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# Spatio-Temporal Analysis of Land Use Dynamics Using Change Detention Analysis: Case Study of Umuahia Municipal, Abia State. Nigeria. (GIS and Remote Sensing)

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**Abstract.** Land use/land cover changes have directly or indirectly drawn much attention globally in the recent years. These changes have really affected the global village. In Umuahia Municipal, environmental changes influenced with dramatic urban growth and their likely changes can have extensive unforeseen ramification. Thus, the objectives of this research were to map and determine the nature, extent and rate of changes and to analyze the spatio-temporal land use/land cover change patterns in the area. Multi-temporal Landsat ETM+1991 and ETM+2015 images were acquired. Classification of the Landsat images was done in ArcGIS 9.2. Subsquently, change detention analysis was performed using ERDAS Imagine 9.1 and ENVI 4.5. Land cover maps were generated and Spatio-Temporal analysis was performed. The results show that distinct changes occurred on the land use/land cover. Built up areas increased through out the study period as other land uses fluctuated to accomodate the increment. The change analysis integrated with spatial metrics performed in this research allowed for the monitoring of land use/land cover changes over time and space in the study area. Mapping of the spatiotemporal land use/land cover changes in an accessible GIS platform can be used to supplement the available tools for urban planning and environmental management.

**KEYWORDS:** Urban growth, Spatio-temporal, Umuahia Municipal, ArcGIS 9.1, ERDAS Imagine 9.1, ENVI 4.5

## I. INTRODUCTION

Issues of Land use dynamics are now of international concern. Understanding its evolution and addressing questions regarding changes in the spatio-temporal patterns of intra- and inter-urban forms are still primary objectives in urban and academic research. Globally, it is observed that the impact of human activities has grown enormously, altering the entire landscape, and impacting the earth's nutrient and hydrological cycles as well as climate.(Nnaji et al, 2016). Understanding the trend, the nature, extent and pattern of land use dynamics of an urban area will go a long to help in planning and controlled development and urbanization.

Land use denotes how humans use the biophysical or ecological properties of land(Turner et al, 2007). Land use is the modification and/ or management of land for agriculture, settlement, forestry and other uses including those that exclude humans from land, as in the designation of nature reserves for conservation (Ellis, 2010). Land use is the function of land; what it is used for. Land use varies from area to area. In other words land use is the employment of land by man. Humans have been modifying land to obtain food and other essentials for thousands of years, current rates, extents and intensities of Land use dynamics are far greater than ever in history, driving unprecedented changes in ecosystems and environmental processes at local, regional and global scale (Nnaji et al., 2016). It is worth nothing that these changes encompass the greatest environmental concern of human population today.

Spatio-temporal is an adjective that connotes space and time. It is used to describe something that exists in both space and time. Remote Sensing and the spatial analysis technology have been recognized and used as powerful and effective tools to monitor land usage and surface changes. Satellite Remote Sensing collects multi-spectrum, multi resolution,

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and multi period data and provides valuable information in understanding and monitoring the process of land use change and in constructing land use databases. Change detection is a process that measures how the attributes of a particular area have changed between two or more periods (Peter et al., 2017) Change detection has been widely used to assess shifting cultivation, deforestation, and urban growth, impact of natural disasters like tsunamis, earthquakes, and land use land cover changes. This technique involves acquisition of landsat imageries, processing those imageries in GIS and remote sensing environment and the output will be in form of geographical referenced information (Peter et al., 2017). There are many change detection techniques and analytical methods that can be employed to achieve LULCC. Change detection methods are as follows; Image differencing, image rationing, image regression, change vector analysis, vegetation index differencing, manual on-screen digitization of change, and multi-date principal component analysis.
This study is aimed at detecting, analyzing and monitoring the spatio-temporal land use changes of Umuahia Capital City using change detection approach. It has the objectives of assessing the pattern and magnitude of changes in the Land Use Land Cover through various multi-temporal satellite data through Image Processing, Post classification and change vector detection.

### A. RELATED WORK

Prakasam (2010) writing on the topic "Land use and Land cover Change detection through remote sensing approach" A case study of Kadaikanal Taluk, Tamil nadu, applied GIS/ Remote Sensing techniques in mapped Land Use/ Land Cover and in utilizing land sat imageries of May 2003 and April 2008, the land use land cover classification was performed based on the survey of India Kodaikanal Taluk map and satellite imageries. GIS software was used to prepare the thematic maps. ARCGIS 9.2 and Erdas Imagine 9.2 were the powerful GIS and Remote Sensing tools used to extract land use, land cover layer from the satellite imageries. The GIS tools used helped not only to detect the land use and land cover changes but also to classify these changes. Omo-Irabor et al (2006), Applied Hybrid Image Classification Approach for the Systematic Analysis of Land Cover (LC) changes in the Niger Delta Region of Nigeria. They used satellite images obtained from the Global Land Cover Facility 2005 of the study with the help of GIS and Remote Sensing. The raw satellite imageries was analyzed in the Remote Sensing software. The paper also introduced a combined use of unsupervised and supervised image classification for detecting land use/land cover classes. The techniques utilized the spectral recognition of the unsupervised classification in the performance a principal component analyzed image of the supervised classification in the training mode. His approach provided an initial basis of monitoring LC change, which is an important factor to consider in the design of an environmental decision making framework. They identified four main surface of geological units; fresh water swamp, coastal plains. Furthermore, their approach provided a means of improving on the deficiencies of the unsupervised and supervised classification methods. On the other hand, Efiony(2011) worked on "changing pattern of land use in the Calabar River catchment used GIS and Remote Sensing" , used integral Land and Water information system (I L W I S) version 3.2 software as the Remote Sensing software and Arc Map 9.0 as the GIS software. By performing change detection analysis, supervised and unsupervised classification analysis the study was able to determine the change and percentage change in Land use Land cover of study area.

## B. STUDY AREA

The rapid population growth and bid for Urbanization has necessitated and prompted reckless and indiscriminate deforestation in Umuahia Municipal and Its Environs and changes in Land Cover.
Umuahia is the capital city of Abia State in southeastern Nigeria with cordinates of 5$^{o}$3'N 7$^{o}$29'E. It is 148m over sea level. Umuahia is located along the rail road that lies between Port Harcourt to Umuahia's south and Enugu city to its north. Umuahia has a population of 359,230 according to the 2006 Nigerian census. Umuahia's indigenous ethnic group are the Igbo.
Umuahia is well known as being an agricultural market center since 1916. It is also a railway collecting point for crops such as yams, cassava, corn (maize), taro, citrus fruits, and palm oil and kernels. There are several breweries in Umuahia, and there is also a palm-oil-processing plant. Nigeria's National Root Crops Research Institute, at Umudike, is adjacent to the town. Umuahia also has several colleges including Trinity College (theological) and several hospitals.
In the past and recent years Umuahia has been a colonial administrative centre for government and churches. These churches set up secondary schools and hospitals and many more developmental projects. Umuahia was also the defected capital of Biafra, it housed the famous Ojukwu's bumker, The Nigeria National War Museum. All these have

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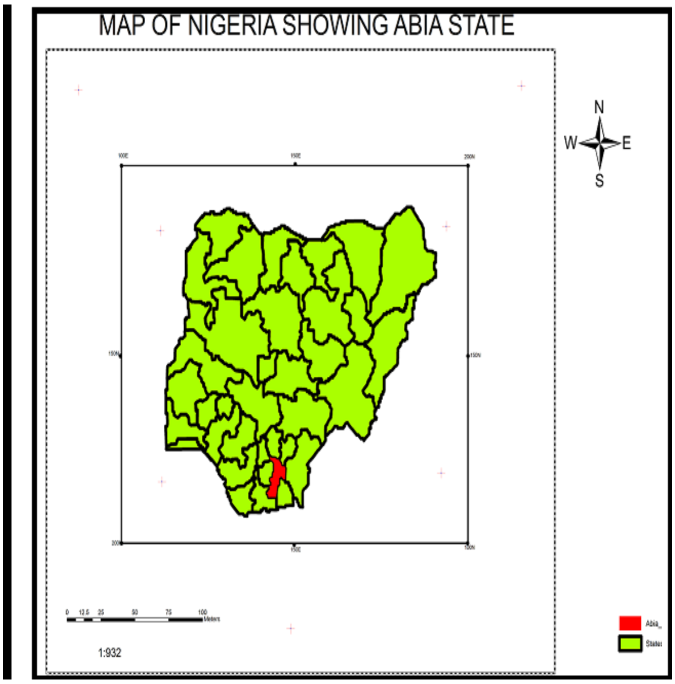
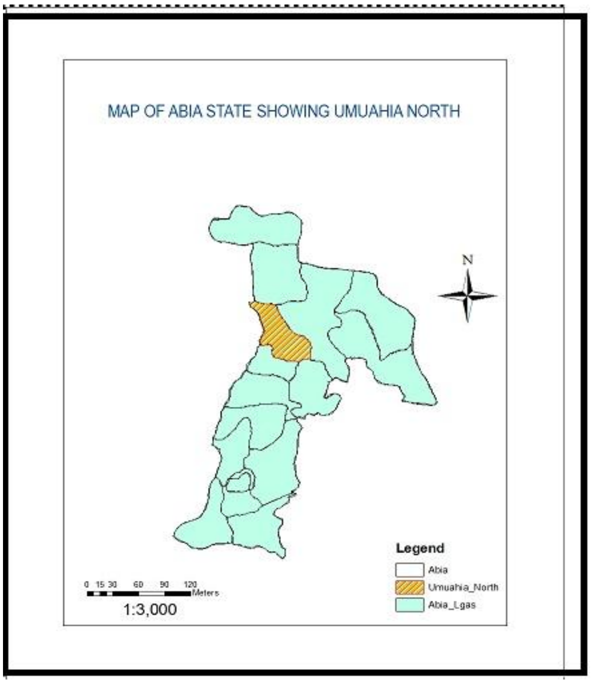
affected landuse/landcover of the area. As there were conversions from one type of use to another- i.e. changes in the mix and pattern of land uses in an area or (b) modification of a certain type of Land Use. Modification of a particular land use may involve changes in the intensity of this use as well as alterations of its characteristics qualities/ attributes- such as changes from low-income to high-income residential areas (the buildings remaining physically and quantitatively unaltered), changes of suburban forests from their natural state to recreation uses (the area of land staying unchanged), and so on.



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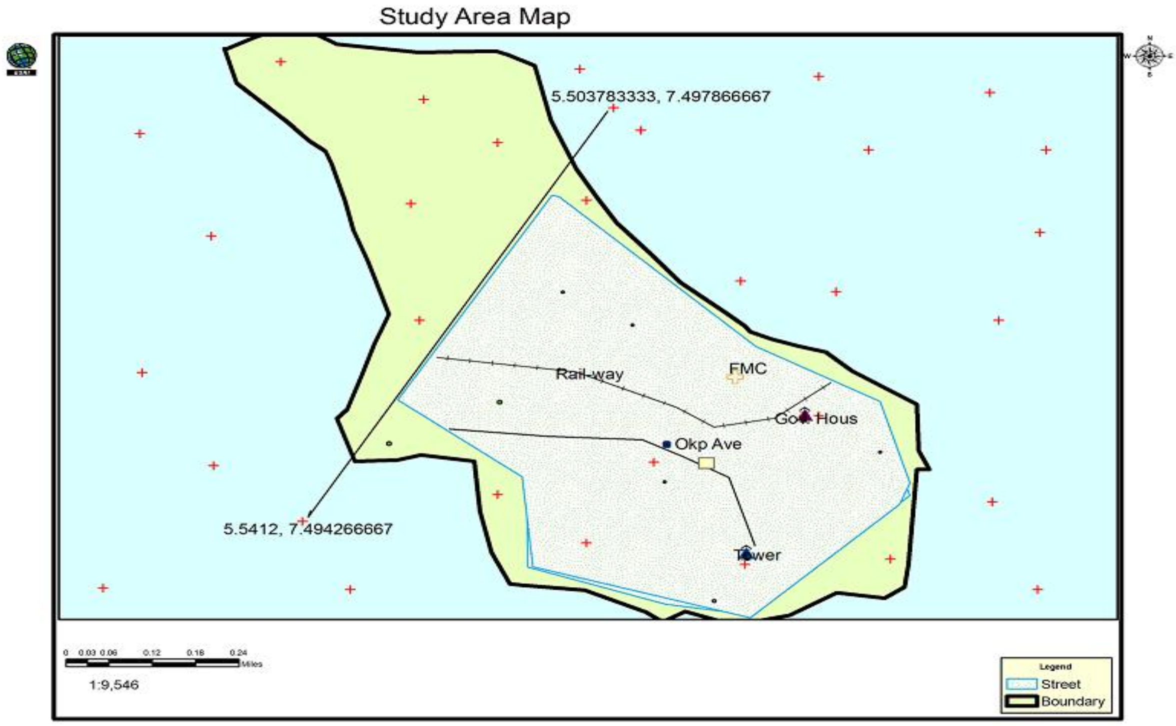


**Figure I: Study Map**

## II MATERIALS AND METHOD

This section describes the materials and methods that were applied in data acquisition, pre-processing (geo-reference and geometric correction), processing, presentation and analysis of data with a view to achieve the aim and designed objectives of the research. This allowed us to analyse and to draw conclusion on the spatio-temporal land use land cover dynamics in the municipality.

Land Use/Land Cover Classification Scheme and their General description.

| Classes | Description |
|---|---|
| Built Up Area | Residential, Commercial, Industrial, Facilities and settlement |
| Open Space | Open Land and Non-Vegetated land |
| Forest | Evergreen forest and Mixed forests with higher density of trees. |
| Farmland | All Types of Agricultural crops |
| Vegetation | Including mangrove, sparse vegetation etc. |
| Water bodies | Areas covered by dams water such as rivers, ponds, lagoons, dams and waterlogged areas. |

A. **DATABASE DESIGN**

Database design otherwise known as data modeling is the process of defining features to be included in the database, their attributes and relationships, and their internal representation. Database is the core or heart of any GIS operations. It allows system to meet up with the information or needs of the people (purpose) for which a GIS project is carried.

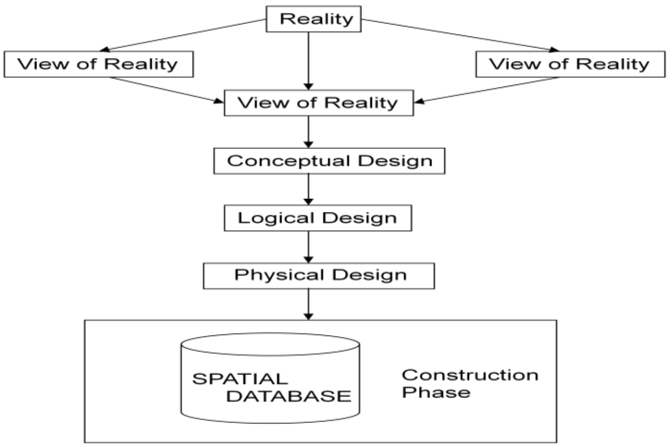


**Figure II: Design and Construction Phases of A Spatial Database (Kufoniyi, 1998)**

**Table 1: Data Required and Their Sources.**

| Name | Source | Year | Resolution |
|---|---|---|---|
| ETM LandSat Imagery | Global Land Use and Land Cover Facility. | 1991 | 30 by 30m |
| ETM LandSat Imagery | Global Land Use and Land Cover Facility | 2015 | 30 by 30m |
| Map of Nigeria | Cartographical Design | | |
| Map of Abia State | Cartographical Design | | |
| Map of Study Area | Cartographical Design | | |

**Table2: Software used**

| Program | Version | Purpose |
|---|---|---|
| ArcGIS (ArcView, ArcMap, ArcCatalog) | 9.2 | To extract land use information |
| ERDAS | 9.1 | Analysis of relationship |
| FRAGSATS | 3.3 | Tabulation and graphical representation |
| ENVI | 4.5 | For classification, Post Classification. |
| MS Access | 2007 | Aspatial Attributes. |

Knowledge of Remote Sensing and Geographic Information System were used in the production of land use land use cover maps. The Landsat images ETM+ at band 2, 3, 4 for the years in consideration were made to pass through the processes of image composition, enhancement, geo-referencing and Region of Interest selection. In order to store, analyze and display information, software from ESRI and ENVI 4.5 Geo-systems were employed. Hence, both

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ArcView/GIS 9.2 and ERDAS Imagine 9.1 were used to extract land use/land cover information and further analysis of relationships, patterns and trends in a multi-temporal approach. Furthermore, open source gvSIG- GIS client software was used for visualization of raster. In order to determine spatial metrics and detect changes and fragmentation of land covers, public domain statistical package FRAGSATS 3.3 software was used. Besides, Microsoft Access for tabulations and graphical representations were used to present describe and analyze land use/land cover dynamics and trends of changes that were undertaken during the periods.

### B. Geo-reference and Geometric Correction

To prepare the satellite imageries for accurate change analysis and detection, the Landsat images were pre-processed using standard procedures including geo-referencing and geometric correction. The European Datum 1950 (D_European_1950) was used as the coordinate system. Subsets of Landsat satellite images were rectified using orthophotos with UTM projection Zone 30 (ED_50datum) using first order polynomial method and nearest neighbor image re-sampling algorithm. ERDAS Imagine Version 9.1, was used.

### C. Image Classification

After the images were goeoreferenced and geometrically rectified, image clipping was performed. This pre-process was performed using spatial analyst tool on a sub-scene from the full image on the basis of a frame covering the municipality. These preprocessing tasks allowed us to export the satellite images to the ERDAS Imagine for classification and extracting land cover information. Image classification and interpretation was performed using ERDAS Imagine 9.1. Land use/land cover was mapped by means of visual interpretation of satellite images.

### D. Accuracy Assessment

Evaluation of classification results is an important process in the classification procedure because Land Use maps contain so errors due to factors like classification techniques to methods of satellite data capture. In so doing among the common measures used for measuring the accuracy of thematic maps derived from multispectral imagery, error/confusion matrix was used. Kappa analysis was performed.

## III. RESULTS AND DISCUSSION

This section presents the results and discussion of the generated land cover maps from classification of Landsat images. It includes assessment of the maps' accuracy, analysis of the nature, extent and rate of land cover change maps and statistics.

### A. Classification Accuracy Assessment

Evaluation of classification results is an important process in satellite image classification procedure. In doing so confusion/error matrices were used, Kappa analysis was done to determine the level accuracy. Kappa statistics/index was computed for each classified map to measure the accuracy of the results. The resulting classification of Landsat land use/cover maps of the periods of 1991 and 2015 had a Kappa statistics of 85.85% and 88.65% respectively. The Kappa coefficient expressed the proportionate reduction in error generated by a classification process compared with the error of a completely random classification.

The equation for weighted K is:

$$K = N \sum_{1-i}^{r} X_{ii} - \sum_{1-i}^{r} (X_{i+} \text{ x } X_{+i}) / N^2 - \sum_{1-i}^{r} (X_{i+} \text{ x } X_{+i})$$ (Congalton and Green ,1999):

Where,

r = the number of rows in the error matrix

X*ii* = the number of observations in row *i* column *i* (along the diagonal)

X*i*+ = is the marginal total of row *i* (right of the matrix)

X+*i* = the marginal total of column *i* (bottom of the matrix)

N = the total number of observations included in the matrix

**Table 3: Summary of overall classification accuracy**

| Year | Overall Classification accuracy (%) | Overall Kappa Co-efficient |
|---|---|---|
| 1991 | 85.854 | 0.7514 |
| 2015 | 88.646 | 0.7971 |

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The summary of the classification accuracy show that the overall classification accuracy for 1991 was 85.854% with Kappa Co-efficient of 0.7514 and for 2015; the overall Classification accuracy was 88.646% and 0.7971 kappa Co-efficient. The Land use map was accurately classified.

### B. Nature, Extent and Rate of Land Cover Change Maps and Statistics

Using the approaches adopted in the methodology, land cover maps were generated for the two years (figures II and III) area estimates and change statistics were computed. Individual class area and change statistics for the periods were summarized in Table 4 below.

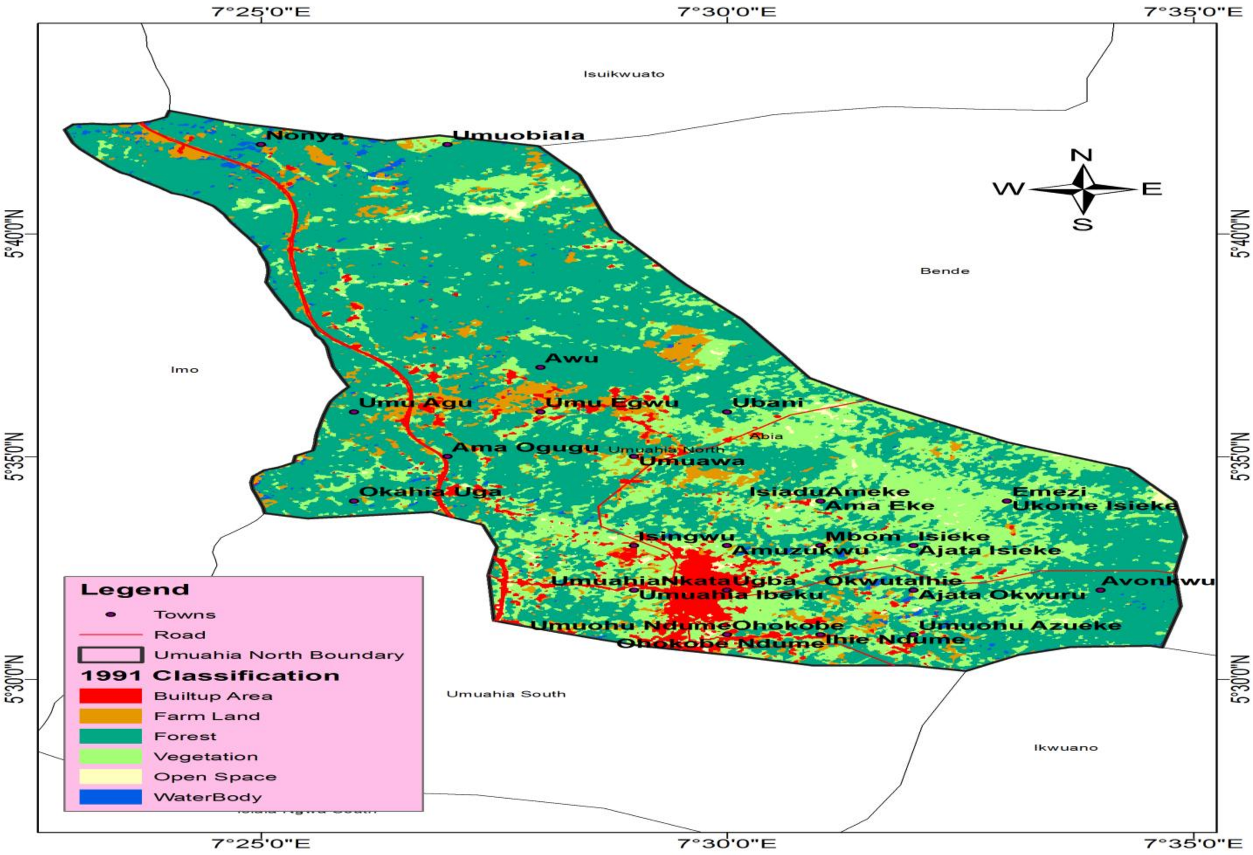


Figure II. LandUse Map of The Study Area for 1991

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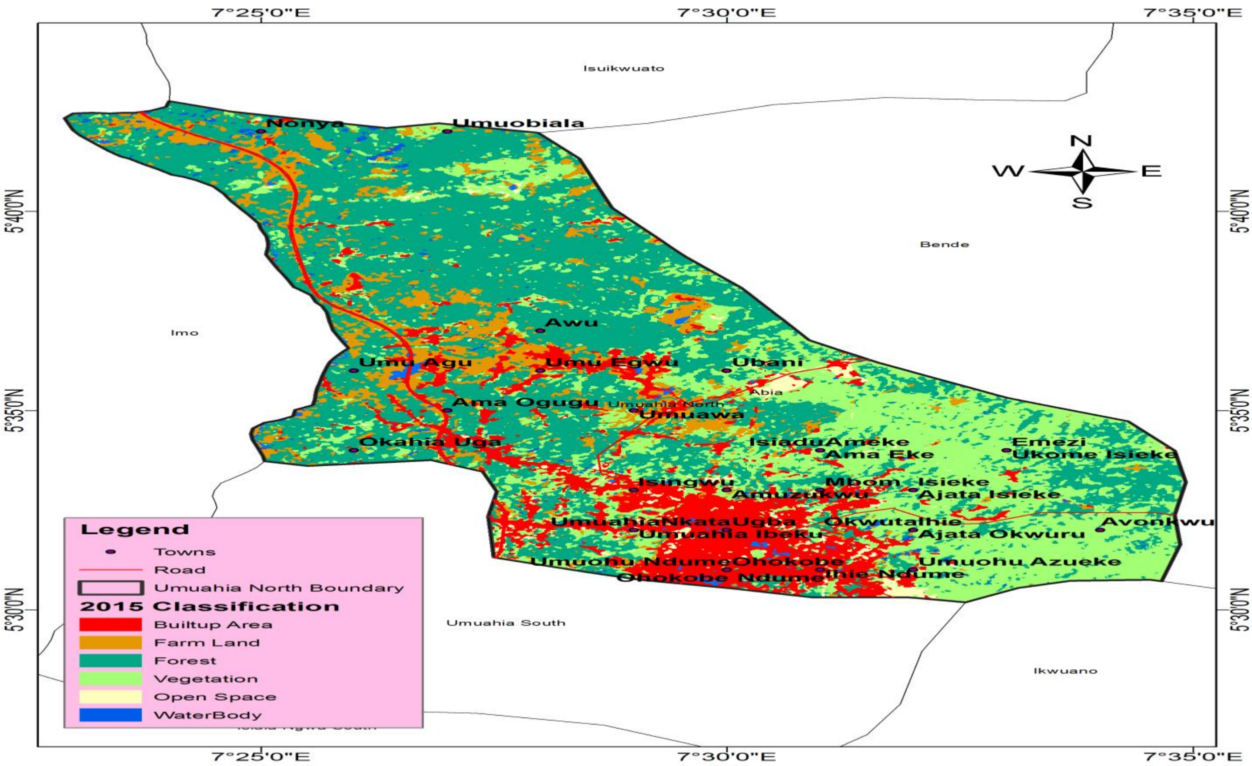


Figure III. Land Use map of The Study Area For 2015

**Table 4: Area statistics and Percentage of the land use/cover units in 1991-2015**

| LAND USE/ LAND COVER TYPE | AREA ($KM^2$) 1991 MASS CLASS | 1991 % OCCURRENCE | AREA ($KM^2$) 2015 MASS CLASS | 2015 % OCCURRENCE |
|---|---|---|---|---|
| BUILTUP AREA | 11.40 | 4.67 | 61.40 | 25.13 |
| FARMLAND | 10.10 | 4.13 | 18.40 | 7.53 |
| VEGETATION | 66.60 | 27.26 | 38.40 | 15.72 |
| OPEN SPACE | 2.60 | 1.64 | 3.40 | 1.39 |
| FOREST | 151.20 | 61.19 | 120.90 | 49.49 |
| WATERBODY | 2.50 | 1.02 | 1.80 | 0.74 |
| TOTAL | 244.30 | 100 | 244.30 | 100 |

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In the study periods covered, the major land cover classes identified are Built-Up Area, Farmland, Vegetation, Open space, Forest and water body. Among all the land cover types identified, and in the three periods, Built-Up Area, Vegetation and Forest constituted the predominant type of land cover with an approximate area of 4.67%, 27.26% and 61.19% respectively in their spatial extent in the study area. Farmland, Open Space and water body, accounted for 4.13%, 1.64% and 1.02% of the total area respectively.

During the investigation periods, distinct changes occurred on the major land use/land cover types. From 1991 to 2015, the built up environment increased from 11.40km$^2$ to 61.40km$^2$, while Farmland increased from 10.10km$^2$ to 18.40km$^2$, vegetation, forests and Water body decreased from 66.60km$^2$ to 38.40km$^2$; 151.20km$^2$ to 120.90km$^2$ and 2.50km$^2$ to 1.80km$^2$ respectively. Open Space increased from 2.60km$^2$ to 3.40km$^2$.
In order to determine the extent and rate of change in the land cover dynamics in the Municipal, the following variables were developed and computed.

- Total area (Ta)
- Changed area (Ca)
- Change extent (Ce)
- Annual rate of change (Cr)

These variables can be described by the following formula:
Ca= Ta(t2)-Ta(t1);
Ce=Ca/Ta(t1) ;
Cr=Ce/(t2-t1) ; Where t1 and t2 are the beginning and ending time of the land cover studies conducted.

**Table 5: Overall amount, extent and rate of land cover change (1991-2015)**

| LAND USE/ LAND COVER TYPE | $Ta_1$ (km$^2$). 1991 | $Ta_2$ (km$^2$). 2015 | Ca (km$^2$) Change ($\Delta$ /km$^2$) | Ce Extent | Cr Rate of $\Delta$ |
|---|---|---|---|---|---|
| BUILTUP AREA | 11.40 | 61.40 | 50.00 | 4.386 | 0.088 |
| FARMLAND | 10.10 | 18.40 | 8.30 | 0.822 | 0.099 |
| VEGETATION | 66.60 | 38.40 | -28.20 | -0.423 | 0.015 |
| OPEN SPACE | 2.60 | 3.40 | 0.8 | 0.307 | 0.383 |
| FOREST | 151.20 | 120.90 | -30.30 | -0.200 | 0.0066 |
| WATERBODY | 2.50 | 1.80 | -0.7 | -0.28 | 0.40 |

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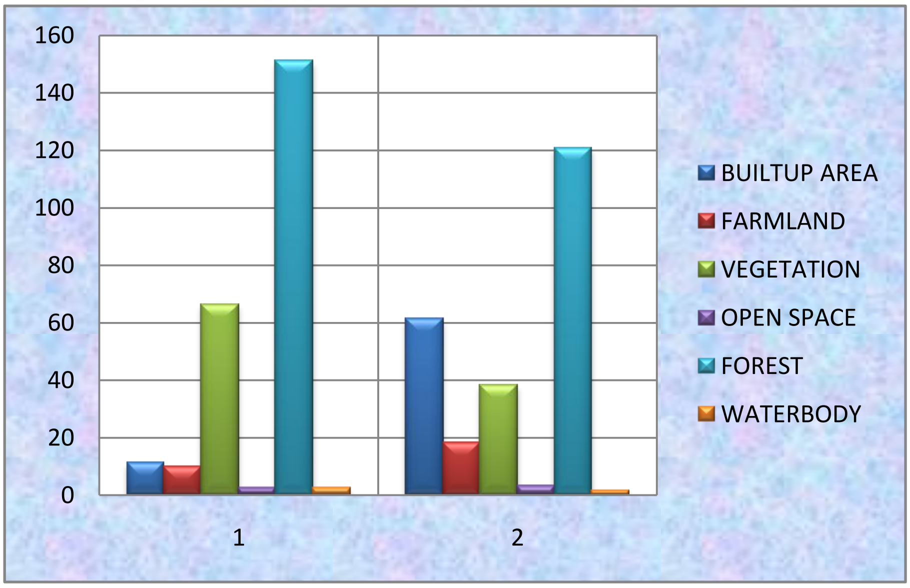


**Figure IV: Nature of Relative Land Use Changes**

Figure IV, depicted the relative land cover change trends from 1991 to 2015 in Umuahia Municipal. The major land use of built up surface had an increasing positive trend of change in its areal extent while Vegetation lands decreased continuously in the two periods. There has been also an observable declining trend of change in the other land cover classes of waterbody, Forest and farmland.

In general, the change values in the Table 5 indicated that increase in built up areas mainly emanated from conversion of other land covers to urban land uses during the period of study following increasing development pressure within the municipality. Besides the summary statistics, graphical representations of the classification and visual comparison offer a general insight into the relative amounts of the defined classes across the landscape and the changes observed.

Furthermore, in a close look at figures II and III Land Use maps revealed that built up area expansion/growth followed certain directions and this was dependent on the new plan for land type for management, developing highways and relatively population growth. Built-up areas showed dramatic increase while other non built-up surfaces substantially decreased. There had been a continuous conversion of non-built up areas to built-up environments especially in areas adjacent to the existing urban boundaries in temporal dynamics.

In conclusion, based on these results, Umuahia Municipal is a fast growing city in spatial and temporal terms. As a result, an integrated assessment of land use/land cover change mapping and spatial and temporal modeling works should be done. The task has to integrate remote sensing, spatial metric tools and socio-economic data to manage urban growth and expanding impervious surfaces.

## IV. CONCLUSION AND RECOMMENDATION

This study has shown that information from satellite remote sensing and integrated with GIS can play a useful role in understanding the nature and extent of changes in land use/ land cover, where they are occurring and monitoring these changes at local scale. The change detection analysis integrated with spatial metrics performed in this research allowed for the monitoring of land use/ land cover changes overtime and space. The analysis provided valuable insight into the extent and nature of changes in the study area and laid foundation for further research.

The dynamics of land use/land cover change pattern have been identified by analyzing the multi-temporal satellite imageries in a GIS platform. The quantitative evidences of land use dynamics revealed the dynamic growth of artificial surface. Conversions of land from agriculture to urban land represent the most prominent land cover change. The rate of change was high for built up. The trend and extent of urban change is likely to continue with the rapid development

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of infrastructure, tourism economy and increasing of population. The majority of changes in urban built up area occurred in most direction of the city.

In order to alleviate the dramatic land use/ land cover change and adverse environmental impacts of urban expansion and increasing built up surfaces, the current growth pattern needs to be managed through effective land use planning and management.

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