LAND USE/ LAND COVER DYNAMICS AND URBAN SPRAWL MOVEMENT (A Case Study of Owerri, Imo State Nigeria)

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ABSTRACT

Urban expansion is responsible for different types of issues related to urban environment like declining of air quality, increase in local temperature, deterioration of water quality, increase in the surface run-off and consequent flooding etc. The study of land use/ land cover dynamics is essential to the assessment of consequent environmental impacts. Hence, land use/ land cover (LULC) change detection studies has become an essential part in modern strategies for the management of natural resources and monitoring of different social and environmental changes. In this work Owerri is taken as case study to observe the extent of urban sprawl in 29 years from 1986 to 2015. It is worthy of note that both remote sensing and GIS (Geospatial information system) technologies were adopted to study the occurrence of geo-physical land use/land cover dynamics and urban sprawl. Landsat TM, ETM+ and OLI images covering Owerri were obtained from The U.S Geological Survey (USGS). After image pre-processing, supervised and unsupervised classification were done to classify the images into various land use/land cover classes. Four land use/land cover categories were identified as built environment, water bodies, vegetation and agricultural land. Field verification exercise was also embarked upon to estimate the classification accuracy. The resultant accuracy was found to be between 97 to 100% for all the land use/cover categories. The change detection analysis done indicated that between 1986 and 2015 the agricultural lands and vegetation reduced by 50.2% and 12.3% respectively while the built environment increased by 198.5%. However, water bodies didn't show any significant change. The information about land use land cover dynamics and urban sprawl movement presented in this study is very helpful to urban planners and relevant authorities for suitable future planning and developmental sustainability of the capital territory.

Keywords — Urban sprawl, Remote sensing, GIS, LULC, Owerri

1. INTRODUCTION

The term "Urban sprawl" has received increasing attention from planners, geographers and policy makers who are advocating for sustainable urban development. Urban sprawl is a land transformation pattern characterized by low-density settlement, often random development and rapidly expanding in a manner that radiates from urban centers. It is characterized by development patterns along the periphery of cities and highways or roads connecting major settlements. Urban sprawl has several social and economic consequences, such as but not limited to loss of open space, environmental pollution, and congestion. It is also associated with loss or fragmentation of natural areas (e.g. wetlands, wildlife corridors), increased flood risks, and overall reductions in quality of life.

Owerri being the capital of Imo state is experiencing a rapid urbanization. The urban growth and sprawl has severely altered the bio-physical environment. Land-use and land-cover dynamics, as one of the main driving forces of global environmental change, is central to the sustainable development debate. Land use and land-cover dynamics have

impacts on a wide range of environmental and landscape attributes including the quality of water, land and air resources, ecosystem processes and function, and the climate system itself through greenhouse gas fluxes and surface effects.

An understanding of the processes that cause the shifting mosaic of land cover in any region should be based on fundamental knowledge of the physical environment's influence on vegetative communities as well as human impact on the landscape. The incorporation of physical and human factors is especially important for environmental or ecosystem analysis in urbanizing and urban landscapes. Human impact has become a major determinant for land cover through the various modifying activities associated with land use. The land use/land cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressure.

In attempting to understand these relationships, scientists and decision makers often rely upon classification systems to document or map the spatial extent of land cover, land use, or a combination of land cover and land use. Comprehensive analyses of land cover and the influence of land use on environmental services for water, soil, air, and biodiversity, often require combining land cover and land use parameters.

The United States Geological Survey (USGS) Anderson et al. (1976) classification is a prime example of a recognized national land use/land cover classification system. However, this combination is not as simple or straightforward as the existence and extensive use of land cover/land use maps and classification systems might lead an observer to believe (Loveland et al., 1991; Westmoreland and Stow, 1992).

Land use and land cover change has been reviewed from different perspectives in order to identify the drivers of land use and land cover change, their process and consequences. Urban growth, land use and land cover change studies are very useful to local government and urban planners for the betterment plan of sustainable development Shdhira et al. (2004). Urban growth, particularly the movement of residential and commercial land to rural areas at the periphery of metropolitan areas, has long been considered a sign of regional economic vitality. But, its benefits are increasingly balanced against ecosystem impacts, including degradation of air and water quality and loss of farmland and forests, and socio-economic effects of economic disparities, social fragmentation and infrastructure costs.

2. STUDY AREA

Owerri is the capital of Imo State, set in the south eastern geopolitical area of Nigeria. Owerri consists of three Local Government Areas including Owerri Municipal, Owerri North and Owerri West, (see figure 1) it has an estimated population of about 401,873 as of 2006 but projected to about 516,610 in 2015 (National Population Commission, 2006) and is approximately 550.848 square kilometres in area. Owerri is located at the southern part of Imo State. It extends from longitudes $6^0$52'35"E to $7^0$10'26"E and latitudes $5^0$32'59"N to $5^0$16'1"N. The city is drained mainly by River Nwaorie and River Otamiri and their tributary streams. Like most cities in Nigeria, it experiences two distinct climatic seasons; namely dry (October to March) and wet (April to September) seasons. A period of cold, dry, dusty winds known as "Harmattan" occurs from December to February annually. Owerri has a mean temperature range between 24^0C to 34^0C with a relative humidity of 70% in dry months and 90% in wet months (Emeribeole, A.C., 2015).

Owerri has a well-developed network of major roads, access roads and streets. This assemblage of infrastructure makes Owerri the hub of economic and industrial activities. With an upsurge in the number of tertiary institutions and volume of activities in city has resulted to an increase in the rate of migration from surrounding rural communities towards Owerri. Due to the increasing population and settlement, the vegetation coverage in the city is decreasing day by day.

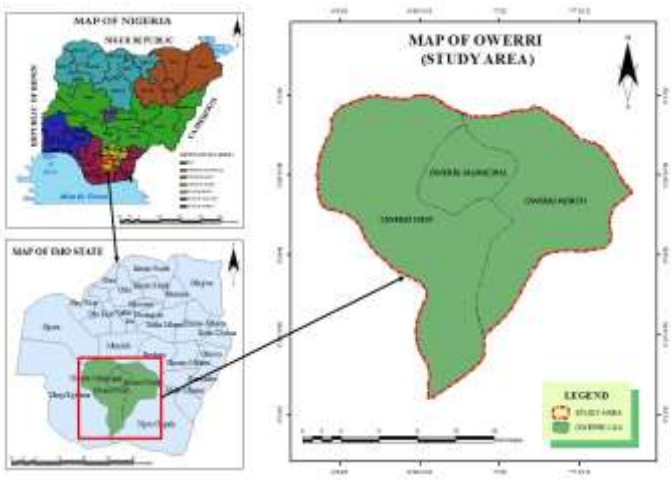

Figure 1:- Location map of the study area

3. METHODOLOGY

3.1. Data Acquisition

In this study, three (3) cloud-free Landsat satellite images/scenes were downloaded from U.S. Geological Survey (USGS) web site (http://glovis.usgs.gov/). Landsat 5 TM (Thematic Mapper) of the year 1986, the Landsat 7 ETM+ (Enhanced Thematic Mapper Plus) of the year 2000 and the Landsat 8 OLI (Operational Land Imager) of year 2015. The images are referenced to the World Geodetic System (WGS) 1984 ellipsoid and the Universal Transverse Mercator (UTM), Zone_32N coordinate system. Additionally, the images are characterized by a spatial resolution (pixel size) of 30 meters in the visible and IR (infrared) bands and each image covers 170 km * 183 km. The Properties of the downloaded Landsat Images are shown in Table 1.

Table 1: Details of the Landsat images used

S/N	Date of image Yyyy/mm/dd	Sensor	Resolution (m)	Cloud cover (%)	Path/row
1	1986/12/19	Landsat 5 TM	30	0	188/56
2	2000/01/08	Landsat 7 ETM+	30	0	188/56
3	2015/01/07	Landsat 8 OLI	30	0	188/56

Ancillary data such as administrative and topographic maps covering the study area as well as demographic information from the primary census data of the study area were also obtained from the ministry of lands and survey, Owerri and National population commission respectively.

3.2. Image Pre-processing

The image preprocessing executed in this study includes; image stacking, band selection, band combination and finally image cropping. For both Landsat 5 and 7 the false color composite in which bands 4, 3 and 2 are displayed in the red, green and blue, respectively and for Landsat 8 bands 5, 4 and 3 were used to enhance the distinction among different LU/LC types. In these band combination, urban areas appear in cyan blue, vegetation in shades of red, water bodies from dark blue to black, soils with no vegetation from white (sand, salt) to brown (Bayes, A., 2012). After the band combination the images were then cropped using the boundary layer of the study area (Owerri).

3.3. Image Classification

This study focuses mainly on the land use/ land cover dynamics and urban sprawl movement. Therefore, it was determined to limit the classification results to four classes, namely; built environment, water bodies, vegetation and agricultural land.

Table 2. The LU/LC classification scheme

LULC Category	Description
Built Environment	All man-made features (residential, commercial and industrial areas, settlements and transportation infrastructure and mixed urban)
Water bodies	Waterbodies such as (lakes, rivers, streams and canals)
Vegetation	Area occupied by vegetation
Agricultural land	Includes all croplands and other types of agricultural practices

Supervised as well as un-supervised classification methods were applied to classify the pre-processed Landsat images. According to the required number of classes and the digital number of the available pixels the ISO DATA clustering algorithm is built in the ERDAS Imagine software by un-supervised classification method. On the other hand in the supervised classification the maximum likely hood algorithm classified the images based on the training sites (signatures) obtained from field knowledge given by the researcher. Finally, both classifications give the land use/ land cover image of the study area to study the changing scenario and urban sprawl. Figure 2 shows the workflow adopted for the supervised classification.

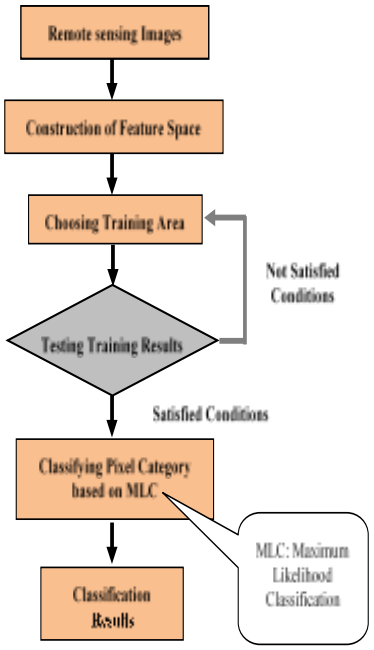

Figure 2:- Workflow for supervised classification (adopted from Dolui Gour et.,al 2014)

3.4 Accuracy Assessments

The accuracy assessments of the classified maps for 1986, 2000 and 2015 were evaluated using the base error matrix. The base error matrix evaluates accuracy using parameters such as agreement/accuracy, overall accuracy, commission error, omission error and the Kappa coefficient. The agreement/accuracy is the probability (%) that the classifier has labeled an image pixel into the ground truth Class. It is the probability of a reference pixel being correctly classified. The overall accuracy specifies the total correctly classified pixels and is determined by dividing the total number of correctly classified pixels by the total number of pixels in the error matrix. Commission error represent pixels that belong to another class but are labeled as belonging to the class; while the Omission error represent pixels that belong to the truth class but fail to be classified into the proper class. Finally, the Kappa coefficient (K_{hat}) measures the agreement between classification map and reference data. It is a discrete multivariate technique of use in accuracy assessment. K_{hat}>0.80 represent strong agreement and good accuracy. 0.40-0.80 is middle, <0.40 is poor. All accuracy parameters have index values between 0 and 1, where 0 symbolize poor and 1 strong classification accuracy/agreement.

3.5 Built-up area extraction

The built-up areas were extracted from the classified Landsat images of the various epochs, from which we can know the dynamic changes of urban sprawl in Owerri. The changes in the built-up areas are considered as one of the indicators to measure urban sprawl.

3.6 Change Detection

Change detection analysis describes and quantifies differences between images of the same scene at different epochs. The classified images of three epochs were used to estimate the area of various land use/ land cover changes of the different epochs. The spatiotemporal changes of urban sprawl were also evaluated by creating LULC maps for the three epochs (1986, 2000 and 2015) on maps reclassified into built-up and non-built-up land.

4. RESULTS AND DISCUSSION

4.1. LU/LC Classification and Accuracy Assessment

The results of LU/LC classifications of the Landsat images of 1986, 2000 and 2015 are shown in Figure 3. Accordingly, four major LULC types were identified in Owerri. These are built environment, water bodies, vegetation and agricultural land.

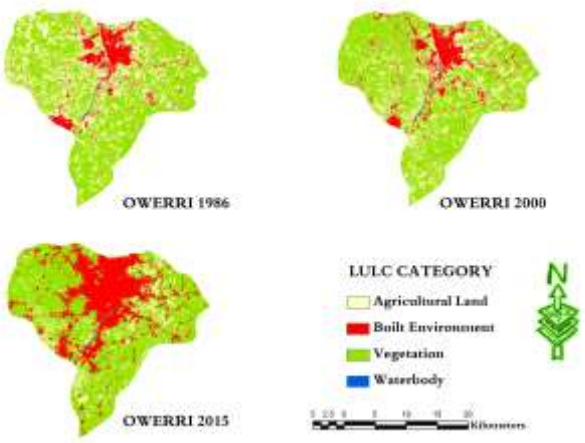

Figure 3:-. LU/LC maps obtained from classification of the 1986, 2000, and 2015 Landsat Images

Table 3. LU/LC Area in square Kilometers and percentage for each LU/LC category, during the 1986, 2000, and 2015

LU/LC Category	1986		2000		2015	
	Area (Sq. km)	Area (%)	Area (Sq. km)	Area (%)	Area (Sq. km)	Area (%)
Built Environment	55.163	10	79.159	14	164.638	30
Agricultural land	128.553	23	120.716	22	64.019	12

Water bodies	1.021	0	1.091	0	1.104	0
Vegetation	366.111	67	349.882	64	321.087	58
Total	550.848	100	550.848	100	550.848	100

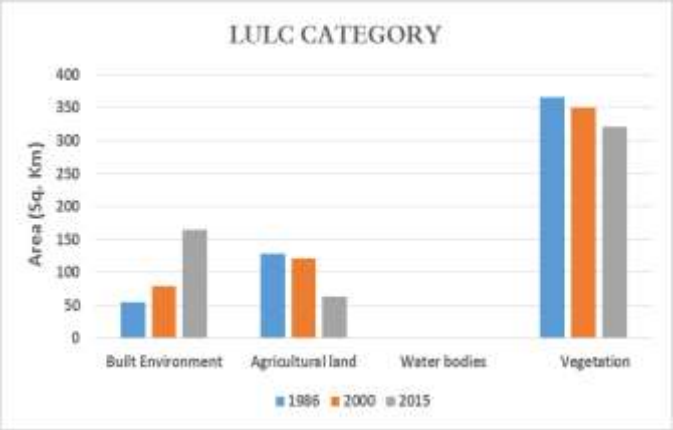

Figure 4:- Bar graph showing the distribution of the various LULC classes

The accuracy of the classified maps are shown in Table 4. The overall accuracy of the map for 2015 image is 100%, whereas the accuracies for 1986 and 2000 were 97% and 99% respectively. On the other hand, the Kappa coefficient, which evaluated the overall agreement between a classification map and reference data demonstrated a strong agreement (i.e., between 79% and 100%) between the classification maps and the reference data. The commission and Omission errors were found consistently good ranging from (79% - 100%) for all categories in each study year. However, higher values of overall accuracy parameters and Kappa coefficient indicates that the classification results are good.

Table 4. Classification Accuracy Assessment Report

Year	LULC Category	Commission error	Omission error	K_{hat} per Class
1986	Built Environment	1	.79	.79
	Agricultural Land	0.98	1	1
	Water bodies	1	1	1
	Vegetation	0.97	1	1
	Overall accuracy	0.97		
	Overall K_{hat}	0.98		
2000	Built Environment	1	0.93	.93
	Agricultural Land	0.94	1	1
	Water bodies	1	1	1
	Vegetation	1	1	1
	Overall accuracy	0.99		
	Overall K_{hat}	0.99		
2015	Built Environment	1	.83	.83
	Agricultural Land	0.99	1	1
	Water bodies	1	1	1
	Vegetation	0.99	1	1
	Overall accuracy	1		
	Overall K_{hat}	1		

4.2 Extent of Urban Sprawl

As population pressure increases, the area also expands to provide accommodation of this growing population, this growth is considered as urban sprawl. Figure 5 presents the result of the extent of the urban sprawl in 1986, 2000 and 2015. According to the result, the highest Urban Sprawl was experienced in the suburban areas where there are concentrations of agricultural lands and natural preserves. It shows the urban growth spilling beyond the boundary of the existing built up land in the municipality into the rural areas of Owerri-west and Owerri-north local government areas (L.G.A's). The largest urban land expansion was noticed in Owerri-west L.G.A, to the west, where the populations has also increased over the years. When it comes to the far suburbs, the fastest growth of the built environment was noticed in Owerri-west L.G.A. In Summary, the proportion of the built environment was only 10% (i.e., 55.163 square Kilometers) until 1986, and non-built environment (other land use/cover categories) amounts to 90% (i.e., 495.685 square Kilometers). In 2000 and 2015 the built environment grew to 14% and 30%, respectively, indicating the trend of the urban sprawl (Table 5).

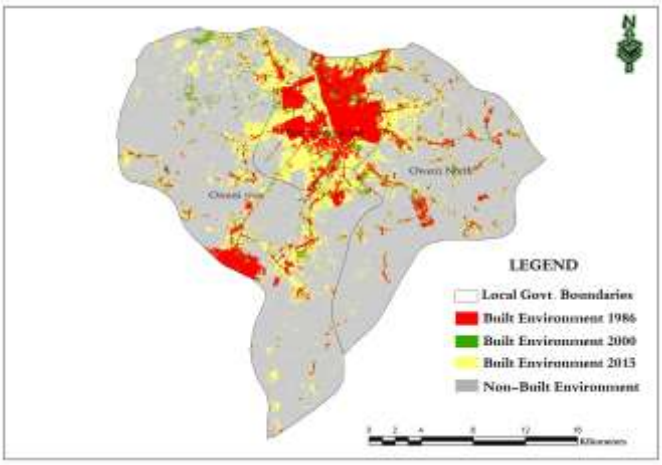

Figure 5. Extent of urban sprawl in 1986, 2000 and 2015

Table 5. Percentage of built environment in Owerri in 1986, 2000 and 2015

LU/LC Category/Year	1986		2000		2015	
	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)

Built Environment	55.163	10	79.159	14	164.638	30
Non Built Environment	495.685	90	471.689	86	386.21	70
Total	550.848	100	550.848	100	550.848	100

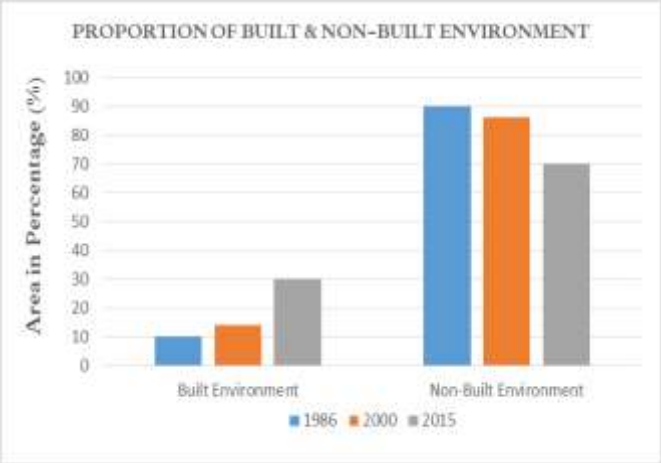

Figure 6:- Proportion of built & non-built environment in Owerri in 1986, 2000 and 2015

4.3 Change Detection Analysis

The change analysis (Table 6) shows that from 1986 to 2015, significant changes have occurred in the various LU/LC categories. For instance, between 1986 and 2000 the built environment gained about 109.475 square kilometers (i.e., 198.5%), while the agricultural land lost about 7.837 square kilometers (i.e., -6.1%). The Water bodies increased by 0.07 square kilometers (i.e., 6.9%), and the Vegetation decreased by 16.229 square kilometers (i.e., -4.4%). Similarly, in the second epoch, between 2000 and 2015, the built environment gained approximately 85.479 square kilometers (i.e., 108%), whereas agricultural lands lost about 56.697 square kilometers (i.e., -47.1%), Vegetation also decreased by approximately 28.795 square kilometers (i.e., -8.2%). Water bodies increased by 0.013 square kilometers (i.e., 1.2%). In summary, between 1986 and 2015 the built environment expanded by about 109.475 square kilometers (i.e., 198.5%), while agricultural lands and vegetation were reduced by 64.534 square kilometers and 45.024 square kilometers; respectively. Water bodies stayed relatively unchanged. There are so many reasons behind the expansion of built-up environment. Owerri is the capital of the state with an upsurge in a number of tertiary institutions and health facilities. Thus, the rate of people migrating (both daily and seasonally) from surrounding communities increases rapidly.

Table 6. LU/LC change in square kilometers and percentage during the three time periods

LU/LC	1986 -2000		2000 -2015		1986-2015	
	Change (sq. km)	Change (%)	Change (sq. km)	Change (%)	Change (sq. km)	Change (%)
Built Environment	23.996	43.5	85.479	108	109.475	198.5
Agricultural land	-7.837	-6.1	-56.697	-47.1	-64.534	-50.2
Water bodies	0.07	6.9	0.013	1.2	0.083	8.1
Vegetation	-16.229	-4.4	-28.795	-8.2	-45.024	-12.3

5. CONCLUSIONS

Owerri is the largest city in Imo State and commercial capital of the state. It is experiencing a rapid urbanization. The urban sprawl is seen as one of the potential threats to sustainable development where urban planning with effective resource utilization and allocation of infrastructure initiatives are key concerns. This study has attempted to investigate the urban growth in Owerri. Remote sensing and GIS techniques were employed for analyzing the LU/LC change, the quantitative analysis of the LU/LC maps provided a strong evidence that during twenty nine years (from 1986 to 2015) the area has experienced an extensive urban growth, associated with a huge loss of the valuable agricultural lands and a decline in the vegetation. This tremendous growth was mainly taking place in suburban areas, and at times in an unstructured and fragmented fashion raising concerns over the current city's urban planning.

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