Original Research Article

URBAN SPRAWL ANALYSIS AND TRANSPORTATION USING CELLULAR AUTOMATA AND MARKOV CHAIN

ABSTRACT

This work examines the effects of urban sprawl in three (3) Local Government Areas (LGAs) of Lagos State so as to determine changes that have taken place between 1984 and 2006. Land Consumption Rate and Land Absorption Coefficient were introduced to aid in the quantitative assessment of the change, urban sprawl models were developed and the spread of urban sprawl in the next 14 years (2006 to 2020) were projected.

Landsat Imageries of three epochs (1984, 2000 and 2006) were processed, classified and analysed. CA-Markov modelling was carried out to predict for 2020. From the research, it was discovered that the Built-up Areas will increase from 8.76% to 17.60% of the Land use/land cover i.e. continuous urban sprawl in future. Finally, the effects of urban sprawl on transportation were discussed.

Key Words: Urban Sprawl, Land-Use/Land-Cover, Change Detection, Remote Sensing, Geographic Information Systems (GIS).

1.0 INTRODUCTION

Maya (2008) described urban sprawl as a pattern of haphazard, automobile-dependent development on the fringes of existing cities. With rising personal incomes and persistent consumer demand for single-family homes on large lots in ethnically and physically homogeneous jurisdictions, urban sprawl has boomed. While Adams (2010) described urban sprawl as the unchecked spreading of a city or its suburbs. It often involves the construction of residential and commercial buildings in rural areas or otherwise undeveloped land at the outskirts of a city. Most residents of typical urban sprawl neighbourhoods live in single-family homes and commute to their jobs in the city. Concerns over urban sprawl and its consequences have been raised and largely focus on negative consequences for residents and the local environment. On the other hand, some argue that "urban sprawl" illustrates positive growth of a local economy (Adams, 2010).

Remote Sensing (RS) and Geographic Information Systems (GIS) are now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the analysis of Earth - system function, patterning, and change at local, regional and global scales over time; such data also provide an important link between intensive, localized ecological research and regional, national and international conservation and management of biological diversity (Willkie and Finn, 1996). In the recent times, Geographic Information Systems (GIS) is being widely used for mapping and monitoring of urban sprawl of cities and transportation systems. The spatial patterns of urban sprawl and transportation systems over different time periods, can be systematically mapped, monitored and accurately assessed from satellite data along with conventional ground data.

Therefore, attempt was made through this study to map out urban sprawl and changes in land cover in Lagos Island and its environs (i.e. Lagos Island, Eti-Osa and Ibeju-Lekki) between 1984 and 2006 to aid quick and useful decision-making process for the purpose of land development, administration and planning for a sustainable environment. To achieve this, prediction was made on the possible changes that might take place over the next ten years.

Among significant benefits of this research include; aid strategic planning for physical and infrastructural development through making informed, guided and useful decisions; unfold the available greenbelts and arable lands for Peri-urban farming and food production; a useful tool for strategic planning to curb the problems associated with urbanisation and population explosion; aid effective forecast of future urban growth and it socio-economic consequences such as on transportation.

2.0 THE GEOGRAPHY OF THE STUDY AREA

The city of Lagos (Fig. 1) lies in south-western Nigeria, on the Atlantic coast in the Gulf of Guinea, west of the Niger River delta, located between longitudes 2°42' E and 3° 24' E and between latitudes 6° 22' N and 6° 52' N. Lagos Island is connected to the mainland by three large bridges which cross Lagos Lagoon to the district of Ebute Metta. It is also linked to the neighbouring islands of Ikoyi and Victoria Island. Ikoyi is situated on the eastern half of Lagos Island and joined to it by a landfill. Ikoyi is also connected to Victoria Island by a bridge crossing over the Five Cowrie creek. Along with Ikoyi, Victoria Island occupies a major area in the suburbs of Lagos which boasts of several sizable shopping districts. On its sea shore along the Atlantic front, there is environmentally reconstructed Bar Beach.

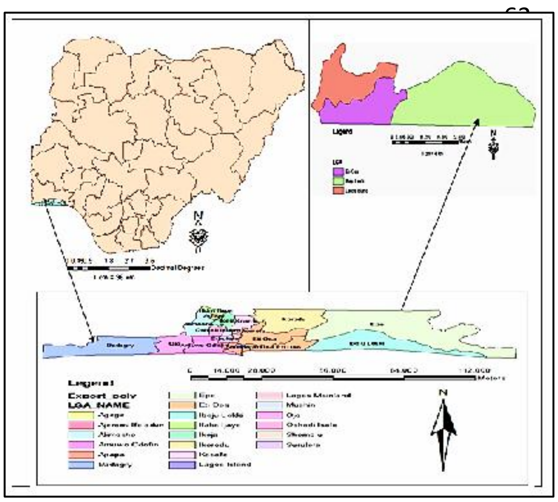

Fig.1. Map of Nigeria and Lagos State's LGAs Showing the Study Area (Lagos-Island, Eti-Osa and Ibeju-Lekki LGAs).

3.0

RESEARCH METHODOLOGY

The procedure adopted in this research forms the basis for deriving statistics of land use / land cover expansion. The methodology adopted is given below:

3.1 Data Sources

This study was limited to the periods between 1984 and 2006 based on accessible dataset. Landsat imagery of 30m resolution was used since imagery of higher resolution (e.g. Spot) was not readily available and accessible. The 1984, 2000 and 2006 Landsat imageries (Table 1) were used because the 1990 to 1999 versions had cloud cover. Similarly, the 2007 to 2010 versions have stripes that make them unfit for use in this study. Furthermore, the 2000 landsat image used for this study does not cover the eastern edge of Ibeju-Lekki LGA, while even the 2006 Landsat image used had some stripes. Therefore, the super-imposed boundary vector used for clipping the images was slightly adjusted to leave out the eastern edge of Ibeju-Lekki, in order to make our results comparable for the three Landsat epochs under study.

Table 1. Data types and sources.

S/N	DATA TYPE	PRODUCTION DATE	SCALE	SOURCE
1.	Landsat image	2006-12-07	$30M^{ETM+}$	GLCF
2.	Landsat image	2000-02-06	$30M^{ETM+}$	GLCF
3.	Landsat image	1984-12-18	$30M^{TM}$	GLCF
4.	Lagos State Local Government Administrative Map	2006	1:140,000	LASPPDA
5.	Lagos State Government Basic Statistical Record	2006		Central office of Statistics-Lagos State Ministry of Economic planning and Budget.

3.2 Data Processing

The following activities were carried out on the acquired data:

3.2.1 Development of a Classification Scheme and Percentage Change Determination

The classification scheme developed gave a rather broad classification where the land cover categories (Olaleye, Abiodun & Igbokwe, 2009) were each identified by a single digit as shown in the Table 2.

Table 2. Land Cover Classification Scheme.

CODES	LANDCOVER CATEGORIES	DESCRIPTION
1	Built-Up Areas	Urbanised areas and some scattered developments
2	Water bodies	Rivers, lagoons and the ocean
3	Wetlands	marshy areas and light mangrove swamp forests
4	Vegetal cover	Heavy and light forests, woodlands, grasslands, scrubs, etc.
5	Waste-lands/Bare-ground	Undeveloped lands without vegetal cover e.g. sandy beaches, dry grasslands, rocky areas, some farmlands and other human induced barren lands

After the land cover classification (Eastman, 1999; Ndukwe, 1997), the comparison of the land cover statistics was carried out to assist in identifying the percentage change, trend and rate of change (Km^2) between 1984 and 2006. Percentage change was determined from Equation 1:

$$Pc = Oc / Sc * 100 \qquad \text{-------------------------------------- (1)}$$

(ESRI, 2008)

where:

Pc = Percentage change/trend

Oc = Observed change

Sc = Sum of change

3.2.2 Land Consumption Rate and Land Absorption Coefficient

The Land Consumption Rate (LCR) is the measure of compactness which indicates a progressive spatial expansion of a city, while the Land Absorption Coefficient (LAC) is a measure of change in consumption of new urban land by each unit increase in urban population. The LCR and LAC were determined using the Yeates and Garner (1976) formulas:

$$LCR = A / P \qquad \text{-- (2)}$$

and,

$$LAC = (A_2 - A_1) / (P_2 - P_1) \qquad \text{-- (3)}$$

where, A = areal extent of the city in hectares

P = population

A_1 and A_2 = areal extents (in hectares) for the early and later years,

P_1 and P_1 = population figures for the early and later years, respectively.

3.2.3 Overlay Operations and Modelling with CA-Markov

Image differencing and Overlay operations were carried out to identify locations and magnitude of changes over time which was limited to the built-up area. CA-Markov was used as the modelling technique to determine the change. The CA-Markov is an integration of two modelling techniques: Markov Chain analysis and Cellular Automata (CA). A Markovian process is one in which the state of a system at time 2 can be predicted by the state of the system at time 1 given a matrix of transition probabilities from each land cover class to every other land cover class.

In this research, Markov Chain model treated the urban expansion as a stochastic process where the later state (of a land cover type) is only related to its immediate preceding state represented by Equation 4:

$$P_{ij} = \sum_{K=1}^{r} p_{ik} p_{kj} \qquad \text{-- (4)}$$

(Balzter, Braun & Kohler, 1998; Wilkipedia, 2011)

where: P_{ij} is the transition probability from state i to j, p_{ik} is the transition probability from i to k and p_{kj} is the transition probability from k to j. The OVERLAY and MARKOV modules of IDRISI were used to create the transition probability matrix used.

3.2.4 Population Determination

While the 1991 and 2006 population figures were obtained directly from the population census, that of 1984 and 2000 were estimated using the Zubair (2008) formula:

$$r = [Py - Px * 100/Px] / t \qquad \text{--- (5)}$$

where:

r - Population Growth Rate

Py - Population of Later year

Px - Population of Earlier year

t - Number of years projecting for.

The Lagos State population figures for 1991 and 2006 were given as 5,725,116 and 9,113,605 respectively, therefore using Equation 5, the Lagos population growth rate equals 3.9458.

Using Equations 6a and 6b, the estimated population figures for 2000 and 1984 were obtained:

$$N = r/100 * Po \qquad \text{--- (6a)}$$

$$Pn = Po + (N * t) \qquad \text{--- (6b)}$$

(Zubair, 2008).

where:

Pn = Estimated population

Po = Base year population

r = Growth rate

N = Annual population growth

t = Number of years projecting for.

4.0 RESULTS PRESENTATION AND ANALYSIS

The following results were obtained and analysed:

4.1 Land Cover Distribution

The land cover distribution for each study year was derived from the classification of Landsat imageries of 1984, 2000 and 2006 and presented in the Table 3.

Table 3. Land Cover Distribution (1984, 2000 and 2006).

Land Cover Categories	1984		2000		2006	
	Area in Km²	Area (%)	Area in Km²	Area (%)	Area in Km²	Area (%)
Built-up Areas	85.169554	8.76	113.286593	11.65	136.189834	14.00
Water bodies	385.079470	39.59	377.755252	38.84	377.262665	38.79
Wet-Lands	30.106046	3.10	56.560695	5.81	54.147737	5.57
Vegetal Cover	378.473801	38.91	360.058282	37.02	344.342796	35.40
Waste-Lands/ Bare grounds	93.802295	9.64	64.970344	6.68	60.688134	6.24
Total	**972.631166**	**100**	**972.631166**	**100**	**972.631166**	**100**

An important aspect of change detection is to determine the quantity of change which will assist in decision making (Ifatimehin & Ufuah, 2006; Ujoh, Kwabe & Ifatimehin, 2010). Based on the Land Cover Distribution, the following can be deduced:

<u>As at 1984</u>-

Table 3 reveals that as at 1984, Water bodies and Vegetal covers representing 78.67% of the total land cover of the study area. Wetlands were the least visible land cover representing 3.10%. Built-up Areas in 1984 occupy 8.76% of the total classes. Graphical illustration of the land cover categories of the study area for 1984 is given in Fig. 2.

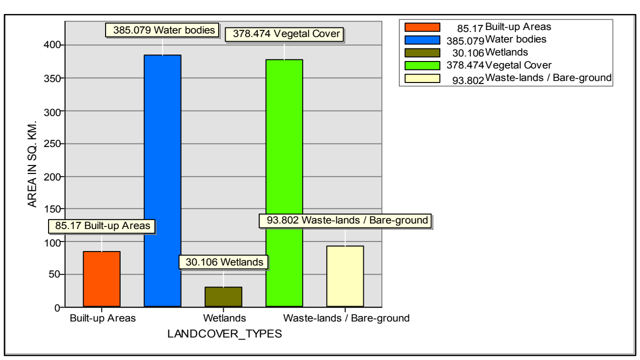

Fig. 2. The Land Cover categories (1984).

Lagos State created on 27th of May, 1967 had its physical development from both colonial rule and from indigenous administrators and governors. As at 1984, some outstanding housing estates such as Jakande, Dolphin and a number of others were already developed. The land cover map of the study area for 1984 is shown in Fig. 3.

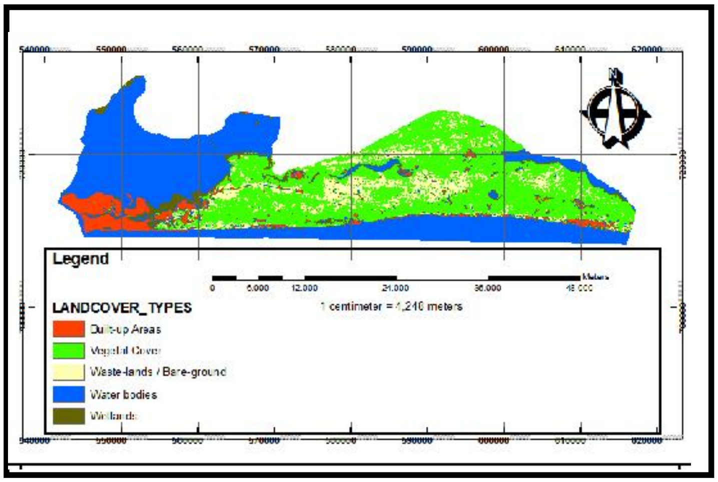

Fig. 3. Derived Land Cover Map of Lagos Island and Its Environs in 1984.

<u>As at 2000</u>-

The built up areas have increased to 11.65% from the 8.76% in 1984. On the other hand, vegetal cover has decreased from 38.91% to 37.02% in 2000. Similarly, the waste-lands/bare grounds have decreased to 6.68% from 9.64%, and water bodies to 38.84% from 39.59% of the study area. The 2000 land cover categories of the study area are shown in Fig. 4.

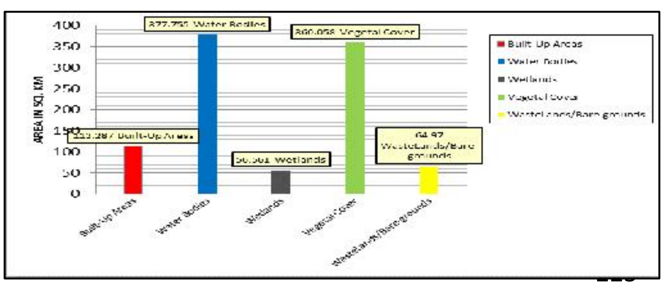

Fig. 4. The Land Cover categories (2000).

The increase in the built-up area at this time is not unconnected to the physical development efforts of the then administrators and governors. A lot of land reclamation and housing estates projects were embarked upon around this time. Some of the housing estates include Oniru, Lekki, Victoria Garden City (VGC), and so on. Previously isolated islands such as Banana Island were joined to the other major part of Lagos Island by land reclamation. The land cover map of the study area as at 2000 is shown in Fig. 5.

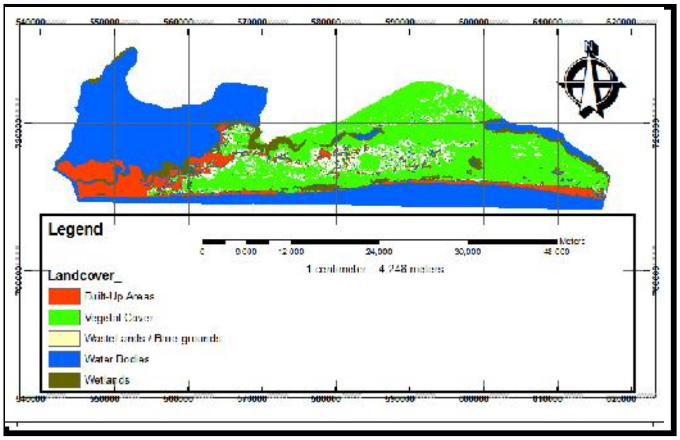

Fig. 5. Derived Land Cover Map of Lagos Island and Its Environs in 2000.

As at 2006-

As at 2006, built-up areas have grown to 14% occupying about 136.189834 Km² of the study area. This sprawl could be accounted for from the continuous physical development programmes of the State Government. Around this time, more lands were reclaimed, new housing estates were developed and existing ones were expanded and improved upon as evident in Lekki Phases I and II, Ajah and VGC to mention but a few. The wastelands/bare grounds slightly decreased to 6.24% from 6.68% of 2000. There is also a slight decrease in water bodies. This could not be unconnected with the land reclamation efforts. Both wetlands and vegetal covers recorded slight decrease occupying 5.57% and 35.40% respectively. The land cover categories of the study area for 2006 is shown in Fig. 6, while the land cover map of the study area for 2006 is given in Fig. 7.

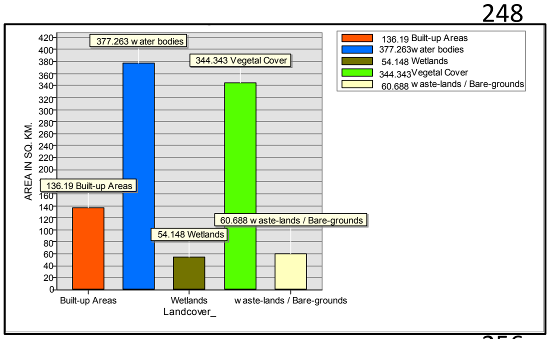

Fig. 6. Land Cover categories (2006).

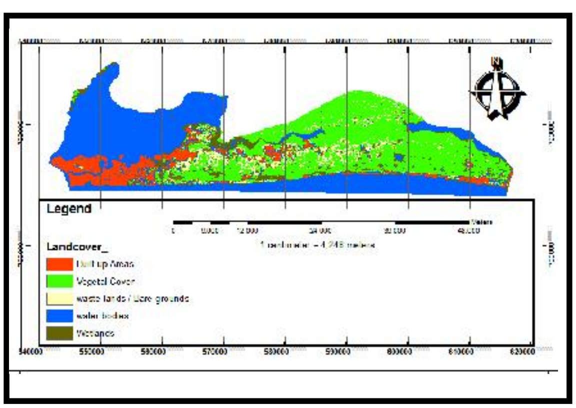

Fig. 7. Derived Land Cover Map of Lagos Island and Its Environs in 2006.

4.2 Land Consumption Rate and Land Absorption Coefficient Determination

The Land Consumption Rate (LCR) which is the measure of compactness that indicates a progressive spatial expansion of the city and the Land Absorption Coefficient (LAC) which is the measure of change in consumption of new urban land by each unit increase in urban population as given in Equations 2 and 3 respectively. The results obtained are shown in the Table 4. The population figures, obtained from Equations 6a and 6b, used are given in Table 5.

Table 4. Land Consumption Rate and Absorption Coefficient

YEAR	LAND CONSUMPTION RATE (LCR)	YEAR	LAND ABSORPTION COEFFICIENT (LAC)
1984	0.032	1984-2000	0.011
2000	0.022	2000-2006	0.025
2006	0.022		

Table 5. Population Figures of the Study Area

YEAR	POPULATION FIGURES			TOTAL	SOURCE
	ETI-OSA LGA	LAGOS ISLAND LGA	IBEJU-LEKKI LGA		
1984	127,171	120,147	18,049	265,367	Estimated from Equations 6a and 6b.
2000	238,095	194,018	89,906	522,019	Estimated from Equations 6a and 6b.
2006	283,791	212,700	117,793	614,284	Obtained from Office of Statistics (2006)

The LCR and LAC indicate city expansion via the built-up areas between 1984 and 2000, and also between 2000 and 2006, but the latter at a reduced rate (Tables 4).

4.3 Land Cover Expansion: Trend and Rate

The Land cover expansion or growth was calculated by simply deducting the value for each land cover category of an early year from the latter year understudy. The trend, that is the percentage growth/change, was obtained from Equation 1, while the annual rate of expansion was obtained by dividing the percentage growth/change (i.e. land cover expansion value) by the number of years between the two years understudy. The results obtained for the land cover expansion, trend and annual rate are shown in the Table 6. The gains (or increase) in built up areas are shown in Tables 7 and 8 for 1984/2000 and 2000/2006 respectively.

Table 6. Land Cover Expansion: Trend and Rate.

LAND COVER CATEGORIES	1984-2000		2000-2006		ANNUAL RATE OF CHANGE	
	AREA (KM²)	AREA (%)	AREA (KM²)	AREA (%)	1984-2000	2000-2006
Built-Up Areas	28.117039	2.89	22.903241	2.35	1.757315	3.817207
Water Bodies	-7.324218	-0.75	-0.492587	-0.05	-0.457764	-0.082098
Wet-Lands	26.454649	2.71	-2.412958	-0.24	1.653416	-0.402160
Vegetal Cover	-18.415519	-1.89	-15.715486	-3.51	-1.150970	-2.619248
Waste-Lands/ Bare Grounds	-28.831951	-2.96	-4.28221	-0.44	-1.8019	-0.713702

Table 7. Gain in Built-Up Areas of the Study Area between 1984 and 2000.

YEAR	BUILT-UP AREA (KM^2)	GAIN IN BUILT-UP AREA		TIME IN YEARS	AVERAGE GAIN (PER YEAR)
		KM^2	(%)		
1984	85.169554	28.117039	33	16	1.76
2000	113.286593				

Table 8. Gain in Built-Up Areas of the Study Area between 2000 and 2006.

YEAR	BUILT-UP AREA (KM^2)	GAIN IN BUILT-UP AREA		BUILT-UP AREA (KM^2)	AVERAGE GAIN (PER YEAR)
		KM^2	(%)		
2000	113.286593	22.903241	20.22	6	3.82
2006	136.189834				

From Tables 6, 7 and 8, there was a negative change i.e. a reduction in vegetal cover between 1984 and 2000. The built up areas and wetlands had a positive change (i.e. increase). As mentioned earlier, the increase in the built–up areas, which is indicative of urban sprawl, may not be unconnected to the land reclamation and rapid physical development of the area at this time. A lot of housing estates such as Jakande, Dolphin, Oniru, Lekki, and so on were developed.

Equally at this period, Water bodies decreased slightly. Historically, Victoria Island was originally entirely surrounded by water: bordered by the Atlantic Ocean on the south, the entrance of Lagos Lagoon on the west, the Five Cowrie Creek to the north and swamps on the east. The colonial government began the process of sand filling in the eastern swamps to reduce mosquito breeding areas. This created a land bridge between Victoria Island and Lekki Peninsula terminating its existence as a true island. After independence, successive state governments expanded this development, culminating in the construction of a highway connecting Victoria Island to Epe. This activity along with the rapid commercialisation of Victoria Island, stimulated residential development along Lekki-Epe Corridor starting with Lekki Phase I.

The area of the land bridge composed of the former swampland (called Maroko) which became a large slum and housed many of the new migrants to Lagos State. Due to complaints from Lagos Island residents, the then Military Administrator of the State forced the slums and squatters to be removed, cleared and sold to wealthy residential buyers. The reclaimed Maroko became Victoria Island Annex and has witnessed rapid development and expansion to the extent that it is presently connected to Lekki Pennisula. This newly developed and enlarged area is now referred to as 'Oniru Estate' after the name of the ruling family of the area (Wikipedia, 2011).

The image differencing and overlay operations for the 1984/2000 change in the Built-Up areas is shown in Fig. 8.

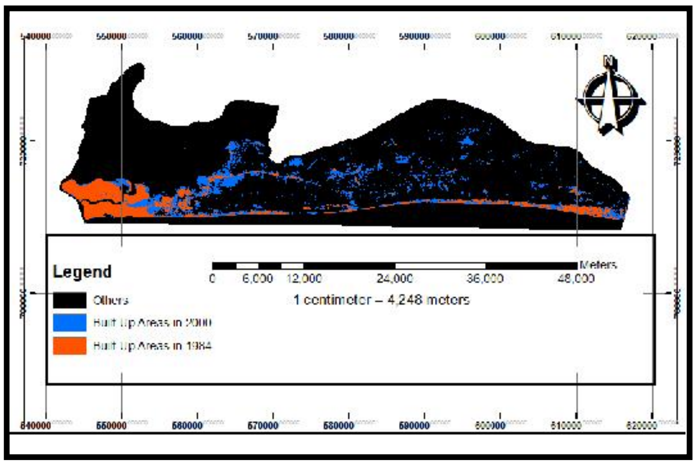

Fig. 8. Map showing Overlay of Built-Up Areas of Lagos Island and Its Environs to Depict 1984/2000 Urban Sprawl.

Also from Tables 6, 7 and 8, between 2000 and 2006 the Built-up area continued to have positive change. This growth could be attributed to the continued physical development and establishment of new housing estates such as Ajah, VGC, and so on. For instance, Victoria Garden City (VGC) is a uniquely planned comprehensive city of approximately 200 hectares by the Lagos Lagoon consisting of residential, commercial and public services areas. It was originally planned for 30,000 residents and as at December, 2001, half of its planned residents were already living there.

At this period (between 2000 and 2006), all the other land cover categories apart from Built-up areas experienced negative changes. To further buttress the fact that a lot of land reclamation and urbanisation took place at this period, Water bodies and Waste lands slightly decreased. Vegetal Cover and Wetlands also decreased. This is equally indicative of high level of urban sprawl. The image differencing and overlay operations for the 2000/2006 change in the Built-Up areas is shown in Fig. 9.

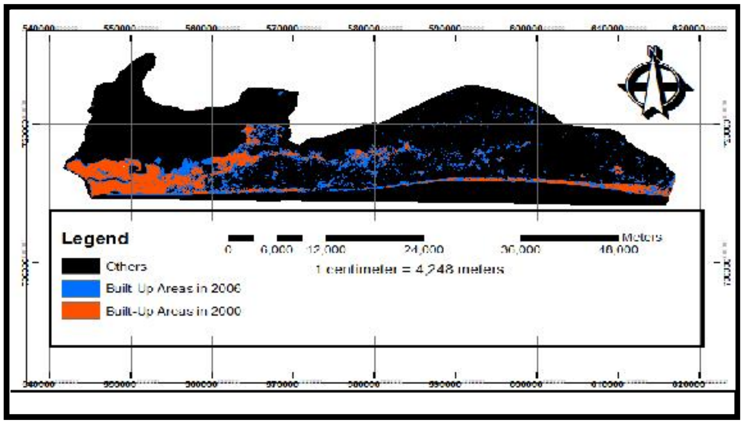

Fig. 9. Map showing Overlay of Built-Up Areas of Lagos Island and Its Environs to Depict 2000/2006 Urban Sprawl.

4.4 Transition Probability Matrix and Modelling of the Study Area

The CA Markov of Idrisi was used to model and produce the projected land cover map of the study area for 2020. The transition probability matrix generated the probability that each land cover category will change to the other category. This matrix is produced by the multiplication of each column in the transition probability matrix with the number of cells of corresponding land cover in the later image. The transition probability matrix and the cross tabulation of 2000 and 2006 are presented in the Tables 9 and 10.

In the 5 by 5 matrix, Table 9, the rows represent the older land cover categories and the column represents the newer categories. Although this matrix can be used as a direct input for specification of the prior probabilities in maximum likelihood classification of the remotely sensed imagery, it was however used in predicting land cover categories of 2020.

Table 9. Transition Probability Table.

Land Cover Categories	**Built-up Areas**	**Water-bodies**	**Wetlands**	**Vegetal Cover**	**Waste-lands/ Bare grounds**
Built-up Areas	**0.7427**	0.0159	0.0301	0.0751	0.1362
Water-bodies	0.0110	**0.9729**	0.0130	0.0027	0.0004
Wetlands	0.2037	0.1835	**0.4201**	0.1792	0.0135
Vegetal Cover	0.0485	0.0009	0.0353	**0.8320**	0.0833
Waste-lands	0.2592	0.0002	0.0037	0.3835	**0.3534**

Table 10. Cross-tabulation of 2000 and 2006 Landsat Images

Land Cover Categories	**Built-up Areas**	**Water-bodies**	**Wetlands**	**Vegetal Cover**	**Waste-lands/ Bare grounds**
Built-up Areas	861201	18423	35001	87066	157941
Water-bodies	41373	3640095	48600	10062	1467
Wetlands	115191	103797	237564	101367	7614
Vegetal Cover	174384	3222	127035	2991870	299286
Waste-lands	168579	117	2403	249480	229896

From Table 9, the built-up areas have a 0.7427 probability of remaining built-up areas. This therefore shows that there is a relatively high probability of Lagos Island and its environs experiencing continuous sprawl in the future. The Markov chain's state diagram to show the transition probability matrix is given in Fig. 10.

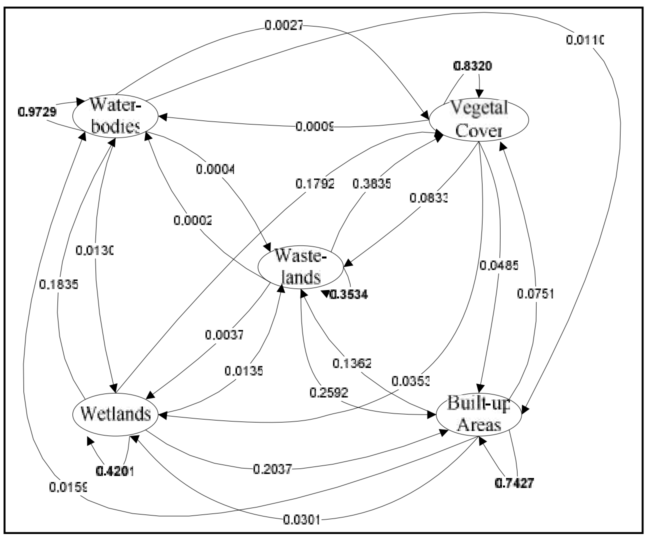

Fig. 10. State Diagram of the Markov Chain showing the Transition Probability.

4.5 Projected Land Cover Distribution for 2020

The Projected Land Cover Distribution for 2020 is shown in Table 11.

Table 11. Distribution of Projected Land Cover Categories for 2020.

Landcover Categories	**Area (Km²)**	**Area (%)**
Built-Up Areas	171.162241	17.60
Water Bodies	377.510338	38.81
Wetlands	53.458761	5.50
Vegetal Cover	309.690114	31.84
Wastelands/Bare Ground	60.809712	6.25
Total	**972.631166**	**100**

Table 11 shows the statistics of land cover projection of the study area for 2020. It can be easily observed that by 2020, water bodies and vegetal cover are expected to be the greatest of the land cover categories. Built-up area is expected to have grown to 17.60% of the total land cover and wastelands are expected to be about 6.25%. Wetlands are expected to be the smallest of the land cover categories. The projected land cover categories of the study area for 2020 are shown in Fig. 11.

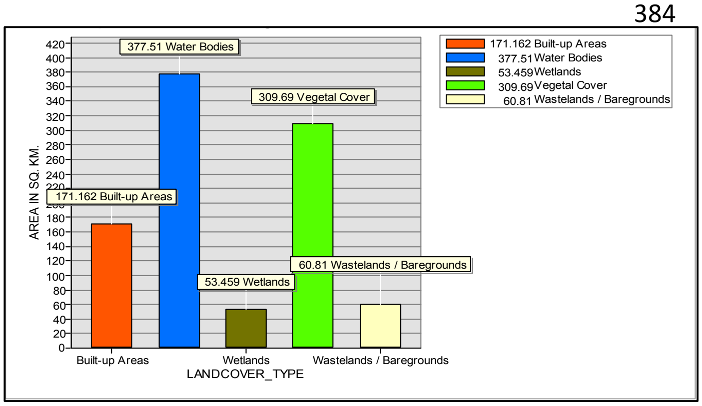

Fig. 11. The Projected Land Cover categories for 2020.

This projected land cover pattern is similar to those of the previous years understudy (1984, 2000 and 2006) in this research. The built-up areas continue to grow indicating dynamic urban sprawl. However, due to the natural obstacle of water bodies (the Ocean and Lagoons), by 2020, Lagos Island and its environs is expected to be highly compacted at its western axis (Ikoyi and Victoria-Island). The sprawl is expected to continue majorly to its eastern part (Ibeju-Lekki area). The projected land cover map of the study area for 2020 is given in Fig. 12.

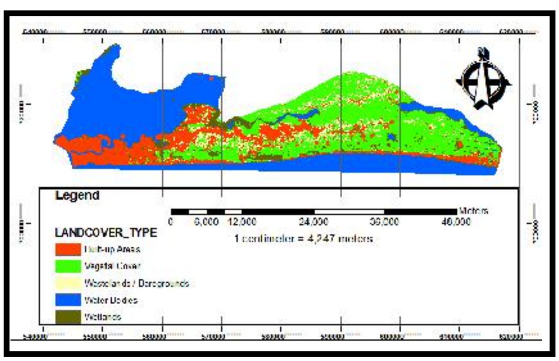

Fig. 12. Projected Land Cover Map of Lagos Island and Its Environs by 2020.

Table 12 shows the expected changes in the land cover categories of the study area between 2006 and 2020.

Table 12. Future/Expected Land Cover Expansion between 2006 and 2020

LAND COVER CATEGORIES	2006-2020		ANNUAL RATE OF CHANGE
	AREA (KM²)	AREA (%)	
Built-Up Areas	34.972407	3.6	2.498029
Water Bodies	0.247673	0.02	0.017691
Wetlands	-0.688976	-0.07	-0.049213
Vegetal Cover	-34.652682	-3.56	-2.475192
Wastelands / Bare Grounds	0.121578	0.01	0.008684

Wetlands and Vegetal covers are expected to experience negative changes or decrease by -0.07% and -3.56% respectively. Wastelands are expected to increase slightly by 0.01% to possibly indicate that more of the wetlands will be reclaimed and opened up for future development. Water bodies are expected to slightly increase by 0.02% and can be justified in the annual and increasing floods and beach erosion experienced in some parts of Lagos (Awosika, 2001).

Built-up area is expected to record the largest percentage of positive change or growth with about 3.6% increase. Its expected annual rate of increase or growth is about 2.498029 Km². This is indicative of continuous urban sprawl and can be justified in the continuous real estate development in Lekki and Ajah axis of the area. The expected map of the built-up areas of Lagos Island and its environs for 2020 is shown in Fig. 13. The 2006/2020 image differencing and overlay operations is shown in Fig. 14 to depict the 2006/2020 expected changes. Outstanding among the physical development and real estate projects on Lagos Island and its environs is the Eko Atlantic City (Elumoye, 2007). The Eko Atlantic City project involves reclaiming over eight square kilometres of land adjacent to Lagos Bar Beach. This also adds to urban sprawl.

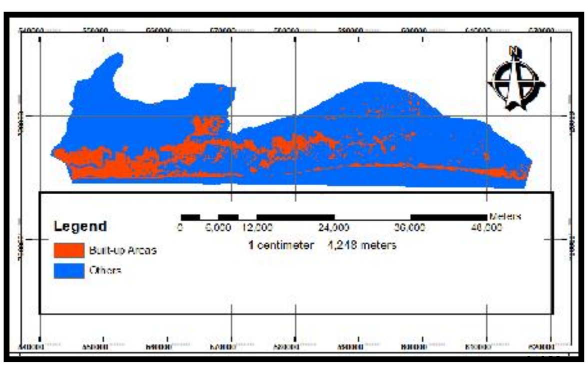

Fig.13. Projected Built-Up Areas Map of Lagos Island and Its Environs by 2020.

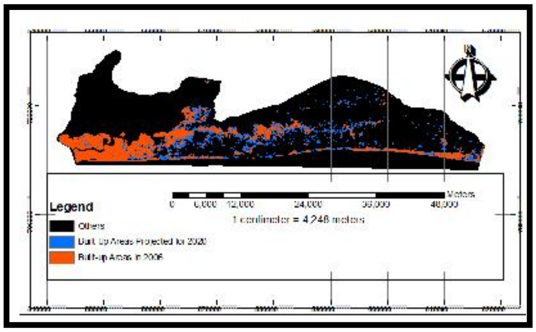

Fig. 14. Overlay of the Projected Built-Up Areas of Lagos Island and Its Environs Depicting Expected 2006/2020 Urban Sprawl.

The growth of the Built-up areas and changes in other land cover categories between 1984 and 2020 are shown in Fig. 15.

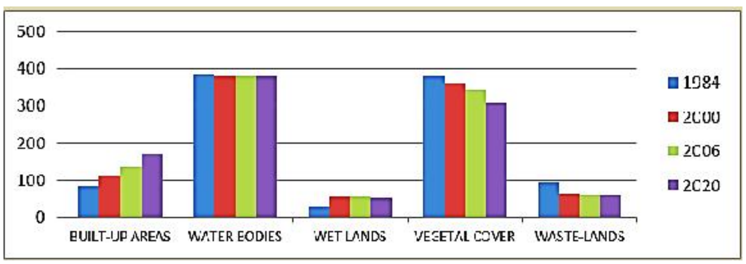

Fig. 15. Graphical Illustrations of Changes in Land Cover Categories between 1984 and 2020.

Urban sprawl is a function of accessibility. The faster one can move from the urban centre to the sprawled area, the faster the growth of the sprawl. Section 5.0 briefly discussed the effects of urban sprawl on transportation.

5.0 CONSEQUENCES OF URBAN SPRAWL ON TRANSPORTATION

The effects of urban sprawl on transportation cannot be emphasized. Maya (2008) mentioned some of these basic effects of urban sprawl on transportation:

- Sprawled areas does not support public transportation resulting in; greater dependence on roads and highways that often become heavily congested with private automobiles and demand for new roads, which then lead to even more sprawl.
- In economic terms, sprawl created congestion imposes a variety of costs on drivers: wasted time, increased gasoline consumption, and greater wear and tear on vehicles.
- As a result of the congested roads, the added cost of driving to and from the suburban fringe would be more than the savings realized in living in lower price housing sprawls.
- Similarly new roads constructed, allow residents drawn by lower housing prices to move farther and farther from the urban core, thereby increasing the total amount of driving in a given metropolitan area.

- On the environmental effects of sprawl, as a result driving greater distances, there will be rise in automobile emissions causing air pollution and contributes to global climate change through greenhouse gas emissions.

While Ontario College of Family Physicians (2005) on the Health Impact of Urban Sprawl also mentioned the consequences of long travel on the inhabitants of urban sprawl:

- Social integrity and health impacts of urban sprawl- it erodes social capital, robbing people of balanced healthy lifestyle, degrading the surrounding natural environment, and increasing the stress of commuting, which not only impacts on mental health but also physical health.
- Commuting and driver's stress- Researches have shown that: (i) urban sprawl commuters spend 3 to 4 times more hours driving than individuals living in well-planned, dense communities; (ii) traffic congestion also impairs health, psychological adjustment, work performance and overall satisfaction with life; (iii) job satisfaction and commitment declines with increased commuting distance on the road, but not with public transit use; and (iv) high impedance commuting has adverse effects on blood pressure, mood, frustration tolerance, illness occasions, work absences, job stability and overall life satisfaction.
- More driving, more road rage- Road rage is characterized by violent disputes between drivers that sometime causes serious injuries or even death.
- Urban sprawl harms high risk groups- Researches also showed that: (i) living in car-dependent areas with high traffic affects children even before they are born; (ii) without easy access to effective public transit, the elderly and disabled, who may be homebound having difficulty in going from place to place, on the overall are more isolated, and may be lonelier than the average person, finally, (iii) women are more likely than men to indicate problems of managing stress and feelings of sadness, worthlessness and hopelessness.

6.0 CONCLUSIONS

In Conclusion, this research demonstrates the ability of Geographic Information Systems (GIS) and Remote Sensing in capturing spatial-temporal data such as urban sprawl. Attempt was made to capture as accurate as possible five land cover classes as they change through time.

From this study, the built-up areas had continuous positive changes for all the years considered (1984-2000, 2000-2006 and 2006-2020). This shows that Lagos Island and its environs (especially the Ibeju-Lekki axis) will continue to experience sprawl in the coming years.

The said growth is naturally expected to have some socio-economic consequences such as increased pressure on land resources and infrastructures, increased attraction of population explosion, housing problems, increased rate of unemployment, increased crime rate, increased travel costs and environmental pollution plus other decadences associated with urban sprawl transforming to urban centres. Therefore, there is need for the various governments to have strategic plans to curb these challenges. These strategic plans must include: (i) need to experience more of vertical growth than the usual horizontal sprawl; (ii) carrying out environmental impact assessment of projects in the study area to avoid future occurrence of natural disasters like floods and tsunamis; (iii) measures should be put in place to curb excessive vegetal loss to guide against global warming; and (iv) as mentioned in Section 2.0, the links between Lagos Mainland and Lagos Island that extended to the suburbs, of Lagos Island, have resulted in high travel costs. Hours are spent on roads to commute with the urban centre. Therefore, challenges of an increase in vehicle miles travelled (VMT) per capita as a result of any urban sprawl must be tackled with plans that will have significant expansion in transit service and land use changes that will allow for higher-density development. The transportation element shall be to plan for a multimodal transportation system that places emphasis on public transportation systems which must include mass transit, bicycle and pedestrian routes that will ensure safety, comfort and affordability.

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