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Assessment of environmental responses to land use/land cover dynamics in the Lower Ogun River Basin, Southwestern Nigeria

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This study investigates the pattern of land use/land cover change in the Lower Ogun River Basin between 1984 and 2012. Two sets of topographical maps, a Landsat-5 TM image of 1984, Landsat-7 ETM+ of 2000 and a Google Earth image of 2012 were used for the study. The topographical maps and satellite images were digitally processed using ILWIS 3.2™ software and exported to ArcGIS 9.3™ for further processing and analysis. The processed images were subsequently classified using the maximum likelihood classification algorithm, resulting in the identification of seven land use classes. Furthermore, change detection analysis was carried out using Cross Module in ILWIS™. The result of the change detection analysis indicated that between 1984 and 2000, 80.08% of the land cover in the study area has been converted to other land uses while only 19.92% remained unchanged. Also, within the same period, light forests, non-forested wetlands and forested wetlands decreased at average annual rates of 8.26, 4.66 and 2.81%, respectively, while water bodies also decreased at an annual rate of 0.17%. On the other hand, farmland, shrubs and urban/built-up areas expanded at average annual rates of 7.23, 6.74 and 4.65%, respectively. The result further indicates that between 2000 and 2012, 49.86% of the land cover has been converted to other land uses, while 50.14% remained unchanged, and that farmlands, shrubs, urban/built-up areas and forested wetlands expanded at average annual rates of 6.01, 1.95, 0.89 and 0.17%, respectively, just as light forests, non-forested wetlands and water bodies decreased annually by 8.26, 2.70 and 1.40%, respectively. Five randomly collected soil samples were analyzed for their physicochemical properties. Findings show the growing impact of urban agriculture on wetland ecosystem within the study area, manifesting in soil degradation and biodiversity loss. The implication of these findings is that the area is susceptible to devastating flooding which can culminate in the loss of lives and properties. This study recommends the development of effective land management information system and policies that will ensure sustainable management of fragile ecosystem.

Key words: Change detection, river basin, urban agriculture, land use/land cover, wetlands.

INTRODUCTION

FAO (1995) stated that land use concerns the function or purpose for which the land is used by the local human population and can be defined as the human activities which are directly related to land, making use of its resources or having an impact on them. Land use and land cover change has emerged as one of the key independent themes in the global change, climate change, earth systems and sustainability research programs (Gutman et al., 2004). The environmental impacts of land use change have been documented in urban, suburban, rural and open space areas. For example, Awoniran (2012) observes that land use changes (land conversion) occur at the periphery of large urban concentration where urbanization and industrialization pressures frequently result in loss of prime agricultural lands and tree cover. These often result in unprecedented changes in the hydrological balance of the area, increase in the risk of floods and landslides, air and water pollution among others. Other local impacts are soil erosion, sedimentation, soil and groundwater contamination and salinization, extinction of indigenous species, marine and aquatic pollution of local water bodies, coastal erosion and land pollution.

Though humans have been modifying land to obtain food and other essentials for long, current rates, extent and intensities of landuse/landcover change (LULCC) are far greater than ever in history; driving unprecedented changes in ecosystem and environmental processes at local, regional and global scales (Lambin et al., 2007). Various estimates indicate that 50% of the ice-free land surfaces has been affected or modified in some ways by human activities (Vitousek et al., 1997), while 10 to 55% of the net primary productivity has been captured by human land use activities (Rojstaczer et al., 2001). The intergovernmental panel on climate change (IPCC) estimates that the cutting down of forests contributes close to 20% of the overall greenhouse gases that are entering the atmosphere, making the goal of reducing deforestation an urgent and immediate one (United Nations Development Programme, 2009). These anthropogenic-cally induced land use change has, to a greater or lesser extent, resulted in major environmental problems such as desertification, eutrophication, acidification, climate change, flooding, greenhouse effect and biodiversity loss.

The Lower Ogun River Basin, because of its proximity to the urban periphery of Lagos, is presently under intense pressure occasioned by increasing urbanization rate. Increasing population pressure, increasing demand for food, high cost of land and urban agricultural activities are having serious environmental impact on the basin (Tejuoso, 2006). The consequence of this is: land degradation, flooding and threatened food security.

The use of remotely sensed data with the integration of Geographic Information System technology provides a strong and analytical framework for assessing land use/land cover inventory, annual rate of change and evaluating the emerging environmental response at the periphery of a fast growing city. The importance of geospatial information to be generated from such an endeavor cannot be over emphasized as Adeniyi and Omojola (1999) submitted that information based on urban land use changes can shed more light on the growth process, since physical changes in the distribution of urban land uses are direct indications of social and economic changes.

This study assesses land use/land cover change, evaluate the proportion of changes and analyze the environmental impacts of the change on the Lower Ogun River Basin within 28 years using Remote Sensing and GIS technology. This is considered germane in addressing emerging environmental problems and ensuring sustainable land use management which may be anchored on accurate and up to date land use data and map that serves as bedrock for evolving a sound land use planning and policy for the area under study.

The study area

The study area is located partly in Ifo South Local Government Area of Ogun State and Kosofe Local Government Area of Lagos State, and lies between Latitudes 06° 35ˈN and 06° 45ˈN and Longitudes 3°17ˈE and 3°25ˈE (Figure 1). It is approximately 161.4 km^2. It is located within the sub-equatorial zone, which is characterized by rainfall throughout the year with two maxima (May to July and September to October). December and January have very little rain, and the annual rainfall is between 1500 to 2000 mm. The effective temperature (ET) is between 32 and 36°C. However, the highest diurnal range of temperature in the dry season (mid November-mid March) is 20°C while the mean range is about 10°C during the warm and wet season (May to October). The highest air temperature occurs in April/May and the lowest occurs in December through February. (The mean annual temperature is about 27°C while the annual range does not exceed 6°C (Ekanade, 1985). It lies within the rainforest belt (dry lowland rainforest). The vegetation of the region is swamp and marsh forest, part of which had given way to the construction of houses, markets and other infrastructures. Tree species here consist of typical colonizer or invaded species. These are plants with numerous and easily dispersed seeds and capacity for fast and vigorous establishment in cleared or open location. The river channels are characterized by vegetation of the wet southern segment of the rainforest belt. The characteristic vegetation include tall trees like *Tarriefa utilis*, *Geophila* sp., epiphytic ferns (*placycerina* sp.), *Tuchomanes* sp. *Nephrolepis* sp. Mosses and Lierworts (Ogunbajo, 2005).

Generally, the relief of the area may be described as belonging to the belt of coastal plains. The land rises from the sandy beaches along the Atlantic Ocean to a belt of fresh water swamps with an intricate network of lagoons and creeks. The coastal belt is about 10 km wide and is generally less than 20 m in height. Further inlands, it gives way to a sandy plain which in turn leads up to a plain of eroded sandstones standing less than 20 m above

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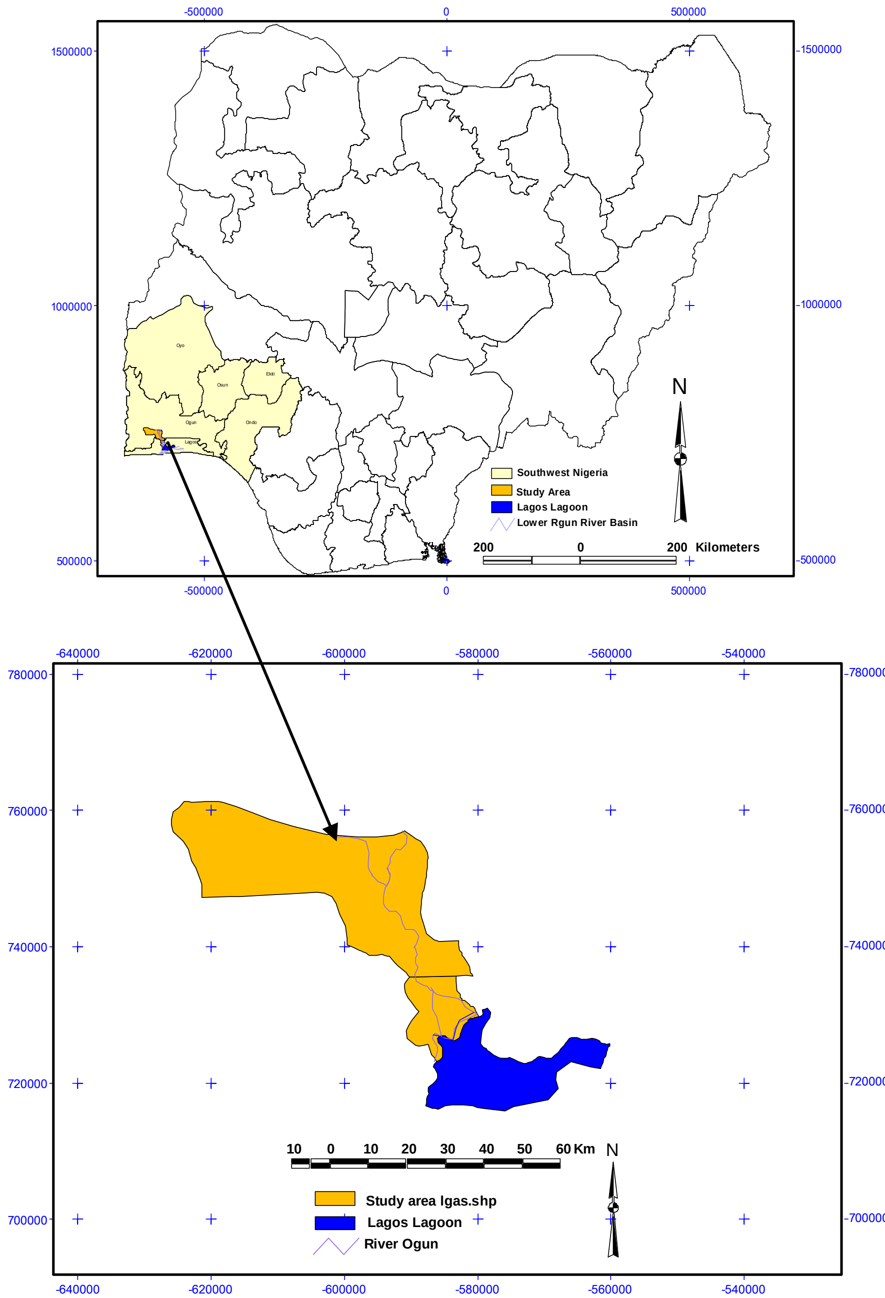

Figure 1. Lower Ogun River Basin in SW, Nigeria.

sea level. Taking its source from the northeastern portion of the study area, River Adiyan is the only major tributary to River Ogun and discharges into River Ogun, north of Iseri-Oke. The drainage is dendritic and the Adiyan River flows throughout the year and forms a major valley in the vicinity. Farming, hunting and fishing have been the chief occupations of the local people for many decades. Crops grown in the area include cocoa, vegetables, sugar cane and maize. However, sand mining along the channel of River Ogun that traverses the study area is a major human activity.

Conceptual framework

The analysis of land use change is embedded within the broader discourse on global environmental change, a variety of theoretical approaches which are called “man-environment” theories. More balanced theoretical frame-works for the study of nature-society relationship are offered by ecologically sensitive approaches known as "human ecology" or "cultural ecology" (Briassoulis, 2000). These approaches draw upon ecology and systems theories to provide comprehensive descriptions of the complex interactions between people and their bio-physical environment (Sack, 1990, Butzer, 1990).

Land use change research has evolved out of global efforts to identify, predict and manage ecologically damaging land use changes such as deforestation. Indeed, the international global environmental change research community has chosen land use/cover change as a major area of research not only because it provides broad scale data on changing carbon storage and sequestration by plants, but also because it provides an entry into understanding the human dimensions of environmental change (Turner et al., 1995; Lambin et al., 1999; Sherbinin, 2002). Political and cultural ecology, intensification theory, economic theories and other concepts have informed LULC research associated with the International Geosphere-Biosphere Progamme (IGBP).

The early interests of social scientists in explanation and ecologists in prediction are evidently convergent in the spatially explicit model. Ecologists have provided strong motivation with their focus on the landscape as a biogeographic unit of analysis subject to fragmentation processes. On their part, social scientists have filled the explanation gaps on the human side of the equation. Now, social scientists and ecologists are even found to publish jointly on the topic (Turner et al., 1996; Wear and Bolstad, 1998). The spatially explicit model is increasingly used to predict landscape change and is often evaluated both in terms of conventional inference on variable coefficients and goodness-of-fit and with respect to ability to predict actual landscape change (Nelson and Hellerstein, 1997; Wear and Bolstad, 1998; Mertens and Lambin, 2000).

MATERIALS AND METHODS

Research locale

The main data used for this study included a Landsat TM satellite image of December 1984, and ETM+ of February 2000 obtained from the Global Land Cover Facility and 2012 Google Earth® image. Two sets of topographical maps on a scale of 1:50000, Lagos NE Sheet 279 and Lagos SE Sheet 279, published in 1964 were obtained from the Federal Survey, and used as base map and supportive ground-truth information required for classification and accuracy estimation of the classified TM and ETM+ images was collected through a field survey carried out in 2012.

Digital image processing

Preprocessing operations in the form of linear contrast stretch and spatial filtering were performed on the images which were also geo-rectified to Universal Transverse Mercator (UTM) coordinate system. Subsets of the satellite images and topographical maps were geo-referenced using georeferenced tie points and affine transformation method. The supervised Maximum Likelihood Classification method was used for all the images. Training areas corresponding to each classification item (land use class) were chosen from among the training samples collected from the field and the topographical map of the study area.

Thereafter, seven land use/land cover classes were identified on the two images for change detection analysis. These include urban, light forest, forested wetland, non-forested wetland, farmland, shrub and water body. Change detection analysis was performed using the cross algorithm of the ILWIS software. Choice of the emerging land use classes was guided by i) the objective of the research ii) expectation of certain degree of accuracy in image classification and iii) the ease of identifying classes on the topographical map. The classified images were further subjected to majority filtering operation to smoothen and eliminate noise (salt and pepper) from the images. The evolving land use/land cover types were quantified using cross tabulation statistics to carry out land use/land cover change. The classified images were subsequently vectorized and exported to ArcGIS 9.3™ for the graphical illustration of land use/land cover change in the study area.

Soil sampling and analysis

Two study sites were selected on the classified images for soil quality analysis. That is, forested wetland which was relatively less disturbed and non-forested wetland which was under cultivation. Five composite soil samples, replicated thrice, each to the depth of 0-20 cm to give a total of 30 soil samples were randomly collected using soil auger and analyzed for their physicochemical properties to determine the impact of land use change on soil quality in the selected forested and non-forested wetlands. The coordinate of each soil samples were also taken using GPS.

The soil samples were air-dried for seven days, crushed and sieved through 2 mm opening. The hydrometer method (Bouyoucos, 1962) was used for particle size analysis. Soil pH was determined potentiometrically in H_2O at a ratio of 1:1 (soil to water) (Mclean, 1982). The Kjeldahl method was used to determine total nitrogen (Bremner and Mulvaney, 1982). The determination of soil organic carbon was based on the Walkley-Black chromic acid wet oxidation method (Nelson and Sommers, 1982), while available phosphorus was determined using Bray P1 method (Olsen and Sommers, 1982). Exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were determined using 1 M NH_4OAc (Ammonium acetate) buffered at pH 7.0 as extractant (Thomas, 1982). The K^+ and Na^+ concentrations in soil extracts were read on Gallenkamp Flame photometer while Ca^{2+} and Mg^{2+} concentrations in soil extracts were read using Perkin-Elmer Model 403 atomic absorption spectrophotometer. Descriptive statistics was used to detect the changes that have taken place in the study area from 1984 to 2000. Test of significance for differences in means of soil physico-chemical properties under forested and non-forested wetland was done using least square difference (LSD) method.

Vegetation sampling

In this study, four corners of each of the two sites were marked with pegs at the defined dimension (100 m^2) and were gridded into 10 quadrants having dimensions of 10 by 10 m. For each 10 m^2 grid observations of height of trees and herbs were recorded. During the study, a tree was taken to be a woody specie of erect posture with a minimum breast circumference of 7 cm and a minimum height of 2 m (Salami and Aladenola, 2003). Shrubs on the other hand are woody plants not having a main trunk but several main branches. In general, shrubs are smaller than trees. The vegetation data recorded in the field were entered into a database using Microsoft Excel® software and analyzed using the tools in the spreadsheet.

Focus group discussion (FGD)

As an additional source of ground-truth information, four focus discussion and the in-depth interviews were based on convenience

Table 1. Landsat TM 1984 land use/land covers accuracy assessment.

LULC	FML	FWT	LF	NFWL	SRB	URB	WB	TR
FML	487	14	429	0	66	60	0	1056
FWT	85	2321	301	200	0	25	2	2934
LF	1051	464	3087	239	176	202	1	5220
NFWL	134	242	185	2235	0	138	12	2946
SRB	917	43	762	24	730	21	3	2500
URB	19	46	38	16	5	4461	134	4719
WB	0	0	0	0	0	94	2182	2276
RELIABILITY	0.18	0.74	0.64	0.82	0.75	0.89	0.93	
LULC	FML	FWT	LF	NFWL	SRB	URB	WB	TR

Average accuracy = 68.55%, average reliability = 70.9%, overall accuracy = 71.6%.

Table 2. ETM+2000 land use/land cover accuracy assessment.

LULC	FML	FWT	LF	NFWL	SRB	URB	WB	TR
FML	1127	181	62	43	554	15	0	1982
FWT	208	1308	378	140	629	55	0	2718
LF	60	114	1913	97	67	73	0	2324
NFWL	33	42	26	1723	432	509	3	2768
SRB	114	77	33	932	2276	401	0	3833
URB	9	4	1	255	71	6531	53	6924
WB	0	0	0	17	0	59	2077	2153
RELIABILITY	0.73	0.76	0.79	0.54	0.56	0.85	0.97	
LULC	FML	FWT	LF	NFWL	SRB	URB	WB	TR

Average Accuracy = 71.4%, average reliability = 74.4%, overall accuracy = 74.7%.

and purposeful sampling (Miles and Huberman, 1984). The focus group had three themes for discussion, that is, the history of land use in the study area, the major types of land use, and the impact of land use.

RESULTS AND DISCUSSION

Land use/land cover accuracy assessment

The general acceptance of the error matrix as the standard descriptive reporting tool for accuracy assessment of remotely sensed data has significantly improved the use of such data. An error matrix is a square array of numbers organized in rows and columns which express the number of sample units (i.e. pixels and clusters of pixels) assigned to a particular category relative to the actual category as indicated by reference data (Coppin and Bauer, 1996). For instance, Table 1 shows the producer's accuracy for the image classification of Landsat TM 1984 into seven classes of land use/land cover types: Farmlands (Fm) = 46%; forested wetlands (FW) = 79%; light forest (LF) = 59%; non forested wetlands (NFW) = 76%; scrubs (SS) = 29%; urban (U) = 95%; water body (WB) = 96%.

Also, the user's accuracy as shown in the same table indicates the probability that a pixel classified into a given category are the true representation of that category on the ground: Farmlands (Fm) = 18%; forested wetlands (FW) = 74%; light forest (LF) = 64%; non forested wetlands (NFW) = 82%; scrubs (SS) = 75%; urban (U) = 89%; water body (WB) = 93%; Overall accuracy = TD (sum of major diagonal) divided by TR (row totals) = 15503/21651 x 100 = 71.6%. The accuracy is essentially a measure of how many ground truth pixels were classified correctly. Thus, for the 1984 land use/land cover classification an average accuracy of 66.23% and overall accuracy of 71.23% was generated. This indicates that error is considered to be consistent with limits of the available technology.

Table 2 shows the producer's accuracy for the image classification of Landsat ETM+ 2000 into seven classes of land use/land cover types: Farmlands (Fm) = 57%; forested wetlands (FW) = 48% light forest (LF) = 82%; non forested wetlands (NFW) =62%; scrubs (SS)= 59%; urban (U) = 94%; water body (WB) = 96%. Also, the user's accuracy as shown in the same table indicates the probability that a pixel classified into a given category are the true representation of that category on the ground:

Table 3. Google Earth Image 2012 land use/land cover accuracy assessment.

LULC	FML	FWT	LF	NFWL	SRB	URB	WB	TR
FML	1213.7	147.2	0	0	634.88	70.8	0	2066.72
FWT	294.76	1274	278.8	84.08	709.88	110.8	0	2752.68
LF	146.76	80.28	1813	41.08	147.88	128.8	0	2358.68
NFWL	119.76	8.28	0	1667.08	512.88	564.8	0.96	2873.76
SRB	200.76	43.28	0	876.08	2356.88	456.8	0	3933.8
URB	95.76	0	0	199.08	151.88	6586.8	50.96	7084.48
WB	86.76	0	0	0	80.88	114.8	2074.96	2357.4
RELIABILITY	0.84	0.64	0.8	0.48	0.52	0.92	0.98	
LULC	FML	FWT	LF	NFWL	SRB	URB	WB	TR

Average accuracy = 73.68%, average reliability = 73.75%, overall accuracy = 77.34%.

Farmlands (Fm) = 73%; forested wetlands (FW) = 76%; light forest (LF) = 79%; non forested wetlands (NFW) = 54%; scrubs (SS) = 56%; Urban (U) = 85%; water body (WB) = 97%; overall accuracy = TD (sum of major diagonal) divided by TR (row totals) = 16955/22702 x 100 = 74.9%. Thus, 2000 land use/land cover average accuracy is 70.40% and overall accuracy is 74.9%. This indicates that error is considered to be consistent with limits of the available technology.

Table 3 shows the producer's accuracy for the image classification of Google Earth Image 2012 into seven classes of land use/land cover types: Farmlands (Fm) = 80%; forested wetlands (FW) = 66%; light forest (LF) = 62%; non forested wetlands (NFW) = 55%; scrubs (SS) = 59%; urban (U) = 96%; water body (WB) = 99%. Also, the user's accuracy as shown in the same table indicates the probability that a pixel classified into a given category are the true representation of that category on the ground: farmlands (Fm) = 84%; forested wetlands (FW) = 64%; light forest (LF) = 80%; non forested wetlands (NFW) = 48%; scrubs (SS) = 52%; urban (U) = 92%; water body (WB) = 98%; overall accuracy is estimated to be 77.34%. Thus, 2012 land use/land cover average accuracy is 73.68%. This indicates that error is considered to be consistent with limits of the available technology.

Changes in land use/land cover between 1984 and 2012

Figures 2, 3 and 4 show the spatial distribution of the static land use/land cover of the study area in 1984, 2000 and 2012, respectively. Table 4a and b below showed the entire study area covering 16140 ha. In 1984, light forest constituted the most extensive land use/land cover occupying 5350 ha (33.2%) and urban/built up area was 2690 ha (16.7%). The non-forested wetland, forested wetland, shrub, water body and farmland occupied {ha, (%)} 2380 (14.5), 2170 (13.5), 1720 (10.7), 1180 (7.3) and 650 (4.0) respectively of the study area.

However, in 2000 urban or built up area expanded quite rapidly, increasing to 4690 ha (29.1%) of the study area. The shrub and farmland areas increased to {ha, (%)} 3580 (22.2) and 1400 (8.7) respectively. During the same period, non-forested wetland, forested wetland, light forest and water body decreased to {ha, (%)} 1960 (12.1), 1790 (11.1), 1570 (9.7) and 1150(7.1) respectively. By 2012 urban built up, shrub, farmland and forested wetland has increased to {ha, (%)} 5191 (32.16), 4417 (27.37), 2409 (14.92) and 1827 (11.32), respectively. On the other hand, light forest, non forested wetland and water body had decreased to {ha, (%)} 14 (0.09), 1325 (8.21) and 957 (5.93) respectively.

Also, the pattern of land use/land cover change within the period under consideration indicated that between 1984 and 2000 farmland, shrub and urban/built up were expanding at the rates of 7.2, 6.7 and 4.7% per annum. Light forest, non-forested wetland and forested wetland were decreasing at the average rates of 8.3, 4.7 and 2.8% per annum, respectively, and water body decreased marginally at an annual rate of 0.2% per annum. The table also indicated that between 2000 and 2012 farmland, shrub and urban/built up increased by 72.1, 23.4 and 10.7% per annum, and forested wetland increased marginally by 2.1%. On the other hand light forest, non-forested wetland and water body were decreasing at the average annual rates of 8.26, 2.70 and 1.40% respectively.

Land use/land covers conversion pattern between 1984 and 2000

Table 5a show the pattern of land use change between 1984 and 2000. In Table 5a, while 19.92% of the land use/land cover in the study area remained unchanged, 80.08% have been lost to other land uses. The table also reveals that 12.00% of farmlands, 20.74% of forested wetland, 9.16% of light forest and 23.99% of non-forested wetland, as well as 24.59% of shrub, 35.76% of urban and 20.42% of water body respectively remained unchanged between 1984 and 2000. It was also observed

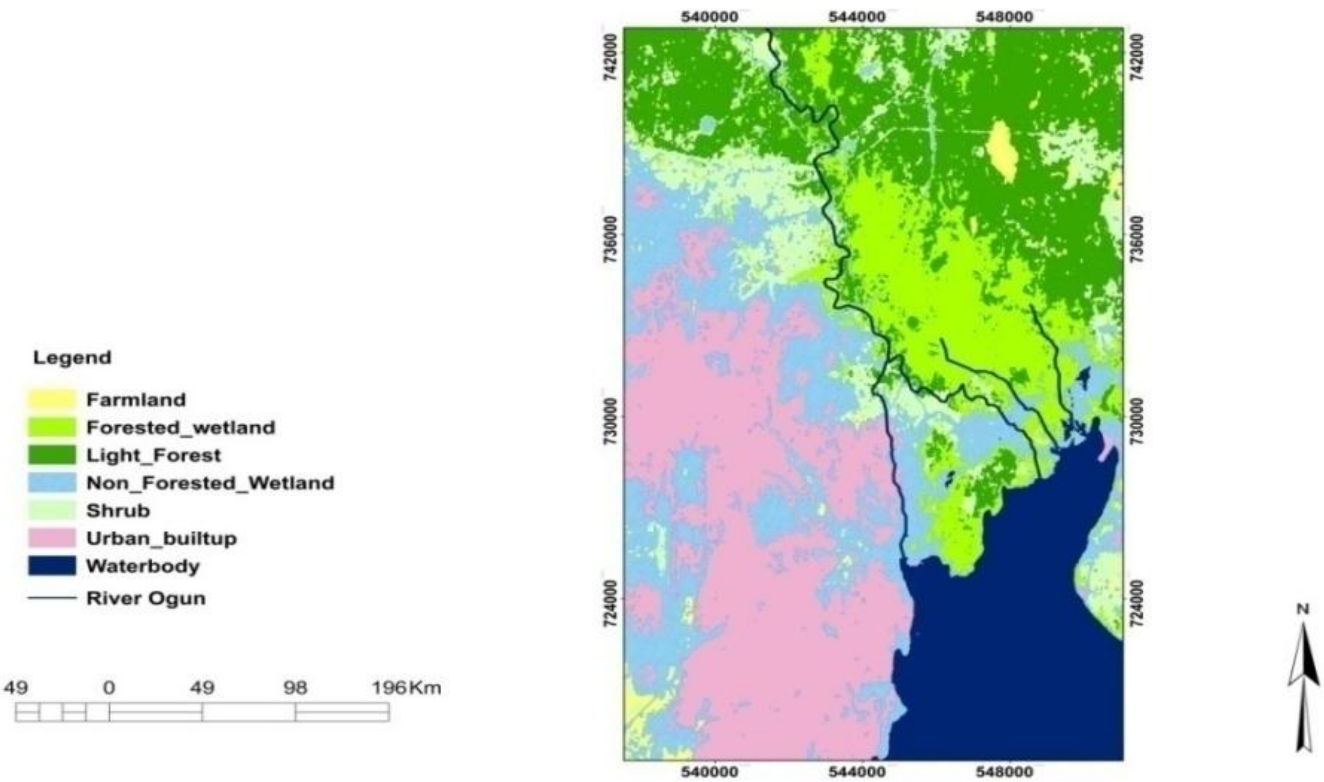

Figure 2. Land use/land cover map of Lower Ogun River Basin, SW Nigeria, in 1984.

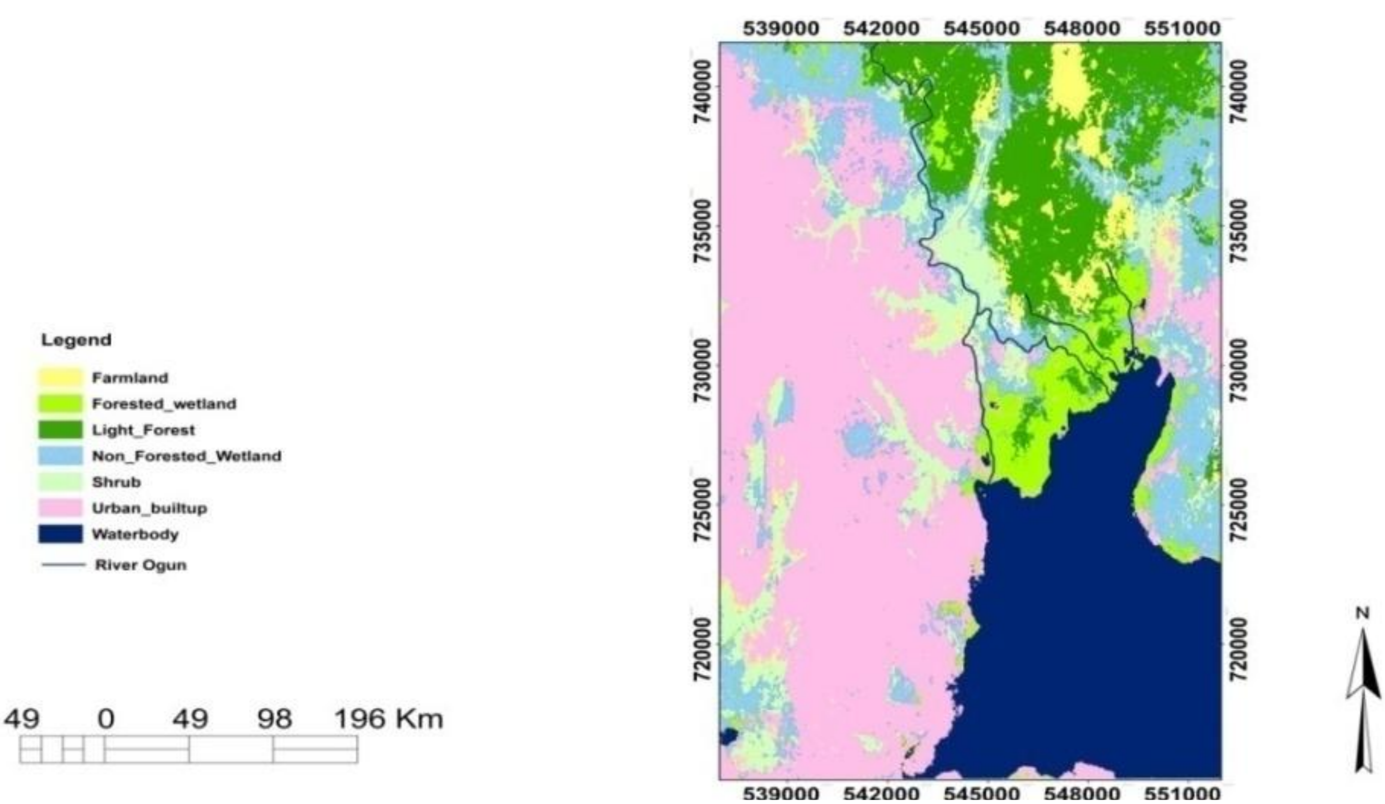

Figure 3. Land use/land cover map of Lower Ogun River Basin, SW Nigeria, in 2000.

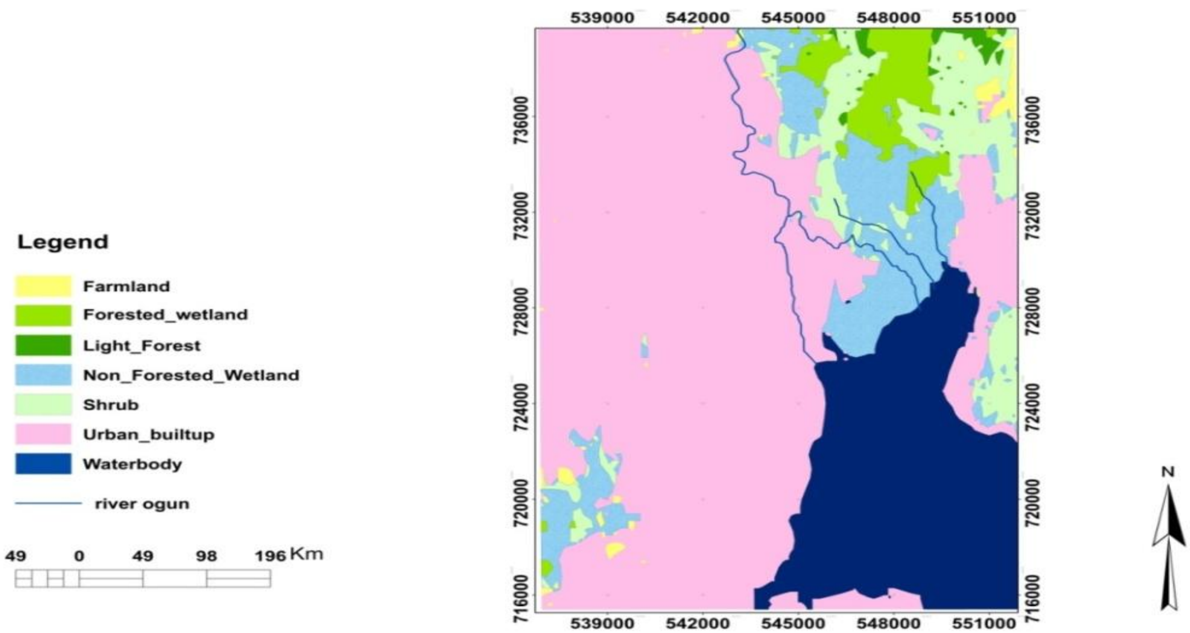

Figure 4. Land use/LAND COVER MAP of Lower Ogun River Basin, SW Nigeria, in 2012.

Table 4a. Extent and rate of change in land use/land cover from 1984 to 2000.

LULC	1984		2000		Change b/w 1984 & 2000		Av.Rate of Change	
	Area (ha)	Area (%)	Area (ha)	Area (%)	ha	%	ha	%
FML	650	4.0	1400	8.7	750	+115.4	47	+7.23
FWT	2170	13.5	1790	11.1	-980	-35.4	-61	-2.81
LF	5350	33.2	1570	9.7	-3780	-70.7	-442	-8.26
NFWL	2380	14.5	1960	12.1	-420	-17.7	-111	-4.66
SRB	1720	10.7	3580	22.2	+1860	+108.1	116	+6.74
URB	2690	16.7	4690	29.1	+2000	+74.3	125	+4.65
WB	1180	7.3	1150	7.1	-30	-2.5	-2.0	-0.17
Total	16140	100	16140	100	-	-	-	-

Authors' Image Analysis, 2013.

Table 4b. Extent and rate of change in land use/land cover from 2000 to 2012.

LULC	2000		2012		Change b/w2000 & 2012		Av.Rate of Change	
	Area (ha)	Area (%)	Area (ha)	Area (%)	ha	%	ha	%
FML	1400	8.7	2409	14.92	+1009	+72.1	+84.06	+6.01
FWT	1790	11.1	1827	11.32	+37	+2.1	+3.09	+0.17
LF	1570	9.7	14	0.09	-1556	-99.1	-129.68	-8.26
NFWL	1960	12.1	1325	8.21	-635	-32.4	-52.91	-2.70
SRB	3580	22.2	4417	27.37	+837	+23.4	+69.76	+1.95
URB	4690	29.1	5191	32.16	+501	+10.7	+41.75	+0.89
WB	1150	7.1	957	5.93	-193	-16.8	-16.08	-1.40
Total	16140	100	16140	100				

Authors' image analysis, 2013.

Table 5a. Land use/land cover change pattern between 1984 and 200

	Landuse/Landcover classes of 2000 (ha)								
1984 landuse/landcover classes (ha)	**FML**	**FWT**	**LF**	**NFWL**	**SRB**	**URB**	**WB**	**Total area**	**FML**
	FML	**78**	117.74	50.96	110.74	393.4	407.82	235.20	1400
		12.00%	8.41%	3.64%	7.91%	28.10%	29.13%	16.87%	100
	FWT	98.12	**450**	277.63	92.01	146.06	248.631	481.75	1790
		5.48%	**20.74%**	15.51%	5.14%	48.16%	13.89%	26.99%	100
	LF	93.62	144.44	**490**	154.80	346.50	346.19	311.017	1570
		5.96%	9.20%	**9.16%**	9.86%	22.07%	22.05%	19.81%	100
	NFWL	363.28	194.824	157.98	**571**	433.552	205.21	134.46	1960
		18.53%	9.94%	8.06%	**23.99%**	22.12%	10.47%	6.86%	100
	SRB	287.11	271.01	167.90	352.63	**423**	1113.74	157.16	3580
		8.02%	7.57%	4.69%	9.85%	**24.59%**	31.11%	4.39%	100
	URB	32.41	35.64	25.80	189.01	413.189	**962**	903.76	4690
		0.69%	0.76%	0.55%	4.03%	8.81%	**35.76%**	19.27%	100
	WB	0	0	0	0	0	202.75	**241**	1150
							17.63%	**20.41%**	10.0
	Total	952.329	1213.654	853.747	1291.577	2739.042	5614.572	3270.603	16140

Authors' image analysis, 2013.

that 88.00% of farmlands, 79.26% of forested wetland, 90.84% of light forest and 76.01% of non-forested wetland, as well as 75.41% of shrub, 64.24 and 79.58% of water body have been converted to other uses, within the same period.

Furthermore, the table also indicated that 5.48% of forested wetland, 5.96% of light forest, 18.53% of non-forested wetland, as well as 8.02% of shrub and 0.69% of urban have been changed to farmlands. While at the same time, 29.13% of farmland, 13.89% of forested wetland, 22.05% of light forest, as well as 10.47% of non-forested wetland, 31.11% of shrub and 17.63% of water body have been converted to urban land use. Thus, the conversion of light forest, forested and non-forested wetlands as well as shrub at the rates indicated above give an indication that farming and urbanization are the most important drivers of land use in the study area, and these also reflect the increasing scale of human activities in the study area.

Table 5b show the predominance of farmland and urban over other land use/land cover types with 80.7 and 53%, respectively. The table also reveal that 95.1 ha (10.5%) forested wetland, 35.8% light forest, 20.7% non-forested wetland, 15.2% shrub, 53% urban and 62.9% water body remain unchanged over the twelve years that constitute the latter part of the study period. According to the table, 13.7% of the farmland, 6.3% of forested wetland, 11% of the non-forested wetland and 1.9% of water body have been converted to urban. This suggests that environmentally fragile areas have been prone to urban encroachment without conscious effort to mitigate the devastating consequences such flooding, loss of biodiversity and destruction of ecosystem.

Table 6a and b present the results of the analyses on the proportions of LULC units gained and/or lost between 2000 and 2012 in the study area. From Table 6a, farmlands maintained 3360 ha equivalence of 41.5% but 805.5 ha (13.1%) of its total area over 12 years had been converted to other land use/land cover types. Nevertheless, farmlands had gained 2021.0 ha (20.3%) from other land use/land cover types, second highest to urban land use. This is further affirmed by the gained/lost analysis over the 12 years of the study which reveals that farmland record net gain of 1215.5 ha (60.1%). This suggests the growing interest of the urban dwellers in urban agriculture that constitutes one of the drivers of land use/land cover change in the study area. This is in line with the findings of Awoniran et al. (2011) who reported that urban agriculture and rapid urbanization are major drivers of land use/land cover change in the Lower Ogun River Basin.

This finding is further strengthened by the soil test carried out by the study which revealed the micro-variability of the soil, with significant ($p < 0.01$) differences in the properties compared. According to the results presented in Table 7, soils of the forested wetland areas are mainly clay while the non-forested areas are clay loam and sandy clay loam. The mean soil pH (1:1 soil-H_2O) ranged from 5.0 to 6.5, indicating slightly acidic soil condition. In the forested wetland areas, total nitrogen (TN; 0.98 to 2.63 g kg^{-1}), organic carbon (OC; 12.50 to 37.40 g kg^{-1}) and available phosphorus (24.05 to 44.80

Table 5b. Land use/land cover change pattern between 2000 and 2012.

2000 land use/land cover classes (ha)	2012 land use/land cover classes (ha)							
	FML	FWT	LF	NFWL	SRB	URB	WB	Total
FML	**3360**	124.6	525.4	34.8	111.0	9.7	0	4165.5
	80.7%	3.0%	12.6%	0.8%	2.7%	0.2%	0	100
FWT	174.0	**95.1**	160.5	114.5	179.3	143.9	39.1	906.4
	19.2%	**10.5%**	17.7%	12.6%	19.8%	15.9%	4.3%	100
LF	517.6	262.2	**632.0**	92.7	225.0	33.1	3.2	1765.8
	29.3%	14.8%	**35.8%**	5.2%	12.7%	1.9%	0.2%	100
NFWL	252.3	183.5	349.0	**267**	185.0	50.8	3.8	1291.4
	19.5%	14.2%	27.0%	**20.7%**	14.3%	3.9%	0.3%	100
SRB	317.2	371.3	232.4	87.6	**241.0**	325.5	8.1	1583.1
	20.0%	23.5%	14.7%	5.5%	**15.2%**	20.6%	0.5%	100
URB	752.0	346.8	258.5	604.2	516.2	**2909.1**	105.8	5492.6
	13.7%	6.3%	4.7%	11%	9.4%	**53.0%**	1.9%	100
WB	7.9	3.7	0	63.8	161.1	110.9	**587.8**	935.2
	0.8%	0.4%	0	6.8%	17.2%	11.9%	**62.9%**	100
Total	5381	1387.2	2157.8	12 64.6	1618.6	3583	747.8	16140

Authors' Image Analysis, 2013.

Table 6a. Proportion of LULC unit gained and/or lost between 1984 and 2000.

Land use classes	Proportion of LULC in 2000 and unchanged in 2012		Proportion of LULC in 2000 lost to other LULC by 2012		Proportion of LULC in 2000 gained from other LULC type by 2012		LULC in 2012 (unchanged + gained)		Difference of (2000-2012) LULC gained-lost	
	ha	%	ha	%	ha	%	ha	%	ha	%
FML	3360	41.5	805.5	13.1	2021.0	20.3	5381	100.00	+1215.5	+60.1
FWT	95.1	1.2	811.3	13.2	1292.1	13.0	1384.2	100.00	+480.8	+37.2
LF	632.0	7.8	1133.8	18.5	1525.8	15.3	2157.8	100.00	+392	+25.7
NFWL	267	3.3	1024.4	16.7	997.6	10.0	1264.6	100.00	-26.8	-2.7
SRB	241.0	3.0	1342.1	21.9	1377.6	13.8	1618.6	100.00	+35.5	+2.6
URB	2909.1	36.0	673.9	11.0	2583.5	25.9	3583	100.00	+1909.6	+73.9
WB	587.8	7.3	347.4	5.7	160.0	1.6	747.8	100.00	-187.4	-117.1
Total	8092	50.14	8048	49.86	8048	49.86	16140	100	-	-

Authors' image analysis, 2013.

mg kg^{-1}) values were obtained. Also, the cation exchangeable capacity (CEC) in the forested areas ranged from 9.55 to 12.37 cmol kg^{-1}. However, in the non-forested areas, TN, OC, available phosphorus and CEC values were low. Within each of the study area, soil properties varied significantly from one sample location to another. These results are in agreement with those reported by Adepetu et al. (1979) under continuous soil manipulation as a result of human activities. The soil physical properties such as soil texture known to be relatively 'stable' over-time (Mbagwu, 2008) changed from clay in the forested wetland to sandy clay loam in nearby non-forested wetland where anthropogenic activities are on-going.

Though, urban land use retained 2909.1 ha (36.0%) in 2012 and lost 673.9 ha (11.0%) to other LULC but still maintained its predominance by gaining 2583.5 (25.9%) from other land use/land cover types. The net gained analysis shows that this land use has gained 1909.6 ha, an equivalence of 73.9% over the twelve years of the latter study period. This revelation provides a strong signal about possible lost of farmlands that constitutes second largest land use in the area to urban land use in the nearest future. This may be attributed to the fact that

Table 6b. Proportion of LULC unit gained and/or lost between 2000 and 2012.

Land use classes	Proportion of LULC in 1984 and unchanged in 2000		Proportion of LULC in1984 lost to other LULC by 2000		Proportion of LULC in 1984 gained from other LULC type by 2000		LULC in 2000 (unchanged+gained)		Difference of (1984-2000) LULC gained-lost	
	ha	%	ha	%	ha	%	ha	%	ha	%
FML	78	12	572	88.0	1322	94.43	1400	100.00	750	53.57
FWL	450	20.74	1720	79.26	1340	74.86	1790	100.00	-380	21.23
LF	490	9.16	486	90.84	108	68.79	1570	100.00	-3780	-40.76
NF W	571	23.99	1809	76.01	1389	70.87	1960	100.00	-420	-21.43
SHR	423	24.59	1297	75.41	3157	88.18	3580	100.00	1867	52.15
URB	962	35.72	1728	64.24	3728	79.49	4690	100.00	2200	46.91
W B	241	20.42	939	79.58	909	79.04	1150	100.00	-30	-2.61
Total area	3215	19.92	12925	80.08	12925	80.08	16140	100.00	-	-

Authors' Image Analysis, 2013.

Table 7. Mean values of physico-chemical properties of soils of forested and non-forested wetland.

	pH	Sand	Silt (g kg-1)	Clay	P (mg kg-1)	OC	TN (g kg-1)	Mg	Ca	K (cmol kg-1)	Na	Exchangeable acidity	Textural Class
Non forested wetland													
1	5.1c	320	300	380	21.66d	20.30^{a}	1.93^{a}	1.23d	5.50d	0.17^{b}	0.50^{b}	2.00^{b}	CL
2	5.4b	440	250	310	29.57^{b}	15.60d	1.30^{c}	1.22d	6.52^{a}	0.23^{ab}	0.48^{b}	1.80^{b}	CL
3	5.3b	360	210	430	23.15^{c}	19.90^{b}	1.67^{b}	2.23^{b}	5.33d	0.27^{a}	0.48^{b}	1.22^{b}	C
4	5.0c	400	240	360	31.36^{a}	13.70e	1.07d	2.03^{c}	5.95^{c}	0.20^{b}	0.46^{b}	1.40^{a}	CL
5	5.9a	500	200	300	29.42^{b}	16.80^{c}	1.38^{c}	3.25^{a}	6.28^{b}	0.33^{a}	0.59^{a}	1.30^{b}	SCL
Forested wetland													
1	5.4c	120	270	610	44.80^{a}	22.50^{c}	1.72^{b}	2.22^{a}	8.70^{a}	0.93^{a}	0.52^{b}	1.00^{bc}	HC
2	6.2b	100	370	530	33.25^{b}	37.40^{a}	2.63^{a}	1.83^{b}	8.20^{b}	0.67^{a}	0.59^{a}	1.10^{b}	C
3	5.3c	120	380	500	31.63^{c}	18.70e	1.57^{c}	0.81^{c}	8.30^{b}	0.65^{a}	0.59^{a}	1.30^{a}	C
4	6.5a	40	400	560	33.15^{b}	19.50d	0.98e	1.83^{b}	7.45^{c}	0.56^{ab}	0.57^{a}	1.40^{a}	C
5	5.2c	100	320	580	24.05d	24.20^{b}	1.24d	1.83^{b}	6.90d	0.30^{b}	0.52^{b}	0.90^{c}	C

Means with the same alphabet(s) are not significantly different at $p < 0.01$. CL = Clay loam, C = clay, SCL = sandy clay loam, HC = heavy clay.

farmlands possess some characteristics that favour urban development and hence increases its vulnerability to urban encroachment. This implies a devastating decline in urban food production if the trend is not controlled to a sustainable level.

It is equally important to note from the table that a substantial loss in areas occupied by water body and non-forested wetland estimated at 117.1 and 2.7%, respectively, occurred over the study period. Keeping this trend going will not only amount to loss of vital parts of ecosystem that may trigger the conditions encouraging local climate modification but increase the vulnerability of the study area to destructive and pernicious effects of urban flooding that may culminate into loss of lives and properties magnitude of which may be horrified to imagine. Meanwhile, forested wetland, light forest and shrub, according to the table have net gain of 37.2, 25.7 and 2.6% over the study period but Table 5b reveals that these land covers are prone to conversion to other land uses particularly farmland and urban. This suggests that it requires conscious effort to stem down the inevitable conversion of these land covers to the sustainable path. The modification of these land covers through a programme of Lagos State Government; greenness and beautification of environment will go a long way to sustainably conserve the threatened land covers. The study has been able to identify two major processes of land use/land cover change in the study area, namely conversion and modification.

Table 6b shows that 19.3% of the area occupied by farmland over the study period has been converted to other LULC, in which light forest recorded 12.6% which happens to be the highest in the study period, followed by forested wetland 3.0%, shrub (2.7%), non-forested wetland (0.84%) and urban (0.23%). In spite of this loss, farmland has continued to increase in spatial extent by gaining 19.2% from forested wetland, light forest (29.3%), non-forested wetland (19.5%), shrub (20.0%), urban, that is undeveloped plots of land within urban (13.7%) and water body through reclamation of land (0.8%). Urban land use obviously is competing with farmland for available space in the process 33.1% of light forest, 20.6% of shrub, 11.9% of water body, 3.9% of non-forested wetland and 0.23% of farmlands that are previously non-forested wetland or forested wetland or shrub or light forest have been converted to urban use within the study period. This may partly provide clue to contemporary issue of building collapse in the Lagos mega city where large hectares of land have been reclaimed from water, non-forested wetland and shrub as revealed by this study and utilized for urban development without appropriate geotechnical analysis. The modification noticed is in the area of tree planting and beautification programme targeted at promoting green environment which, to a large extent, deserves encouragement.

Drivers of landuse/landcover change in the study area

Land use/land cover changes reflect the dynamics observed in the socio-economic condition of a given area. Similarly, changes in the socio-economic situations cause land use/land cover changes through their influence on land management techniques used and other various aspects of farming systems, institutional settings, environmental policy and others (Mengistu and Salami, 2007). As many researchers indicated in Nigeria, several factors have been modifying the original form of land cover. These include human activities such as agricultural colonization (Adejuwon, 1971); spread of rural settlements (Osunade, 1991); evolution of rural road networks and government policy (Ekanade et al., 1996) noted in Salami (2001).

The results obtained from the change detection analysis gave a clear indication that most of the light forests have disappeared, having been cleared for property development, road construction and provision of utilities such as the two waterworks in the study area.

Information obtained from field work also confirmed that the forested wetlands were being cleared for the cultivation of vegetables and sugarcane. Andreas and Hugh (2009) in a study of land use/land cover change in sub-Saharan Africa over a 25 year period concluded that land cover change in Africa is mainly driven by the expansion of croplands. The expansion of croplands may lead to a growth in agricultural output such as food and fiber production and impact positively on the socio-economic condition of the people. However, at the same time the land left available for future agricultural expansion is decreasing, and with population increase the agricultural zone itself is more crowded exacerbating potential friction amongst and in between agriculturalists and pastoralists alike. Such changes require rapid adjustments to land management so as to avoid crises in food security and conflict over dwindling access to natural resources, which are becoming more evident. The continued expansion of urban built up and farmlands have serious implications for the hydrology, microclimatology and soil health of the river basin, which would only be revealed by further studies.

Environmental consequences of land use/land cover change

From the results of the analyses carried out the dominant land use/land cover (drivers of land use/land cover) in the study area are urban and farmlands. Therefore, the analysis of land use impact that follows will examine the impacts of these two land use classes.

The results obtained from the various ecological approaches adopted in this study, that is, change detection analysis, focus group discussion, soil and vegetation sampling, were used to assess the biophysical status of the Lower Ogun River Basin ecosystem. This assessment focused primarily on: (a) soil quality (b) biodiversity (c) socio-economic impacts and (d) hydrological impact.

Soil quality has been viewed as the capacity of a soil to function within its ecosystem boundaries and interact positively with the environment external to that ecosystem (Olayinka, 2009). Soil quality has emerged as a unifying concept to address the larger issue of sustainability of ecosystem in general and agriculture in particular (Eswaran et al., 2005). From the point of view of land use and land management decision making soil quality is a measurable component of the environment which provides a quantitative basis for evaluating different land use options and impacts of technology. As indicated in Table 7, the impact of LULC is quite noticeable on the soil quality in the study area. Conversion of native forests to cultivation is usually accompanied by a decline in soil organic carbon and nutrients, and deterioration of soil structure. The result obtained from the soil analysis carried out indicated that the growth of urban agriculture in the study area engendered by rapid urbanization is having negative impact on the physical, chemical and organic properties of soil in the study area. The result of the vegetation profile conducted in the study area indicated that the combination of urban growth and the concomitant increase in population has resulted in the loss of biodiversity as manifested in almost complete degradation of the non-forested wetland.

Table 8. FGD findings on the impact of landuse change.

Impacts of land use	Maidan (forested wetland)			Isasi (non-forested wetland)		
	Sand Miner	Farmer	Fishermen	Sand miner	Farmer	Fishermen
Increased flooding	+	+	+	+	+	+
Pollution	+	+	+	+	+	-
Reduction in plant and animal species	+	+	+	+	+	+
Global Warming	-	-	-	-	+	+
Income Generation	+	+	+	+	+	+

+, Where the opinions were expressed by the respondents; -, where the opinions were not expressed at all.

Thus the original vegetation cover has given way to shrub and herbs while trees have completely disappeared, in contrast with the forested wetland. This development also has a serious implication on the microclimate of the study area and carbon emission. Information gathered from field work and focus group discussion also revealed that the dominant life form in the non-forested wetland was herb which covered 83% of the study site, while the remaining 17% was covered by shrub, there were no trees, as plant height ranged between 0.1 to 5 m. This result also indicated that this site has been seriously degraded. On the other hand, life forms in the forested wetland showed degradation from low shrub, medium shrub, tall herb and tall trees, which were the dominant life form, at 43%. This result also demonstrated the characteristic feature of tropical rainforest in which tree canopies occur in tree layers. Thus heights of plants ranged from <2 to >25 m.

A major source of hydrological impact of land use/land cover change in the study area are the two water works (Adiyan and Iju water works) sited within the study area. Ogunbajo (2005), in a study carried out on the impact of the two water works reported that, flooding of the immediate environment, change in the flow regime of river Ogun, silting of the river bed and pollution from sludge biomass were the observable impacts of the two waterworks. The waste water and high amount of silt contained therein are discharged into the downstream sector of river Adiyan resulting in the alteration of the morphology of the area which induces large scale erosion when it rains and consequently large flooding of the area.

Urban agriculture as with other urban activities has both positive and negative social, environmental, and economic impacts and externalities. Urban agriculture is an important source of income for some of the inhabitant of the communities within the study area. Findings from FGD, according to Table 8, confirmed the fact that in addition to income from sales of surpluses, farming households save on household expenditure by growing their own food.

Conclusion

Changes in the patterns of land use/land cover as demonstrated in this study are a reflection of increasing anthropogenic pressure on landscape which needs to be seriously addressed. Rapid population growth and its twin brother, urbanization remain the major causes of environmental degradation. More and more people, especially the urban poor, are getting engaged in urban agriculture using the mostly unprotected and uncontrolled wetlands in the Lower Ogun River Basin. Although this could lead to increased food production and food security there is need for further research into sustainable management and utilization of fragile ecosystem such as wetlands. There is a need for the control and planning of activities around the existing wetlands by government to avoid unsustainable encroachment of the fragile wetlands.

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