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Dynamics of Peri-Urban Land Use Structure in the Period 2000-2022 in Ilorin, Nigeria

John Olayemi Afolayan [a*] and Michael Adedayo Adebayo [a]

[a] *Estate Management Department, Federal University of Technology Akure, Ondo State, Nigeria.*

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: To analyze the trend of peri-urban spatial growth structure between 2000 and 2022 in a rapidly urbanizing peri-urban area in Ilorin, Kwara State, Nigeria.
Study Design: Longitudinal survey research.
Place and Duration of Study: Eyenkorin, Kwara State 2022.
Methodology: The spatial data was obtained from the Google Earth Engine Data Catalog, and machine learning algorithm was used to extract and classify three main land uses. Quantitative data was also simulated with the use of the Transitional Matrix that looked at the most likely path taken by the growth structure as it transitioned from one land use to another. The spatial growth structure was examined on a 12-year interval of 2000 – 2011; 2011 – 2022 and 2000 – 2022.
Results: The study revealed that the present spatial structure of Eyenkorin (as at 2022) is majorly dominated by vegetation land/agricultural land Area 71.81 km^2 (37.1%), followed by built-up land 79.77 km^2 (33.4%) and bare land/ natural land 63.42 km^2 (27.5%). The study revealed that the most dominant transition in the growth structure within the study time frame (2000 – 2022) is the built-up land which increased by 44.29 km^2 (160.94%) and the most dominant loss is from vegetation land/agriculture land which decreased by 75.09 km^2 (-48.49%).

**Corresponding author: E-mail: afolayan.j.olayemi@gmail.com;*

Conclusion: The findings of the study attests to the vulnerability of the non-built up land (agricultural land and bare land) that metamorphose into built-up land at the peripherals. In the next few years, it can be predicted that excessive unguided land development would have caught-up completely with the peripheral lands at the detriment of placing more need on the preservation of the environment. Government in developing countries should have a concrete development plan that actively controls the unhabitual expansion at the peripherals if sustainable land use and management will be achieved at the Peri-Urban.

Keywords: Peri-Urban; land use; spatial structure; expansion.

1. INTRODUCTION

The tendency toward urban growth has evolved over time, taking on numerous forms and patterns. As cities grew during the Middle Ages, city walls were enlarged, and as transportation became more accessible during the Industrial Revolution, the radius of urban settlements significantly increased [1]. Urban growth has been greatly aided by the improved transformation of city centers brought about by increased economic growth and technological advances since the late 19th century. Urban expansion has been specifically identified in Nigeria by the intensification of land usage, which has led to changes in the urban spatial structures inside the previously developed portions of cities and the outward extension of the developed portions towards the periphery [2]. When this happens, the nearby grasslands, forest environments, and agricultural lands get developed into residential, commercial, industrial, and other types of built-up developments [3].

In many developed nations, the increase in land usage is frequently regulated [4]. However, limited voice in urban planning and development in many developing nations, such as Nigeria; results in dispersed developments and the unplanned growth of peripheral regions. Many commercial and manufacturing expansions into the peri-urban area are institutionally supervised, but many residential settlements brought about by urban sprawl from city centers and unauthorized settlements are often disregarded [5]. As a result, there isn't a well-organized process for land usage in the peripheral regions. This has some effects on the physical, economic, environmental and social aspects of such a peri-urban area. This includes, an enormous decline in vegetation and open space, the encouragement and the development of dispersed human settlements among other things. As a result, a sustainable land use and management system is required for urban growth in peri-urban areas of these developing countries.

Globally, studies have been conducted on the subject of peri-urban land use change. [6] investigated Bangkok's peri-urban area and its changing patterns of settlement. The study made clear that Bangkok's peri-urban districts had reached an advanced level of urbanization, as exhibited by the swift rise of built-up areas. This is caused by the increase in the population of people in these areas and the shift in the economy's foundation from agriculture to other sectors. Mainly along major roadways, built-up areas are found. The growth of built-up areas is a reflection of the changes in land use patterns, which are now more concentrated and have higher densities.

Li et al. [7] investigated the factors influencing urban growth in Beijing, China. It was discovered that, throughout the last forty years, Beijing's urban area has grown remarkably and quickly. This expansion has been impacted concurrently by physical, socioeconomic, and neighborhood factors. Except between 1972 and 1984, socioeconomic concerns were the main motivating factor.

Kuang et al. [8] in a comparison of the growth of megacities in China and the United States. It was discovered that in the last thirty years, Chinese megacities have grown to be five times bigger than their American counterparts. Especially during the first ten years of the twenty-first century, when they became up to eleven times larger. Particularly in Beijing and Shanghai, the Chinese megacities spread outward from the CBD to the periphery in circles, which causes urban areas to rapidly increase. In contrast, American megacities grow mostly from the core city centres with blotch patterns; as a result, the size of the urban area has stayed constant.

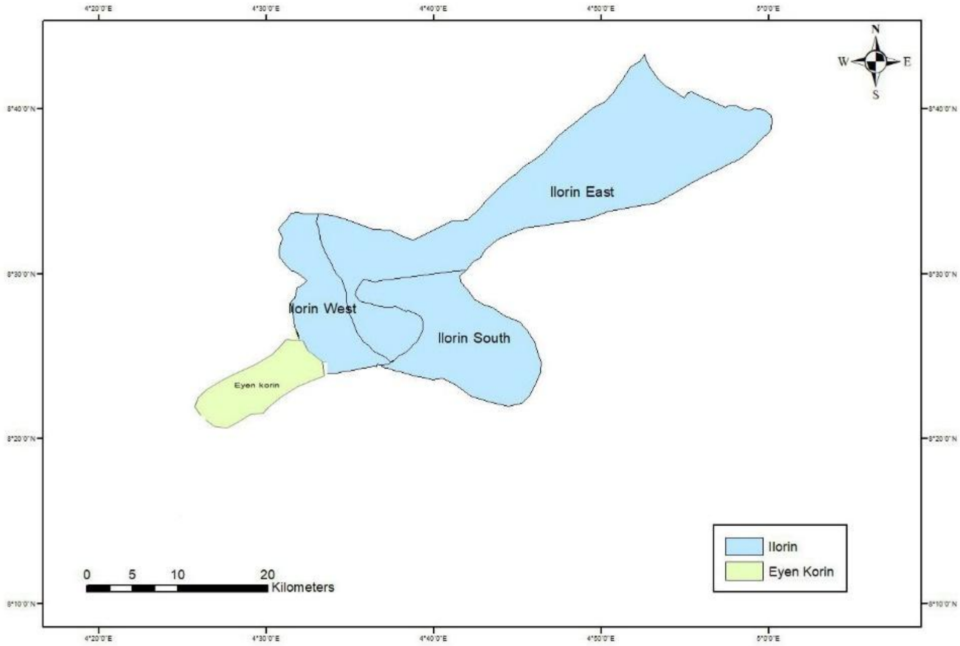


Fig. 1. Map of ilorin highlighting eyenkorin

Source: Department of geography, University of Ilorin, Kwara State (2020)

Gibson et al. [3] examined the urban land growth in India between 1992 and 2012 in 47 agglomerations with a minimum of one million inhabitants as of the 2011 census. The 47 agglomerations grew by roughly 16,000 sq. km, in accordance with a yearly expansion rate of 2.4%. Only 25% of the area that was agricultural land metamorphosed into urban use; the majority was previously woodland, shrub, or grassland. Agglomeration expansion rates vary, but they are highest in the southern region of India and in regions with shorter growing seasons.

Wang and Maduako [9] examined the dimensions of urban expansion in Lagos, Nigeria between 1984 and 2015. According to the research, the amount of developed land grew from 367.99 km^2 to 1,393.98 km^2 in the period of study. Over the same time period, the area of undeveloped land declined from 3,707.04 km^2 to 2,607.95 km^2. The study also found that, starting in 2000, the Lagos metropolitan area's expansion entirely surpassed Lagos State's administrative borders and reached the neighboring state of Ogun. Numerous Ogun State neighboring towns and localities have been included in the expansive and continuous urban augmentation.

Ayele and Tarekegn [10] investigated how urbanization growth affected agricultural land in Kutaber, Ethiopia. It was found that downtown have been physically spreading into satellite areas by developing more land in places where people had previously relied on agriculture as their primary source of livelihood as land demand increased over time. It was highlighted that urbanization had increased demand for the peri-urban land that peri-urban farmers had been holding informally and illegally.

Bakoji et al. [11] examined land use types and the effects of urbanization in Makurdi, Nigeria. The built-up area rose from 116 square kilometers to 452 square kilometers between 1984 and 2014, whereas the natural vegetation declined from 263 square kilometers to 95 square kilometers and the agricultural land decreased from 620 square kilometers to 420 square kilometers. In order to develop solid and efficient urban policies, the study underlined the need to comprehend the structural dynamics of urbanization. For potential crises to become opportunities, such policies must be modern. Similar to how agricultural lands are being rapidly converted to urban space, urban land use planning systems should incorporate agricultural areas as a necessary component of urban development.

All of the reviewed literature confirms the consistency of urban expansion in peri-urban areas, both locally and globally. However, depending on the political and institutional framework of land use management in these locations, the technique of land use transitioning and its pattern vary from one location to another.

As none of the examined research were conducted in Ilorin, Kwara State, this study concentrated on patterns in peri-urban growth structure there. A rapidly growing city like Ilorin, where land usage and occasionally communities might be tied by strong cultural and religious ties, needs to be examined. Eyenkorin was picked because it has undergone substantial urban expansion initiated from the core city centre of Ilorin. Eyenkorin lies beyond the borders of the Ilorin International Airport and also serves as the location for various manufacturing industries and religious campgrounds. This study was restricted to the beginning of the 21st century as the major land transformation due to urban expansion, has been more rapid since then.

2. METHODOLOGY

The spatial data was obtained from Google Earth Engine Data Catalog. Satellite imageries of Eyenkorin covering 2000, 2011 and 2022 were used for peri-urban growth structure. Remote Sensing and GIS techniques were employed. Satellite imageries, image processing and classification techniques were used in extracting the information needed. For image classification training set, three classes of features were adopted, which are: Built-up area; vegetation/agriculture and bare land/forest. These training sets were later transposed to ArcGIS 10.3 software to compose the graticules, legend, scale bar and the true north. The procedures for obtaining the data are revealed in Fig. 2. They are:

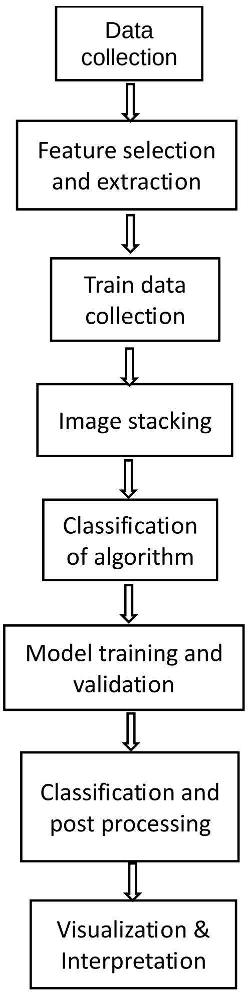


Fig. 2. Procedure for the spatial data processing and classification
Source: Field survey, 2022

2.1 Data Collection and Preparation

This was carried out by Identifying and acquiring relevant satellite imagery for the study area from Google Earth Engine Data Catalogue and to ascertain that the imagery covers the spatial-temporal band required for the Region of Interest (ROI) - Eyenkorin.

2.2 Feature Selection and Extraction

This was the choice of the spectral bands that was relevant for spatial classification to describe with colours a large set of data accurately. This may include red, green, blue, near-infrared (NIR), and short-wave infrared (SWIR). Also, the extraction was carried out by calculating the Normalized Difference Built-up Index to enhance the discrimination of spatial classification.

2.3 Training Data Collection

This was the collection of training data points by creating a set of points within the Region of Interest and the assigning of each training point a corresponding land cover classification label. The three major label for this study were Built-up, vegetation/agriculture and bare land.

2.4 Image Stacking

This was carried out by stacking the pre-processed spectral bands into a single image collection as input for the classification algorithm.

2.5 Classification Algorithm

Machine learning algorithm was then used to split the training data into training and validation datasets to assess the accuracy of the classification.

2.6 Model Training and Validation

The chosen classification model was trained using the training dataset. This was carried out by using a trainset of 80% and a testset of 20%.

2.7 Classification and Post-processing

The trained model was applied to the entire image collection to obtain the spatial details for the entire region of interest. It was then post-processed to remove small noise patches and perform any necessary smoothing.

		Time t+1				
		Category 1	Category j	Category J	Total Y_t	Loss of i
Time t	Category 1	C_{t11}	C_{t1j}	C_{t1J}	$\sum_{j=1}^{J} C_{t1j}$	$\sum_{j=1}^{J} C_{t1j} - C_{t11}$
	Category i	C_{ti1}	C_{tij}	C_{tiJ}	$\sum_{j=1}^{J} C_{tij}$	$\sum_{j=1}^{J} C_{tij} - C_{tii}$
	Category J	C_{tJ1}	C_{tJj}	C_{tJJ}	$\sum_{j=1}^{J} C_{tJj}$	$\sum_{j=1}^{J} C_{tJj} - C_{tJJ}$
	Total Y_{t+1}	$\sum_{i=1}^{J} C_{ti1}$	$\sum_{i=1}^{J} C_{tij}$	$\sum_{i=1}^{J} C_{tiJ}$	$\sum_{j=1}^{J}\sum_{i=1}^{J} C_{tij}$	$\sum_{i=1}^{J}\left(\sum_{j=1}^{J} C_{tij} - C_{tii}\right)$
	Gain of j	$\sum_{i=1}^{J} C_{ti1} - C_{t11}$	$\sum_{i=1}^{J} C_{tij} - C_{tjj}$	$\sum_{i=1}^{J} C_{tiJ} - C_{tJJ}$	$\sum_{j=1}^{J}\left(\sum_{i=1}^{J} C_{tij} - C_{tjj}\right)$	

Fig. 3. Format for transitional matrix as adopted from [12]

2.8 Visualization and Interpretation

The spatial details were then visualized to interpret the results and to identify potential misclassifications. Also, make adjustments to the classification parameters or retrain the model to improve accuracy if needed.

Additionally, using Transitional Matrix, the data was simulated in order to examine the transition path of the spatial growth structure from one land use to another across the time interval of the study. A prototype of the transitional matrix is revealed in Fig. 3, which examined the gain and loss of 3 categories across one time frame. However, in this study, three different time frame were analyzed for the transitional matrix. They are; 2000 to 2011; 2011 to 2022; and 2000 to 2022.

3. RESULTS AND DISCUSSION

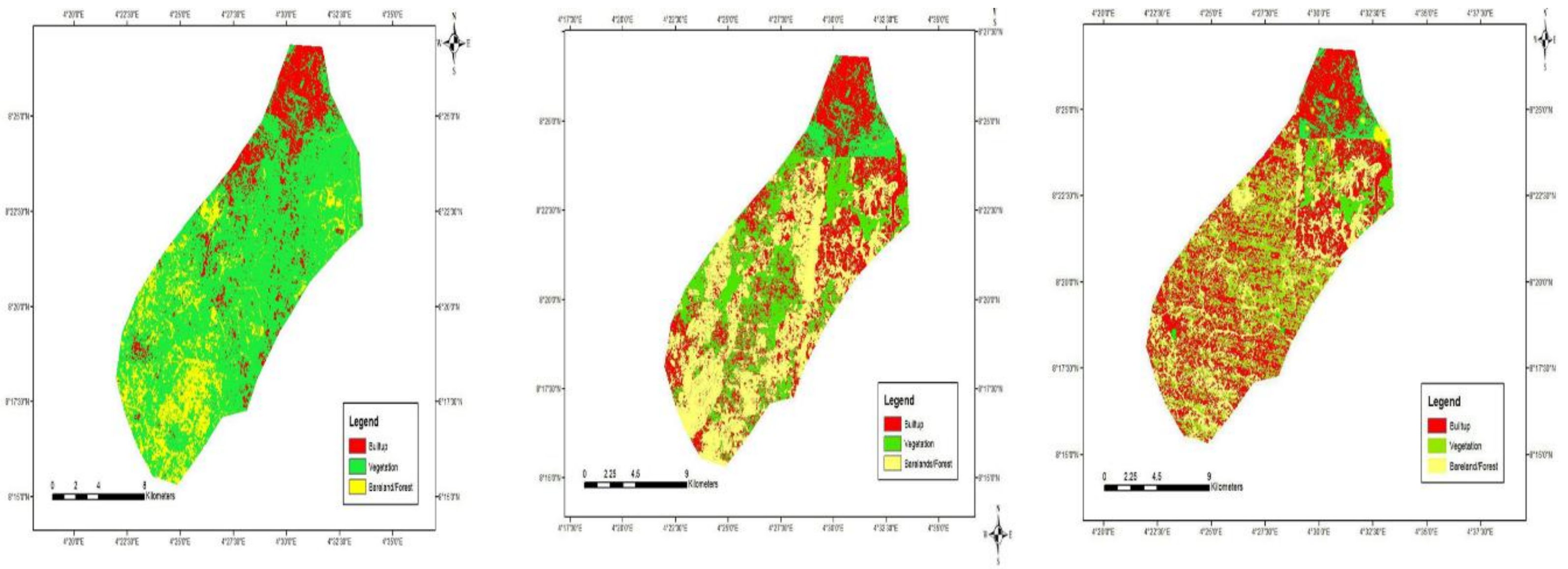
Fig. 4 and Table 1 show the spatial distribution of land use classification for the three time periods for Eyenkorin. It was discovered that in 2000, bare land/natural land made up 32.62 km2 (15.17 percent of the total area), vegetation/agricultural land covered 154.86 km2, and built-up land covered 27.52 km2 (12.80% of the total area). As of 2011, it was found that the total area was divided as follows: Bare land/natural land covered 91.38 km2 (42.50% of the total area), vegetation/agricultural land covered 68.37 km2 (31.80% of the total area), and built-up land covered 55.25 km2 (25.70% of the total area).

Table 2 shows that during period 1(2000-2011), built-up had a net gain of 27.73 km^2 (100.76%). Vegetation and agricultural land had a net loss of 86.49 km^2 (-55.85%) and bareland/natural land had a net gain of 58.76 km^2 (180.13%). The major feature during the period 1 was the magnamanimous loss of vegetation and agricultural land which was due to the increase in urban expansion. However the most gain was not the built-up area but the bareland/natural land which indicates that purchase of the land for speculation and development projects that did not commence, individual personal interest amongst others where dominant between 2000 and 2011, because there were not situation of political insecurity in the study area.

Furthermore, during period 2 (2011-2022) built-up additionally had a net gain of 16.56 km^2 (29.97%), vegetation and agricultural land had a net gain of 11.40 km^2 (16.67%) and bareland/natural land had a net loss of 27.96 km^2 (-30.60%). The major feature during the period 2 was the drastic loss of bareland/ natural land, accompanied by increase in vegetation and agricultural land and also increase in the built-up land showing consistency in the urban expansion. Hence, because of the increase in the built-up land which will be accompanied by increase in population at the location, the vast expanse of bareland/ natural land was quite substituted for more vegetation/agricultural land use.

However, period 3 (2000-2022) gives an holistic perception to the trend of growth structure at Eyenkorin. Built-up land had a net gain of 44.29 km^2 (160.94%), vegetation and agricultural land had a net loss of 75.09 km^2 (-48.49%) and bareland/natural land had a net gain of 30.80 km^2 (94.42%). Hence even though vegetation and agricultural land had the most loss, it is still the most dominant land use at Eyenkorin. Also, justapoxing the built-up land that have almost tripled it original size of 2000 and the transitioning of the vegetation land, there is high tendency that a substatial amount of the bare/land and vegetation land are used for things like land speculation and other personal interest of the owners.

For the period 1 (2000-2011), the table indicates that the change that cumulated to the built-up area emanated from the previous built-up consisting 50% (0.50) of 2011. Vegetation/agriculture land that transited into the built-up consisted 38% (0.38) while bare land/natural land consisted 12% (0.12) of the built-up area in 2011. The probability of change that cumulated to the vegetation/agricultural area in 2011 from 2000 emanated from the previous existing vegetation/agricultural area consisting 83% (0.83) of 2011. The bare land/natural land that transited into the vegetation/agricultural consisted 17% (0.17). However, there was not significant change from the built-up area to vegetation/agricultural 0% (0.00). The probability of change that cumulated to the bare land/natural land in 2011 from 2000 emanated from the previous existing vegetation/agricultural area consisting 63% (0.63) of 2011. The bare land/natural land retained as bare land/natural land consisted 37% (0.37). However, there was no significant change from the built-up area to bare land/natural land 0% (0.00).



(a) Spatial structure 2000 **(b) Spatial structure 2011** **(c) Spatial structure 2022**

Fig. 4. Spatial structure of Eyenkorin in 2000, 2011 and 2022

Source: Google earth engine data catalog: 2000, 2011 and 2022 respectively

Table 1. Area statistics of spatial structure in 2000, 2011 and 2022 at Eyenkorin

Land Classification	2000		2011		2022	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Built-up	27.52	12.80	55.25	25.70	71.81	33.40
Vegetation	154.86	72.03	68.37	31.80	79.77	37.10
Bare land/Natural	32.62	15.17	91.38	42.50	63.42	29.50
Total	**215**	**100**	**215**	**100**	**215**	**100**

Source: Field survey, 2022

Table 2. Trend of growth structure between 2000 and 2022 at Eyenkorin

Land Classification	2000 (km^2)	2011 (km^2)	2022 (km^2)	Period 1 (2000-2011) (km^2)	Period 2 (2011-2022) (km^2)	Period 3 (2000-2022) (km^2)
Built-up	27.52	55.25	71.81	+27.73 (100.76%)	+16.56 (29.97%)	+44.29 (160.94%)
Vegetation/Agricultural	154.86	68.37	79.77	-86.49 (-55.85%)	+11.40 (16.67%)	-75.09 (-48.49%)
Bare land/Natural	32.62	91.38	63.42	+58.76 (180.13%)	-27.96 (-30.60%)	+30.80 (94.42%)

Source: Field survey, 2022

Table 3. Transitional matrix for the spatial structure transitionings between 2000 - 2022 at Eyenkorin

Year	Land Classification	Built-up	Vegetation	Bare land/Natural
2000-2011	Built-up	0.50	0.00	0.00
(Period 1)	Vegetation	0.38	0.83	0.63
	Bare land/Natural	0.12	0.17	0.37
	Total	**1.00**	**1.00**	**1.00**
2011-2022	Built-up	0.70	0.00	0.01
(Period 2)	Vegetation	0.11	0.45	0.35
	Bare land/Natural	0.19	0.55	0.64
	Total	**1.00**	**1.00**	**1.00**
2000-2022	Built-up	0.38	0.00	0.01
(Period 3)	Vegetation	0.47	0.43	0.52
	Bare land/Natural	0.15	0.57	0.48
	Total	**1.00**	**1.00**	**1.00**

Source: Field survey, 2022

For the period 2 (2011-2022), the table indicates that the change that cumulated to the built-up area emanated from the previous built-up consisting 70% (0.70) of 2022. Vegetation/agriculture land that transited into the built-up consisted 11% (0.11) while bare land/natural land consisted 19% (0.19) of the built-up area in 2022. The probability of change that cumulated to the vegetation/agricultural area in 2022 from 2011 emanated from the previous existing vegetation/agricultural area consisting 45% (0.45) of 2012. The bare land/natural land that transited into the vegetation/agricultural consisted 55% (0.55). However, there was no significant change from the built-up area to vegetation/agricultural 0% (0.00). The probability of change that cumulated to the bare land/natural land in 2022 from 2011 emanated from the previous existing vegetation/agricultural area consisting 35% (0.35) of 2022. The bare land/natural land retained as bare land/natural land consisted 64% (0.64). However, there was little significant change from the built-up area to bare land/natural land 1% (0.01).

For the period 3 (2000-2022), the table indicates that the change that cumulated to the built-up area emanated from the previous built-up area consisting 38% (0.38) of 2022. Vegetation/agriculture land that transited into the built-up area consisted 47% (0.47) while bare land/natural land consisted 15% (0.15) of the built-up area in 2022. The probability of change that cumulated to the vegetation/agricultural area in 2022 from 2000 emanated from the previous existing vegetation/agricultural area consisting 43% (0.43) of 2000. The bare land/natural land that transited into the vegetation/agricultural consisted 57% (0.57). However, there was not significant change from the built-up area to vegetation/agricultural 0% (0.00). The probability of change that cumulated to the bare land/natural land in 2022 from 2000 emanated from the previous existing vegetation/agricultural area consisting 52% (0.52) of 2022. The bare land/natural land retained as bare land/natural land consisted 48% (0.48). However, there was little significant change from the built-up area to bare land/natural land 1% (0.01), as built-up land is not often converted to vegetation nor natural land/bare land.

4. CONCLUSION

From 2000–2011, there was a rapid increase in the built-up land. However, the dominant land use classification was bare land/natural land in the study area. The shrink in agricultural land may be link to urban expansion leading to activities like land speculation and other activities leading to be abandonment of agricultural land for other urban land use at the peripheral lands. It was also discovered that till 2022, built-up lands had the most consistent growth (160.94%) while other land use dwindled because the urban expansion forced land use succession on the peripheral lands.

This study's findings confirm that bare land and agricultural land are more vulnerable to built-up areas at the periphery. At the periphery, a sizable portion of the land mass is still undeveloped. However, it may be projected that excessive unplanned land expansion will have entirely caught up with the periphery areas in the next few years, necessitating a greater need for environmental preservation. Therefore, the problem of poor land use planning is a beckoning for the government to establish and implement a balanced, inclusive urban development and land use policy for the sustainable use of the land because the maintenance of agricultural areas and forested areas next to urban areas is a necessary component for the livelihood of cities. Hence, the increase in bare land resulting from deforestation or abandonment of former agricultural areas is a land depreciation factor that should be accounted for in real estate speculation due to losses generated to the environment, and the need for a balanced, inclusive and sustainable use of land, especially because of the accelerated and intense urban growth. Additionally, the performance of the land use development plans should be reviewed and evaluated on a regular basis in relation to what is anticipated and what is occurring in the peri-urban neighbourhoods.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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