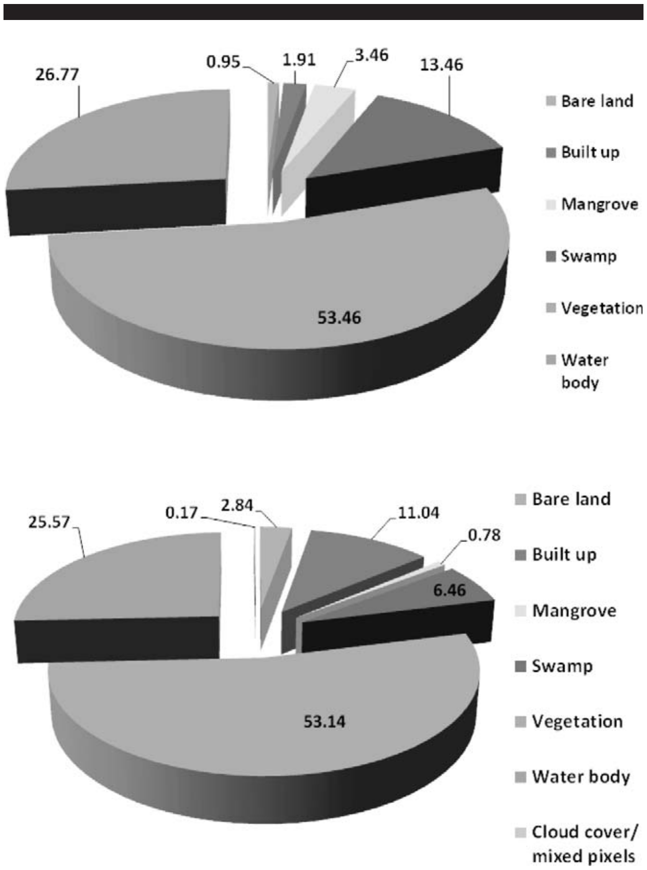


Figure 3. Percentage of distribution of land cover for 1984 and 2006.

1361.08 km^2 at –0.37 km^2/y all between 1984 and 2006 (Figure 2; Table 1).

Results also indicate that annual erosion rates in Etiosa LGA from 1985–2006 ranged from 4.23–6.19 m, with the rate of 4.70 m near Kuramo Waters in the first segment. Erosion rates in the Ibeju-Lekki LGA of the same period, however, ranged from 7.64–15.95 m, with a total loss of 335 m of beach line in segment five within the period. Etiosa LGA, for which data was available from 2006–09, indicates increased annual rates of erosion of 8.75–10.11 m in those years.

DISCUSSION

The highest increase in built-up area from 1985–2006 occurred in the Ikorodu LGA (78.83 km^2 or 3.58 km^2/y) followed by Etiosa LGA (68.91 km^2 or 3.13 km^2/y) and the Kosofe LGA with 33.32 km^2 or 1.51 km^2/y (Tables 2 and 3; Figure 3). The Ibeju-Lekki LGA, which had no built-up area in the base year, recorded 18.03 km^2 in 2006. Significantly, most of the built-up area in this LGA and the eastern portion of the Etiosa LGA reflect linear development, occurring mostly along the main access spine, the Lekki–Epe Expressway (Figure 4). These increases in built-up area coincided with some areas of high decline or conversion of mangroves and swamps. Over those years, the Ikorodu LGA experienced decreases in mangroves and swamps of –12.5 km^2 and –22.36 km^2, respectively; Etiosa recorded similar decline in mangroves and swamps of –18.13 km^2 and –11.57 km^2, respectively, while Kosofe recorded decline in mangroves and swamps of –11.52 km^2 and –1.51 km^2, respectively. Although the Epe LGA recorded the highest decline in mangroves (–20.83 km^2) and swamps (–72.01 km^2) and Ibeju/Lekki lost –1.09 km^2 and –71.84 km^2, respectively, over the period, these did not match with the increases in built-up area. The Ikorodu LGA, with the highest growth, shows this urban growth concentrated mainly on the western part with some dispersion of built-up area toward the eastern flanks of the LGA. This reflects the need for attention to the possible drivers of this rapid growth and concentration along with the consequence of the dispersion. The marginal decline in vegetated areas reflects their location away from areas of development pressure in more rural LGAs, such as Epe, Ibeju/Lekki, and Ikorodu. Similarly, the decrease in water bodies, such as in Five Cowrie Creek, and a part of Lagos Lagoon coincides with the appearance of Banana Island over a prior Horse-shoe Island; the sand filling of portions of Ozumba Mbadiwe Street, Victoria Island and Ogudu Foreshore on Lagos Lagoon; and the appearance of several small islands around the fresh-water delta on Lekki Lagoon. The high increase in bare land in Etiosa, Epe, and Ibeju/Lekki LGAs is attributable to both reclamation of wetlands and clearing of large tracts for the development of Free Trade Zone (FTZ) Phase 1 and associated development in those areas.

Erosion occurred along the coastline in 1985–2006 with generally higher erosion rates in Ibeju-Lekki LGA (Figure 5). However, the rates in Etiosa LGA are still within the annual range of 2–6 m recorded at Badagry Beach (Ibe, 1988), while all are still within the range for the Nigerian coastline and well below the rapid rates earlier recorded at Victoria Beach. Yet, these losses are no less environmentally and economically significant.

Some of the environmental consequences of this land cover change and alteration of coastal habitats are known to include increased surface temperature, runoff, flooding, erosion, pollution, threats to groundwater, effects of climate change, and rising sea levels (Brody *et al.,* 2007; Okude and Ademiluyi, 2006a, 2006b; UNEP, 2002; Weng, 2001; Weng, Liu, and Lu, 2007). Studies have argued that as mangroves and coastal wetlands provide protection for coastal areas (UNEP, 2002), their depletion and replacement with impervious surfaces would increase flooding and disrupt associated marine processes, food web, and biodiversity among others. Perhaps the perennial severe flooding in the Lagos coastal area (Okude and Ademiluyi, 2006b) may have been exacerbated by the land cover changes and large scale conversion of mangroves and wetlands observed here and in similar studies.

An effect of urbanization is that the thermal environment will be reasonably altered. This happens because the increased imperviousness from the increased built-up area alters the reflectivity and thermal capacity of the resulting landscape causing conversion of net radiation into ground and sensible heat. This consequently affects and results in elevated surface temperature or urban heat island enlargement (Xiao *et al.,* 2007). This consequence has been observed in a tangential study by Nwilo *et al*. (2012) using remote sensing and methods

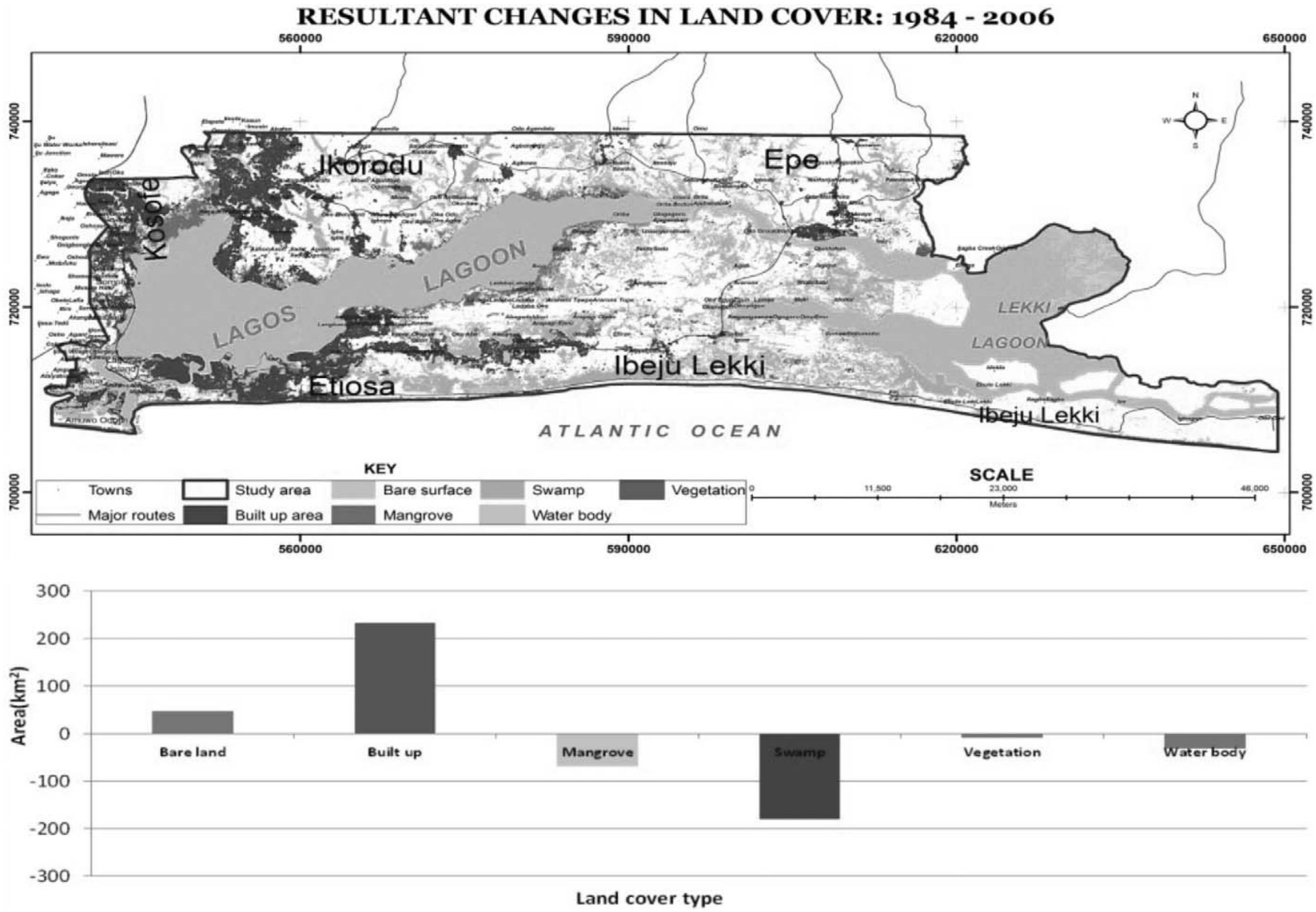


Figure 4. Resultant changes in land cover.

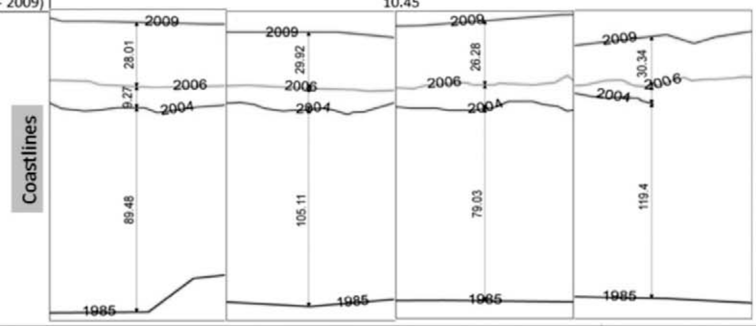
prescribed in Weng, Lu, and Schubring (2004). In this study, the phenomenal growth in built-up area in parts of the metropolis, including the study area, resulted in significant increase in surface temperature values by an average of about 1°C over the study period in spite of the decline in industrial production. For instance, an area in Ikorodu council with the highest growth in built-up area reflected a temperature increase of about 1.9°C over the period, while that of the water body remained the same. An obvious implication of this increase is its effect on urban thermal comfort within and without buildings, necessitating the need for mechanical cooling in the midst of current harrowing national deficiency in power supply. The current greening projects and tree planting programs of the State authority, inspired partly by its membership of C40 Large Cities Climate Summit (Mehrotra *et al.,* 2009), is thus a step in the right direction. These have served both in enhancing the visual quality of some urban spaces and notable streetscapes while assisting carbon sequestration toward surface temperature attenuation.

Devegetation, large scale conversion of wetlands and mangroves, has implications for water quality, aquifer recharge, and flood risk. Aquifer recharge is critical considering the lack of comprehensive municipal water supply and reliance on boreholes and shallow wells in the majority of metropolitan districts, although currently, considerable effort is being deployed to remedy this. Increased imperviousness decreases infiltration, thereby increasing potential runoff and flood risk. Wetland reclamation and building in fragile areas coupled with inadequate drainage infrastructure, low topography, and indiscreet disposal of waste into the drainage channels by some residents all combine to make flooding and traffic gridlock an integral part of the rainy season (June–October) in the metropolis (Figures 6a, 6b).

The rapid change in built-up land cover or urban sprawl in the study area and other parts creates infrastructure deficiencies, as these cannot match the rate of expansion. The result is that many of the new areas lack such features as all-weather roads and appropriate drainage structures, among others (Figures 7a, 7b), in addition to some lack of appropriate conformity with planning regulations in some areas. It is noteworthy that the subsisting metropolitan planning documents guiding development currently are the

ETIOSA LGA

Interval	Segment 1 (m)	Segment 2 (m)	Segment 3 (m)	Segment 4 (m)
1985 - 2004	89.48	105.11	79.03	119.40
2004 - 2006	9.27	11.41	9.83	10.54
Total (1985 - 2006)	98.75	116.52	88.86	129.94
Rate of erosion (21yrs)	4.70	5.55	4.23	6.19
2006 - 2009	28.01	29.92	26.28	30.34
Rate of erosion (3yrs)	9.34	9.97	8.76	10.11
Total (1985 - 2009)	230.22	268.51	208.24	296.41
Rate of erosion (24yrs)	9.59	11.19	8.68	12.35
Average rate of erosion (1985 - 2009)	10.45			



IBEJU LEKKI LGA

Interval	Segment 1 (m)	Segment 2 (m)	Segment 3 (m)	Segment 4 (m)	Segment 5 (m)	Segment 6 (m)
1985 - 2001	215.07	215.36	275.50	271.14	305.83	133.14
2001 - 2006	20.55	16.82	20.85	25.31	29.14	27.28
Total (1985 - 2006)	235.62	232.18	296.35	296.45	334.96	160.42
Rate of erosion (21yrs)	11.22	11.06	14.11	14.12	15.95	7.64
Average rate of erosion (1985 - 2006)	12.35					

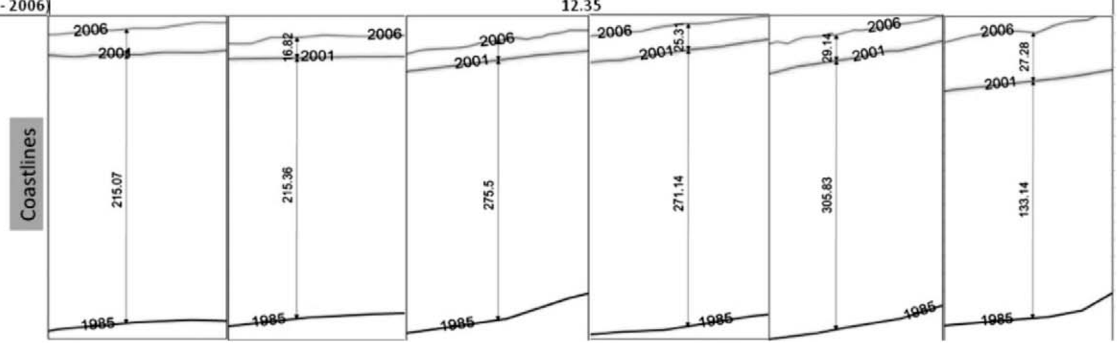


Figure 5. Rates of erosion along the coast of Lagos.

(a) (b)

Figure 6. (a) Wetland reclamation, low topography, inadequate drainage, and (b) flooding.

(a.) unpaved roads (b.) no surface drainage

Figure 7. (a) Lack of all-weather roads and (b) appropriate drainage structures.

Revised Land Use Plan 2000/2001 and the Lagos State Regional Existing Land Use Plan 2002. Furthermore, the resultant sprawl has effect on solid waste collection and disposal as municipal collection and disposal infrastructure can hardly match the spread and rate of waste generation. Consequently, until the advent of the current Private Sector Participation (PSP) program, push-cart operators held sway. With the general nature of the terrain of the metropolis and the state, locating alternative dump sites within easy reach has become a challenge. The few sites currently in operation are completely rimmed by development and thus are posing hazards. While the state is considering the far-flung Epe council area for possible sites, it conceivable that for suitable sites cooperation with the neighboring and more land-endowed Ogun State may be a reasonable option in future.

The steady erosion of the coastlines portends long-term danger to the teeming inhabitants of this area. Both Etiosa and Ibeju/Lekki councils, whose coastlines are eroding, are rapidly developing parts of the barrier island of Lekki Peninsula. Located here are many upscale housing estates, businesses, recreational beaches, an FTZ, and a proposed sea port, all serviced by one single access: the Lekki/Epe Expressway. While mostly low lying, the beaches are sandy, erosive, and characterized by high energy wave action. With the migratory nature of low-lying coastal plain barrier islands, such as this coupled with the erosion rates observed, in a decade or two, housing estates located and proposed close to the Atlantic shoreline (*e.g*. proposed Beach Estate on Maiyegun Beach abutting the primary dune or beach berm) may become vulnerable to erosion. This is in addition to the loss of precious recreational beaches, tourist attractions, and disrupted livelihoods for recreational operators. The projected sea level rise will further put these locations at risk even as it has been projected that a 1 m sea-level rise (SLR) will put about 600 km^2 of the entire barrier coast of Lagos, of which this is a part, at risk (French, Awosika, and Ibe, 1995).

Finally, the result of land cover dynamics as shown here reveals the nature of change and sprawl in the eastern half of the metropolis and state. Indirectly, it points to the fact that the state authorities, both in their exercise of police power and provision or upgrade of infrastructure after years of neglect, are faced with daunting challenges in coping with sprawl and demands for infrastructure.

CONCLUSIONS

A large chunk of the urban development (built-up) in the study area within the study period occurred mostly in areas where it displaced sensitive natural ecosystems consisting of wetlands, vegetation, and water bodies. This therefore impairs the capacity of these systems to play their natural roles, such as flood retention/dispersal, carbon sequestration, nutrient recycling, food production, *etc*. The continuing coastal erosion in the area calls for an understanding of applicable coastal processes operable on barrier islands, proactive, sustainable coastal protection, and development measures relying on informed knowledge and locational criteria instead of the current *ad hoc* and reactive approach.

It is also recommended that the tree planting and general upgrade of green infrastructure should be continued and intensified. Also, exercise of police power or planning control toward reining in urban sprawl should be strengthened.

Having derived answers to the nature and magnitude of land cover changes over the study period, it is imperative in the next phase of this study to model the potential contribution of wetland conversion and increased impervious cover to the flooding problems being experienced in the study area and in the metropolis in general.

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