LAND USE DYNAMICS AND FUTURE LAND USE SCENARIOS IN NIGERIA

Eseosa Halima IGHILE[1] and Hiroaki SHIRAKAWA[2]

[1]Dept. of Environmental Engineering and Architecture, Graduate School of Environmental Studies,

Nagoya University

(Furo-Cho, Chikusa-Ku, Nagoya, 464-8601, Japan)

E-mail: ighileeseosa1@gmail.com

[2] Dept. of Environmental Engineering and Architecture, Graduate School of Environmental Studies,

Nagoya University

(Furo-Cho, Chikusa-Ku, Nagoya, 464-8601, Japan)

E-mail: sirakawa@urban.env.nagoya-u.ac.jp

Nigeria has experienced various changes in the areas of socio-economic development, population growth and urbanisation. Along with the changes in socio-economic development and urbanisation, their effects can mainly be observed in the changes in land use. These land changes have led to an increase in environmental damage, which has overtime been amplified by climate change. The most observed changes exist in the land cover characteristics in the areas of agricultural, settlement and forestry, which will continue due to rapid urbanisation. The objectives of the study are; i) to understand land use dynamics over time, ii) investigate the driving factors responsible for the land use changes, and iii) predict land use changes based on three development scenarios. For the study, a Logistic-CA-Markov model is used to understand and allocate land use demand under the selected scenarios. The logistic regression analysis quantifies the effects of each selected variables from economic, demographic, accessibility, biophysical and climatic factors on land use change between 1975 and 2013. The results revealed that the drivers of land use change are; population density, GDP and slope. For the future simulations using the Markov chain model; in the Business as Usual (BAU) scenario in 2026, agriculture land increases to 554,978 km2, forest land further declines to 213,490 km2 and settlement increased slightly to 55,761 km2. In the market-oriented scenario; to 487,053, 282,635 and 53,986 km2 respectively. The study highlights that; the introduction of policies that support and mitigate against indiscriminate land use practises while ensuring sustained economic growth serves as a logical approach towards sustainable land use development in the future.

Key Words: *Nigeria; land use/Land cover; Logistic-Markov modelling; prediction*

1. INTRODUCTION

From the 1960s, the nature and intensity of land use across the different cultural and social regions of Nigeria have become more evident. The rapid changes to the land cover have resulted in increased levels of environmental degradation and other environmental hazards[1)]. Following the rapid urbanisation of most regions across the country, the primary focus on studying land use changes is now on investigating what factors influence land use conversion, and how the alterations to these factors would impact land use demand, influence current

environmental issues and affect Nigeria's sustainability[2]. At present, Nigeria's high population, and the increase in rural-urban migration already places enormous pressure on the intensity of land use conversion and led to increased exposure to both natural and anthropogenic hazards.

Besides, the nature of the land conversion in both urban and rural areas are still unclear and has become a subject of discussion in recent years. Due to the lack of comprehensive studies that simulate current and future land use trends in Nigeria, it has become difficult to address the problems relevant to land use planning and sustainable development.

Several researchers have undertaken with different approaches to studying land use changes. These existing land use models can effectively analyse the causes of land use change, land use interaction, simulate spatial patterns, their driving forces and predict multiple scenarios under different natural and socio-economic conditions at a regional, national or global scale [3,4]. The currently available land use models are in three distinct groups [5].

The first group of land use models are the statistical models, for example, the logistic regression model. These models are based on mathematical equations to perform statistical analysis of the factors responsible for land use change [6].

The second group are the rule-based models such as the cellular automata and dynamic models. They can model land use patterns of the past, present and future. However, some of the challenges to these models are the inability to portray human factors in the model computation[7]. A hybrid model that sometimes integrates the logistic regression, Markov chain and cellular automata to model the existing patterns of land use change and future changes [7].

The third type of land use models is agent-based models. They are useful in simulating land use changes based on individual factors. However, some of the challenges of these types of models are their inability to model complex land use processes[8]; an advantage of these models are the ability to combine cellular landscape models with an agent-based representation of the overall decision-making process.

Despite the availability of several land use models which combine both biophysical and socio-economic data to simulate land use changes, the challenge faced by most land use models remains mainly on the quantity and quality of the input data at different scales. Therefore, to effectively model, simulate and predict land use changes, integrating multiple models has become a hot topic in the research community.

In this study, since the nature and complexity of Nigeria's natural and socio-economic character are being considered in the understanding, modelling, prediction and simulation of land use changes, the integration of both statistical and spatial land use models have been adopted. We would integrate the Logistic regression model, the Markov Chain model and the CLUE model for the study.

As Nigeria is experiencing a transition from a rural to an urbanised society, developing strategies that promote the effective use of land, ensures environmental protection and promotes sustained growth is now more than ever relevant. For this reason, It is, therefore, necessary to understand what factors are responsible for land use change, as well as predict and simulate how these factors would affect land use demand in the future. A strong understanding of these factors would enable the design and implementation of policies, programs and planning methods that promote land use sustainability. The objectives of the study are to; i) to understand land use dynamics over time, ii) investigate and identify the driving factors responsible for the land use changes, and iii) predict and simulate land use changes based on different development scenarios.

2. MATERIALS AND METHODS

(1) Study Area

Nigeria is a country in Western Africa (fig. 1). Nigeria consists of 36 states, and the capital Abuja, occupying an area of 923,768 sq.km, including the land surface area of 910,770 sq.km, and the maritime area of 200 nautical miles. The land use types comprise of a total of twenty-four (24) distinct categories such as; agriculture, forests, savannahs, woodland, and settlement.

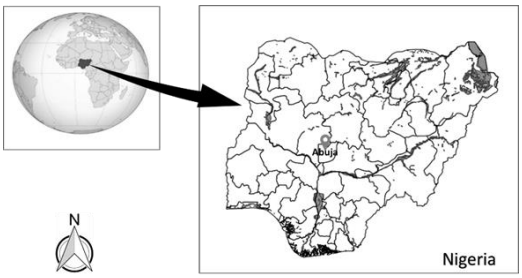


Fig. 1 Geographical Location of Nigeria (Source: Authors)

Nigeria has a population of about 190 million, with over 48% resident in urban areas across multiple cities above a million(1,000,000) residents[9]. Agriculture, Trade, Information & Communication, Manufacturing, and Mining are significant contributors to the economy of Nigeria [10], which is evident, with its GDP at about 500million dollars as at the 2015 estimates[10]. The massive economic growth has contributed significantly to the changes in its land use patterns, evident in several regions across the country, exhibiting rapid changes in its developmental patterns. Despite the evident growth and development, issues about wealth distribution and income inequality are still visible. The variations in wealth distribution also influence the changes in land use across various regions of the country.

In the aspects of land use and land cover changes, between 1975 and 2013, forest land use experienced the highest reduction from 418,557 km2 to 269,094 km2; settlement experienced gains from 45,352 km2 to 51,364 km2 and agriculture land with the most growth from 262,606 km2 to 480,925 km2 respectively [11].

(2) Land use model

(a) Markov Chain Model

The Markov chain model is used to represent the nature of land use categories and the possible directions of land use change in all the land use categories. The Markov chain model observes the transition probability matrix, which explains how each land category changes from one group to another within the selected periods, represent the number and the probability of land shifting from one land use group [12]. Based on natural and socio-economic information, land use planning and related policies in Nigeria between 1975 to 2013, three future socio-economic scenarios have been defined to predict land use demand for 2026 with the aid of the Markov Chain model.

(b) CLUE Model

The CLUE model was developed in 1996 by Tom Veldkamp and Louis Fresco aimed at modelling land use and land cover changes at the local, regional and global levels[13]. The CLUE model helps in exploring the relationship between land use change, natural and socio-economic factors at different scales. Several studies have been performed around the world with the aid of the CLUE model application. Such studies include the simulation of deforestation and degradation patterns, urbanisation trends and assessing changes to land use and land cover. The CLUE model comprises of two sections. The first is the spatial analysis module, and the second is the non-spatial analysis module.

In the CLUE model computation, the first part is the spatial analysis module; which allocates land use demand from the Markov model based on the different transition probability and transition rules for each land use category [14]. The second part is the non-spatial analysis module; focusing on the factors that influence land use change based on the natural and socio-economic variables. To investigate the drivers of land use change; the multinomial logistic regression model is selected to estimate the influence of all selected factors on different land use types. The multinomial logistic model is used in this context to investigate the relationship between the dependent variables (land use types) and the multiple independent variables, which assists in the prediction of the probability of occurrence to each land use type. The independent variables selected takes into consideration both natural and socio-economic factors that may influence these changes.
The formula for the land use probability (πij) is;

$$\pi_{ij} = \frac{\exp(x_i \beta_j)}{\sum_{r=i}^{J} \exp(x_i \beta_j)} \quad j = 1, \ldots, J \tag{1}$$

Where, *í* denotes the index of the location; *j* is the index of land use type; *πij* is the probability of land use *j* at 1, β, the vector of parameters and χ, vector of variables.

(c) Scenarios

This study predicted future land use pattern in three scenarios. The first scenario is Business as Usual (BAU) development, where we assume that the factors that currently influence land use remain unchanged from 1975 to 2013 and will remain the same between 2013 to 2026.

The second scenario is the market-oriented development, assuming that focus is placed on the

growth of GDP and urbanisation level and diversification of the economic sectors to obtain the demand for land use in 2026.

The third scenario focuses on ecological conservation and biodiversity protection. Here, we place restrictions on forest land conversion and land use restrictions. The designated protected regions are fixed and prevented from transforming into other land use categories.

BAU scenario is simulated by the Markov chain model, while the Market and Conservation scenarios are done by Clue model.

3. RESULTS AND DISCUSSION

(1) *Driving force analysis*

In observing the forces behind land use change, factors such as demography, socio-economic, biophysical and accessibility play vital roles in the changes to land use. **Table 1, 2 and 3** show the result of the regression analysis for the drivers of agriculture, settlement and forest land use. The negative coefficients signify that these variables do not influence land use change. In contrast, the positive coefficients are the factors that promote land use change for the selected land use types in the study.

a) Forest Land Use

The result in **Table 1** indicates that; elevation, population density, distance to roads, and slope are the drivers of forest land use change, as they present a positive coefficient estimate from the land use modelling results. The understanding of the results in **Table 1;** is that for a unit change in any of the favourable variables, there is a higher probability of change to become forest land use. However, the variables with negative coefficients do not influence forest land use conversion. For example, population density with a positive coefficient: if the population density of the area around a forest land area increases, there is the likelihood that forest land would be converted, to either forest land in itself or other land use type.

b) Agriculture land Use

In the case of agriculture land use (**Table 2**), elevation, gross domestic product, rate of internal migration, population density, slope, temperature distance to water are the drivers of land use change. The results explain that for example, areas closest to waterbodies have a higher tendency to become agriculture land as compared to farther regions. That is because, easy access to water for agriculture purposes attracts agricultural development, as it reduces the operating cost of the agricultural process, improving yield and creating an opportunity for economic growth (**Table 2**). Migration as a driver of agricultural land use change explains that; increase in the movement from rural to urban areas, the demand for agricultural products in the urban centres will continue to grow. In turn, lead to the peri-urban areas increase agriculture production to supply urban needs. The trend is also evident in the changes in the GDP (income); areas with lower income depend solely on primary production as a means of livelihood. Therefore, having a higher number of the population with a low income increases the probability of the expansion of the agriculture sector to generate gainful employment and income.

Table 1 The logistic regression result between LUCC and driving force factors (Forest)

Variables	Estimate	Std. Err	Z Value	Significant probability (pr>[z])
Pop d	1.55	1.71	-	-
Dem	5.73	1.79	0.32	0.75
GDP	-1.41	2.44	-0.58	0.56
Temp	-3.06	3.18	-0.96	0.34
Road	2.92	5.48	0.53	0.59
Migr	-4.30	1.09	-0.39	0.69
Precip	-8.70	7.19	-1.21	0.23
Slope	6.21	8.29	7.49	7.10
Water	-2.08	8.16	-0.26	0.80

c) Settlement Land Use

The results (**Table 3**) show that for settlement land use; GDP, population density and slope are the factors that promote settlement land use change. According to Ighile and Shirakawa (2020), an increase in the GDP significantly influences settlement land use. Their study provides evidence that areas in Nigeria with higher GDP, had a higher likelihood of land use changes to become settlement land. They also explained that, as the overall GDP of Nigeria continues to increase, settlement land use will continue to increase.

Table 2 The logistic regression result between LUCC and driving force factors (Agriculture)

Variables	Estimate	Std. Err	Z Value	Significant probability (pr>[z])
Pop d	9.87	1.26	0.01	0.99
Dem	1.14	1.77	0.64	0.52
GDP	1.14	2.44	0.12	0.56
Temp	1.19	3.18	0.38	0.71
Road	-2.35	5.53	-0.43	0.67
Migr	3.82	1.09	0.35	0.73
Precip	-4.98	7.18	-0.69	0.49
Slope	5.64	7.61	7.42	1.18
Water	5.78	8.14	0.07	0.94

Table 3 The logistic regression result between LUCC and driving force factors (settlement)

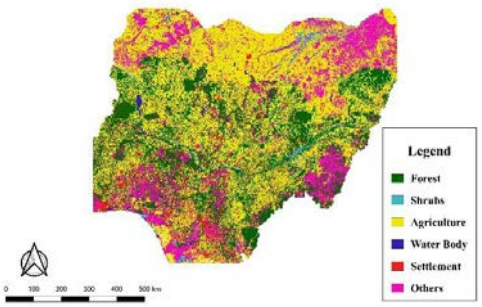
Variables	Estimate	Std. Err	Z Value	Significant probability (pr>[z])
Pop d	1.03	1.65	0.01	0.99
Dem	-5.51	1.81	-0.31	0.76
GDP	4.66	2.41	0.19	0.85
Temp	-3.91	3.22	-1.22	0.22
Road	-5.85	6.02	-0.97	0.33
Migr	-9.92	1.11	-0.09	0.93
Precip	-1.02	7.28	-1.40	0.16
Slope	7.39	1.87	0.40	0.69
Water	-3.26	8.27	0.04	0.97

(2) *Simulation and prediction of land use change*

Based on the results of the land use change from 2000 to 2013, the Markov chain model is used to predict the different land requirements in 2026, based on the three selected future scenarios earlier discussed. The prediction results are presented in Table 6. The table shows that forest land is decreasing in both the natural and market-based scenarios, while agriculture and settlement areas increase. However, in the conservation scenario, forest and settlement land increases while agriculture land reduces. In each of the scenarios (**Table 4**), the land use requirements vary.

Under the BAU scenario (**Fig. 2a, Table 4**), the trend is that agriculture and settlement land continue to expand, and forest land continues to diminish in comparison with the initial land use statistics of 2013 (**Table 4**). In the market-based scenario, the rate of agriculture expansion diminishes as, we can observe that settlement land increases, while forest land areas to increase significantly (**Table 4**). The observed trend for the market-based scenario is that; there appears to be less dependence on agriculture production and improvement in the socio-economic characteristics, thereby promoting settlement expansion. The trend in the market scenario was observed in the study by Ighile and Shirakawa (2020), were their results explained that increasing GDP(economic factors) played a vital role in settlement land use expansion and reduction in agriculture land conversion. The different trends in land use demand under the thee, different scenarios show that depending on the existing policies in place, the direction of land use change would also vary.

A)



B)

C)

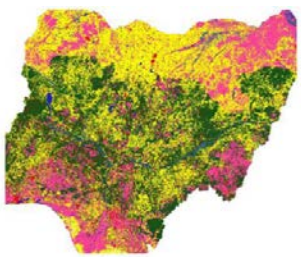


Fig.2 Simulation map of land use and cover change for (a) BAU (b) market-oriented and (c) conservation for the year 2026

Table 4 Simulation results of land use and cover change for the three different scenarios in 2026

scenario	Forest	Agric	settle
Initial 2013	269,094	480,925	51,364
BAU	213,490	554,978	55,761
Market	283,527	474,950	58,613
Conservation	297,116	472,423	56,897

We used land use and cover data sets of 1975, 2000 and 2013 for the land use change simulation, utilising the results of its driving factors. From 1975–2013, the forest land area noticeably decreased, and agriculture land increased all across Nigeria. Under the three simulated land use scenarios, we observed that changes to policies centred around natural and social factors would play a vital role in land use demand in the coming years. If the current socio-economic conditions continue to follow the existing trends of 2013, the result shows that agriculture land would continue to expand, and there would be an increase in deforestation by the year 2026. However, with a review on socio-economic and conservation policies, we can observe that the changes may occur within each land use category would significantly differ. In the market-based scenario, there would be improvements in forest land conversion, less focus on primary production and increased infrastructural development. In this paper, although the selected driving factors were limited, the categories from which we selected the drivers highlights how different natural and social characters play essential roles in land use change.

4. CONCLUSION

From the research results, the land use area changed significantly between 1975 to 2013. Forest area decreasing from 28.84% to 18.54% of the total area. Whereas agriculture and settlement, areas increased from 18.10 % to 33.14 % and 3.13 % to 3.54 %, respectively. The drivers of land use change are population density, GDP and slope. From the land use model, we could simulate how each selected driver have varying effects on each land use type and future land demand. The results from the three scenarios suggest that the current trends of land use in Nigeria are unsustainable and adopting a system that takes into consideration changing market trends and environmental protection is needed for the accelerated and sustainable socio-economic development of Nigeria.

REFERENCES

1) Fasona M.J. (2007). Land Degradation And Environmental Change In Ondo State, South-West Nigeria.
2) Idowu I.A. (2012). *An Assessment Of Land Use/ Land Cover Changes In A Section Of Niger Delta, Delta, Nigeria.* Zaria, Kaduna, Nigeria: Department Of Geography, Ahmadu Bello University.
3) Verburg, P.H.; Schot, P.P.; Dijst, M.J.; Veldkamp, A. Land use change modelling: Current practice and research priorities. *Geojournal* **2004**, *61*, 309–324.
4) Kidron, G.J.; Karnieli, A.; Benenson, I.; Grinblat, Y. Simulating land-use degradation in West Africa with the ALADYN model. *J. Arid. Environ.* **2015**, *112*, 52–63.
5) Han, H.; Yang, C.; Jinping, S. Scenario Simulation and the Prediction of Land Use and Land Cover Change in Beijing, China. *Sustainability.* **2015**, 7, 4260-4279.
6) Pei, B.; Pan, T. Land use system dynamic modeling: literature review and future research direction in China. *Prog. Geogr.* **2010**, *29*, 1060–1066.
7) Arsanjani, J.J.; Helbich, M.; Kainz, W.; Boloorani, A.D. Integration of logistic regression, Markov chain and cellular automata models to simulate urban expansion. *Int. J. Appl. Earth Obs. Geoinf.*2013, *21*, 265–275.
8) Parker, D.C.; Manson, S.M.; Janssen, M.A.; Hoffmann, M.J.; Deadman, P. Multi-agent systems for the simulation of land-use and land-cover change: A review. *Ann. Assoc. Am. Geogr*. **2003**, *93*, 314–337.
9) Usgs. (2015). Retrieved 02 27, 2018, From Https://Eros.Usgs.Gov/Westafrica/Land-Cover/Land-Use-Land-Cover-And-Trends-Nigeria
10) The National Bureau of Statistics (2018). Internally Generated Revenue at State level for 2017 Fiscal year. Retrieved 05 19, 2019, from www.nigerianstat.gov.ng
11) Ighile E.H and Shirakawa. H. (2020). A Study On The Effects Of Land Use Change On Flooding Risks In Nigeria.http://technicalgeography.org/pdf/1_2020/08_ighile.pdf.
12) Lu, R.C.; Huang, X.J.; Zuo, T.H.; Xiao, S.S.; Zhao, X.F.; Zhang, X.Y. Land Use Scenarios Simulation Based on CLUE-S and Markov Composite Model—A Case Study of Taihu Lake Rim in Jiangsu Province. *Sci. Geol. Sinica,* **2009**, *29*, 577–581.
13) CLUE Model; Verburg and Overmars, 2009. Landscape Ecology 24(9) 1167-1181.
14) Verburg, P.H.; Soepboer, W.; Veldkamp, A.; Limpiada, R.; Espaldon, V.; Mastura, S.S. Modeling the spatial dynamics of regional land use: The CLUE-S model. *Environ. Manag*. **2002**, *30*, 391–405.

(Received June 19, 2020)