URBAN SPRAWL ANALYSIS AND TRANSPORTATION USING CELLULAR AUTOMATA AND MARKOV CHAIN

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ABSTRACT

The uncontrolled urban spread (urban sprawl) has both positive and negative implications. The adverse effects are more pronounced than its gains. Among others adverse effects is infrastructure provision (such as roads, etc.) which usually becomes a problem. 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 adverse effects of urban sprawl on transportation in this area have resulted in high congestion cost and high level of air pollution just to mention but a few. The sprawl pattern has opened up the rural areas (such as Oniru, Ajah, Eti-Osa) and till today the sprawl is still unabated.

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

1. INTRODUCTION

[1] described urban sprawl as a pattern of haphazard, automobile-dependent development on the fringes of existing cities. With rising personal incomes and persistent consumer

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23 demand for single-family homes on large lots in ethnically and physically homogeneous
24 jurisdictions, urban sprawl has boomed. While [2] described urban sprawl as the unchecked
25 spreading of a city or its suburbs. It often involves the construction of residential and
26 commercial buildings in rural areas or otherwise undeveloped land at the outskirts of a city.
27 Most residents of typical urban sprawl neighbourhoods live in single-family homes and
28 commute to their jobs in the city. Concerns over urban sprawl and its consequences have
29 been raised and largely focus on negative consequences for residents and the local
30 environment. On the other hand, some argue that "urban sprawl" illustrates positive growth
31 of a local economy [2].

32

33 Remote Sensing (RS) and Geographic Information Systems (GIS) are now providing new
34 tools for advanced ecosystem management. The collection of remotely sensed data
35 facilitates the analysis of Earth - system function, patterning, and change at local, regional
36 and global scales over time; such data also provide an important link between intensive,
37 localized ecological research and regional, national and international conservation and
38 management of biological diversity [3]. In the recent times, Geographic Information Systems
39 (GIS) is being widely used for mapping and monitoring of urban sprawl of cities and
40 transportation systems. The spatial patterns of urban sprawl and transportation systems over
41 different time periods, can be systematically mapped, monitored and accurately assessed
42 from satellite data along with conventional ground data.

43

44 The implications of an uncontrolled urban sprawl cannot be overemphasized, especially for a
45 developing city like Lagos. Therefore, the need to map the rate of urban sprawl in this part of
46 Lagos, that is experiencing fast uncontrolled growth, is crucial to aid quick and useful
47 decision-making process by all stakeholders especially government agencies.. An attempt
48 was made through this study to map out urban sprawl and changes in land cover in Lagos
49 Island and its environs (i.e. Lagos Island, Eti-Osa and Ibeju-Lekki, an area over 972 Km²)
50 between 1984 and 2006 to assist in land development, administration and planning for a
51 sustainable environment. To achieve this, prediction was made on the possible changes that
52 might take place over the next fourteen years.

53

54 Among significant benefits of this research include; aid strategic planning for physical and
55 infrastructural development through making informed, guided and useful decisions; serving
56 as a useful tool for strategic planning to curb the problems associated with urbanisation and
57 population explosion; aid effective forecast of future urban growth and it socio-economic
58 consequences such as on transportation.

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59
60　**THE GEOGRAPHY OF THE STUDY AREA**

61　The city of Lagos (Fig. 1) lies in south-western Nigeria, on the Atlantic coast in the Gulf of

62　Guinea, west of the Niger River delta, located between longitudes 2°42' E and 3°24' E and

63　between latitudes 6°22' N and 6°52' N. Lagos Isla nd is connected to the mainland by three

64　large bridges which cross Lagos Lagoon to the district of Ebute Metta. It is also linked to the

65　neighbouring islands of Ikoyi and Victoria Island. Ikoyi is situated on the eastern half of

66　Lagos Island and joined to it by a landfill. Ikoyi is also connected to Victoria Island by a

67　bridge crossing over the Five Cowrie creek. Along with Ikoyi, Victoria Island occupies a

68　major area in the suburbs of Lagos which boasts of several sizable shopping districts. On its

69　sea shore along the Atlantic front, there is environmentally reconstructed Bar Beach.

70

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

86
87
88　**2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY**
89

90　The procedure adopted in this research forms the basis for deriving statistics of land use /

91　land cover expansion. The methodology adopted is given below:

92

93　**2.1 Data Sources**

94　This study was limited to the periods between 1984 and 2006 based on accessible dataset.

95　Landsat imagery of 30m resolution was used since imagery of higher resolution (e.g. Spot)

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96   was not readily available and accessible. The 1984, 2000 and 2006 Landsat imageries

97   (Table 1) were used.

98   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.

99

100

101   **2.2 Data Processing**

102   The following activities were carried out on the acquired data:

103

104   **2.2.1 Development of a Classification Scheme and Percentage Change Determination**

105   Supervised classification scheme was developed. This gave a broad classification where the

106   land cover categories [4] were each identified by a single digit as shown in the Table 2.

107

108   Table 2. Land Cover Classification Scheme.

CODES	LANDCOVER CATEGORIES	DESCRIPTION
1	Built-Up Areas	Urbanized 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

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110   After the land cover classification [5], [6], the comparison of the land cover statistics was
111   carried out to assist in identifying the percentage change, trend and rate of change (Km²)
112   between 1984 and 2006. Percentage change was determined from Equation 1:

113

114             $$Pc = Oc / Sc * 100$$ ------------------------------------ (1)

115   [7]

116   where:

117   Pc = Percentage change/trend

118   Oc = Observed change

119   Sc = Sum of change

120

121   **2.2.2 Land Consumption Rate and Land Absorption Coefficient**

122   The Land Consumption Rate (LCR) is the measure of compactness which indicates a

123   progressive spatial expansion of a city, while the Land Absorption Coefficient (LAC) is a

124   measure of change in consumption of new urban land by each unit increase in urban

125   population. The LCR and LAC were determined using the [8] formulas:

126             $$LCR = A / P$$ -- (2)

127   and,

128             $$LAC = (A_2 - A_1) / (P_2 - P_1)$$ --- (3)

129   where, A = areal extent of the city in hectares

130   P = population

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

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

133

134   **2.2.3 Overlay Operations and Modelling with CA-Markov**

135   Image differencing and Overlay operations were carried out to identify locations and

136   magnitude of changes over time which was limited to the built-up area. CA-Markov was used

137   as the modelling technique to determine the change. The CA-Markov is an integration of two

138   modelling techniques: Markov Chain analysis and Cellular Automata (CA). A Markovian

139   process is one in which the state of a system at time 2 can be predicted by the state of the

140   system at time 1 given a matrix of transition probabilities from each land cover class to every

141   other land cover class.

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

145 $$P_{ij} = \sum_{K=1}^{r} p_{ik} p_{kj}$$ --- (4)

146 [9], [10]

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

150

151 **2.2.4 Population Determination**

152 While the 1991 and 2006 population figures were obtained directly from the population
153 census, that of 1984 and 2000 were estimated using the [11] formula:

154

155 $$r = [Py - Px * 100/Px] / t$$ -- (5)

156 where:

157 r - Population Growth Rate

158 Py - Population of Later year

159 Px - Population of Earlier year

160 t - Number of years projecting for.

161

162 The Lagos State population figures for 1991 and 2006 were given as 5,725,116 and
163 9,113,605 respectively, therefore using Equation 5, the Lagos population growth rate equals
164 3.9458.

165

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

168

169 $$N = r/100 * Po$$ --- (6a)

170 $$Pn = Po + (N * t)$$ -- (6b)

171 [11].

172 where:

173 Pn = Estimated population

174 Po = Base year population

175 r = Growth rate

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| 176 | | N = Annual population growth |
| 177 | | t = Number of years projecting for. |

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180 3. RESULTS AND DISCUSSION
181 The following results were obtained and analysed:

182

183 3.1 Land Cover Distribution

184 The land cover distribution for each study year was derived from the classification of Landsat

185 imageries of 1984, 2000 and 2006 and presented in the Table 3.

186 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**

187

188 An important aspect of change detection is to determine the quantity of change which will

189 assist in decision making [12] and [13]. Based on the Land Cover Distribution, the following

190 can be deduced:

191

192 Table 3 reveals that as at 1984, Water bodies and Vegetal covers representing 78.67% of

193 the total land cover of the study area. Wetlands were the least visible land cover

194 representing 3.10%. Built-up Areas in 1984 occupy 8.76% of the total classes. Graphical

195 illustration of the land cover categories of the study area for 1984 is given in Fig. 2.

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199
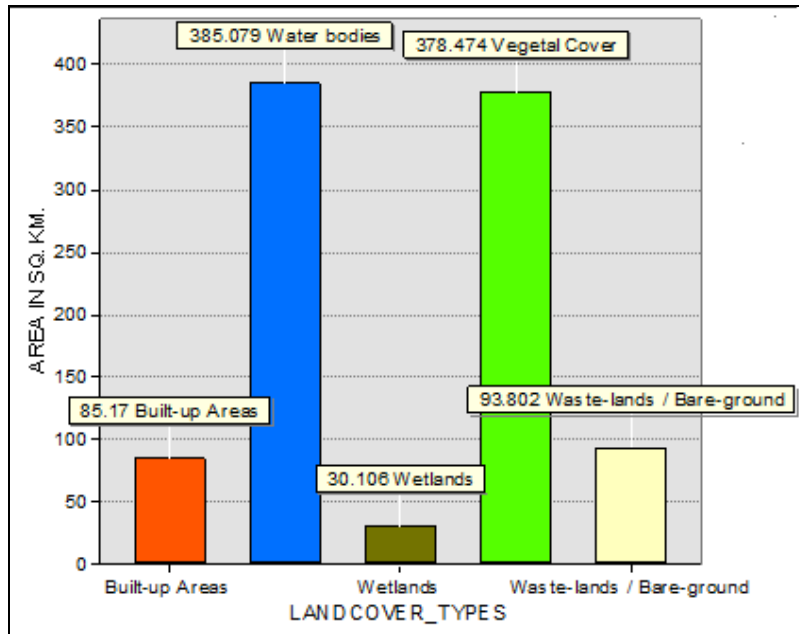
200   Fig. 2. The Land Cover categories (1984).

201

202   Lagos State created on 27th of May, 1967 had its physical development from both colonial

203   rule and from indigenous administrators and governors. As at 1984, some outstanding

204   housing estates such as Jakande, Dolphin and a number of others were already developed.

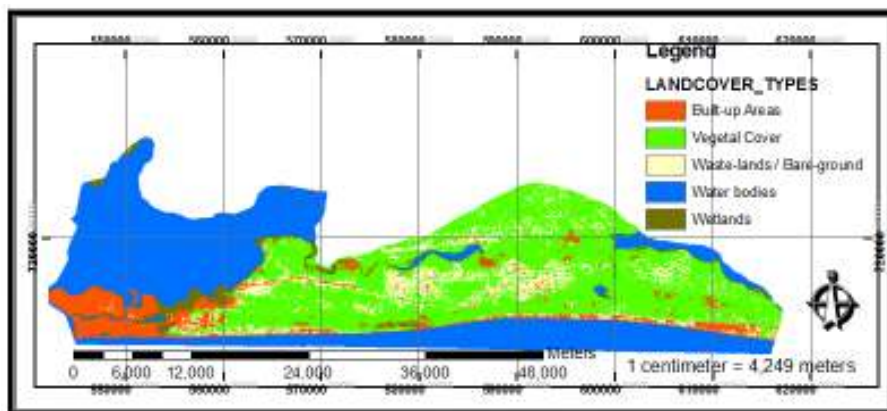205   The land cover map of the study area for 1984 is shown in Fig. 3.

206

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

208

209   The built up areas have increased to 11.65% from the 8.76% in 1984. On the other hand,

210   vegetal cover has decreased from 38.91% to 37.02% in 2000. Similarly, the waste-

211   lands/bare grounds have decreased to 6.68% from 9.64%, and water bodies to 38.84% from

212   39.59%. The 2000 land cover categories of the study area are shown in Fig. 4.

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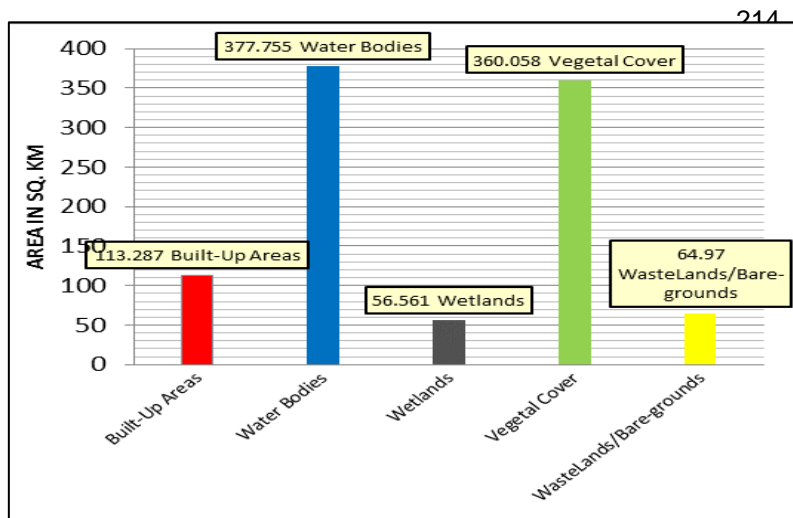
Fig. 4. The Land Cover categories (2000).

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229

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

236

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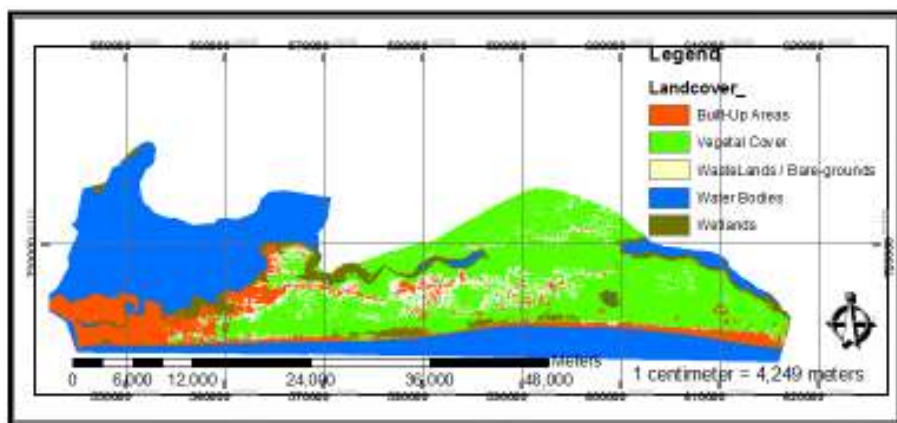
238   Fig. 5. Derived Land Cover Map of Lagos Island and Its Environs in 2000.

239

240   As at 2006, built-up areas have grown to 14% occupying about 136.189834 Km² of the study
241   area. This sprawl could be accounted for from the continuous physical development
242   programmes of the State Government. Around this time, more lands were reclaimed, new

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243 housing estates were developed and existing ones were expanded and improved upon as
244 evident in Lekki Phases I and II, Ajah and VGC to mention but a few. The wastelands/bare
245 grounds slightly decreased to 6.24% from 6.68% of 2000. There is also a slight decrease in
246 water bodies. This could not be unconnected with the land reclamation efforts. Both
247 wetlands and vegetal covers recorded slight decrease occupying 5.57% and 35.40%
248 respectively. The land cover categories of the study area for 2006 is shown in Fig. 6, while
249 the land cover map of the study area for 2006 is given in Fig. 7.

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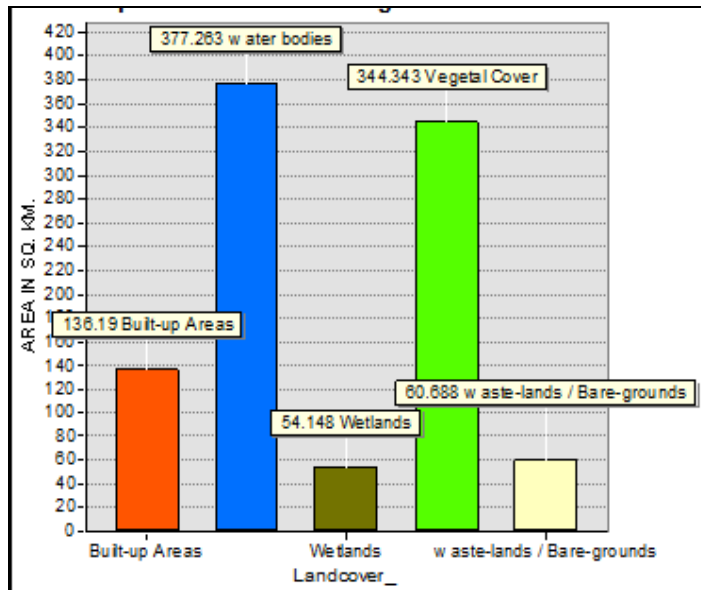
251
252
253 Fig. 6. Land Cover categories (2006).
254
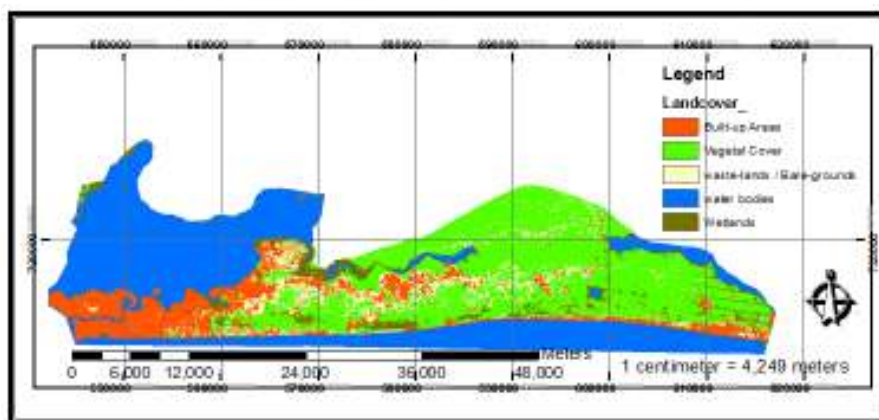
Fig. 7. Derived Land Cover Map of Lagos Island and Its Environs in 2006.

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256

257 **3.2 Land Consumption Rate and Land Absorption Coefficient Determination**
258 The Land Consumption Rate (LCR) which is the measure of compactness that indicates a
259 progressive spatial expansion of the city and the Land Absorption Coefficient (LAC) which is

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260 the measure of change in consumption of new urban land by each unit increase in urban
261 population as given in Equations 2 and 3 respectively. The results obtained are shown in the
262 Table 4. The population figures, obtained from Equations 6a and 6b, used are given in Table
263 5.

264

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		

265

266

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)

267

268 From Tables 4 and 5, the LAC indicated an increase in the consumption of new urban land
269 per each unit increase in urban population between the time intervals (between 1984-2000,
270 it was 0.011 and between 2000-2006, it was 0.025), while the LCR showed a slower
271 increase in city expansion (as at 1984, it increased by 0.032; as at 2000, it increased by
272 0.022 and as at 2006, no substantial increase i.e. 0.022). These two results showed that as
273 population increases, land consumption, especially for the built-up areas, will increase more
274 than the land gain by the city.

275

276 **3.3 Land Cover Expansion: Trend and Rate**
277 The Land cover expansion or growth was calculated by simply deducting the value for each
278 land cover category of an early year from the latter year understudy. The trend, that is the
279 percentage growth/change, was obtained from Equation 1, while the annual rate of
280 expansion was obtained by dividing the percentage growth/change (i.e. land cover

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281 expansion value) by the number of years between the two years understudy. The results

282 obtained for the land cover expansion, trend and annual rate are shown in the Table 6. The

283 gains (or increase) in built up areas are shown in Table 6 for 1984/2000 and 2000/2006

284 respectively.

285

286 Table 6. Land Cover Expansion: Trend and Rate.

LAND COVER CATEGORIES	GAIN IN BUILT-UP AREA (1984-2000)		GAIN IN BUILT-UP AREA (2000-2006)		GAIN IN BUILT-UP AREA (1984-2006)		ANNUAL RATE OF CHANGE		
	AREA (KM²)	AREA (%)	AREA (KM²)	AREA (%)	AREA (KM²)	AREA (%)	1984-2000	2000-2006	1984-2006
Built-Up Areas	28.117039	2.89	22.903241	2.35	51.02028	5.25	1.757315	3.817207	2.319104
Water Bodies	-7.324218	-0.75	-0.492587	-0.05	-7.8168	-0.80	-0.457764	-0.0821	-0.35531
Wet-Lands	26.454649	2.71	-2.412958	-0.24	24.04169	2.47	1.653416	-0.40216	1.092804
Vegetal Cover	-18.415519	-1.89	-15.715486	-3.51	-34.131	-3.50	-1.15097	-2.61925	-1.55141
Waste-Lands/Bare Grounds	-28.831951	-2.96	-4.28221	-0.44	-33.1142	-3.40	-1.8019	-0.7137	-1.50519

287
288
289 From Tables 6 there was a negative change i.e. a reduction in vegetal cover between 1984

290 and 2000. The built up areas and wetlands had a positive change (i.e. increase). As

291 mentioned earlier, the increase in the built–up areas, which is indicative of urban sprawl,

292 may not be unconnected to the land reclamation and rapid physical development of the area

293 at this time. A lot of housing estates such as Jakande, Dolphin, Oniru, Lekki, and so on were

294 developed.

295

296 Equally at this period, Water bodies decreased slightly. Historically, Victoria Island was

297 originally entirely surrounded by water: bordered by the Atlantic Ocean on the south, the

298 entrance of Lagos Lagoon on the west, the Five Cowrie Creek to the north and swamps on

299 the east. The colonial government began the process of sand filling in the eastern swamps

300 to reduce mosquito breeding areas. This created a land bridge between Victoria Island and

301 Lekki Peninsula terminating its existence as a true island. After independence, successive

302 state governments expanded this development, culminating in the construction of a highway

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303   connecting Victoria Island to Epe. This activity along with the rapid commercialisation of
304   Victoria Island, stimulated residential development along Lekki-Epe Corridor starting with
305   Lekki Phase I.

306

307   The area of the land bridge composed of the former swampland (called Maroko) which
308   became a large slum and housed many of the new migrants to Lagos State. Due to
309   complaints from Lagos Island residents, the then Military Administrator of the State forced
310   the slums and squatters to be removed, cleared and sold to wealthy residential buyers. The
311   reclaimed Maroko became Victoria Island Annex and has witnessed rapid development and
312   expansion to the extent that it is presently connected to Lekki Pennisula. This newly
313   developed and enlarged area is now referred to as 'Oniru Estate' after the name of the ruling
314   family of the area [14].

315

316   The image differencing and overlay operations for the 1984/2000 change in the Built-Up
317   areas is shown in Fig. 8. Also from Tables 6 between 2000 and 2006 the Built-up area
318   continued to have positive change. This growth could be attributed to the continued physical
319   development and establishment of new housing estates such as Ajah, Victoria Garden City
320   (VGC), and so on. At this period (between 2000 and 2006), all the other land cover
321   categories apart from Built-up areas experienced negative changes. To further buttress the
322   fact that a lot of land reclamation and urbanisation took place at this period, Water bodies
323   and Waste lands slightly decreased. Vegetal Cover and Wetlands also decreased. This is
324   equally indicative of high level of urban sprawl. The image differencing and overlay
325   operations for the 2000/2006 change in the Built-Up areas is shown in Fig. 8.

326
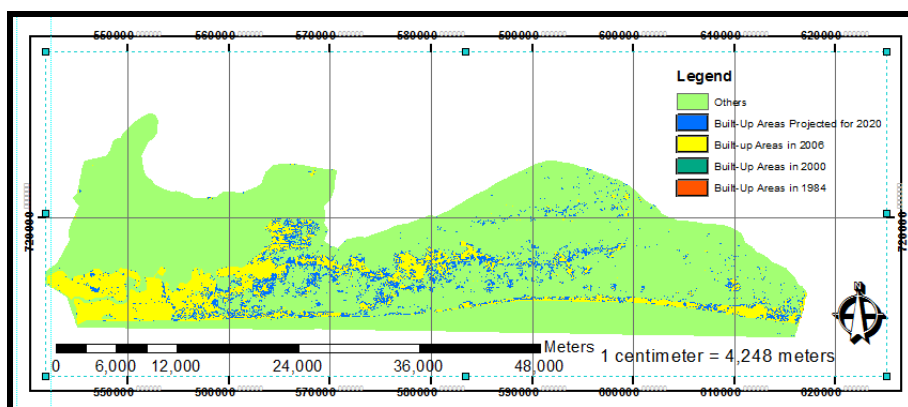
327

328 Fig. 8. Map showing Overlay of Built-Up Areas of Lagos Island and Its Environs to Depict
329 1984/2000, 2000/2006 Urban Sprawls and 2020 Projected Urban Sprawls.

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331 **3.4 Transition Probability Matrix and Modelling of the Study Area**

332 The CA Markov of Idrisi was used to model and produce the projected land cover map of the

333 study area for 2020. The transition probability matrix generated the probability that each land

334 cover category will change to the other category. This matrix is produced by the

335 multiplication of each column in the transition probability matrix with the number of cells of

336 corresponding land cover in the later image. The transition probability matrix and the cross

337 tabulation of 2000 and 2006 are presented in the Tables 7 and 8.

338

339 In the 5 by 5 matrix, Table 7, the rows represent the older land cover categories and the

340 column represents the newer categories. Although this matrix can be used as a direct input

341 for specification of the prior probabilities in maximum likelihood classification of the remotely

342 sensed imagery, it was however used in predicting land cover categories of 2020.

343

344 Table 7. 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**

345

346 Table 8. 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

347

348 From Table 7, the built-up areas have a 0.7427 probability of remaining built-up areas. This

349 therefore shows that there is a relatively high probability of Lagos Island and its environs

350 experiencing continuous sprawl in the future.

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3.5 Projected Land Cover Distribution for 2020

The Projected Land Cover Distribution for 2020 is shown in Table 9.

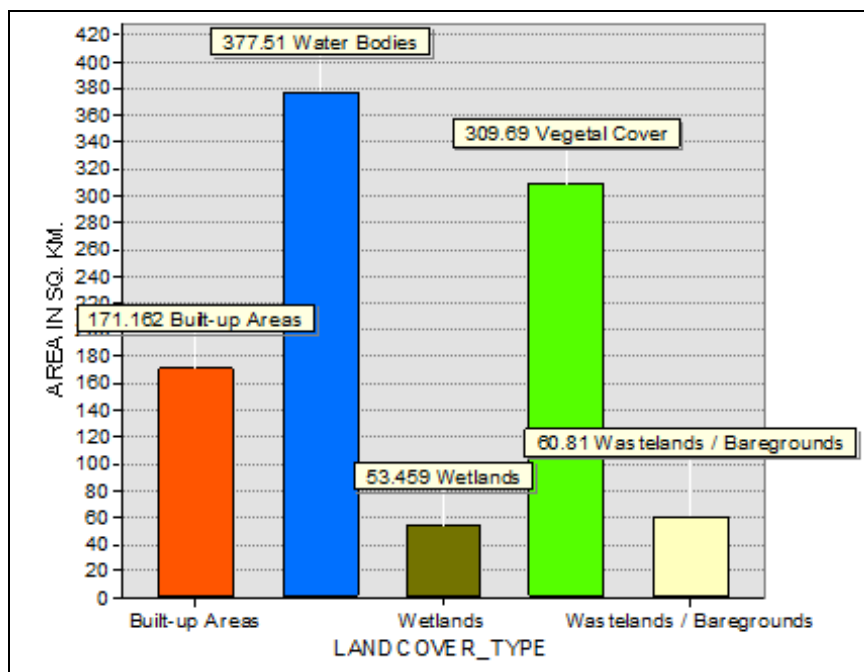Table 9. Distribution of Projected Land Cover Categories for 2020.

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 9 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. 9.

Fig. 9. The Projected Land Cover categories for 2020.

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367

368   This projected land cover pattern is similar to those of the previous years understudy (1984,

369   2000 and 2006) in this research. The built-up areas continue to grow indicating dynamic

370   urban sprawl. However, due to the natural obstacle of water bodies (the Ocean and

371   Lagoons), by 2020, Lagos Island and its environs is expected to be highly compacted at its

372   western axis (Ikoyi and Victoria-Island). The sprawl is expected to continue majorly to its

373   eastern part (Ibeju-Lekki area). The projected land cover map of the study area for 2020 is

374   given in Fig. 10.

375
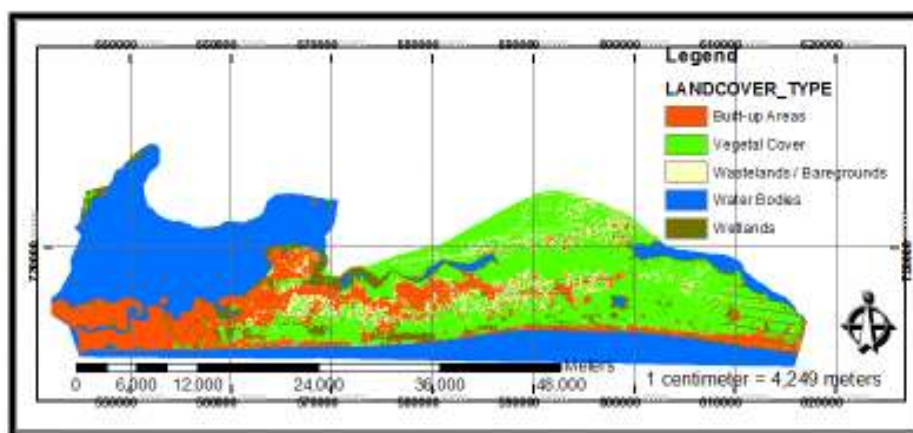
376
377
378   Fig. 10. Projected Land Cover Map of Lagos Island and Its Environs by 2020.
379

380   Table 10 shows the expected changes in the land cover categories of the study area

381   between 2006 and 2020.

382

383   Table 10. Future/Expected Land Cover Expansion between 2006 and 2020

| LAND COVER | 2006-2020 | | ANNUAL RATE |
CATEGORIES	AREA (KM²)	AREA (%)	OF CHANGE
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

384

385   Wetlands and Vegetal covers are expected to experience negative changes or decrease by -

386   0.07% and -3.56% respectively. Wastelands are expected to increase slightly by 0.01% to

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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 [15].

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. 11. The 2006/2020 image differencing and overlay operations is shown in Fig. 12 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 [16]. The Eko Atlantic City project involves reclaiming over eight square kilometres of land adjacent to Lagos Bar Beach. This also adds to urban sprawl.
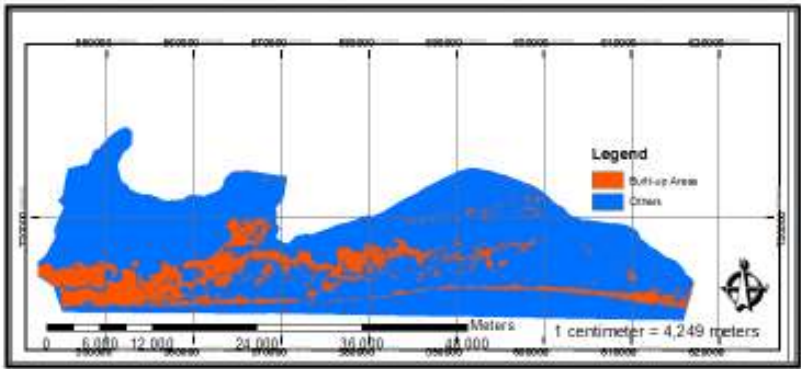
Fig.11. Projected Built-Up Areas Map of Lagos Island and Its Environs by 2020.
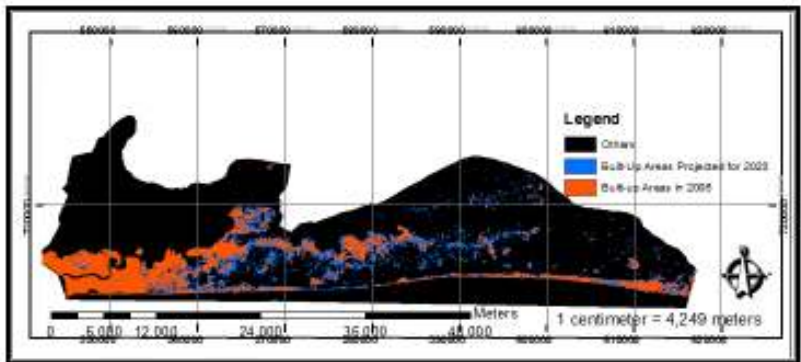
Fig. 12. Overlay of the Projected Built-Up Areas of Lagos Island and Its Environs Depicting Expected 2006/2020 Urban Sprawl.

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409

410 The growth of the Built-up areas and changes in other land cover categories between 1984

411 and 2020 are shown in Fig. 13.
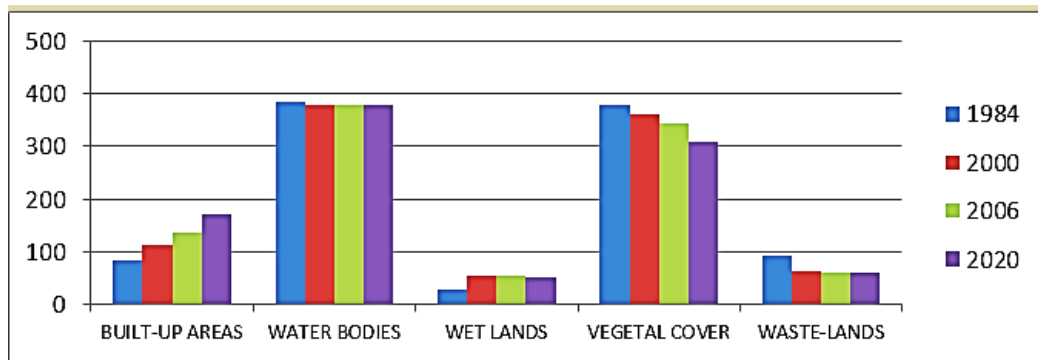
412

413 Fig. 13. Graphical Illustrations of Changes in Land Cover Categories between 1984 and

414 2020.

415

416 Urban sprawl is a function of accessibility. The faster one can move from the urban centre to

417 the sprawled area, the faster the growth of the sprawl. Sub-section 3.6 briefly discussed the

418 effects of urban sprawl on transportation.

419

420 **3.6 Consequences of Urban Sprawl on Transportation in the Study Area**

421 The map of the study area showing the relationship between urban sprawl and

422 transportation between 1984 and 2006 is shown in Figure 14.
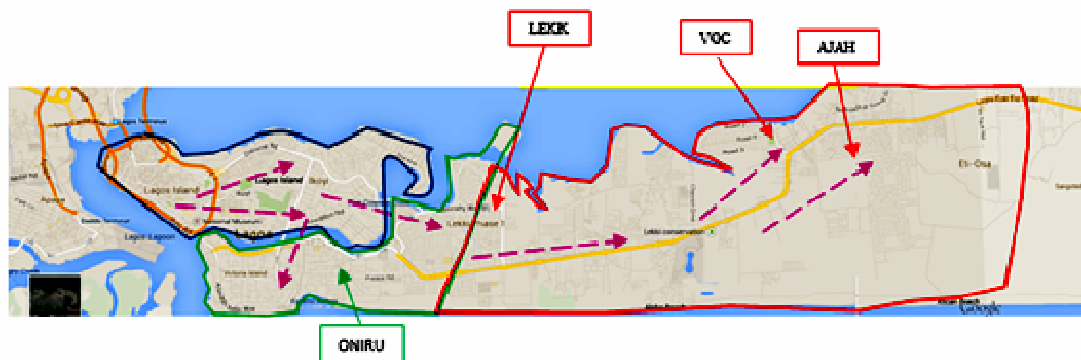
423
424 Fig. 14. Showing Urban Sprawl and Transportation routes (in pink dashed arrows).
425
426 From Fig. 14, area in blue boundary showed the level of development as at 1984 with few

427 roads, area in green showed the extent of the urban sprawl as at 2000 with its more roads

428 and traffic congestion, while area in red showed the extent of the sprawl as at 2006 with the

429 roads now extending beyond Ajah and the local villages. Congestions is now on the increase

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430 as more houses are springing up and the dwellers are auto-dependent people. The urban
431 sprawl and road transportation expansion are further analyzed in Table 11.
432
433 Table 11. Summary of urban sprawl analysis and its effects on transportation.

From	Through Land Reclamation (Road)	To	Year	Approximate No. of Roads	Cumulative Effects of the Sprawl on Approximate No. of Roads
Lagos Island and Ikoyi	Osborne Road	Jakande and Dolphin	1984	≈10Major Roads and >87Minor Roads	≈10Major Roads and >87Minor Roads
Ikoyi	Akin Adesola Street/ Ahmadu Bello Way	Victoria Island/Oniru	2000	≈5Major Roads and >100Minor Roads	≈15Major Roads and >187Minor Roads
Ikoyi	Lekki-Ikoyi Link Bridge/Five Cowries Creek	Lekki			
Lekki	Admiralty Way	Lekki Phase I and Phase II	2006	≈ 6Major Roads and >250Minor Roads	≈21Major Roads and >435Minor Roads
Lekki Phase I	Lekki – Epe Expressway	VGC, Ajah and Eti-Osa			

434
435

436 Analysing the effects of urban sprawl on transportation in the study area. [1] mentioned
437 some of these basic effects of urban sprawl on transportation:

> Sprawled areas does not support public transportation resulting in; greater
438 dependence on roads and highways that often become heavily congested with
439 private automobiles and demand for new roads, which then lead to even more
440 sprawl. The use of public transport (such as Bus Rapid Transit BRT) is difficult in
441 this study area unlike other parts of the city.
442

> In economic terms, sprawl created congestion imposes a variety of costs on drivers:
443 wasted time, increased gasoline consumption, and greater wear and tear on
444 vehicles. The cost of congestion in this axis of Lagos is very high (in terms of
445 transport fare) and long travel time.
446

> As a result of the congested roads, the added cost of driving to and from the
447 suburban fringe would be more than the savings realized in living in lower price
448 housing sprawls.
449

> Similarly new roads constructed, allow residents drawn by lower housing prices to
450 move farther and farther from the urban core, thereby increasing the total amount of
451 driving in a given metropolitan area. The sprawl pattern is illustrated in Figure 14
452

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and Table 11 i.e. Lagos Island/Ikoyi to Ajah/Eti-Osa and till today the sprawl still continues towards Epe town.

- 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. Air pollution and water pollution as a result of vehicular long trips and regular construction activities such sand filling are very high in this part of Lagos.

While [17] 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 incresasing the stress of commuting, which not only impacts on mental health but also physical health. Trips in this axis of Lagos always take hours (3-5hrs.) as a result of auto-dependence nature of urban sprawl inhabitants and their health risks.

- 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. Most of the workers living in this part of Lagos but working on the mainland part of the city witnesses work absences, lack of job satisfaction and declined commitment. Due to stress, they first sleep on getting to work before starting the day's work.

- More driving, more road rage- Road rage is characterized by violent disputes between drivers that sometime causes serious injuries or even death. From our previous study, as a result of rapid developments going on in this area, the volume of vehicles in this part of Lagos has increased six (6) times the volume of vehicles in the mainland. Batching of vehicles and fighting is always the order of the day on most of the roads in this area.

- 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

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likely than men to indicate problems of managing stress and feelings of sadness, worthlessness and hopelessness. <mark>Relationship with family doctors, old classmates and friends living on the mainland are cut off as a result living in urban sprawl environment.</mark>

4. CONCLUSION

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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