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Modeling And Mapping Of Landcover And Landuse Changes In Kaduna, Nigeria Using Cellular Automata And Multiple Logistic Regression

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Abstract: *Sequel to the over proliferation of industries in Kaduna coupled with the ethnic-religious crisis in many other parts of the northern Nigeria, resulting in the migration of very many people to Kaduna, the natural resources in the area, especially land and space became over consumed, causing many other environmental problems over the years. This study, therefore, was conducted to model and map landcover and landuse changes in Kaduna using Cellular Automata and multiple logistic regression with a view to ascertaining changes in the area. The objectives of this research work includes; classifying the multi-temporal satellite imageries of landsat ETM+ into built-up area, open space, farmland, vegetation and water bodies using 2004, 2009 and 2014 imageries; also to model the landcover and landuse changes of Kaduna and Environs using Cellular Automata and to predict the pattern of changes (25 years) with multiple logistic regression. The landsat ETM + of years 2004, 2009 and 2014 were used. The land sat imageries for the different epochs were classified and accuracy assessment carried out. Multiple logistic regression was used to predict changes. Built-up area increased from 16% in the year 2004 to 19% in the year 2009 and 21% in the year 2014. Open space decreased from 8% in the year 2004 to 3% in the year 2009, but increased to 5% in the year 2014. Water bodies increased from 1% in the year 2004 to 2% in the year 2009 and remained the same in year 2014. The result of the hypothesis testing revealed that vegetation and farmland transited to Built-up area. The study recommended that landuse mapping should be carried out at regular intervals for effective and efficient planning of our cities.*

Keywords: *Mapping, Landcover/Landuse, Cellular Automata, and Multiple Logistic Regression*

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I. Introduction

Landcover and landuse change process can be identified and recognized using satellite imageries. Remotely sensed data in conjunction with Geographic Information System can provide significant results of changes of the earth surface. Landuse has changed the ecosystem rapidly and extensively due to consequences of rapidly growing demand on natural resources (Watson and Zakri, 2003). It has resulted in degradation of the natural ecosystem functioning.

It is imperative to develop a sustainable landuse plan by understanding landcover and landuse change process and its impact on the environment. The development of suitable and reliable indicators which can provide all essential information about the viability of a system, its rate of change and how it contributes to sustainable development is essential. Nowadays, this kind of assessment is made possible by data provided by modern earth observing systems to analyze the environment using quantitative (hard number), qualitative (subjective valuation) and spatial form. Change in the use of land occurring at various spatial and temporal levels are sometimes beneficial, but when it is detrimental; the impacts are better analyzed using remotely sensed data which provide planners and decision makers with adequate information necessary for the current state of development and the nature of changes that have occurred. Various techniques exist for modeling and mapping landuse and landcover. These techniques have been studied by various researchers. However, the use of multiple logistic regression analysis and cellular automata in characterizing patterns and rates of landcover and landuse changes is still being investigated globally. Cellular Automata are discrete dynamical systems whose behaviour is specified by the interaction of local cells. Cellular automata have been used for simulating various complex systems in the real world and also modeling (Batty *et al*., 2004). Cellular Automata are dynamic models that are discrete in time, space and state. A hybrid model consisting of logistic regression model and cellular Automata was designed to improve the performance of the standard logistic regression model to simulate urban expansion (Farouq, 2014).

Cellular Automata belongs to a family of discrete connectionist technique that is currently being used to investigate fundamental principles of dynamics, evolution and self-organisation. Cellular automata are composed of five basic elements i.e. cells, states, neighbourhood, probability and transition rules (Araya, 2009). The cells are adjacent objects and can take different shapes and dimensions. The states are the discrete attribute of each cell and the surrounding conditions. The states of each cell may represent any spatial variable e.g the various types of landuse.

The transition rules are uniform and applied in all cells or neighboring states. In other words, cellular automata consist of a simulation environment represented by a raster image (gridded space), in which a set of transition rules determine the attribute of each given cell taking into account the attributes of cells in it's neighbourhood (Rimal, 2011).

Hence, this study is investigating the use of this approach in modeling and mapping of landcover and landuse patterns of Kaduna and Environs. Multiple regression analysis and cellular automata helps in creating models designed to test what if scenarios and predict the nature and patterns of change.

1.1Study Area

The study area selected for this study is Kaduna and environs which is located within Kaduna State in North-Western part of Nigeria. Kaduna is the Capital of Kaduna State. It was the Administrative Capital of former northern region of Nigeria. It is a cosmopolitan town.

It lies between latitudes 10^0 23'27"N and $10^0$40'36"N and longitudes $7^0$20' 18"E and 7^0 31'35"E. It is bounded in the North and South by Igabi and Kachia Local Government Areas respectively. It is also bounded in the East and West by Kajuru and Chikun Local Government Areas (See Figs. 1a, 1b and 1c).

The climate of the study area is characterized by two main seasons, namely rainy and dry seasons. The average rainfall is about 1192.74mm, the mean annual relative humidity is 83.6% and the temperature varies from 15^{0c} to 27^{0c} (Kaduna State Water Board, 2014). The study area experiences high temperature all year round which is a characteristic of the tropics. The mean daily temperature in the area can be as high as 34^{0c} between month of March and May. Temperature could be as low as 20^{0c} during December to January. This temperature is intensified by humidity due to the dry harmattan wind. The study area has two seasons. These two seasons are determined by two prevailing air masses blowing over the area at different periods during the year. The population of the town is 1,128,334 and the breakdown is as follows 357, 694 for Kaduna North, 402,390 for Kaduna South and 368, 250 for Chikun (National Population Commission, 2006).The major ethnic groups in the study area are the Adara, Hausa, Fulani, Gbagyi, Jaba and Kaje.

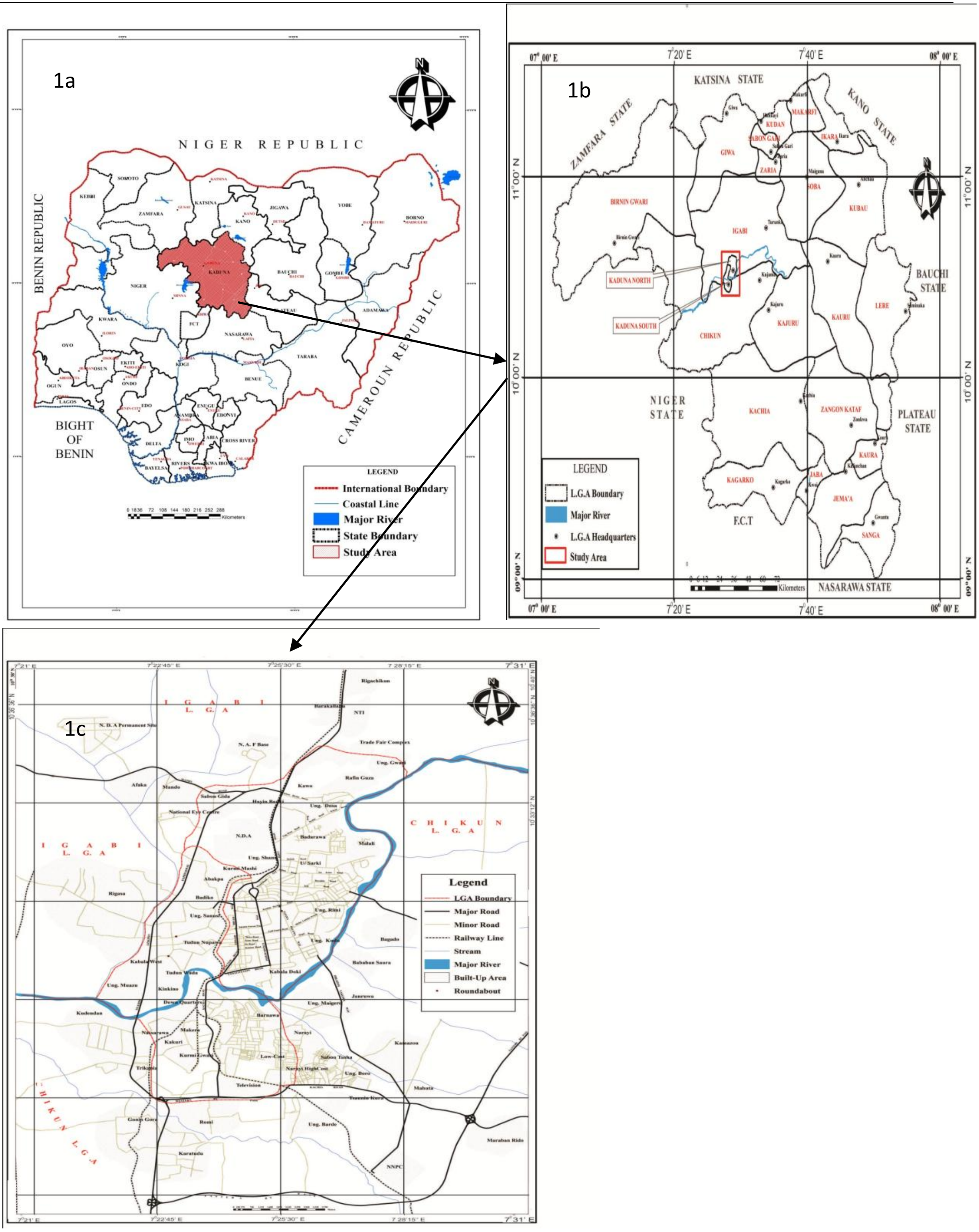

Fig.1a: Map of Nigeria Showing the Location of Kaduna State; Fig.1b: Map of Kaduna state showing the Location of the Study Area (Kaduna North and South Local Government Areas) & Fig.1c: Map of kaduna and Environs (Study Area)

II. Materials and Methods

The Study area was classified into built-up area, farmland, vegetation, open space and water bodies using LandSat imageries of 2004, 2009 and 2014. A model for year 2004 was developed based on time-based data. Cellular automata were used to model the change in the study area on a cell by cell basis to determine the landuse process and develop spatially explicit models to detect urban development. For land change modeler using Terrset, new session was created using the classified image of year 2004 and year 2009. The transitions that were considered were farmland to built-up area, vegetation to built-up area and open space to built-up area. Using the transition potential tab the Boolean images were generated. The Boolean image (true or false) i.e 0 and 1 for built-up area, vegetation, farmland were generated. The transition area helps in showing a class expected to change to other class over the period of five (5) years covering 2004-2009 and 2009-2014. Each transition was modeled using logistic regression. The various classes i.e Built-up area, farmland, vegetation, open space and water bodies within the metropolis were significantly tested to determine which class transit to built-up area at a probability level of 0.05. The t- test was used to determine whether two classes are significantly different. The study area was classified into built-up area, farmland, vegetation, open space and water bodies. The t-test was used to ascertained which of the classes transited to the develop area i.e. built-up area. When the landcover classes are more than 30, then the z-test is used to determine if there were significant changes, but in this research work there are five classes. Hence, the t-test was used.

Analysis of Variance (ANOVA) was also used to determine whether there was a significant between the classes. The landcover and landuse map for 2014 was used to predict for the changes (25 years) later by using the prediction tab in Terrset software to produce the map for 2039. The transition potentials were used to create the prediction. The accuracy of the classified images was carried out by comparing the classified landsat image with known reference pixels.

III. Results and Discussions

The results of the classification process of the LandSat imageries of 2004, 2009 and 2014 were shown in figures 3.1, 3.2 and 3.3 respectively.

Fig. 3.1: classified image of Kaduna and Environs for 2004

Fig. 3.1: classified image of Kaduna and Environs for 2009

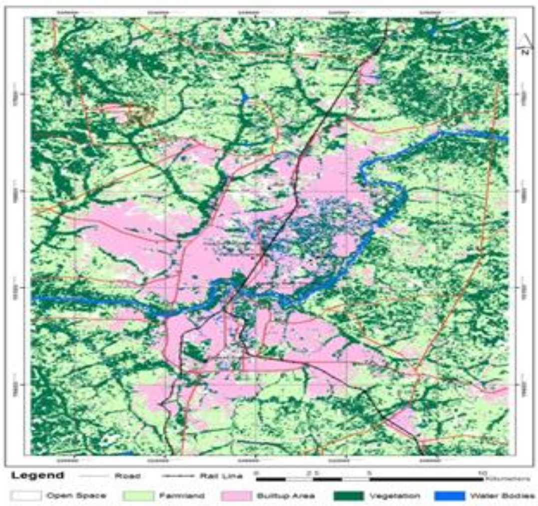

Fig. 3.3: classified image of Kaduna and Environs for 2014

Terrset land modeler software was used to predict the pattern of changes for (25 years) from the 2014 and the result is shown in fig 3.4. Twenty five years from 2014 the vegetation and farmland classes are expected to have transited to built-up areas especially on the fringes of the study area. The water bodies is not expected to increase and this is same for the open space. The Built-up area is expected to increase from 156.119 Km^2 to 227.889 Km^2 and farmland and vegetation will decrease to 126.786Km^2 and 89.12Km^2 respectively.

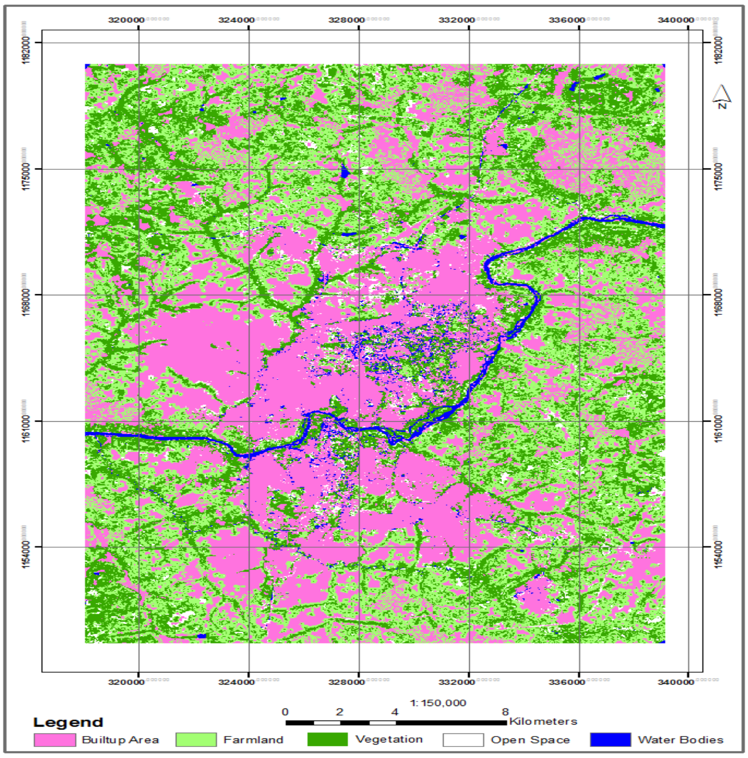

Fig. 3.4: Prediction of Landcover and Landuse patterns of Kaduna and Environs for 25 years ending 2039.

The landuse and landcover changes from 2004 to 2014 are shown in table 2.1.

Class code	Year 2004	Year 2009	Year 2014	Class
22	118574	141765	156119	Built-up area
33	356303	280914	319446	Farmland
44	208988	297945	228337	vegetation
55	62666	20755	35347	open space
66	7788	12940	15070	water bodies

Table 2.1: Pixel values for the three epochs (2004, 2009 and 2014)

Built-up area was 16% of the entire study area in 2004 and increased to 19% and 21% in the 2009 and 2014 respectively. It is obvious that farming activities decreased from 47% in 2004 to 37% in 2009 and increased to 42% in 2014. The vegetation class which was 28% in 2004 increased to 39% in 2009 and decreased to 30% in 2014. The open space which was 8%in 2004 decreased to 3% in 2009 and increased to 5% in 2014. The water bodies remain relatively constant between 1% to 2%. In the year 2004 the built-up area increased from 118.574km^2 to 141.765km^2 in the year 2009 and 156.119km^2 in the year 2014.

IV.Conclusion and Recommendations

Landuse change should conceptualize the relationship between different classes of landcover and their uses. Different disciplinary concepts can assist in the analysis of landuse change in specific situation. The paradigms and theories applied by different disciplines are often difficult to integrate and research results can be used to test theories in specific case studies. The conventional surveying technique is time consuming, the use of landsat ETM+ imageries in modeling and mapping of landcover and landuse changes is an important approach; it structures the model around the human environment relationship which can be improved using cellular Automata. Landcover and landuse maps when prepared at regular intervals will assist relevant Government agencies in the planning of the study area. Kaduna is rapidly undergoing physical development and expansion with remarkable changes in 2004 at 16% to 19% in year 2009 and 21% in the year 2014. These changes may be largely adduced to its proximity to the Federal Capital Territory, Abuja because many people working in Abuja have their houses in Kaduna where they returned to. In the year 2004, farmland was 47%, the inhabitants in Year 2009 took to trading which lead to decrease to 39%. The economic hardship where commercial activities were reduced made the inhabitants to return to farming which resulted in increase to 42% in 2014. The fluctuation in farmland is also as a result of Government taking over large areas used for farming in some areas especially at Igabi and Ungwar Muasu, Urban encroachment has also led to decrease in farmland in the study area. The open space in Kaduna and environs especially the parks and recreation areas in Kabala West and Tudun Wada witnessed decrease of 8% in the year 2004 to 3% in the year 2009 due to Government negligence. The areas were not properly taken care of including the green belts. Increase in water bodies from 1% in 2004 to 2% in 2009 and 2014 was attributed to construction of water reservoirs in the study area. Some streams in the study areas are now wider thereby containing more volume of water including the main river i.e River Kaduna which flows across the city.

It might be argued whether results obtained from modeling and mapping of landcover and landuse changes and the prediction could be used for development and policy making. However, due to dearth of adequate and current landcover and landuse maps, based on findings of this study, the following recommendations are made:

1. Landcover and landuse maps when prepared on regular basis can be used for planning purpose. It is therefore
2. recommended that there should be regular and timely preparation of Landcover and Landuse maps Modeling and mapping of landcover and landuse changes using multiple logistic regression and cellular Automata should be flexible and managed by pre-defined rules. The rules should be properly articulated to ensure successful implementation.
3. The use of ancillary data for ground truthing is inevitable in image classification.
4. There should be consistent multi-temporal landsat satellite imageries in modeling and change analysis.
5. Further studies should be carried out on modeling and mapping of landcover and landuse for sustainable development.

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