Digital Modeling of Land Use Changes in Some Parts of Eastern Nigeria

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Abstract: Landuse expansion, spatial and temporal variability of the area has been studied between 1986 and 2002 via statistical classification approaches based on the remotely sensed images obtained from Landsat Thematic Mapper (TM) and Extended Thematic Mapper (ETM+) sensors. Multi-temporal images, landuse/land cover changes were detected by means of remote sensing. From the result of supervised classification, the process of landuse/land cover changes and the model of expansion were analyzed by Geographic Information System (GIS) technologies. Seven cover classes were identified namely light vegetation, thick vegetation, swamp vegetation, settlement, sand dune, bare soil/erosional areas and water body. The confusion matrix showed a high overall classification accuracy of 77% and Ksat statistics of 71% for the classified map. Digital Elevation Model (DEM) of the area was created from digitized topographic contour lines at 1:50,000 scale. Additional information was derived from geologic and vegetation maps of the area to delineate spatial extent of landuse/land cover. Maps generated for these years were overlaid to obtain a change detection map showing the dynamic growth in land use changes for the two periods. Result also showed that during the study period from 1986 to 2002, the vegetation reduced from 47.7% to 14.4% in the study, more than double in 16 years, showing a strong trend of expansion of settlement as well as growth in baresoil area, perhaps due to sand mine or erosion. The research work shows that land use/land cover change detection using multi-temporal images by means of remote sensing and GIS modeling are good means of analyzing dynamic changes in time sequence.

Keywords: Accuracy Assessment, Change Detection, Digital Modeling, GIS, Multi-Temporal, Remote Sensing

1. Introduction

The land use change in large city area is a complex process; several factors have influences on this process, including both physical aspects and human aspects. on one hand, accelerated urban expansion is usually associated with and driven by the socio-economic factors; and on the other, the process of urbanization has a considerable impact on the economy of the society in that area [1], [5], [20]. for substantial development, municipal authorities need tools to monitor how the land is currently used, assess future demand, and take steps to assure adequacy of future supply; for a better planning of future urban development, municipal authorities need to know situation of urban expansion and in what way it is likely to move in the years to come [6], [8]. so the detection of land change is important for officials and planner in government in

decision making.

In recent time, urbanization is a major trend in big city all around the world [21], [22]. The main change of landuse in these areas can be described as other landuse types which were converted into urban land. Unfortunately, the conventional survey and mapping techniques are expensive and time consuming for the estimation of expansion and such information is not available for most of the centres, especially in developing countries. As a result, increased research interest is being directed to evaluating and monitoring of urban growth using GIS and remote sensing techniques [3]. Remote sensing is increasingly used for detection and analysis of urban expansion since it is cost effective and technologically efficient. The detection of landuse change can

be on either image-to-image comparison or a post-classification comparison. During the past several years, extensive study efforts has been made for urban change detection using remotely sensed images [7], [9], [15]. Despite these efforts, further research is needed in order to reinforce the absolute and comparative relationship between the type and intensity of urban land use change and their causative factors [12], [13].

Many models for urban growth prediction, such as the cellular automata (CA) model and land conversion in the urban fringe area, have been developed [12], [15], [23], [24]. Among these models, Geographical Information System (GIS) based urban models have been widely used [4], [10], [17], [19]. In practice, however, the use of these models has been limited in urban growth analysis because of the difficulty in obtaining the required factors or enough data for the model. Therefore, in this paper, the study tends to evaluate the spatio-temporal dynamics of landuse changes using remote sensing and GIS techniques. The study produced a change detection map showing the dynamic growth in landuse of the eastern Nigeria. This approach is a good tool for decision making by municipal authorities.

1.1. Objectives

The aim of the research paper is to use remote sensing and GIS techniques to evaluate spatio-temporal dynamic landcover changes in Onitsha area of Anambra State, South Eastern Nigeria as case study. Other specific objectives include:

- i To study and predict the spatio-temporal dynamic land cover change using multi-date satellite images.

- ii To analyze the effect of land use and land cover.

- iii To carry out spatial query based on the database creation

1.2. Justification of the Study

The rapid population growth and socio-economic activities in the commercial city of Onitsha has resulted into unplanned urbanization, extensive urban poverty, water logging, growth of urban slums and squatters, traffic jams, environmental pollution and other socio-economic problems. Owing to the process of urbanization, the physical characteristics of the city are gradually changing as plots and vegetated areas have been transformed into building areas or bare land while low land and water bodies have turned into reclaimed lands. If the present scenario continues then Onitsha would soon become an urban slum with the least liveable situation for the city dwellers.

1.3. General Description of the Study Area

The area under study is located at the confluence of River Niger within the severely gullied parts of Anambra State (Fig. 1). Geographically, it lies between Latitude $6^{\circ}00' - 6^{\circ}15'N$ and Longitude $6^{\circ}45' - 7^{\circ}00'E$. It contains parts of Anaocha, Nnewi, Aguata, Orumba, and Idemili Local Government Areas. The total area coverage is about 400km^2 , in the humid tropical rainforest belt of Nigeria. The area is drained by Rivers Nkisi and Idemili both of which discharge into the River Niger. Available rainfall records show an average annual rainfall of about 2000mm, most of which falls within the month of April to October. This period is characterized by moderate temperature and high relative humidity [6].

Fig. 1. Location of the study area in Nigerian map.

2. Method of Study

2.1. Data Used

The main spatial data sources used in this study were Landsat TM (1986) and ETM+ (2002). For detecting Onitsha land use/land cover change from 1986 to 2002, seven bands of Landsat TM images (1986) and ETM+ (2002) were acquired showing the study area. In addition, essential ancillary data including 1: 50,000 topographic map sheet 300 Onitsha SE, 1: 250,000 vegetation and land use map sheet

NB32-5 and geological map sheet 71 were also obtained from the Department of Surveys, Lagos. All the spatial data layers were registered with Universal Transverse Mercator (UTM) coordinate system and sampled to pixel resolution of 30m. A Pseudo-natural color composite of bands (341) was used for the analysis.

2.2. Characteristics of Landsat-7 ETM+

The characteristics of Landsat-7 ETM+ are as shown in Table 1 below.

Table 1. Characteristics of Landsat-7 ETM+.

System	Landsat-7							
Orbit	705km, 98.2o inclination, sun – synchronous, 13:51:22z crossing, 16-day repeat cycle.							
Sensor	ETM+ (Enhanced Thematic Mapper).							
Swath width	185km (FOV = 15o)							
Off-nadir viewing	No							
Revisit time	18 days							
Spectral bands	1	2	3	4	5	6	7	8
Wavelength (um)	0.45 – 0.52	0.52 – 0.60	0.63 – 0.69	0.76 – 0.90	1.55 – 1.75	10.4 – 12.5	2.08 – 2.35	0.50 – 0.90
Spatial resolution	15m (PAN), 30m (bands 1 – 5, 7), 60m (band 6)							
Data archives at	Earthexplorer.usgs.gov							

2.3. Detection of Land Use/Land Cover Change

A two-time series of remotely sensed images (Landsat TM and ETM+) of years 1986 and 2002 were used to obtain landuse change information, using the post-classification comparison technique in both ILWIS and Erdas Imagine softwares. This technique has been employed by other researchers [2], [11], [14], [16], [18] which were characterized by bi-temporal change detection. This approach measures changes based on a ‘two-epoch’ timescale, i.e. the comparison between two dates. For bi-temporal change detection, detection algorithms were attribute to any of the three approaches, namely, directly comparing different data sources (direct comparison method), comparing extracted information (post-analysis comparison method) and integrating all data sources into uniform model (uniform modeling method).

2.3.1. Image Pre-Processing

All information extracted from remotely sensed data is obtained in the consistent technical flow: the geometric rectification, image registration and images matching with each other. The classification schemes include: Light vegetation, thick vegetation, swampy vegetation, settlement, sand dunes, bare soil/erosional area and water body (natural and artificial). The maximum likelihood method was used for the land use classification in ERDAS IMAGINE 9.1 software. Then, post-classification process method including sub-region classification method was used in the workflow.

2.3.2. Extraction of Urban Information

Thematic layers necessary for the analysis were created through digitizing the maps and the satellite image. The contours were digitized from the topographic map of the study

area to create DEM; geologic features from the Geologic map and vegetated features from the Vegetation and Land use map. These layers were updated with the help of the Satellite images. Some portion of the baresoil/erosional areas suggested gully sites. Landsat images were classified using both supervised and unsupervised classification method and different algorithms to determine different land use categories in the study area. The Normalized Difference Vegetation Index ($NDVI = \frac{NIR \text{ band} - R \text{ band}}{NIR \text{ band} + R \text{ band}}$) was performed and applied to the Landsat TM images. The NDVI layer was classified into four groups and a vegetation cover layer was produced. The output map contained NDVI values range from -1 to 1.

2.4. Database Creation

Data were organized based on database conceptual schema with a set of procedures for adding, changing, or retrieving data using Arcview 3.2. This system is capable of handling queries, which selects features based on their location or geographic relationship to others. One of such queries was addressed in this study ‘*which settlement is located near a bare soil with an area of 9656581.731m²*’.

3. Results and Discussions

3.1. Image Classification

The result of the supervised classification for both images is shown in Table 2 and Fig. 2 which yielded more classes than the unsupervised method of classification. The unsupervised method also misclassified the elements. All the seven classes were discriminated under supervised classification with

overall classification accuracy of 77% and Ksat statistics of 71% for the classified map. The high accuracy obtained is possibly due to certain controls applied in defining signatures for image classification.

Table 2. Image classification types and colour representation.

Image Classification	1986	2002
Thick vegetation	Magenta	Forest green
Light vegetation	Red	Light green
Swampy vegetation	Pale green	Cyan
Settlement	Brown	Red
Sand dune	Black	Grey
Baresoil/erosional area	Cyan	Yellow
Water body	Purple	Blue

Fig. 2. Image classification of the area.

3.2. Land Use/Cover Change Analysis

The workflow of multi-temporal land use/land cover change detection proved to be efficient. The outcomes were maps of land use pattern (Fig. 3) in two periods and its proportions (Table 3). Land cover map generated highlighted the spatial spread of baresoil/erosional area (BE) and other classes such as settlement (SE), vegetation (VE), water bodies (WA), etc. The result drawn from the transition table (Table 3) show that 47% of vegetated area in 1986 is reduced to 14% in 2002 while 25% of settlement area is reduced to 21% in the same year. This decrease may be as a result of landuse activities such as indiscriminate built-up, farming, sand mining and other infrastructural development thereby exposing the top soil to erosion. The baresoil/erosional area experienced some changes with an increase from 15% to 18%. This increase could be as a result of soil loss in erosion due to channelization, sand mining as the soil in this area is mostly loose and very porous, thus not consolidated and therefore, detached easily when in contact with rain water. Due to excavation of sands, the mining sites eventually developed into huge gullies which influenced the socio-economic lives of the people in the area. Some communities suffer the consequences of the gullies being expanded. The transition statistics shows the number of pixels of different classes for the period under study.

Fig. 3. Land cover map of the study area.

Table 3. Landcover transition statistics for the period.

Year	V%	SE%	BE%	WA%
1986	47.7	25.3	15.6	1.30
2002	14.4	21.2	18.2	1.22

V: vegetation; SE: settlement; BE: baresoil/erosional area; WA: water body

3.3. Supervised Image Classification Validation

All 7 classes were discriminated under the supervised condition with an overall classification accuracy of 77 percent and Ksat statistics of 71 percent for the classified map. The higher accuracy obtained than in the unsupervised condition may be due to the increased control in defining signatures for the classification. The high confusion for class discrimination was between the thick vegetation and the waterbodies with low reliability (61%) and accuracy (65%). Confusion matrix analysis carried out shows the strength in identifying the nature of the classification error and their quantities resulting in generating a cross map (Fig. 4) which showed well discriminated settlement, baresoil/erosional area and vegetation with patches of error chance of 25% on vegetation (Table 4). In the map, 18985 pixels of baresoil/erosional class were correctly classified while 429 pixels of baresoil were classified as waterbodies. Error of omission occurred where 112 ground truth pixels of settlement were excluded from the settlement class in the classification and ended up in the swampy vegetation. The error chance of 35% was higher in the case of waterbodies because it was possible that this field responded in a manner similar to that of swampy vegetation. Similarly, there was also confusion between the thick vegetation and settlement, but the error chance of 18% was recorded because of similarity in responses.

On the whole, approximately 77% of the baresoil/erosional ground truth pixels appeared as baresoil/erosional in the classified image showing a high level accuracy with 84% reliability. The average accuracy and reliability is 74.5% while the overall accuracy of the land cover classified map is 77%. The Kappa indices (K_{sat}) for the map were 0.71. All these steps above ensure the accuracy of land cover pattern for further spatial analysis.

Fig. 4. Land cover cross map of the area.

Table 4. Confusion matrix of the land cover map.

	BE	LV	SD	SE	SV	TV	WA	ACC
BE	18985	1009	1100	1201	887	662	429	0.79
LV	703	12650	745	277	1080	483	570	0.77
SD	500	869	7020	660	132	0	288	0.74
SE	844	465	300	9610	112	187	184	0.82
SV	295	686	233	0	10978	916	1137	0.77
TV	262	483	0	387	716	5016	625	0.67
WA	1289	394	188	284	1537	925	8588	0.65
REL	0.84	0.76	0.73	0.77	0.76	0.61	0.77	

BE: baresoil/erosional area; LV: light vegetation; SD: Sand dunes; SE: settlement; SV: Swampy vegetation; TV: Thick vegetation; WA: water bodies; ACC: Accuracy; REL: Reliability

Overall accuracy = 77%; K_{sat} = 71%

3.4. NDVI Index Map

The NDVI index (Fig. 5) shows clearly the density of the vegetation in the area with a high value. This is so because of their relatively high near-infrared reflectance and low visible reflectance in the image. Bare soil and rock areas are the light green with similar reflectances in the two bands and resulted in vegetation indices near zero. This result presumes that the area is full of open surface soil which is an index for erosion. On the other hand, vegetated area exerts a strong moderating impact on dissipating the energy supplied by agents of soil erosion because it acts as a cover over the land surface. The favourable effect of vegetation on the causes and intensity of the soil erosion process differ according to the type of vegetation and its condition. The study area which has been overtaken by rapid population growth as a result of urbanization accompanied by poor land use led to possibly blockage of drainage channels resulting in flooding of adjacent areas thus increases surface runoff. This activity also left the area with light vegetation and extensive bare soil surface surrounding settlements.

Fig. 5. NDVI cover layer map 2002.

4. Conclusion

Land use/land cover change detection using multi-temporal

images by means of remote sensing and GIS are good means of research of urbanisation. Through this process, we obtain the two temporal distribution maps of land use in the study area from 1986 to 2002. The present study attempted to reveal the dynamic change detection process in the study area with the aid of remote sensing and GIS technique. As a result of the analysis carried out, dynamic changes in the land cover was noticed such as the encroachment of built up areas into cultivation due to soil erosion threat and demand for shelter and cultivation replacing the shrubs in forested areas. Also, there is a high encroachment of sand miners that caused a landmark of bare soil. The bare soil spectral signatures observed from the images in spite of its rather poor resolution gives a clear indication of soil erosion potential in the study area which decreases structural stability, reduces soil strength, exacerbate erodibility and accentuate susceptibility to transport by overland flow, wind or gravity.

From the result, it could be seen that GIS offers the tools for producing sophisticated models for various purposes, combining attribute tables, spatial data, map algebra, weighing factors, interpolation techniques, etc. Besides these capabilities, GIS offers data visualization in 2D or 3D dimensions.

5. Contribution to Knowledge

- i The study has shown that urbanization processes are often accompanied by rapid spatio-temporal landuse dynamics due to compelling socio-economic factors.
- ii It also identified the need for natural and sustainable use of land in time and space.
- iii The manuscript explained the nature of spatio-temporal dynamics of landuse as an index of land degradation.
- iv In addition, the manuscript also advocates that multi-temporal satellite imagery plays a vital role in quantifying spatial and temporal dynamics of landuse which may be difficult through conventional mapping.
- v Besides, the work has revealed that remote sensing and GIS are powerful and cost effective tools for assessing the spatial and temporal dynamics of landuse.

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