Mapping and Analysis of Land Use and Land Cover for a Sustainable Development Using High Resolution Satellite Images and GIS

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Key words: Geoinformation/GIS, Land distribution, Land Management, Remote Sensing and Spatial Planning.

Environment for Sustainability

SUMMARY

The focus of this paper is to depict the quick and practical approach to Mapping and Analysis of Landuse and Landcover patterns and changes using high resolution satellite images. The study was carried out in Onitsha urban and its environs in south-eastern Nigeria. For this purpose, multitemporal data consisting of existing Topographical map, SPOT-5, and IKONOS images were processed using spatial analysis tools of resampling, georeferencing, classification and post-classification overlay, to map the patterns and extent of landuse and landcover in the study area as well as determine the magnitude of changes between the years of interest, 1964, 2005 and 2008 respectively. The result of the study shows that the built-up areas have been on a constant positive and mostly uncontrolled expansion from 8.12% of the study area in 1964 to 41.64% in 2005 and to 67.62% in 2008. On the other hand, vegetation, including cultivated and uncultivated agricultural lands has been on a steady decline, from 79.10% in 1964 to 51.78% in 2005 and a mere 18.74% in 2008. The study recommended that the Government and public agencies concerned should develop policies and strategies to achieve a balanced, coordinated and sustainable development in the urban area and its environs.

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1. INTRODUCTION

Land is definitely one of the most important natural resources, since life and developmental activities are based on the it. Land use refers to the type of utilization to which man has put the land. It also refers to evaluation of the land with respect to various natural characteritics. But land cover describes the vegetal attributes of land. Land use and landcover data are essential for planners, decision makers and those concerned with land resources management Ndukwe, (1997). Monitoring and analysis of the urban environment make use of up-to-date Landuse and Landcover (LULC) information, for proficient and sustainable management of urban areas. Unfortunately, on the other hand, there is a general lack of accurate and current LULC maps in Nigeria, especially in Onitsha Metropolis, Ezeomedo, (2006).

However, the advant of air-and space-borne remote sensing has made it possible to acquire pre-and post-project landuse and landcover data in consistent manner. In addition, the advent of geographic information system (GIS) has made it possible to integrate multisource and multidate data for the generation of landuse and landcover changes involving such information as the trend, rate, nature, location and magnitude of the changes Adeniyi et al (1999). The main goal of this paper is to apparised the integration of multisource archival remote sensed data and GIS in the mapping and evaluation of landuse and landcover changes within the Onitsha metropolis using a well known application. The information obtained will serve as a base for decision making.

Remote Sensing research focusing on image classification has attracted the attention of many researchers (Lu and Weng 2007) and a number of researches have been conducted using different classification algorithms. It should be noted that valuable surface information extraction and analysis is also well performed using image classification. Image classification is the process of assigning pixels of continuous raster image to predefined land cover classes. It is a complex and time consuming process, and the result of classification is likely to be affected by various factors (e.g. nature of input images, classification methods, algorithm, etc). In order to improve the classification accuracy, thus, selection of appropriate classification method is required. This would also enable analyst to detect changes successfully. In various empirical studies, different classification methods are discussed. (Lu and Weng 2007) reviews two classification paradigms: pixel and object-based as well as advanced classification approaches.
The advent of object-oriented approaches provides a tool for mapping detailed land uses (Mori et al. 2004). This approach considers group of pixels and the geometric properties of image objects. It segments the imageries into homogenous regions based on neighbouring

pixels' spectral and spatial properties. It is based on a supervised maximum likelihood classification. Thus, an object-oriented method has been applied in this project in to avoid the mixed pixel problems. The overall procedure is described below.

Recently, various advanced image classification approaches have been widely used (Lu and Weng 2007). These include artificial neural networks, fuzzy-set theory, Image classification approaches, Training Data Distribution, Algorithm, Pixel Class, Membership, Parametric, Non-Parametric, Unsupervised, Hard Classifiers, Soft (Fuzzy) Classifiers, Supervised 13 decision tree classifier, etc. The pixel-based approach is referred to as a "hard" classification approach and each pixel is forced to show membership only to a single class. Soft classification approach is thus developed as an alternative because of its ability to deal with mixed pixels. The soft classification method provides more information and produces potentially a more accurate result (Jensen et al. 2005). In understanding of the problem and the application of available technologies, the integration of GIS and remote sensing with the aid of models and additional database management systems (DBMS) is the technically most advanced and applicable approach today.

The basic premise in using satellite images for change detection is that changes in land cover result in changes in radiance values that can be remotely sensed. Techniques to perform change detection with satellite imagery have become numerous as a result of increasing versatility in manipulating digital data and increasing computing power. A wide variety of digital change detection techniques have been developed over the last two decades. Singh (1989) and Coppin & Bauer (1996) both provide excellent and comprehensive summaries of methods and techniques of digital change detection. Coppin & Bauer (1996) summarize eleven different change detection algorithms that were found to be documented in the literature by 1995. These include: monotemporal, change delineation or post-classification comparison, multidimensional temporal feature space analysis, composite analysis, image differencing, image ratioing, multitemporal linear data transformation,change vector analysis, image regression, multitemporal biomass index and background subtraction.

Macleod and Congalton (1998) listed four aspects of change detection, which are important when monitoring natural resources: Detecting that changes have occurred, identifying the nature of the change, measuring the areal extent of the change and Assessing the spatial pattern of the change. An image differencing technique has been implemented in this study, because according to recent research by Coppin & Bauer (1996), image differencing appears to perform generally better than other methods of change detection; and such monitoring techniques based on multispectral satellite data have demonstrated potential as a means to detect, identify, and map changes in landuse/land cover. Image differencing is probably the most widely applied change detection algorithm for a variety of geographical environments (Singh, 1989). It involves subtracting one date of imagery from a second date that has been precisely registered to the first.

In most developing countries, especially Nigeria, availability of relevant and current information about our environment and how it changes over time has been lacking, Ezeomedo, (2006). This problem therefore, has consequently been affecting the achievement of change detection and sustainable development, and as such, requires research for accurate and timely information, which is needed for environmental monitoring, planning and forecasting. Although, series of works have been done in a conventional system to produce some information on the LULC in some cities in Nigeria, but no much studies have been done using Remote Sensing and GIS technique in its mapping and analysis. Therefore, the application of GIS using remotely sensed data for change detection analysis of Onitsha and its environs would definitely enhanced the available data for a sustainable development.

2. METHODOLOGY

2.1 Data Used

This study involved primary data collection and secondary data collection. The topographic map of Onitsha and its environment was obtained from the ministry of Land and Survey, Awka. The SPOT-5 2005 and IKONOS 2008 image of study area were obtained from the Archives of the National Centre for Remote Sensing, Jos, Nigeria. The census data were collected from the National Population Commission office, Awka branch. Then field visits to site was carried out to obtain ground control points for georeference and ground truth sampling. The object-oriented approaches was used for mapping detailed land uses. This approach considers group of pixels and the geometric properties of image objects. It segments the imageries into homogenous regions based on neighbouring pixels' spectral and spatial properties. It is based on a supervised maximum likelihood classification. Thus, an object-oriented method has been applied in this project in to avoid the mixed pixel problems.

Table 1: Coordinates of Some Selected Ground Controls

S/N	Name (s)	Eastings (m)	Northings (m)
1	Boromi Round about	679891.33	258121.15
2	Mr.Bigg's Junction	680509.02	254821.21
3	Nkpor Junction	679987.12	260249.95
4	Obosi Junction	680599.69	261606.03
5	Flyover Bridge	678394.46	255676.43

Source: Ezeomedo (2012)

2.2 Data Processing and Analysis

2.2.1 Resampling and Georeferencing

The pre-processing and post image processing and analysis were carried out to enhance the quality of the images and the readability of the features using the spatial analysis tools of Integrated Land and Water Information System (ILWIS 3.3). The scanned and digitized old Topographical map of 1964 and satellite images of SPOT-5, 2005 and IKONOS, 2008 were geometrically corrected and the projection was set to Universal Transverse Mercator (UTM) projection system, zone 32. The spheroid and datum was referenced to WGS84. All the images were geometrically co-registered to each other using ground control points into UTM projection with geometric errors of less than one pixel, so that all the images have the same coordinate system. The nearest neigbourhood resampling technique was used to resample the Topographic map and SPOT-5 into a pixel size of IKONOS during the image-to-image registration.

The ground control points (GCPs) in table 2 are konwn ground points whose positions can be accurately located on the digital imagery. Such features include road intersections, corners of open field or lawns. Co-ordinates of GCPs were obtained using Global Positioning System (GPS). A sufficient number of such pionts is used to solve the transformation coefficient. A geometric transformation of map-to-map were used for the scanned/digitized topographical map of the study area, in the other hand, an image-to-map transformation were applied to the remotely sensed data of SPOT and IKONOS using Affine transformation, the result of the excercise was checked using Root Mean Square (RMS) error which is the process of measuring the deviation between the actual location and the estimated location of the control points in geometric transformation and was found to be 0.7 pixel.

2.2.2 Classification and Post-Classification Overlay

Classification and post-classification overlay was carried out and thematic land-cover maps for the year 1964, 2005 and 2008 were produced for the study area by supervised classifications using a maximum likelihood classifier. Four major landcover classes were mapped see Table 3 for more details: Built-up areas (BA), open/bare lands (OP), vegetations (VG) including the cultivated and uncultivated land and water bodies (WB); to be able to detect possible details, change trajectory of post classification comparison was used to map the patterns and extents of landuse and lancover in the study area as well as determine the magnitude of changes between the years of interest, 1964, 2005 and 2008, respectively.

2.2.3 Assessment of Classification Results Using Error Matrix

The error matrix-based accuracy assessment method is the most common and valuable method for the evaluation of change detection results. Thus, an error matrix and a Kappa analysis were used to assess change accuracy, (see Figure 7). Kappa analysis is a discrete multivariate technique used in accuracy assessments (Congalton and mead, 1983; Jensen, 1996).

Table 2: **Descriptions of classes adopted**

S/N	Land Cover	Description (s)	Code	Colour Assigned
1	Urban or built-up areas	This class includes continuous and discontinuous urban fabric, industrial, commercial, transportation and other related built-up areas.	BA	Red
2	Open/ bare land	Sand plains, unpaved roads, excavation site, are considered as bare lands.	OP	Yellow
3	Vegetated areas	This comprises green urban areas, non-irrigated arable land, irrigated land, scrubs and forest cover,	VG	Green
4	Water bodies	Water related features such as water course, estuaries, Salt marshes and River.	WB	Blue

2.2.4 Applications and Approaches of Change Detection

Change detection has been applied in different application areas ranging from monitoring general land cover change using multi-temporal imageries to anomaly detection on hazardous waste sites (Jensen et al. 2005). One of the most common applications of change detection is determining urban land use change and assessing urban sprawl. This would assist urban planners and decision makers to implement sound solution for environmental management.
A number of approaches have emerged and applied in various studies to determine the spatial extent of land cover changes. It is also reviewed that different methods of detection produce different change maps (Araya and Cabral 2008). The selection of an appropriate technique depends on knowledge of the algorithms and characteristic features of the study area (Elnazir et al. 2004), and accurate registration of the satellite input data. Change detection approaches based on expert systems, artificial networks, fuzzy sets and object-oriented methods are also available in different software platforms (Jensen et al. 2005). In addition, various researchers (Singh 1989; Mas 1999; Belaid 2003; Jensen et al. 2005; Berkavoa 2007) have attempted to group change detection methods into different broad categories based on the data transformation procedures and the analysis of techniques applied. According to (Berkavoa 2007), for example, change detection can be divided into two main groups: pre-classification and post-classification methods. The following section discusses some of the techniques that are available in various software platforms.

2.2.5 Image Differencing

Image differencing is one of the widely used change detection approaches and is based on the subtraction of images acquired in two different times. This is performed on a pixel by pixel or band by band level to create the difference image. In the process, the digital number (DN) value of one date for a given band is subtracted from the DN value of the same band of another date (Singh 1989; Tardie and Congalton 2004). Since the analysis is pixel by pixel, raw (unprocessed) input images might not present a good result.

2.2.6 Image Rationing and Regression

In image rationing method, geo-corrected images of different data are rationed pixel by pixel (band by band). It also looks at the relative difference between images (Eastman 2001). Ratio value greater or less one reflects cover changes. Regression method is based on the assumption that pixels from Time1 are in a linear function of the Time2 (Singh 1989; Ramachandra and Kumar 2004). The regression technique accounts for differences in the mean and variance between pixel values for different dates.

2.2.7 Vegetation Index Differencing:

This method is applied to analyze the amount of change in vegetation versus non vegetation by computing Normalized Deference Vegetation Index (NDVI). NDVI is one of the most common vegetation indexing method and is calculated by $\boldsymbol{NDVI} = \frac{(\boldsymbol{NIR}-\boldsymbol{RED})}{(\boldsymbol{NIR}+\boldsymbol{RED})}$ — 1.0
Where NIR is the near infrared band response for a given pixel and RED is the red response

2.2.8 Post Classification Comparison:

This is the most obvious, common and suitable method for land cover change detection. This method requires the comparison of independently classified images T1 and T2, the analyst can produce change map which show a complete matrix of changes (Singh 1989).

2.2.9 Post-Classification Detection Technique Used

There are a number of detection techniques but the most common approach is the simple technique of post classification comparison (Blaschke 2004). A post-classification comparison, which is the most straightforward technique, has been applied in this study. The land cover maps for the years 1964, 2005 and 2008 were first simplified into four classes: built up area, open/barren, and vegetation and water bodies' areas. The post-classification comparison was then applied by differentiating the corresponding classified maps to generate change maps. The change map of images is generated as a table. The result of the detection change entirely depends on the accuracies of each individual classification. Image classification and post-classification techniques are, therefore, iterative and require further refinement to produce more reliable and accurate change detection results (Fan et al. 2007).

2.2.10 Study Area

Onitsha and its environs lies in the north-western part of Anambra State, in South-Eastern Nigeria. The settlements covered by the study include: Onitsha, Obosi, Nkpor, Okpoko and Iyiowa Odekpe (see figure 1 to 3). It is located between Latitudes $06^{\circ}\ 02'\ 56''N$ and $06^{\circ}\ 38'\ 34''N$ and Longitude $06^{\circ}\ 37'\ 30''E$ and $06^{\circ}\ 59'\ 30''E$. The area is about 3,063 square kilometer. It serves as the gate way between the South-Eastern and South-Western part of

Nigeria. The population figure of Onitsha Metropolis according to 1991 and 2006 population census of Federal Republic of Nigeria is presented in Table 1. The metropolis since it is found about 1680, has been a center of commercial activities, an ecclesiastical center and an administrative center Mozie, et al (2008). Onitsha and its environs constitute one rapidly urbanizing region. The urbanization process was correctly anticipated by Ezeomedo, (2012), while investigating and modelling the urban sprawl pattern of Onitsha. The vegetation of the study area is a sub-climax of the original rainforest, having been virtually cleared due to development. The area mean annual Rainfall is between 22°c to 27.5°c and Mean annual temperature is between 1,500mm to 2,500mm. South west monsoon harmattan winds are experienced around January, May and September respectively.

Table 3: Population figures of the study area

S/N	Name of Areas	1991 Population	2006 Population
1	Onitsha North	121,157	124,942
2	Onitsha South	135,290	136,662
3	Nkpor	64,732	94,697
4	Obosi	85,249	124,699
5	Iyiowa Odekpe	21,844	31,939

Source: Official Gazatte of Nigerian Government (FGP71/52007/2,500(OL24)

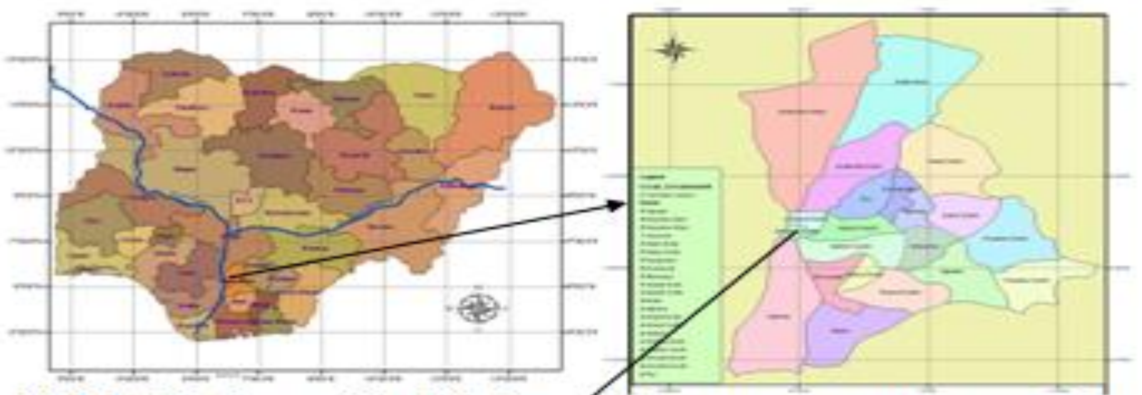

Fig. 1. Administrative map of Nigeria Showing Anambra state.

Fig. 2. Map of Anambra State Showing Local Government Areas.

Fig. 3: The Study Site, Onitsha Metropolis.
Source: Ezeomedo, (2012)

3. RESULTS AND DISCUSSION

3.1. Result of land cover mapping

The outcome of the data processing and analysis were presented in form of digital maps, layout and attribute tables. The area covered by the three-class land cover maps of 1964, 2005 and 2008 are shown in Figure 4, 5 and 6 respectively, figure 7 shows the accuracy of the assessement in terms of average User's accuracy, average producer's accuracy and overall accuracy, and while figure 8 shows trend analysis of the land cover types.

3.2. Change Detection Results

In LULC mapping, the post comparison technique is the only method that resulted in a change matrix that provided ''from-to'' information. The land cover changes were computed between 1964 and 2005 and between 1964 and 2008, table 4 and 5 depicts what happen between 1964 to 2005 and between 1964 to 2008 respectively, the capability of the resampled topographic map was assessed from the results of SPOT- 5 and IKONOS images. The overall result of change detection shows that as urbanization is increasing, the vegetation is decreasing as depicted in figure 8.

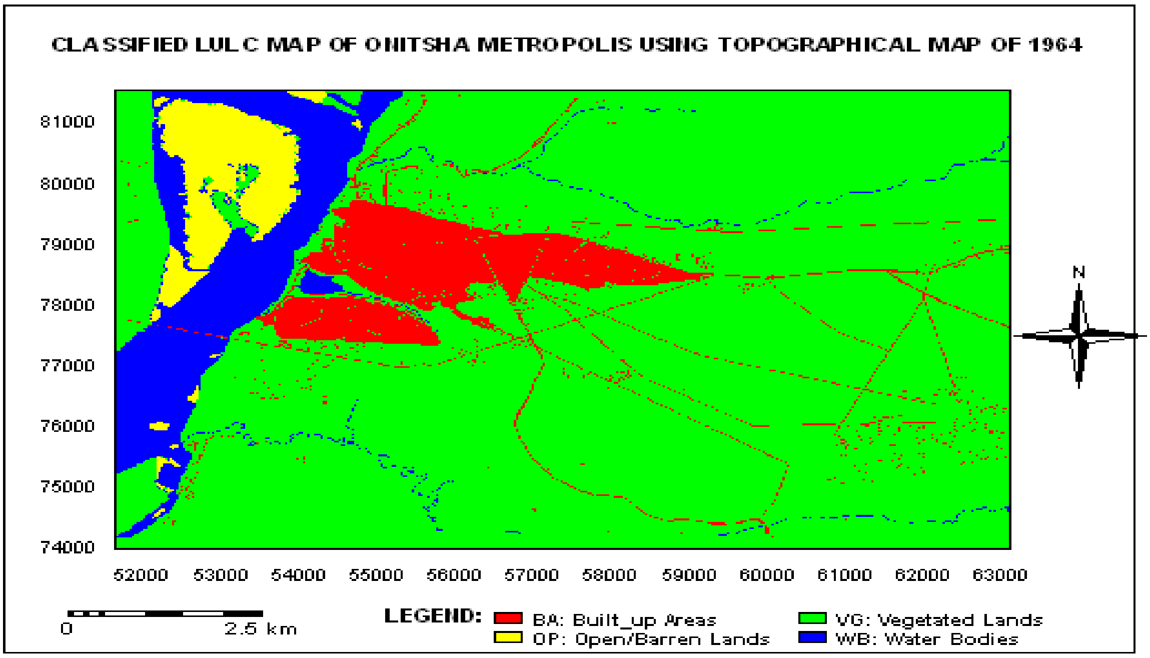

Fig. 4: Classified **Topographical Map** (1964) Resampled into IKONOS Image

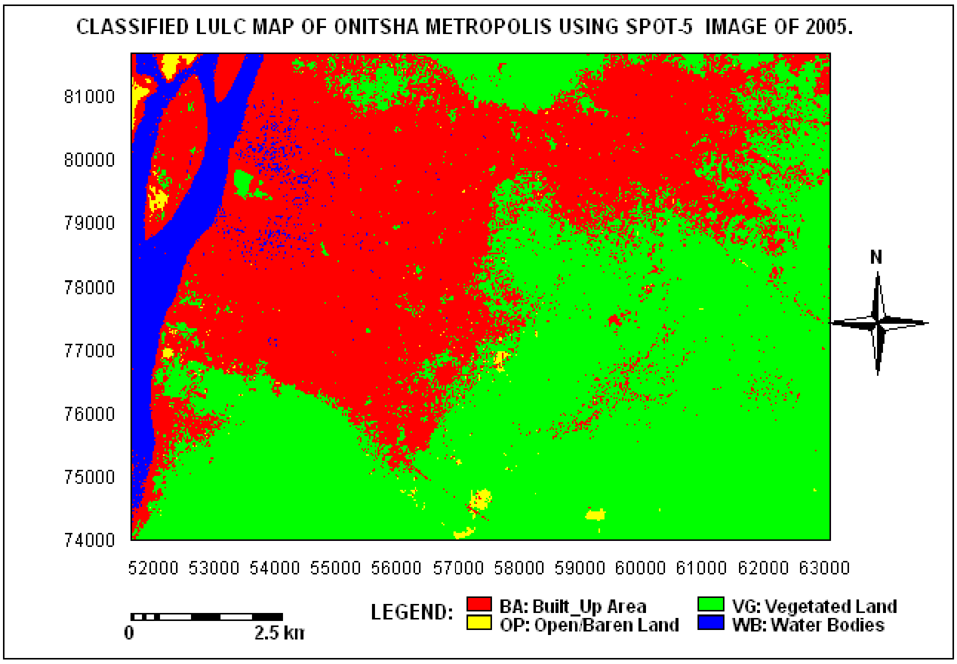

Fig. 5: Classified **SPOT-5** (2005) Resampled into IKONOS (2008) Image.

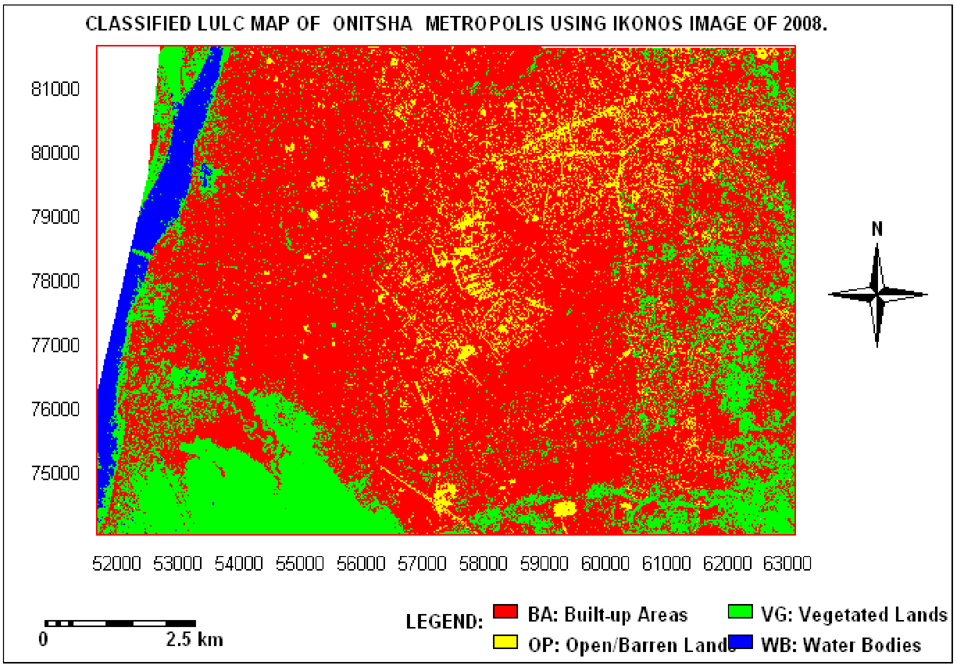

Fig.6: Classified **IKONOS** (2008) image.

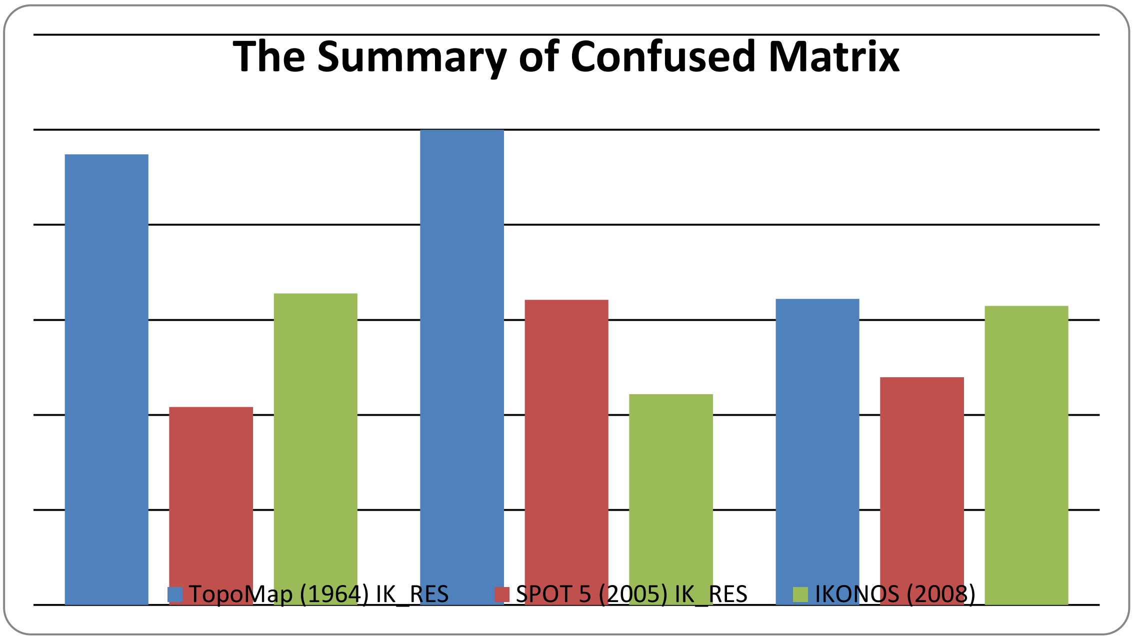

Fig. 7: The Evaluation of Classification Results using Error Matrix.

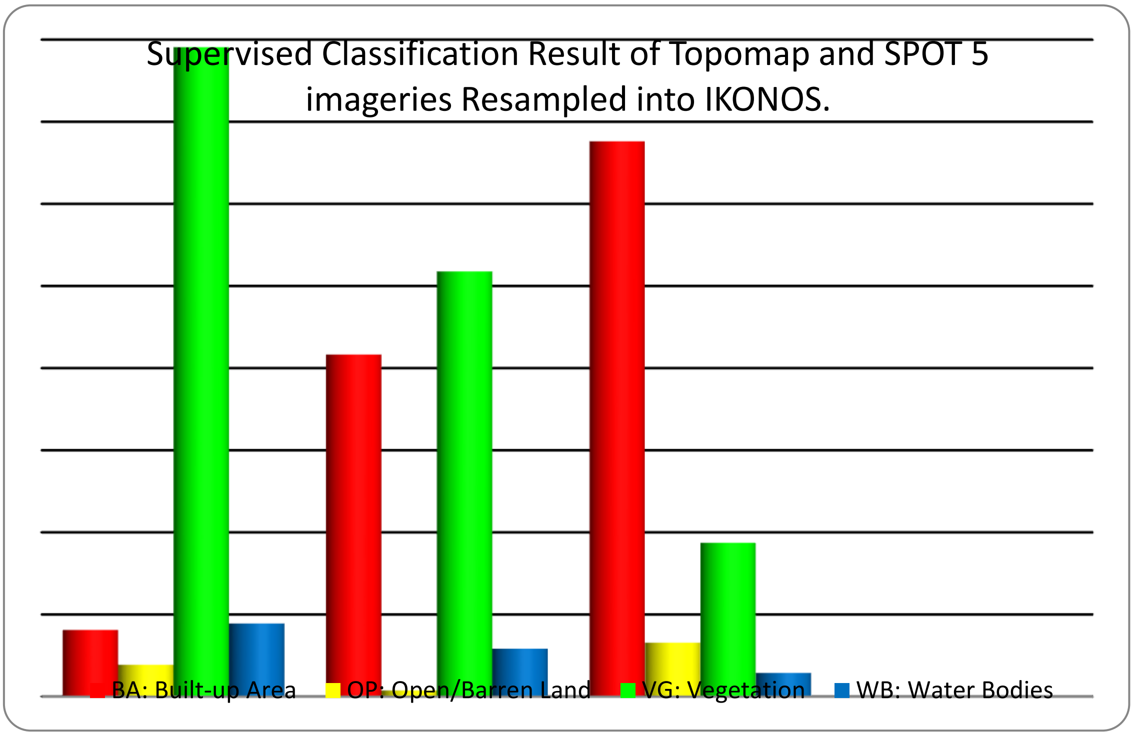

Fig. 8: The Summary of LULC Classification using High Resolution Imagery.

Table 4: Result of change detection between 1964 and 2005 in percentage (%)

CLASSES	TopoMap (1964)	SPOT-5 (2005)	Change Detection (1964-2005)	Annual Rate of Change	Projection (2021)
BA	08.12	41.64	33.52	00.81	54.72
OP	03.88	00.74	-03.14	-00.07	00.38
VG	79.10	51.78	-27.32	-00.66	41.12
WB	08.90	05.84	-03.06	-00.07	04.72

Table 5: Result of change detection between: 1964 and 2008 in percentage (%)

CLASSES	TopoMap (1964)	IKONOS (2008)	Change Detection (1964-2008)	Annual Rate of Change	Projection (2021)
BA	08.12	67.62	59.50	01.35	85.17
OP	03.88	06.57	02.69	00.06	07.35
VG	79.10	18.74	-60.36	-01.37	00.93
WB	08.90	02.88	-06.02	-00.14	01.0

4. DISCUSSION

The application of remote sensing and GIS is mostly in image analysis, mapping and monitoring of urban land use. It was applied to estimate various surface features and provide LULC information for planning. Accuracy assessment is a process used to estimate the accuracy of image classification by comparing the classified map with a reference map. It is critical for a map generated from any remote sensing data. It is also considered as an integral part of any image classification. This is because image classification using different classification algorithms may classify pixels or group of pixels to wrong classes. In a highly urbanized area the spectral characteristics of an object may be conflicting to be correctly classified, see figure 9 showing built up area with tendency of conflicting spectral signatures because of the reflectance of an old building roof is not the same with the recently constructed buildings. The most obvious types of error that occurs in image classifications are errors of omission or commission. The common way to represent classification accuracy is in the form of an error matrix. An error matrix is a square array of rows and columns and presents the relationship between the classes in the classified and reference maps. Using error matrix to represent accuracy is recommended and adopted as the standard reporting convention. In this paper, overall, producer's and user's accuracy were considered for analysis (see Figure 7) and Kappa index result was above minimum frequency.

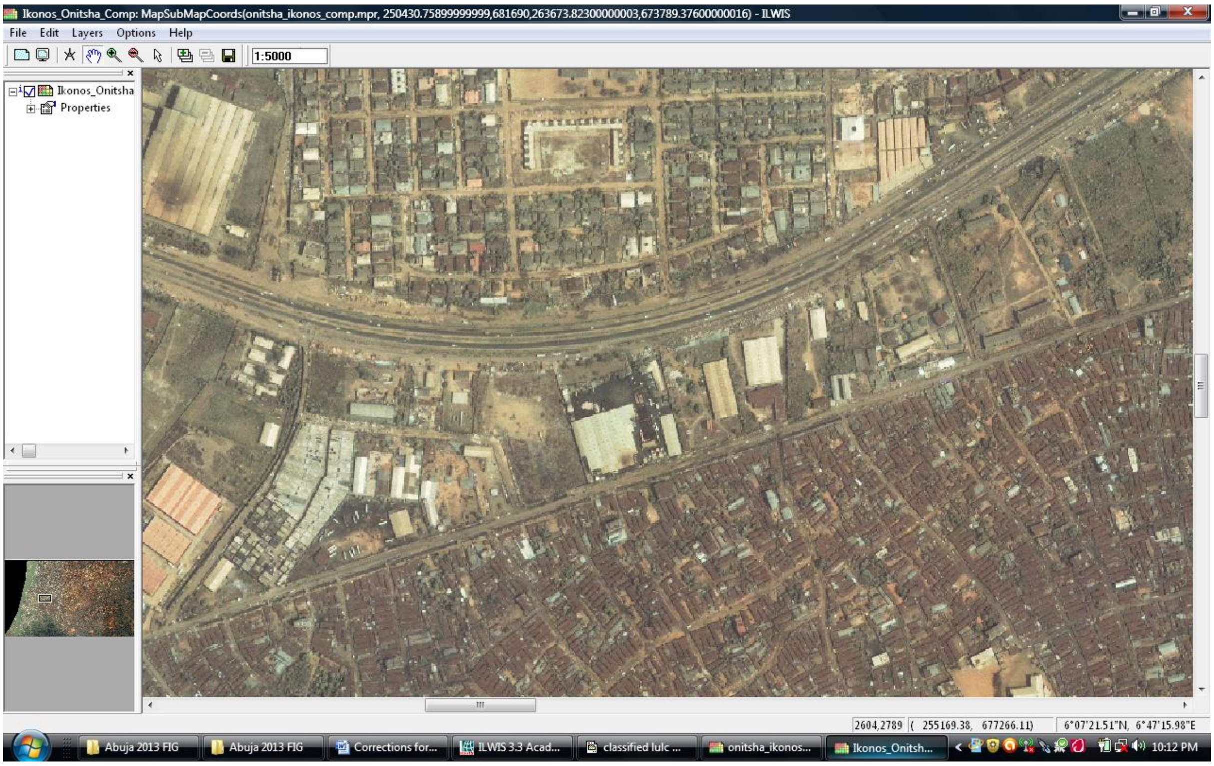

Fig. 9: IKONOS image showing Built-up area and the heterogenous nature of features

4.1 Detail Discussion of the Result of LULC Classification

The result of the land use/land cover change as was analyzed using object-oriented approach which was based on a supervised and Gauss maximum likelihood classification method. Statistical means shows that there was both positive and negative change as depicted below.

—**Built-Up Areas:** They were a great positive change in the built-up areas, more than hundred percent increases. From the statistical analysis of this research the built-up areas formerly occupied a proportion of 8.12% in 1964 and increased to 41.64% and 67.62% in 2005 and 2008 respectively. This is a clear indication of increase in population and infrastructure development in the metropolis, regardless of use or pattern.

—**Open/Barren Land:** This class recorded both positive and negative change over the year under study. Bare surface proportions were 03.88% in 1964 but were decreased to 00.74% in 2005 and were increase again to 06.57% in 2008. This can be attributed to human activities, which includes, over grazing, indiscriminate bush burning, fire wood extraction which are some of the characteristics of most regions of Nigeria. Although, it was observed that development that are recent and their roofing was done with white aluminum roofing sheet have a conflicting spectral signature with this class.

—**Vegetation:** Agricultural lands also regardless of type of crops and their level of intensity; cultivated or uncultivated show a negative increase. In 1964, what was obtainable was

79.10% and while in 2005 its 51.78%, again in 2008 were declined to 18.74%. This can be as a result of built-up areas above, which include construction of all capacity.

—**Water Bodies:** The proportion of the study area under water bodies recorded a negative change although very minimal in nature. In 1964 result shows 08.90%, while in 2005 and 2008 this class represents a proportion of 05.84% and 02.88% respectively. This may be due sand deposit, land reclamation and other developmental activities along the coast, again, the available NigeriaSat-1 imagery were slightly smaller in size around the water body's area.

4.2 Addition to Knowledge

The capability of the digitized and classified topographic map shows that it can serve as basemap for monitoring the constant changes in the built environment.

5. CONCLUSION

Remote sensing nowadays has become a modern tool for mapping and analysis of landuse and landcover for micro, meso, and macro level planning. Remote sensing systems have the capability for repetitive coverage, which is required for change detection studies. For ensuring planned development and monitoring the land utilization pattern, preparation of landuse and landcover map is necessary. The present study demonstrates the usefulness of satellite data for the preparation of accurate and up-to-date land-use/land-cover maps depicting existing land classes for analyzing their change pattern for Onitsha metropolis by utilization of digital image processing techniques. Result of classification clearly shows constant positive increase in urbanization and balanced decline in the urban vegetation.

Furthermore, the developed spatial map can serve as an efficient technical vehicle for spatial analysis and spatial modeling functions, to gain insights into developmental problems, e.g. to evaluate development impacts in the past, and to enhance regional development strategies through facilitating various scenarios. It is expected to be useful for formulating meaningful plans and policies so as to achieve a balanced and sustainable development in the region. It is concluded that satellite imagery can be very effective and fast in change detection of landuse and landcover changes.

It is suggested that Government should encourage its personnel through funding so that changes in landuse at regular interval will be detected. If such funds are made available, more research should be focus towards the use of modern application; such as satellite imagery, GIS and digital equipment to obtain fast and accurate digital data or information. Since ground survey methods are not convenient and aerial or photographic maps production are very expensive and time consuming.

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BIOGRAPHICAL NOTES

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Education/Qualifications
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