Simulation and Prediction of Urbanization in Makurdi City, Nigeria using CA-Markov Technique

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Abstract

The intensification of anthropogenic activities covering agriculture, deforestation, expanding farmland, and urban centers are greatly changing the landscape across the globe. This study uses Land Use and Land Cover Change (LULCC) computed from Landsat TM, ETM+ and OLI datasets of 1986, 2006 and 2016 respectively. These were analyzed using ArcGIS and IDRISI to make clear land use structures. These software enabled us to classify LULC into five classes to examine and monitor the changes that have taken place in the area. IDRISI's Land Change Modeler was ran to model land use and land cover dynamic in the study area. CA-Markov model was used to simulate and predict its spatio-temporal change rules and driving factors using DEM, distance to road and distance to water. The results showed that built-up areas have been on the increase from 24.10% in 2016 to 41.71% in the year 2036, with the spatial trend of built up areas showing that there is a growing trend in the city centre, spreading towards the fringes of north west, north east, sharing boundary with Nassarawa State relative to other directions. Urbanized land maintained the growth momentum while farmland area decreased and other land use types kept a relative stable level. Spatial raster contrast proved that CA-Markov model was in high consistency for the LUCC prediction. Makurdi city has changed dramatically, characterized with the shrinkage of farmland area, vegetation, primarily due to the urbanization and the trend is projected to intensify. Finally, the use of IDRISI in modeling LULC is a suitable approach to understand the future LULC pattern.

Keywords: LULCC, CA-Markov, Urbanization, Simulation, Landsat

INTRODUCTION

Land use and cover change (LUCC) is one of the core themes of the global change research. As the global population, resources and environmental issues become increasingly prominent there is need to study the effect of LULC (Lambin and Meyfroidt, 2011). One of the most important concerns of the world, nowadays, is the change in eco-environment which is mainly caused by human exploitation of resources found on the environment. The intensification of anthropogenic activities greatly changed the landscape across the globe. It is also worthy to note that Land use and land cover change is the basis for today's alarming rate of global environmental change (Venter *et al.*, 2016).

Modelling of land use and land cover is a scientific field that is growing rapidly because of its importance in identifying the effects of LULC changes on the environment. In view of its importance, scientists have constituted different methods in modelling LULC since Land use and Land cover dynamic studies have become key components for managing natural resources and monitoring environmental changes. One of the approaches that have been developed for predicting

Land use/ Land cover (LULC) is Cellular Automata (CA) which is defined as a dynamical discrete system in space and time that works by specific rules on a uniform grid based space (Hand, 2005). This is a powerful tool for modelling and predicting land use and land cover change, hence provides standard methods for mapping, monitoring and modelling LULCC. It is also an important tool in assessing the character of landscapes and quantifying spatio-temporal changes.

Literatures revealed that LULC models can be classified into three categories. The empirical-statistical models are the first group, such as regression models, which are developed by statistical analysis on the factors causing land use change (Pei and Pan, 2010). The spatially explicit models, are the second types simulating change based on transition rules such as the CA model that represent transition rule based change but lack in their causal representation (Asranjani *et al.*, 2013; Vaz *et al.,* 2013). Thirdly, there are agent-based models, which simulate future scenarios based on factors of change also called agents but due to the multi-collinear behavior of the interacting agents, it seldom fails to represent the reality (Parker *et al.,* 2003).

CA-Markov model combines both the concept of a CA filter and Markov change procedure, perfecting the spatial configuration results of Markov analysis prediction, which can effectively simulate research area's land cover change. There are many models for land use dynamic change and simulation, such as cellular automata (CA), Clue-s model, Markov model, CA-Markov model (Wang *et al.,* 2014). This study simulate and predicted future LULC in Makurdi City using the CA-Markov model for the purpose of revealing the characteristics of land cover types in Makurdi City and provide a reference for further research.

Study area

The study area is Makurdi town, the Capital city of Benue state in north central Nigeria. It is the Headquarter of Makurdi Local Government Area and the capital of Benue state. The city is located between longitude 8º 24'E and 8º 38' E of the Greenwich Meridian and latitude 7º 38'N -7º 50'N, of the equator (Figure1). It is situated in the Benue valley in the middle belt region of Nigeria. It is traversed by the second largest river in the country, the river Benue. The climate of Makurdi town is the tropical wet dry type, Koppen's Aw classification, with double maxima (Tyubee, 2009). The rainy season lasts for seven months, starting from April and ends in October with its peak between July and august while, total average annual rains reaches a total of 1173 mm (Clement, 2013), and a Guinea savanna vegetation type.

METHODOLOGY

In this study, two types of software were used: a) ArcGIS- was used for creating slope constraint and providing the administrative shape file, and b) IDRISI TerrSet- was used for change detection analysis and for modeling land use and land cover. The data used is Landsat thematic maps of 1986, 2006 and 2016 that were classified based on Maximum likelihood supervised classification. This is necessary because the predictive model require transition data that gives the pattern of changing to the model. This transition file was extracted by comparing the 2006 and 2016 classified maps. The data were Landsat thematic mapper of 19/12/1986, Enhanced Thematic Mapper of 31/12/2006 and operational Imager (OLI) of 06/01/2016, all on 30m resolution was used for the analysis as well as 2006 population figures of the study area.

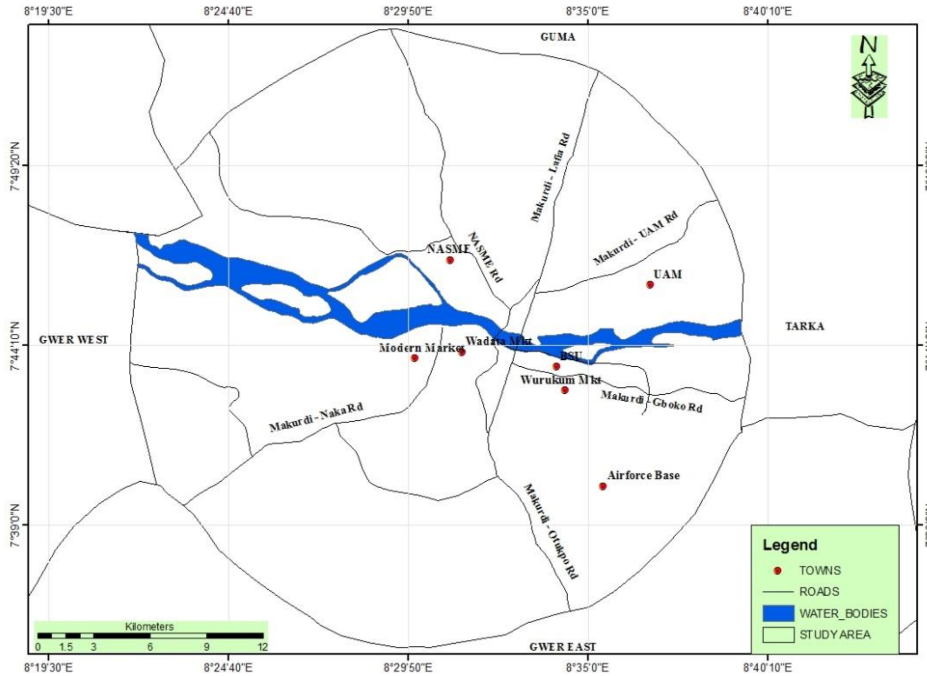

Figure 1: The study area Makurdi Town Benue State, Nigeria
Source: Extracted from Administrative Map of Nigeria

The Area of interest (AOI) to was extracted and images enahanced prior to analysis. The sensitivity of band 4 and 3 to vegetation cover and sensitivity of band 4 to water contents are crucial surface analysis (Robert, Frohn and Autrey, 2009). After the enhancement process, band combination operations was performed as a reason for colour composite to highlight brightness values associated with the data. A band combination of 4, 3, 2 was used for analysis of 1986 and 2006 while band 5, 3, 2 was used for Landsat 8 (OLI). Based on prior knowledge of the area and field survey, a classification scheme of Anderson *et al.,* 1976 level 1 was adopted and modified into five classes representing built up, vegetation, farmland, sand bar and water body.

Modelling in CA-Markov

The requirements of the CA-Markov module were added to the module one by one; basic land cover which is the map of 2016 as the 2030 map had to be predicted, Markov transition areas file which was created using the 1986 and 2006 maps and a transition suitability image collection which was obtained by the decision support wizard. Then, the number of iterations was set to 20 with iteration for each year for the period 2016 to 2036.

The CA-Markov technique is very useful in making spatial-temporal projection by taking into account the trend of land use change and the desired scenario. The Land use change map of 1986 and 2006 were defined as input data into the CA-Markov to validate the 2016 land use map earlier produce, thereafter used to simulate 2036 land-use scenario. The researcher used spatial raster contrast to verify whether land cover type in spatial location was the same as the actual map.

Two techniques, the Markov Chain and Cellular automata (CA) analyses were used to model land use changes. The Markov Chain Analysis quantify and predict land use change and unable to obtain the change degree of the land use types from a spatial view; while CA model has strong dynamic simulation ability to present spatial and temporal changes using known land use datasets for two different time periods for Makurdi, 1986 and 2006, CA Markov model was used to simulate and predict land use types in 2036.

Three (3) driving factors DEM, distance to water body and road was used as static and dynamic driver to simulate the future urban area in 2036. The first driver is the distance from the major roads of 2016; this is because people prefer to stay in houses overlooking the roads as economical places. The second driver is elevation; people prefer high places with fewer slopes as safe places during floods. The third driver is a distance around water body in the area because areas close to the river attract people for socio economic activities such as irrigation farming, boat building, and transportation, fishing and sand excavation from the river. Thereafter, the population of the study area was taking into consideration since there cannot be greater changes on LULC of the area without human beings interacting with the environment. The population of the area was projected using the formula adopted from (Smith *et al.*, 2006)

The geometric population projection formula is $P2 = P1 (1 + r) n$

Where
$P1$ = Base year 2006 (300,377)
$P2$ = Projected Population (2036)
r = Growth rate 3.0
n = Number of years (30 years)

RESULTS AND DISCUSSION

The analysis of 2016 satellite image shows that, there is continuous expansion of built up area in Makurdi. Most importantly, the urban expansion encroached on the river bank and other natural drainages between 1986 and 2016.

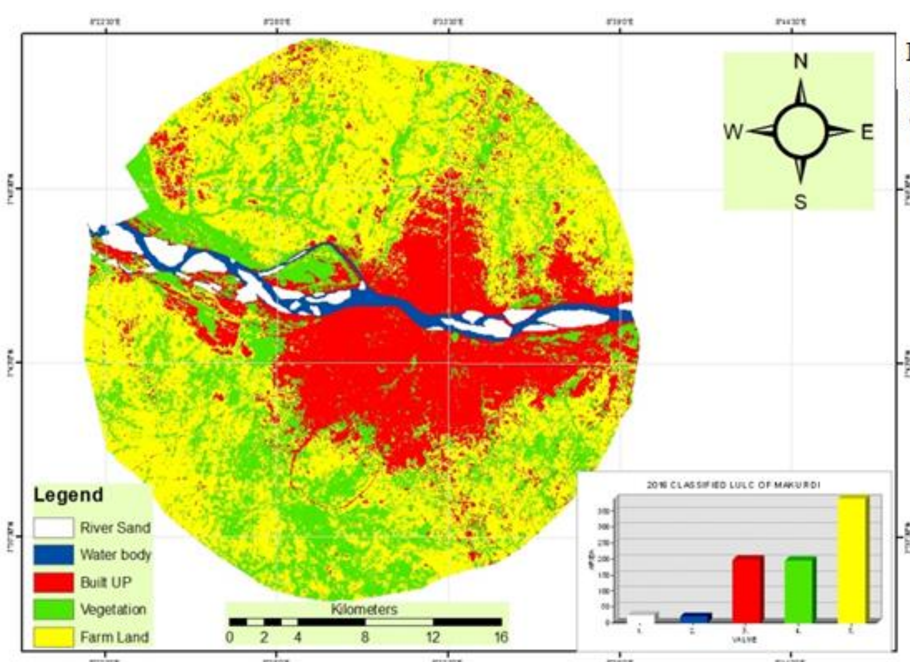

Figure 2: Makurdi 2016 land use land cover distribution

From the various spatial temporal analysis of categorical LULC of the study area, it was clear that the land use have been changing in size noticeably over the years. Table 2 indicates changes that have occurred within the period of 30 years from 1986 to 2006 and 2016. All these occurred as a result to the creation of Benue state with headquarters at Makurdi made the young city to attract massive movement of people for employment, businesses and other purposes. The increase in farmland throughout the study period most especially in 2016 must have been attributed to the government's resolve to encouraging all civil servants and other residents in Makurdi to go back to farming.

Table 1: Land use and land cover Distribution in Makurdi (1986, 2006, and 2016)

Classification Category	1986		2006		2016	
	Area (Sqkm)	Area covered (%)	Area (Sqkm)	Area covered (%)	Area (Sqkm)	Area covered (%)
River Sand	18.3267	2.22	31.9788	3.84	23.0895	2.79
Water bodies	27.8838	3.37	16.6995	2.0	19.8792	2.41
Built up	20.0493	2.43	127.6227	15.31	198.9819	24.10
Vegetation	349.5456	49.69	267.6159	32.10	195.5457	23.66
Farmland	349.5452	42.29	389.871	46.76	388.7649	47.05
Total	826.2576	100	826.2576	100	826.2576	100

The increased farming activities led to the conversion of vegetation lands to farm land. This result disagrees with the work of (Nwafor. 2006; Yirsaw, *et al.*, 2017) who also found that agricultural lands decreased as built-up area increased because in this case farmland/agriculture land increases. Although, not that farmland have not been lost to built-up but the net gain from other LULC classes is more than the net loose to built-up from farmland. Similarly, the study has revealed that, the expansion of farmland has been at the expense of lands with natural vegetation cover which also agrees with the work of Cheruto *et al*. (2016).

LULCC in 1986, 2006, and 2016

Table 4.2 shows the change matrix of the classified images across the study area, it reveals that built up area (Urban areas) has continue to be on increase across the study area. This was witness more between 2006 and 2016 considering the time period between 1986 and 2006 twenty years interval (12.88%) and between 2006 and 2016 ten years interval (8.79%) whereas other land use category was fluctuating.

Urban Expansion Pattern in 1986, 2006 and 2016

The pattern of urban expansion was derived from the three imageries of the study area, overlays analysis from the results of figure 3 and visual interpretation was carried out in determining the patterns of expansion. On the bases of the results obtained from the analysis, three patterns of urban expansion was noticed namely; cluster, radial and leapfrog were found which varied from different study periods (1986, 2006 and 2016). Though, all of the study periods witnessed cluster within the central business district of the study area there still is variation in other periods. It was found that in 1986 the pattern of the expansion was cluster while 2006 and 2016 witnessed both radial and leapfrog pattern of urban expansion as show in Figure 3.

Table 2: Land use and land cover Change in Makurdi (1986, 2006, and 2016)

Classification Category	1986/2006		2006/2016		1986/2016	
	Area (Sqkm)	Area covered (%)	Area (Sqkm)	Area covered (%)	Area (Sqkm)	Area covered (%)
River Sand	13.65	1.32	-8.89	-1.05	4.76	0.57
Water bodies	11.18	1.37	3.18	0.41	-8.00	-0.96
Built up	107.57	12.88	71.36	8.79	178.93	21.67
Vegetation	81.93	-17.59	-72.07	-8.44	-153.99	-26.03
Farmland	40.33	4.47	-1.11	0.29	39.22	4.76
Total	826.2576	100	826.2576	100	826.2576	100

Based on the nature of the pattern of urban expansion in the study area, it was also found out that there was an uncontrolled development of urban area into the surrounding study area forming land density and poorly planned patterns of development as supported by Torren (2000). Therefore, the pattern of urban expansion can be said to be continuous disperse development to low density residential units and isolated tracts, separated from other areas by vacant space forming leap frog pattern along highways or other driving agents, or forming spatial patch within undeveloped land which was in conformity with the research of (Torren, 2000). The result was also in agreement with the research of (Abimbola, 2008) which shows that urban expansion affect the structural growth and economic system of an urban area. Urban growth during this period could be explained by population increase and the urge for urbanization which make people to scramble for space in urban area.

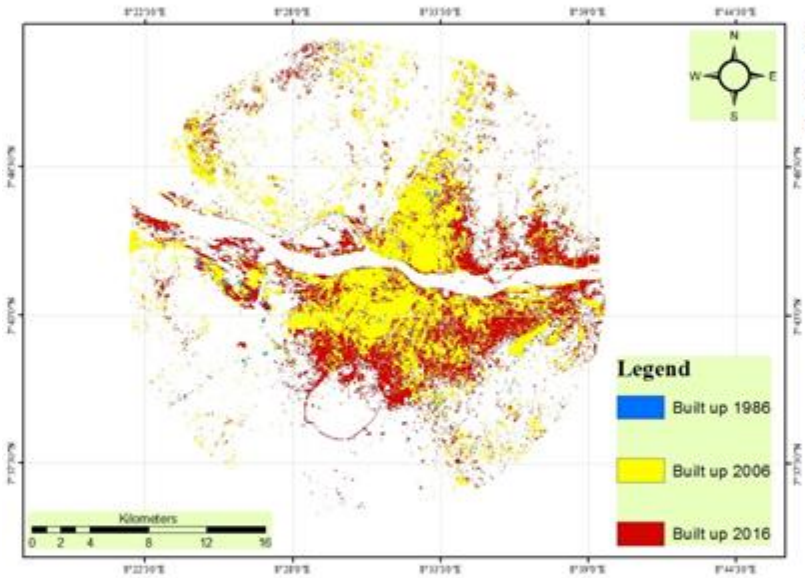

Figure 3: Built up Areas in the study Area, 2018

In addition, the result of the projected land use and land cover shows that the study area will continue to change by the year 2036 (Figure 4). By visual examination and comparison with 2016 Land cover map (Figure 2), it can be seen that there is a significant increase in the urban areas, and this increase is of three types; one of them is in-fill urban expansion which occurs within existing urban areas; the second is extension of existing urban areas and the third is termed 'leap frog' expansion, which refers to dispersed urban area growth that is disconnected from existing urban areas. This expansion could intensify seasonal flood typical of the city in recent times and will have great consequences on sustainability human livelihood across the city. This is in agreement with Cheruto *et al.* (2016) which states that changes in LULC poses serious implications for future prediction that could spell a serious calamity due to inundation and loss of small lakes and ponds considering the fact that the loss of the ecosystem constitutes severe degradation and increases the vulnerability of people to disaster especially flooding in the area.

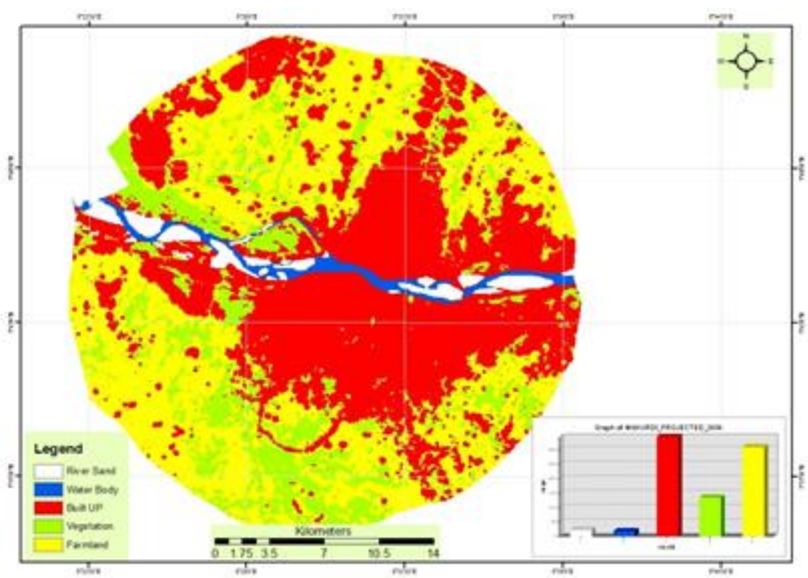

Figure 4: Simulated 2036 LULC

Table 3: Simulation Analysis of Land Use for 2036

	LULC Category	Area (Sqkm)	Area covered (%)
1	Sand Bar	22.1337	2.68
2	Water bodies	16.6428	2.01
3	Built up	334.6523	41.71
4	Vegetation	133.2819	16.14
5	Farmland	309.5469	37.46
	Total	826.2576	100

By using the population growth rate of 3.0 and 2006 population data of 300,377 as base year for population projection, population is expected to increase to 729093.82 people by 2036 and a population density of 882.405 persons per square kilometers projected. Similarly, Farmland representing 47.05% (2016) will reduce to 37.46% (2036) and vegetation representing 23.66% in (2016) will also reduce to 16.14% in (2036) at the expense of built- up. Water body and sand bar indices does not show significant changes to the future (Figure 4). Similarly, this agrees with the work of (Buba *et al.*, 2016) which states increasing population with rapid settlement growth encroaching into vegetation and agricultural land making the area vulnerable to the risks of climate change. The future land use will be highly nucleated at the city center and will spread towards the fringes of north western, north east, sharing boundary with Nassarawa and other local government areas in the state such as Guma, Gwer east and Gwer West, south eastern and South western section of the study area. Furthermore, the future LULC will have great impact on the environment of the study area such as increase urbanization resulting to increase road network, and other impervious surfaces which agrees with the work of (Clement, 2013).

Built-up trend from 1986 to 2036

The period of 1986 - 2006 covering 20 years reveals that built – up increase by just 12.88%. However, from 2006 -2016 covering (10 years) built- up increase by 8.79% more than half of the twenty years period, while the built-up will increase by 17.61% from 2016 to 2036 within the simulated year (Figure 5). Corresponding, this agrees with Buba *et al*., (2016) which states that urban population growth result from high population growth and the influx of people to the urban areas

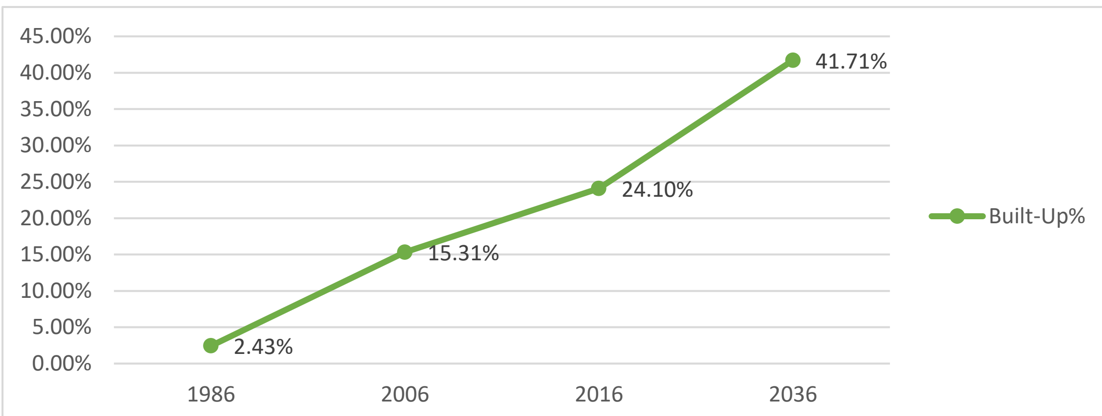

Figure 5: Built-up increasing trend of Makurdi from 1986 – 2006 – 2016 – 2036

CONCLUSION

This paper explored the characteristics of LULC change and simulated future land use by combining Markov model and CA-Markov to study LULCC that have occurred over time and space which gave some insight into a better understanding of possible changes in land use in the area. The simulated land use map for the year 2036 shows spontaneous increase in the built-up, this suggests that future land use will be highly nucleated at the city center and will spread towards the fringes of north western, north eastern parts of the map, sharing boundary with Nasarawa and other LGAs in the state such as Guma, Gwer east and Gwer West, south eastern and South western section of the study area.

In addition, the simulated LULC map has established that urbanization will continue to be on increase on the study area. This was affirmed by the different Spatio-temporal LULC maps produce which unveils higher changes in LULC changes in recent times. It is also paramount to note that human settlement is on the increase towards the various section of the study area particularly along the river bank due to continuous influx of people. This will certainly increase the vulnerability of built-up areas to flood events in 2036. The research reveals the fundamental factors such as land use pattern, low relief, increased in built-up and human activities will continue to intensify, affecting natural water flow, hence leading to flood. Therefore, there is a need to develop adequate understanding of structural urban dynamics in order to have absolute foundation for formulating sound, sustainable and effective urban policies.

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