Dynamics of Land Use Changes in Otamiri Watershed of Owerri, South East Nigeria.

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Keywords: Land-Use / Land-Cover Change, Change Detection, Dynamics, Geographic Information Systems

ABSTRACT

Otamiri watershed in Owerri, South East Nigeria is an urban watershed that is faced with serious ecological stresses due to intense land-use conversion. Siltation of the river, threatening gully erosion and devastating flooding are some of the consequences of this land-use and land cover change. This paper analyses the dynamics of land use changes in Otamiri watershed using the technologies of Remote Sensing and GIS. Datasets were obtained from classified Aerial photographs of 1977, IKONOS satellite image of 2006 and 2012 Google Earth satellite image. Images were resampled and registered to Universal Transverse Mercator, zone 32. Post-classification change detection was employed, using vector data structure model. Analysis of dynamic land use changes was performed using land use transfer analysis, quantitative spatial position conversion and land use dynamicity models. Results show a dramatic fast rate of change in built-up land class in 2006 and 2012 with dynamicity indices of 11.51% and 10.11% respectively. Farmland/light vegetation and thick vegetation/shrubs were the most converted land use classes into built-up. In between 1977 and 2006, sand excavation site showed a dramatic fast rate of change with 25.78% dynamicity index. Riparian vegetation and water body land-use classes were converted more into excavation sites. The major driving forces for these changes were high population density, increase in economic activities and infrastructural developments. These factors results in various pressures and strong effects to change the quantity and quality of the land use.

INTRODUCTION

Land use and land cover change is a general term for human modification and conversion of Earth's terrestrial surface. Though humans have been modifying and converting land resources to obtain food, fibre and other essentials for thousands of years; current rates, magnitude and intensities of land use and land cover changes are far greater than ever in history. These, drive unprecedented changes in ecosystems and environmental processes at local, regional and global scales. These changes encompass the greatest environmental concerns of human populations today, including climate change, biodiversity loss and pollution of water, soil and air (Ellis, 2013). Monitoring and intervening in the negative consequences of land use land cover changes while sustaining the production of essential resources has therefore become a major priority of researchers and policymakers globally.

International research projects such as International Human Dimensions Programme on Global Environmental change/International Geosphere-Biosphere Programme on Global Environmental Change/International Geosphere-Biosphere Programme Land-Use and Land Cover Change (IHDP/IGBP LUCC) program, have measured and monitored studies on changes in land use and land cover at local, regional and global scales.

Remote Sensing and Geographic Information Systems have proved reliable and accurate tools for explicit measurement, mapping and analysis of spatial information. Remote Sensing aids in synoptic observations of large areas. In providing multi-temporal and multi-spectral data that can be used to quantify the type amount and location of land use and land cover, Satellite Remote Sensing has advantage of being effective, cheap and timely tool for monitoring changes in land use change. The analytical and integrative capability of Geographic information systems in providing explicit spatial information has given GIS an edge over all other analytical tools.

Otamiri watershed is an urban watershed. The watershed with its resources is significant to the inhabitants of Imo state capital Territory. The river provides rich economic and cultural resource to the people. The river upstream of the course is a source water for the intake plant of Imo State Water Corporation, the agency responsible for provision of domestic and industrial water needs to an estimated population of over 450,000 persons living within Owerri Capital and beyond. The river is a source of livelihood not only to the people living upstream in Imo State but also downstream in Rivers State.

The watershed is faced with serious ecological stresses due to intense land-use conversion and modification. Siltation of the river source, threatening gully erosion and devastating flooding are some of the consequences of this land-use and land cover change.

Past studies (Ibe *et al.*, 1992; Ibe and Njemanze, 1998) have reported on the environmental contaminations and other anthropogenic impacts on Otamiri and Nworie rivers in Owerri and its environs. The document while calling on the protection of the water resources of Otamiri and its tributary – Nworie River stressed on the importance of exact knowledge of the geographic distribution of all the conflicting land uses impacting on the ecological system. Orisakwe (2008) made an attempt in that direction with the application of SPOT-4 and SPOT-5 multi-date images to map the distribution and quantify the dynamics of land use changes in Owerri, but did not report on the aerial extent of conversion of one land use class to another. This study attempts to provide such knowledge. The study goes further to analyse the varying spatial position conversions of the land use classes. The overall purpose of the analysis is to provide reliable estimates that may guide decisions in the management of the watershed.

THE STUDY AREA

The study area is Otamiri river watershed with its tributary- Nworie River and the immediate environment. Otamiri river watershed is a micro-watershed of the greater Imo river basin. The river with the length of 105 kilometers is the principal tributary of Imo River-a major river that washes through the landscape of Imo state (Imo State Govt. Ministry of Works & transport, 1984). Imo state has a high population density, available statistics show that the study area has a population density of 813.54 persons per square kilometre (Federal Republic of Nigeria, 2009). The study area covers upper sections of the watershed in Owerri Capital Territory facing threat from urbanization. The communities covered are Egbu, Owerri and Nekede settlement. See Figure 1.0.

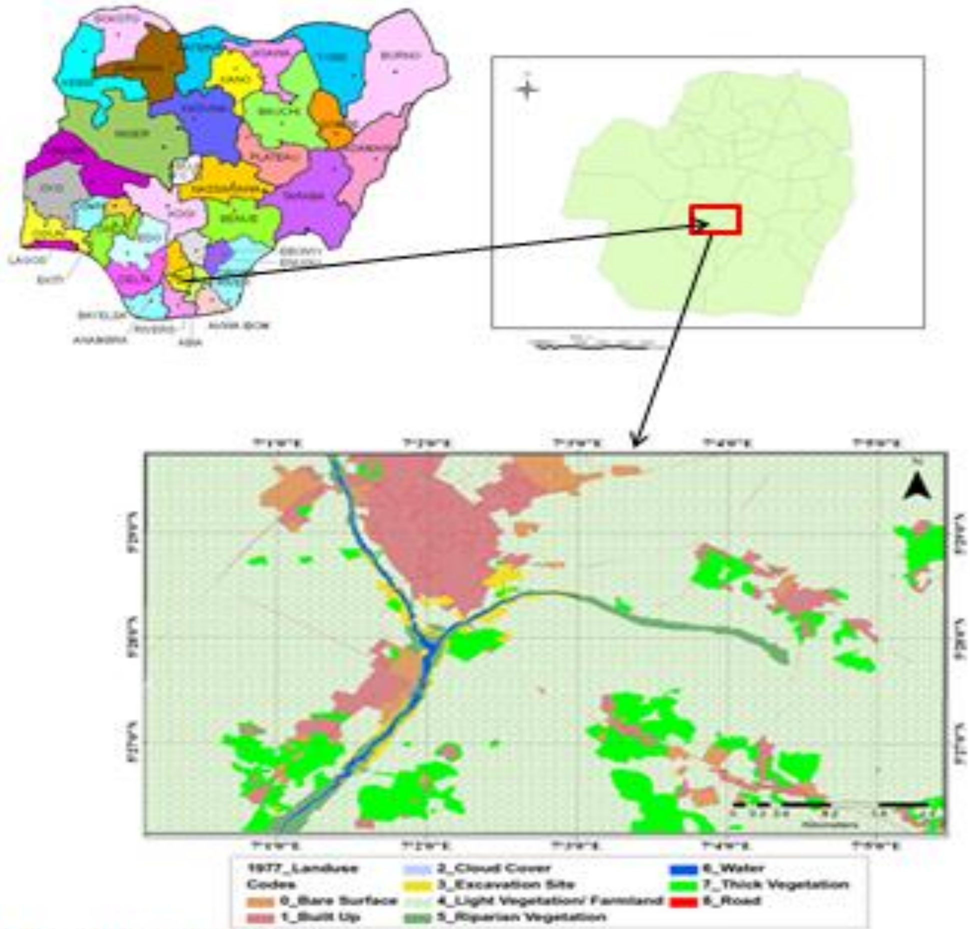

Figure 1: Map of Study Area

Owerri capital territory is located between latitudes $05^{0}25^{1}$ and $05^{0}32^{1}$ North and longitudes $06^{0}\,57^{1}$ and $07^{0}\,07^{1}$. Rainfall is the greatest climatic variable with annual total mean of 2190mm (Imo State Govt. Ministry of Works & Transport, 1984). The mean monthly temperature for dry season is 34^{o}C and 30^{o}C for rainy season. The river has average flow of $10.7m^{3}/s$ in the rainy season (September – October) and a minimum average flow of about $3.4m^{3}/s$ in the dry season (November to February). The total annual discharge of the Otamiri is about $1.7\times10^{8}m^{3}$, and 22percent of this ($3.4\times10^{7}m^{3}$) comes from direct runoff from rainwater and constitutes the safe yield of the river (Egboka and Uma, 1985).

2. MATERIALS AND METHODS

Data sources and acquisition process

The datasets that were used include Aerial photographs of 1977, IKONOS of 2006 and 2012 Google Earth Extraction Satellite Image. The Google Earth image was used to update the 2006 Satellite image. The aerial photographs were obtained from Survey department of Ministry of lands, survey and urban planning Owerri. IKONOS satellite image of 2006 was got from National Population Commission Owerri. While 2012 Satellite image which was used to update the data was acquired from Google Pro. Administrative map of Imo State which was used for delimitation of the study area was acquired from the same Ministry of lands, survey and urban planning.

The aerial photographs and the administrative maps were scanned and the fifty-four photographs mosaicked into one scene. The resultant images were saved in TIF (tagged image format) format and stored in hard disks. A handheld Global Positioning System (GPS) Garmin model 72 and 76cx was used to fix positions of interest in the field and to for verification process.

Image processing and integration

The 1977 mosaicked image was first geometrically corrected from the errors acquired during scanning and mosaicking process, by the use of transformation process in Universal Transverse Mercator (UTM) Coordinate grid system, zone 32N. Subsequently the image was registered to already geo-referenced and radiometrically corrected IKONOS 2006 satellite images through map to image technique with the rectification errors of 0.00016 RMS. 2012 Google Earth was already geo-referenced in the same coordinate system. The overall accuracy assessment was 82%. Table 1.

Table 1: Result of Accuracy assessment

SAMPLE DATA	REFERENCE DATA										
	A	B	C	D	E	F	G	H			
A	**5**	0	0	0	0	0	0	0	5	A	Built up
B	0	**10**	0	0	0	0	0	0	10	B	Excavation
C	0	0	**2**	0	0	1	0	0	3	C	Waste dump
D	0	0	0	**3**	2	1	0	0	6	D	Bare surface
E	1	1	0	0	**5**	0	0	0	7	E	Light vegetation
F	0	1	0	0	0	**3**	0	0	4	F	Thick and shrubs
G	0	0	0	0	0	0	**7**	0	7	G	Riparian
H	0	0	0	0	0	0	0	**2**	2	H	Water body
	6	12	2	4	7	5	7	2	45		

PCC=(5+10+2+3+5+3+7+2)*100/45=82.22%

The vector data structure was employed in the creation of database because of the nature of remote sensed datasets (fine resolution images with differing mixed classes of land use and land cover). This data model will enhance discrimination of the mixed land uses into different classes. The images were polygonized into different classes of land use and land cover using a modified classification scheme (Anderson, 1976) in ArcGIS environment.

The classes were light vegetation/farmland, water body, shrub/thick vegetation, waste dumpsite, excavation site, riparian vegetation, built-up, road network and bare surfaces. The classification scheme is described in table 2. The classification result was integrated with GIS technology. For spatial analysis and land use change detection. The change technique used in this study is post-classification method.

Table 2: Land use land cover classification scheme

Class type	Description
Road networks	Include major roads (all tarred roads) and minor roads (All un-tarred roads)
Bare surfaces	Areas without vegetation
Built-up areas	All developed areas with settlements including residential , commercial and industrial areas
Excavation sites	All types of sand and gravel excavations around the river bank.
Riparian vegetation	All vegetation around the river including thick or light vegetation
Water body	Otamiri River and Nworie River
Light vegetation / Farmland	Grasses and lighter scattered plants and Cultivated and cleared land for crops
Thick vegetation / Shrub	Darker Clustered Plants and Slightly clustered light plants including plantations (trees and shrubs)
Waste dumpsite	Municipal heterogeneous waste dump sites

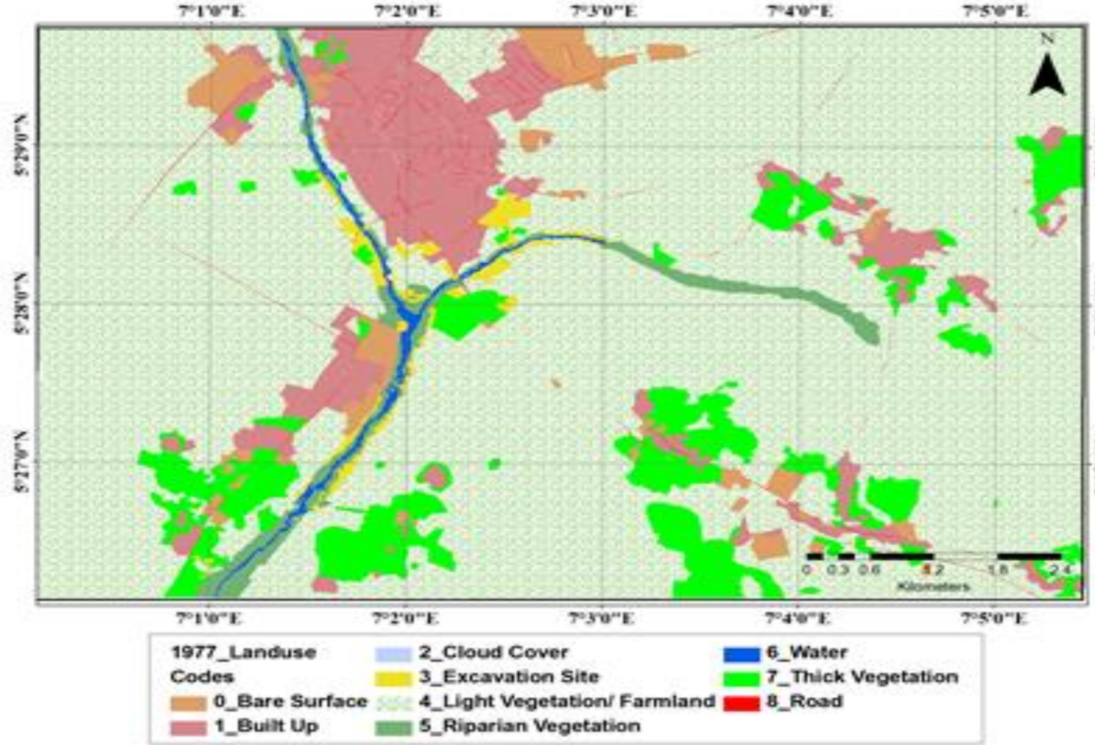

Figure 2.0: 1977 Classified Land Use.

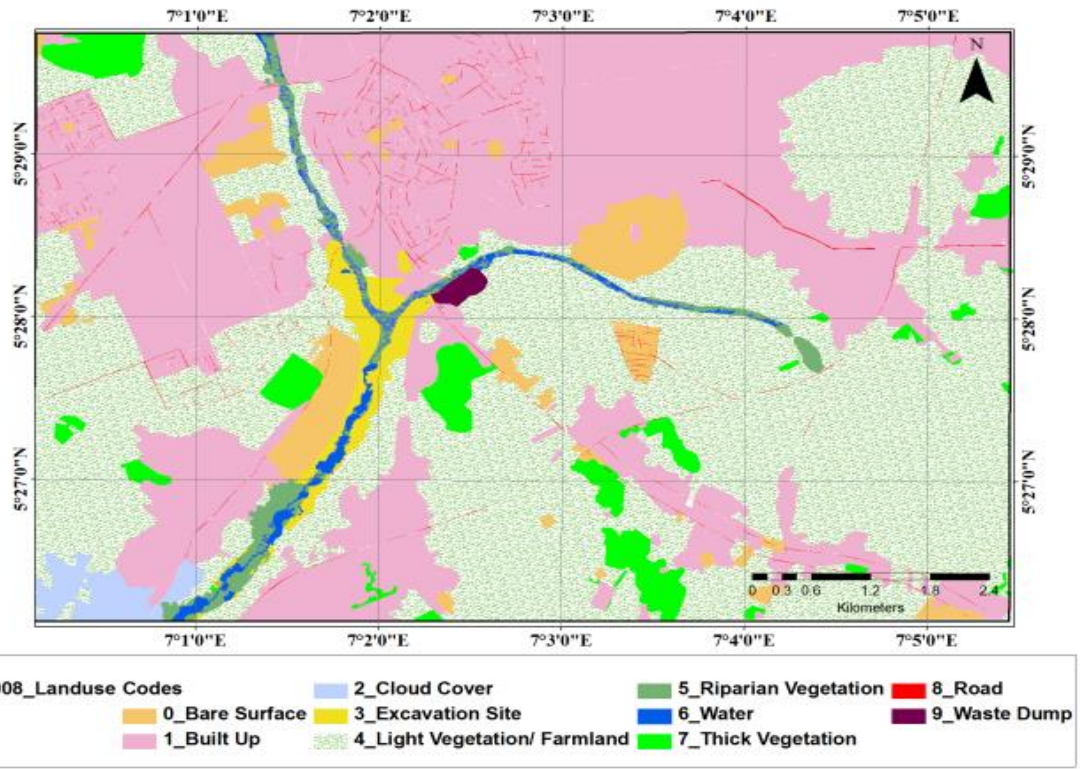

Figure 3.0: 2006 Classified Land Use.

3 ANALYSIS OF DYNAMICS LAND-USE CHANGE

Land use dynamic change analysis is employed to gain understanding of the nature, magnitude and trend of the land-use change.

3.1 Land use transfer analysis

This analytical method is applied to obtain the pattern of transition among different land use classes. The study adopts the calculation model in which the attribute database of intersected layers is used to reach the balance in an iterative process (Gao and Wang, 2004). A transfer matrix of land use change can be obtained from the calculation.

Using overlay analysis tool in ArcGIS environment, spatial distribution of land-use conversions is performed. For example, in order to obtain the spatial distribution of excavation site and other classes, a spatial overlay is performed with change map on the latter year map to obtain an intersection layer. Then a query language is further used to select areas that were converted to another.

3.2 Land-use spatial position conversion and quantity change

Spatial position conversion is the conversion in which the position of the land-use classes has changed in the study area. For instance a small portion of forestland may be converted to farmland while an area classified as a light vegetation may have grown to become forestland. The spatial position forestland is therefore changed. The overall area of the corresponding land-use classes, however might not change (Fu et al., 2006). The spatial position conversion can be modelled as (Fu et al., 2006):

$$Sj = 2 \times \min(Pj+ \; - \; Pjj \; , P+j \; - P_{JJ})$$

Where S_j represents the area of cateqory j to which spatial position conversion happens. Pj+ and P+j denote the areas of cateqory j before and after the change, respectively. P_{JJ} stands for the area with no change.

Quantitative change refers to the increase and decrease of the balance of areas of different land-use classes after the position conversion (Wang et al., 2000):

$$Q_j = \max\,(P_{j+} - P_{jj,}\; P_{+j} - P_{JJ}) - \min\,(P_{j+} \; - P_{jj,}\; P_{+j} \; - P_{JJ})$$

Where C_j stands for quantitative change of area of cateqory j. the total change of cateqory j can thus be calculated as (Wang et al., 2000):

$$C_j = S_j + Q_j$$

Where $C_{j\,=}$ Stands for the total change of category j.

3.3 Land-use dynamicity model

The quantity change of land-use can further be analysed with land-use dynamicity model. Land-use dynamicity gives us information on the rate of change and how fast a land-use is changing relative to another. It can be calculated for a single land-use, to show the rate of change within the land-use class or for comprehensive land-use classes, to show the rate of change of several classes in a region (Sun et al., 2005). The single land-use dynamicity can be calculated as (Zhu et al., 2001)

$$K = \frac{(U_b - U_a)}{U_b} \times \frac{1}{T} \times 100\%$$

Where k denotes the dynamicity of one land-use type over the given period, U_a and U_b denote the areas of one land-use class at the beginning (moment a) and at the end (moment b) of the study period, respectively, and T stands for the time span from moment a to b. if T is set to be multiple years, the value of k will be the annual changing rate of the land-use class during the given period.

4. RESULTS AND DISCUSSIONS

4.1 Result of land-use transfer model

The results of land use transfer models are shown in tables 3 and 4 for 1977-2006; 1977-2012 periods.

Table 3: Land use Transfer Model 1977 - 2006

LAND-USE TRANSFER ANALYSIS (AREAS IN HECTARE)										
Land use	**Bare surface**	**Built up**	**Cloud Cover**	**Excav. Sites**	**Light Vegetation/ Farmland**	**Riparian Vegetation**	**Water body**	**Vegetation**	**Road Network**	**Waste Dump**
Bare surface	**0.00**	127.05	0.00	9.71	19.96	1.43	1.76	1.26	1.45	0.15
Built up	37.57	**0.00**	0.14	2.07	33.20	1.65	0.15	9.35	9.71	0.00
Cloud Cover	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Excavation Sites	0.14	17.75	0.89	**0.00**	10.07	5.80	4.15	0.87	0.07	4.59
Light Vegetation/ Farmland	214.69	1683.09	62.99	22.11	**0.00**	31.06	7.64	133.81	19.01	8.27
Riparian Vegetation	3.66	17.75	0.00	27.02	39.01	**0.00**	19.31	0.31	0.07	0.06
Water body	0.04	0.07	0.00	6.73	3.52	15.93	**0.00**	0.00	0.02	0.00
Vegetation	7.38	277.21	9.09	6.04	157.30	8.02	1.01	**0.00**	2.26	0.43
Road Network	1.13	16.16	0.22	0.13	2.47	0.14	0.01	0.00	**0.00**	0.06
Waste Dump	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**

Table 4: Land use Transfer Model 1977 - 2012

LAND-USE TRANSFER ANALYSIS (AREAS IN HECTARE)										
Land use	**Bare surface**	**Built up**	**Cloud Cover**	**Excav. Sites**	**Light Vegetation/ Farmland**	**Riparian Vegetation**	**Water body**	**Vegetat ion**	**Road Network**	**Waste Dump**
Bare surface	**0.00**	130.98	0.00	14.06	13.41	2.27	4.47	2.25	4.69	0.00
Built up	20.26	**0.00**	0.00	2.30	22.92	1.83	0.30	15.67	11.39	0.00
Cloud Cover	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Excavation Sites	0.41	21.29	0.00	**0.00**	4.50	15.95	3.13	1.75	0.34	5.30
Light Vegetation/ Farmland	350.82	1770.9 4	0.57	24.48	**0.00**	45.67	6.77	385.06	99.34	13.34
Riparian Vegetation	2.87	0.51	1.18	20.82	24.95	**0.00**	27.33	3.27	0.26	0.06
Water body	0.08	0.28	0.00	4.59	0.14	21.38	**0.00**	0.04	0.12	0.16
Vegetation	10.62	298.79	0.74	2.88	134.76	5.72	0.69	**0.00**	11.25	0.15
Road Network	0.97	16.37	0.00	0.03	1.84	0.08	0.01	0.11	**0.00**	0.06
Waste Dump	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**

A general trend is observed in the spatial structure of land use changes in the time periods under review. The vegetation related classes were observed to change most into other classes especially built-up. Conversion of farmland/light vegetation into built-up was the highest in value, accounting for 1683.09 ha or 77% of the total decreased area of farmland/light vegetation class. The next highest in transition to built-up is thick vegetation/shrubs, which accounts for 227.21ha or 48% of the total decreased area of thick vegetation. This gives indication of the pattern of changes-a process of urbanisation, which started after the creation of the state Imo, in 1976. This also implies loss of urban watershed and its resources.

In 2012 year, 20.82 ha (22.92%) and 4.59 ha (6.64%) of riparian vegetation and water body respectively were converted into excavation sites. Between the periods 1977 and 2006, 27.02 ha (36.60%) and 22.11 (29.95%) of riparian vegetation and light vegetation/farmland were converted to excavation site.

In the immediate watershed of Otamiri, a total of 33.75ha (45.72%) from riparian and water body were converted to excavation site.

4.2 Result of the spatial position conversion and quantity change model

The results of the land use spatial position conversion and quantity change are shown in Table 5 and 6. Farmland/light vegetation, bare surface and thick vegetation are the largest spatial position conversion Farmland/light vegetation has the highest value for spatial position conversion with 531.05 ha from 1977 to 2006. And also has the largest total change of 2448.21ha. Almost same trend is observed in 1977 to 2012 spatial position conversion; here vegetation-related classes (thick vegetation and farmland/light vegetation) were the greatest 931.230ha and 405.059ha accounting for 42% and 18% of the total spatial position conversion.

Table 5: spatial position conversion and quantity change model for 1977 - 2012

SPATIAL POSITION CONVERSION AND QUANTITY CHANGE OF LAND-USE					
Land use	**Converted into**	**Converted from**	**Total Change**	**Spatial position Conversion**	**Quantitative Change (Absolute Change)**
Bare surface	264.61	162.78	427.39	325.56	101.83
Built up	2139.08	93.84	2232.93	187.69	2045.24
Cloud Cover	73.32	0.00	73.32	0.00	73.32
Excavation Sites	73.82	44.33	118.14	88.65	29.49
Light Vegetation/ Farmland	265.52	2182.68	2448.21	531.05	1917.16
Riparian Vegetation	64.02	107.19	171.21	128.05	43.17
Water body	34.03	26.31	60.34	52.61	7.73
Vegetation	145.59	468.73	614.32	291.18	323.14
Road Network	32.61	20.32	52.93	40.64	12.28
Waste Dump	13.56	0.00	13.56	0.00	13.56

Table 6: spatial position conversion and quantity change model for 1977 - 2012

SPATIAL POSITION CONVERSION AND QUANTITY CHANGE OF LAND-USE					
Land use	**Converted into**	**Converted from**	**Total Change**	**Spatial position Conversion**	**Quantitative Change (Absolute Change)**
Bare surface	386.04	172.15	558.19	344.30	213.89
Built up	2239.17	74.68	2313.84	149.35	2164.49
Cloud Cover	2.48	0.00	2.48	0.00	2.48
Excavation Sites	69.16	52.68	121.85	105.36	16.48
Light Vegetation/ Farmland	202.53	2696.98	2899.51	405.06	2494.45
Riparian Vegetation	92.89	81.24	174.14	162.48	11.65
Waterbody	42.71	26.79	69.50	53.57	15.92
Vegetation	408.15	465.62	873.77	931.23	-57.47
Road Network	127.39	19.47	146.86	38.95	107.91
Waste Dump	19.01	0.00	19.01	0.00	19.01

The reasons may be given to the increase in economic activities and infrastructural developments in the study area. The increase in sand and gravel excavation at the river banks of Otamiri River contributed to the total changes that took place in the watershed management zone (150m from the river banks). In the year 2006 and 2012 (29 years and 35 years) built-up and farmland had the two largest magnitude in absolute changes.

4.3 Result of land use dynamicity model

Table 7 and Table 8 shows the result of the land use dynamicity model of 1977-2006 and 1977 – 2012.

Table 7: Land Use Dynamicity Model of 1977 - 2006

AREA AND DYNAMICITY OF INITIAL AND LAST STAGE OF LAND-USE CLASS			
Land use	**Area of 1977**	**Area of 2006**	**Dynamicity (%)**
Bare surface	186.85	288.68	1.88
Built up	612.63	2657.87	11.51
Cloud Cover	0.00	73.32	0.00
Excavation Sites	65.44	94.93	1.55
Light Vegetation/ Farmland	4966.54	3049.38	-1.33
Riparian Vegetation	154.58	111.41	-0.96
Water body	35.50	43.23	0.75
Vegetation	554.61	231.47	-2.01
Road Network	20.71	33.00	2.05
Waste Dump	0.00	13.56	0.00

Table 8: Land Use Dynamicity Model of 1977 - 2012

AREA AND DYNAMICITY OF INITIAL AND LAST STAGE OF LAND-US CLASS			
Land use	**Area of 1977**	**Area of 2012**	**Dynamicity (%)**
Bare surface	186.91	400.80	3.27
Built up	611.46	2775.96	10.11
Cloud Cover	0.00	2.48	
Excavation Sites	65.55	82.03	0.72
Light Vegetation/ Farmland	4967.93	2473.47	-1.43
Riparian Vegetation	137.75	149.41	0.24
Water body	35.31	51.23	1.29
Vegetation	554.50	497.03	-0.30
Road Network	20.67	128.58	0.15
Waste Dump	0.00	19.08	

Land-use dynamicity analysis tells us how fast a land-use type is changing relative to the other classes. In 2006 land use classes-excavation site and built up have the highest dynamicity index values of 25.78% and 11.51% respectively. Sand excavation site land use class having the fastest rate of change in the upper sections of Otamiri implies high rate of infrastructural developments in Owerri Capital Territory and its environs. Tons of Sand and quarries are daily loaded are sold out. The environmental implications of this intense land-use conversion is manifest in the threatening size of gully erosion site at the Nekede head bridge and at Naze settlements. These settlements are the neighbouring communities that have lost their productive lands to bad lands (borrow pits). The built-up land use class continued to have the fastest rate of change in 2012 with 10.11% dynamicity.

CONCLUSION/RECOMMENDATIONS

The result of the structural analysis of Otamiri watershed has shown that built-up class has the greatest dynamicity in the years under review. It implies creation of impervious soil surfaces that encourage flooding and erosion. The watershed lies in a fragile ecosystem with high percentage of sandy soils. The high intensity of the riparian vegetation conversion to excavation site has led to stream bank erosion and loss of aquatic species to the neighbouring community that make their living out of the business. And the increasing loss of farmland to built-up and sand excavation activities have also brought loss of means of livelihood to the surrounding villagers.

The author recommends that the state government should enforce the 1985 watershed management edict that calls for the protection of 150m riparian vegetation on the sides of the river. The forestry department of the state ministry of environment should be empowered to ensure that regulations in the edict are complied. Also the federal government should provide guidelines through the federal ministry of mines and power that will specify sustainable ways of mining and excavating soils (sands and gravels).

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