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# IDENTIFICATION OF URBAN SPRAWL USING REMOTE SENSING AND GIS TECHNIQUE: A CASE STUDY OF ONITSHA AND ITS ENVIRONS IN SOUTHEAST, NIGERIA

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## Abstract

Urban sprawl has been investigated, analysed and modelled by considering the built-up areas as the key feature of sprawl, which was obtained through remote sensing and GIS. In view of this, supervised classification approach was utilized to derive six land cover maps from Digitized Topographical Map, NigeriaSat-1 and LANDSAT ETM+ multi-spectral images for the years 1964, 2004 and 2006 respectively; after the digitized Topographical map and NigeriaSat-1 were co-registered to LANDSAT ETM+. The result shows that urban area increased by 56.15% between 1964 and 2006, 33.96% between 2004 and 2006.

In contrast, the same digitized Topographical map, (1964) and SPOT 5, (2005) image was also co-registered into IKONOS, (2008) image of the same study area to obtain a common Georeference and Coordinate system, and after classification in ILWIS 3.3 window, indicated an increase by 59.50% between 1964 to 2008, and with a fast growth of 25.98% between 2005 and 2008 only. Shannon's Relative Entropy (E) was used to measure the degree of urban sprawl which indicates that total Entropy value is 0.7, indicating a high rate of sprawl. Yet again, the zones within the metropolis have individual Entropy values that range from -0.2 to 0.5. This revealed some compacted zones, while some have a tendency towards intensive urban sprawl. Finally, the urban land use change for the year 2021 was modelled and predicted using Remote Sensing and GIS result, population figures of (1991, 2006 and 2008), and Shannon's Entropy technique.

The result shows that between: 2008 to 2011 the built-up areas witnessed 71.68% increase; while 2011 to 2021 will experience 85.20% growth, with an annual rate of 1.35%. It is recommended among others, that, Government and relevant agencies should embark on detail mapping of urban and regional areas at the relevant scales, to update the old existing maps, and to monitor closely urban environment.

**Key words:** Urban Sprawl, Remote Sensing/GIS, Satellite imageries, Built-up Areas, and Shannon's Entropy Approach.

## 1.1. Introduction

The term urban sprawl is widely used in many disciplines dealing with urban development and urban form. Unprecedented population growth coupled with unplanned developmental activities has led to urbanization, which takes place along highways, or surrounding the city and in rural country side (Theobald, 2001[1]). This phenomenon is thus referred to as urban sprawl, and it has posed serious implications on the resource base of the region. Urban sprawl may be defined as the scattering of new development on isolated tracts, separated from other areas by vacant land, (Lata, et al. 2001[2]). It has also been described as leapfrog development (Torrens and Albert, 2000[3]). The direct implication of such urban sprawl is the change in landuse and landcover (LULC) of the region.

Patterns of sprawl can take place either in radial direction, around a well-established city or linearly along the highways (Theobald, 2001). However, the identification of the patterns and analyses of spatial and temporal changes would help immensely in the planning for proper infrastructural facilities. This could be done effectively and efficiently with the help of spatial and temporal technologies such as GIS and Remote sensing, along with collateral data such as Survey of existing maps, etc. (Barnes et al., 2001[4]). In order to accurately characterize this complex spatial environment, specific spatial and spectral sensor characteristics and improved image analysis techniques are required. New data resources and innovative concepts in image analysis have the potentials for improving the mapping and analysis of spatial urban land use and land cover using satellite sensors which are available.

Furthermore, spatial identification, analysis, Modelling and periodic monitoring of Urban Sprawl/Slums formation require land use/ land cover information and its changes. This is thus desirable for any effective planning, management and monitoring at local, regional and national levels. This information not only provides a better understanding of land utilization aspects but also play a vital role in the formulation of policies and programs required for development of the future and making provisions for it, (i.e. ensuring sustainable development). To monitor the ongoing changes in land use/ land cover pattern over a period requires the present and past land use information of the area and pattern of changes with respect to urban settlements and other local resources.

Recent advancement in GIS and remote sensing tools and methods also enable researchers to model and predict urban growth more efficiently. Several modelling approaches have also been developed to model and forecast the dynamics of urban features. One of the approaches is Shannon's entropy (Hn), which reflects the concentration of dispersion of spatial variable in a specified area, to measure and differentiate types of sprawl. This measure is based on the notion that landscape entropy or disorganization increases with sprawl. The urban land uses are viewed as interrupted and fragmented previously homogenous rural landscapes, thereby increasing landscape disorganization (Yeh and Li, 2001[5]). Lata et al (2001) have also employed a similar approach of characterizing urban sprawl for Hyderabad City, India. Another approach is the Cellular Automata-CA. CA is a dynamical discrete system in space and time that operates on a uniform grid-based space by certain local rules (Alkheder and Shan, 2005[6]). The CA is consisting of cells and transition rules are applied to determine the state of a particular cell. Its ability to represent complex systems with spatio-temporal behaviour from a small set of simple rules and states made it very interesting for urban studies (Alkehder and Shan, 2005).

An increased urban population and growth in urban areas is inadvertent with an unpremeditated population growth and migration. The United Nations has forecast that the world's population will increase from 7.2 billion today to 8.1 billion in 2025 and 9.6 billion in 2050, with most growth in developing countries and more than half in Africa. Among the fastest growing countries is Nigeria, whose population is expected to surpass the US population before the middle of the century, (UN, 2013[7]).

Anambra State has a population of more than 4 million (4,182,032 out of which 50.84% is women).The State is the 8th populous and the second densely populated state in Nigeria with almost 700 people per sq km. With an annual population growth rate of 2.21 percent per annum, Anambra State has over 60% of its people living in urban areas. Anambra State's high population density coupled with high rate of urbanization is rapidly assuming that of Lagos State (former capital of Nigeria), that is almost completely urbanized and has emerged as a city-state spreading to neighbouring Ogun State to form a Mega city, according to (UN-HABITAT, 2009[8]). In a similar way, the cities of Anambra State are growing rapidly to merge with each other across local government boundaries as demonstrated in the structure planning of three major cities of Anambra State, (UN-HABITAT, 2009) and can be clearly seen in the IKONOS image covering this area, (Ezeomedo, 2012[9]). As a matter of fact, the cities of Awka, Onitsha and Nnewi, have grown during the past decades, especially since the end of the Nigerian civil war, to merge with their surrounding settlements, showing several patterns of urban sprawl.

Although, there has been a worldwide increase in awareness and studies on land use and land cover change analysis in the last four to five decades, but there is still an extremely low level of research attention on land use and land cover change studies in Nigeria. Ademiluyi, et al; (2008[10]). Also, some of the few prominent land use and land cover analysis and change detection attempts in the country relied heavily on manual analysis procedure as against the modern recognized digital image interpretation and analysis procedure. Ademiluyi, et al; (2008). It was on these premises that an integrated approach of using Shannon's Entropy, Remote Sensing technology and GIS, a well known methodology were applied to identify, analyze and model the patterns of urban changes and provide quantitative and spatial information on developments of Onitsha and its environs.

# 2. Materials and Method

## 2.1. Study Area

Onitsha and its environs lie 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[11]).

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

1,500mm to 2,500mm and Mean annual temperature is between 22̊c to 27.5̊c. South west monsoon harmattan winds are experienced around January, May and September respectively.

Onitsha is one of the largest market in Africa and one of the fastest growing commercial cities in Nigeria. There are many markets existing in this city, the popular ones are: the foremost Onitsha Main market, Marine market, Ochanja market, Relief market, Ose okwe odu Market, and Nkpor new/old motor spare parts market. These enabled the area to develop as an important industrial centre, east of River Niger in Nigeria, (Igbokwe, et al, 2004[12]).

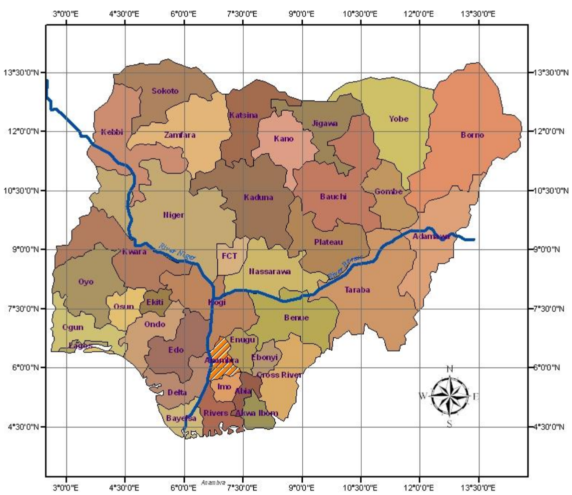


**Figure 1**. Administrative map of Nigeria Showing Anambra state.

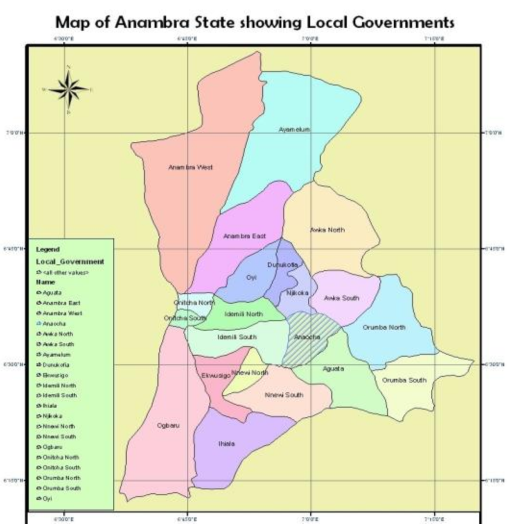


**Figure 2.** Map of Anambra State Showing Local Government Areas.

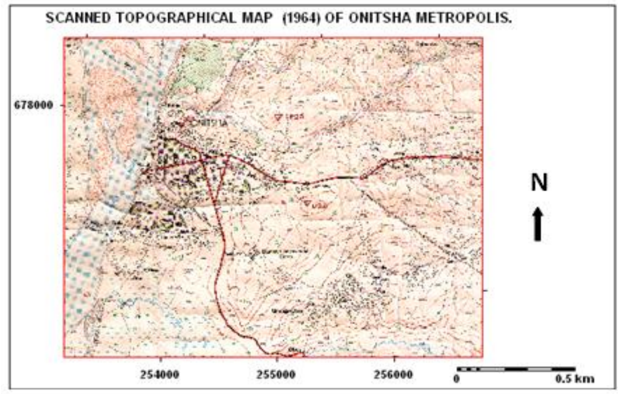


**Figure. 3**: Study Site map, Onitsha Metropolis.
**Source:** Ezeomedo (2012)

## Table 1: Population figures of the study area

| S/N | Name | 1991 | 2006 |
|---|---|---|---|
| 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:** National Population Commission (2007[13])

## 2.3. Data Used

The following data set were used for this research:

1. The topographic map of Onitsha and its environment was obtained from the ministry of Land and Survey, Awka. Produced at scale 1:50,000.00 and published 1964 By Federal Survey.
2. NigeriaSat-1 image of November 2004 and LANDSAT ETM+ image of November, 2006 of study area were obtained from the Achieves of the Department of Surveying and Geoinformatics, Nnamdi Azikwe University, Awka While, IKONOS image of November, 2008 and SPOT 5 image of September 2005, of study area were obtained from the National Remote Sensing Centre, Jos, Nigeria.
3. The census data were collected from the National Population Commission office, Awka.
4. The field visits to site were done for ground truth sampling and other attributes collection.

## 2.4. Data Processing and Analysis

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). They images 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 20 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 in resampling during the image-to-image registration.

In classification process, the satellite images of interest were classified into four spectral classes (as Urban or built-up areas, Open/ bare land, Vegetated areas and Water bodies), using the conventional supervised Maximum Likelihood Classification Alogorithm. The geometric rectification is critical to produce a spatially corrected map of land use/cover changes through a period. The geometric correction was applied using topographic maps at the scale of 1:50,000 which completed with a numbers of control points extracted from GPS. The nearest neighbour resampling method was used to avoid altering the original pixel values of the image data. Thus, the images of were geometrically corrected using 20 control points. The root mean square error (RMSE) was estimated about 0.55 pixels. Other important operations carried out includes: Submapping, Resampling, Colour Separation, Maplist creation as a colour composite, Sample set and Domain creation as representation of LULC was carried out using ILWIS 3.3 software.

## 3.1. Land Use/Land Cover Classification System

In the present study, a very detailed classification system is being adopted for mapping using large scale topographic map, low and high resolution satellite data. A Supervised Classification technique using Gauss's Maximum Likelihood classification system were used for mapping existing topographic map, low and high resolution satellite data of Onitsha. The following Land use was classified for this study: Built-up areas; Vegetation, Water bodies/wet land; and Open/barren lands.

## 3.2. Evaluation of Classification Results

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, (Congalton 1991[14]). In this paper, overall, producer's and user's accuracy were computed for this analysis and result obtained were within the minimum threshold. Kappa analysis is a discrete multivariate technique used in accuracy assessments (Congalton and mead, 1983[15]; Jensen, 1996[16]). Thus, the Kappa coefficient, which is one of the most popular measures in addressing the difference between the actual agreement and change agreement, was also calculated. (See figure 11)

## 3.3. Analysis of Urban Sprawl Pattern Using the Shannon's Entropy Approach.

Entropy has its origins in the information theory. Information theory consists of the measurement and transmission of information. Entropy measures the quantities of transmitted information, however not the meaning of the information (the value or meaning a person gives to information). It quantifies the abstract concept of information, describing the information by using mathematics, (Pászto et al., 2009[17]).
In this context Shannon's entropy measures the degree of spatial concentration and dispersion of a variable in a given area. It measures whether the geographical phenomenon (here urban land) is more dispersed in the area or shows a compact pattern.

Shannon's spatial entropy (Hn) is given by:

$$\mathrm{Hn} = \sum_{i}^{n} \mathrm{pi}\ \log\left(\frac{1}{\mathrm{pi}}\right) \quad (1)$$

Where, p is the probability of a variable occurring in the *i*th one. The entropy is a robust spatial statistic, and where other spatial sprawl statistics (for example the Gini coefficient or the Lorenz curve) are dependent on size, shape, and amount of regions, "and the results can change substantially with different levels of areal aggregation" Yeh et al., (2001), entropy is less affected by these variables. The relative entropy is Shannon's entropy normalized by *log(n)* which means that the amount of the variable is taking into account, which is a better method to calculate the entropy, "because its value is invariant with the value of *n*, the number of regions" (Yeh et al., 2001).

Relative entropy*:*

$$Hn = \sum_{i}^{n} pi \ \log\left(\frac{1}{pi}\right) / \log(n) \qquad (2)$$

If the value is close to 1 then the built-up areas are unevenly dispersed around the area, if the value is close to 0 the built-up areas are concentrated. But still relative entropy is to some extent sensitive to different shapes and sizes of regions. If two different scales are used to measure the sprawl, the outcome will be different. This problem can be solved, as it is possible to exactly measure the differences of the scales, scale problems do influence in many ways spatial analysis.

## 3.4. PRESENTATION OF RESULTS

The application of remote sensing and GIS is mostly in image analysis, mapping and monitoring of urban land use. The multitemporal data consisting of existing Topographical map, NigerianSat-1, SPOT-5, LANDSAT ETM+, 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, 2004, 2005, 2006 and 2008 respectively (See Figure 6 & 7). The classification results obtained from medium resolution imageries were compared with those of high resolution imageries. Using a of set medium resolution images the result shows that the built-up areas have been on a positive and mostly uncontrolled spreading out from 8.47% of the study area in 1964 to 30.66% in 2004 and to 64.62% in 2006. On the other hand, vegetation, including cultivated and uncultivated agricultural lands has been on a steady decline, from 77.77% in 1964 to 65.03% in 2004 and a mere 20.10% in 2006; and while using a of set high resolution images the result of the study once more shows that the built-up areas have been on a constant positive and mostly uncontrolled growth 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.

Shannon's Entropy technique was used to compute the urban sprawl pattern and the degree of urban sprawling using classification results and population data. The outcome of the data processing and analysis were presented in form of digital maps and attribute table, (see Figure 6, 7, 8 and 9 and Table 4 and 5).

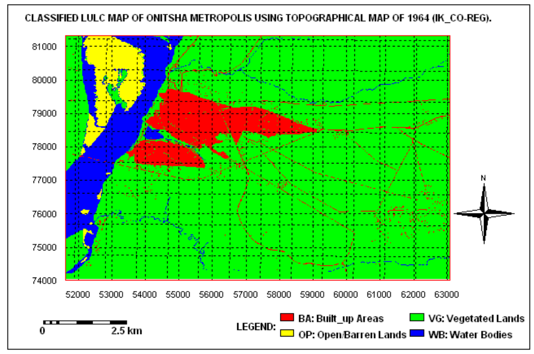


**Figure 6a** Topographical Map (1964) map Co-registered into LANDSAT

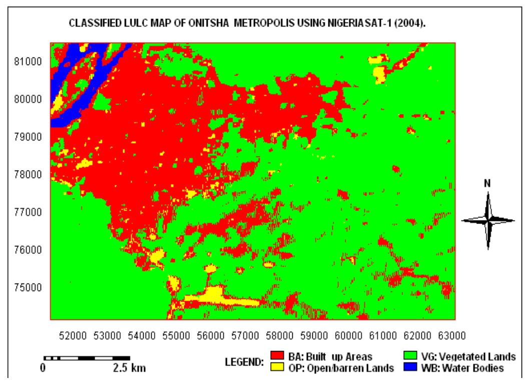


**Figure 6b** Classified NigeriaSat-1(2004) map

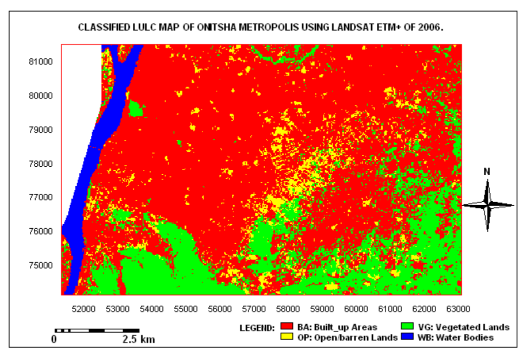


**Figure 6c** Classified LANDSAT ETM + (2006) map

**Figure 6:** Results of Classification of the Topographic Map, NigeriaSat-1 and LANDSAT ETM+.

**Table 4**: Computation of Relative Entropy of Onitsha using Shannon's Entropy Approach

| S / N | Zone(s) | Total Area ($Km^2$) | Built up Area ($Km^2$) | Density of land Dev. (Pi) | Log (1/Pi)/ Log(n) ) | Hn |
|---|---|---|---|---|---|---|
| 1 | Onitsha North | 1,650.335 | 987.947 | 0.6 | 0.3 | 0.3 |
| 2 | Onitsha South | 1,367.337 | 953.553 | 0.7 | 0.2 | 0.5 |
| 3 | Nkpor | 2,339.676 | 903.314 | 0.7 | 0.2 | 0.5 |
| 4 | Obosi | 2,323.969 | 1, 685.213 | 0.4 | 0.6 | -0.2 |
| 5 | Iyiowa Odekpe | 1,170.368 | 315.912 | 0.3 | 0.7 | -0.4 |
| | Total | 8,851.685 | 4,845.939 | 2.7 | 2.0 | 0.7 |

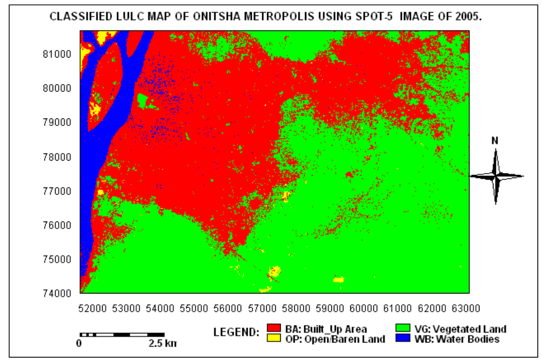


**Figure 7b** SPOT-5 (2005) map

**Table 5:** Result of Change Detection between 1964 and 2008.

| Land Use Classes | Topographical map (1964) | IKONOS (2008) | Change Detection (1964-2008) 44yrs | Annual Rate of Change Detected | Percentage Change for 13 Years |
|---|---|---|---|---|---|
| Built-up area | 08.12. % | 67.62% | 59.50% | 01.35% | 20.10% |
| Open/Barren Land | 03.88% | 06.57% | 02.69% | 00.06% | 01.35% |
| Vegetation | 79.10% | 18.74% | -60.36% | -01.37% | - 19.65% |
| Water Bodies | 08.90% | 03.87% | -06.02% | -00.14% | - 02.10% |

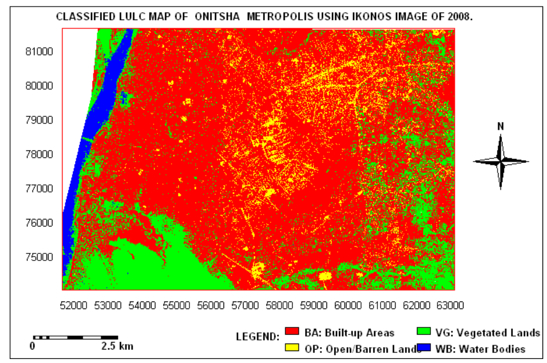


**Figure 7c** IKONOS (2008) map

**Figure 7:** Results of Classification of the Topographic Map, SPOT-5 and IKONOS.

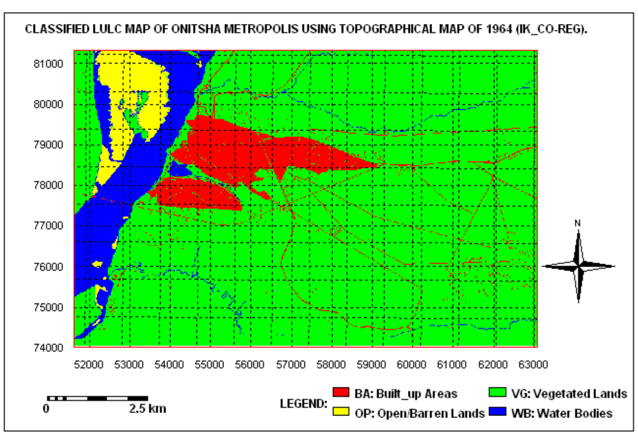


**Figure 7a** Topographical Map (1964) map Co-registered into SPOT-5

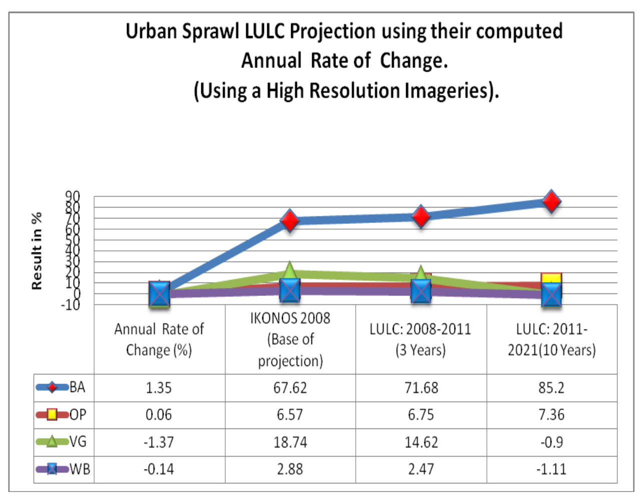


**Figure 9:** Predicted land use graph of 2021 using High Resolution Imageries.

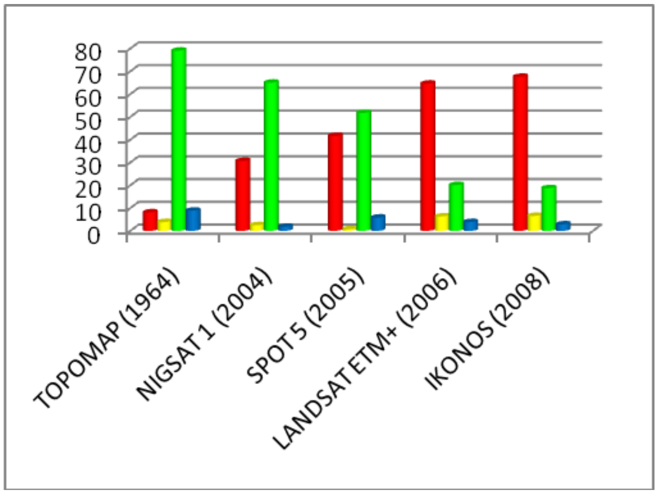


**Figure 10:** The overall results of LULC Classification and Comparison of the capabilities of images used. As the vegetation in green colour is decreasing the built-up in red colour is rapidly increasing.

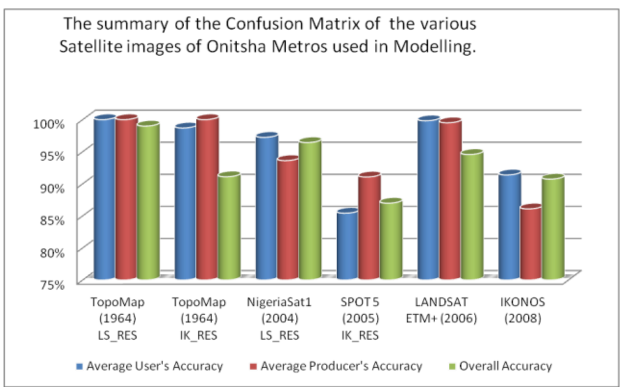


**Figure 11:** The Evaluation of Classification Results using Error Matrix.

# 3.5. Result of Land Use and Land Cover Classification

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

1) **BUILT-UP AREAS:** From the statistical analysis of this research the built-up areas formerly occupied a proportion of 8.12% in 1964 and increased to 67.62% in 2008. This is a clear indication of increase in population and infrastructure development in the metropolis, regardless of use or pattern.

2) **OPEN/BARREN LAND:** This class recorded a positive change over the year under study. Bare surface proportion was 03.88% in 1964 but increased 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.

3) **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 2008 its 18.74%. This can be as a result of built-up areas above.

4) **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% and while in 2008 this class represents a proportion of 02.88%. This may be due sand deposit, land reclamation and other developmental activities along the coast and again, resampling of imagery reduces the size of the water body's area.

# 3.6 Results of Urban Sprawl Using the Relative Shannon's Entropy Approach.

Visualization, land use and land cover maps and Entropy result show that Onitsha metropolis has three major patterns of sprawl namely radial clustered, linear and vertical patterns of sprawl. Remote sensing and GIS analysis show that the city urbanization takes place radially about 2,500km$^2$ from the city centre (Centre Business District-CBD, taking fly-over bridge in Upper-Iweka as the centre of the metropolis). However, we also witnessed a clustered compact city form of urban sprawl around Nkpor junction and linearly along its major road networks.

In addition, two scenarios were used to calculate the degree of urban sprawl: Density of Land development and the total land mass. Thus, to arrive at that, the five zones or areas adopted and considered as Onitsha metropolis was sub mapped and classified individually to obtain their extent of built up area, this is a great innovation that will be tested later with the existing method like buffering function. These thematic maps were used for the computation of the densities of land development (PDENi) in each zone, here the areas and boundaries in km$^2$ were determined using IKONOS 2008 imagery, and the result of the built up areas obtained from the classification analysis in ILWIS environment. Population Density of a zone is equals to Population of a zone divided by the total land mass of a zone.

The results of the entropy calculated are shown in table 4. The results indicate that the sites: Onitsha North, Onitsha South, Nkpor, Obosi,and Iyiowa-Odepke have undergone a significant urban sprawl between 1964 and 2008. As it is evident from table 4 and figure 8 and 9, the entropy value was above 0.50 and indicating high rate of sprawl. Such high entropy values also reveal that land development was spreading over the urban fringe and to the surrounding rural areas.

## 3.8. Urban land use predictions for the year 2021

A much clearer urban land use change trend can be detected when comparing the Scanned, digitized, co-registered and classified topographical map of Onitsha (1964 land use map) with the land use map of 2004, 2005, 2006 and 2008 obtain from satellite imageries. It was also confirmed by the statistics figure of these zones in the years past. Analysis of LULC and Shannon's Entropy computation depicts the patterns and tendency of a continual urban change, especially for short-time forecasting. In order to better understand the trend of the change in the future, the land use maps were studied with reference to the class area metrics. Table 5 and figure 8 and 13 contains a summary of statistics of the class area obtained using ILWIS Window to generate land use maps. The results of the image classification and change analysis, both scenarios, indicate that there will be a significant urban land use changes from 2008 to 2021.

## 4.1. CONCLUSION

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.

The 'Change Detection' and 'Urban Sprawl' analysis shows that agricultural lands are rapidly transforming into lands for housing, both for commercial and industrial purposes. Thus, the developed spatial map can serve as an efficient technical vehicle for spatial analysis and spatial modeling functions, it will help researchers to gain insights into developmental problems, for instance, to evaluate developmental impacts in the past, and to enhance regional development strategies through facilitating various scenarios. It is expected also to be useful for formulating meaningful plans and policies so as to achieve a balanced and sustainable development in the region. It is therefore recommended among others, that, sustainable development and proper urban land use planning can help to stain this tide.

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