Evaluating Urban Sprawl and Land Consumption Rate in Ilorin Metropolis Using Multitemporal Landsat Imagery

[*1]Idrees M. O, [1]Adepoju B. D, [1]Ipadeola A. O, [1]Omar D. M, [12]Alade A. K & [1, 3]Salami I. B

[1]Department of Surveying and Geoinformatics, University of Ilorin, Ilorin
[2]Department of Architecture, Planning, and Geomatics, University of Cape Town, Cape Town, South Africa.
[3]Geospatial Imaging and Information Research Group (Gi2RG), Department of Geoinformatics, Universiti Tecknologi Malaysia, Johor Bahru, Malaysia.
[*]Correspondence: dare.idrees@gmail.com & mohammed.oi@unilorin.edu.ng

Received: 30/10/2021 **Revised: 02/02/2022** **Accepted: 15/02/2022**

This study examines the rate and pattern of urban expansion from 1991 to 2021 using Landsat imageries of 1991, 2002, and 2021. First, the images were classified into a built-up area, open land, vegetation, and water bodies utilizing the supervised Maximum Likelihood classification algorithm. Subsequently, the classified images were used to determine land use/cover change between 1991 and 2002, and also between 2002 and 2021. The result has shown that the city expands radially from 1916.77 ha in 1991 to 3284.82 ha in 2002, and 8770.79 ha in 2021, representing 5.84%, 10%, and 26.72%, respectively, at a growth rate of 9.98% (1991-2002) and 40.02% (2002-2021). It is equally revealed that between 1991 and 2021, the vegetated land decreased from 56.33% to 20.64% whereas the open land from 36.4% to 51.52%. This study allowed measuring the pattern and rate at which urban expansion had occurred in Ilorin. The pattern of sprawling in Ilorin is radial with amplified development along the major roads that lead to the city. This has largely impacted the natural ecosystem and associated environmental problems, including soil degradation, erosion, and reduction in the available land for crop production. It is, therefore, important to implement sustainable measures that evolve policies stimulating urban regeneration, integrated into the ongoing development of Kwara State geographic information system (GIS) to effectively plan, allocate land resources, and monitor development in near real-time.

Keywords: Monitoring, Urban sprawl, Urbanization, Remote Sensing, change detection, urban renewal.
DOI: https://dx.doi.org/10.4314/etsj.v12i2.4

INTRODUCTION

Urban sprawl is one of the foremost threats facing agricultural lands in Nigeria. According to Barnes et al. (2001), at a metropolitan scale, Sprawl may be said to occur when the rate at which land is converted to nonagricultural or non-natural uses exceeds the rate of population growth. Studies have identified unplanned changes in land use and land cover due to urban expansions as a major problem (Owoeye & Akinluyi, 2018). Urban sprawl has been criticized for eliminating agricultural lands, impairing water quality, instigating air pollution, and consuming green space (Allen & Lu, 2003). Unfortunately, in Nigeria, like many other emerging cities in Africa, cities emerge without a clear and logical planning process and also with very little attention to the environmental impacts.

The obvious consequences of this manifest in the aggravated deforestation, soil erosion and degradation, desertification, and destructive flood disaster witnessed in most cities in recent decades (Babatunde, et al., 2014; Jibril & Liman, 2014; Olanrewaju, 2009).

Since the last century, rapid urbanization has constituted a great threat to sustainable urban development. According to the United Nation report of May 2018, New York, it is projected that by 2050, 68% of the human population will be living in the cities (Safder, 2019). As the population increases, so does the need for new housing, and other infrastructural facilities. This will certainly have a downward effect on the available land for crop production and eventually food security. The case of the city (Ilorin) in this investigation provides a good platform to examine the impact of urban sprawl. Ilorin, the Kwara State capital, has witnessed remarkable expansion, growth, and developmental activities since it became the Capital city in 1967 (Babatunde *et al*., 2014). This development has brought about an increase in population and human activities, land-use change, and by extension, a rapid expansion that has not only impacted the socio-economic dynamics of the area but has also affected various land uses, particularly the agricultural land.

In Nigeria, several studies have examined various aspects of environmental change, particularly land cover change (e.g., Ujoh *et a*l., 2010; Aguda & Adegboyega, 2013; Oloukoi *et al*., 2014; Chunwate *et al*., 2019; Purwani & Arvianti, 2020). However, recent and up-to-date studies on the effects of urban sprawl on agricultural land are few in the literature. The present study, this study aims at assessing urban sprawl in Ilorin and its impact on the environment over the last three decades using geo-information technologies, remote sensing (RS), and geographic information system (GIS). These technologies are veritable tools for monitoring urban growth and its management (Olaleye *et al*., 2012; Purwani, & Arvianti, 2020). Remote sensing data provides historical information about the biophysical characteristics of the environment useful for monitoring, determining, and evaluating changes on the Earth's surface over time (Owoeye & Akinluyi, 2018). This, therefore, makes the remote sensing data an effective means of assessing urban growth.

MATERIALS AND METHODS

Description of Study Area and Data Used

Ilorin, situated in the North Central geopolitical zone of Nigeria, is the capital city of Kwara State. According to the 2019 Revision of World Population Prospects by the United Nations Department of Economic and Social Affairs Population Dynamics projected for 2021 (https://population.un.org/wpp/), the city has an estimated population of *974,000* inhabitants spread over a total area of 764.046 km^2 with a population density of 1188 per square kilometre. Geographically, Ilorin is located between 4^o 32'00" E and 8^o 30'00" N shared by three Local Government Areas: Ilorin East, Ilorin South, Ilorin West (Figure 1). The modern Ilorin city has witnessed tremendous growth in the industrial, commercial, and educational sectors (Idrees *et al*., 2022). The city hosts the University of Ilorin, Kwara State Polytechnic, the Federal Agricultural and Rural Management Training Institute (ARMTI), Teacher-training colleges, and vocational trade schools. Ilorin is served by the railway and highway from Lagos (160 miles south-southwest), via Ibadan, which intersects the city, and it has an international airport. Some of the major towns there include Ajikobi, Warrah Osin, Alannamu, Magaji Ngeri, Oloje, Pakata, Idi-Ape, and Oke-Lele.

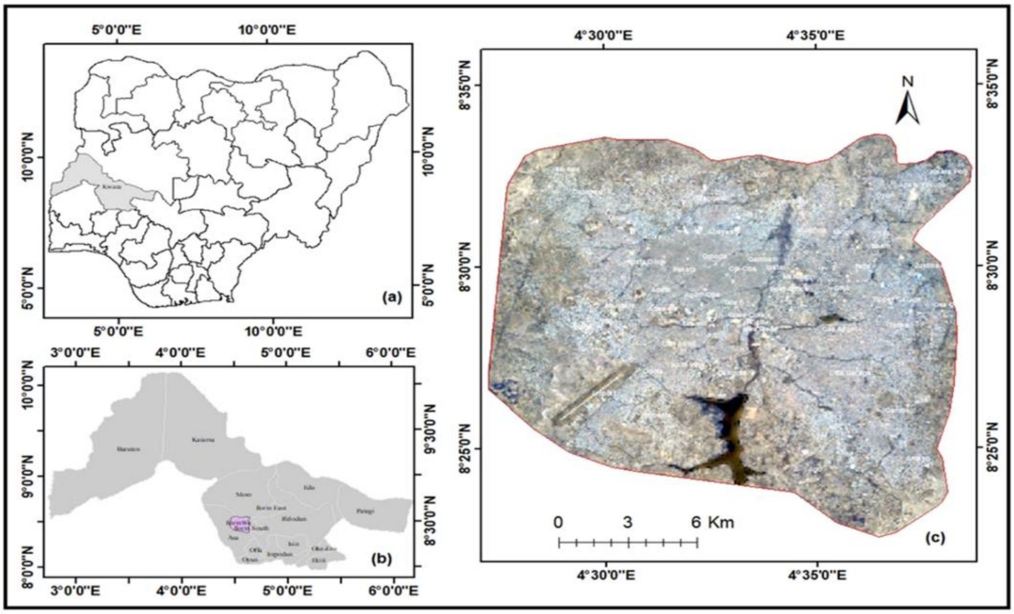


Figure 1: Location of the study area (a) Nigeria, (b) Kwara state, and (c) Landsat imagery of Ilorin Metropolis

In this study, Landsat 4 TM, Landsat 7 ETM, and Landsat 8 OLI TIRS images of the years 1991, 2002, and 2021 were obtained from the United States Geological Survey (USGS) data depository website (http://earthexplorer.usgs.gov) have been utilized (Table 1). In the GIS environment, a high-resolution Google Earth image of the study area was used as the base map for visual examination of the different land cover types and to derive training and validation points (Foody, 2002).

Table 1: Landsat images and date of acquisition

S/N	Data	Acquisition date	Scale
1	Landsat 4 TM	1991-01-05,	30m ™
2	Landsat 7 ETM	2002-04-25	30m ™
3	Landsat 8 OLI_TIRS	2021-01-15	30m ™

Data Processing

The Landsat product has been geocoded to the Universal Transverse Mercator (UTM) coordinates Zone 31, world geodetic system 1984 (WGS 84). The images were corrected for atmospheric errors and stripping (where necessary). Then, the composite image bands were generated which allows the right band combinations that reflect different surface features for the selection of training. Thereafter, the Landsat image of the respective period was classified into four land cover types (vegetation, built-up area, Open land, and water bodies) using the Maximum Likelihood Classification (MLC) algorithm (Ujoh et al., 2010; Ghosh et al., 2017). The Maximum-likelihood allows decisions about change to be made at the pixel level which minimizes the error criterion in the classified image over a large number of individual pixel classifications. Based on the prior knowledge of the study area, the classification scheme was developed using the modified Andersons land use/ land cover classification scheme (Anderson's modification 1967). Thus, the respective class was given a numerical value from 1 – to 4 (Table 2). Accuracy assessment is an integral part of any classification project. The accuracy assessment process compares the classified image to another data source called ground truth data which is considered to be of superior accuracy (Olofsson *et al*., 2014). For this study, high-resolution Google Earth image was used as base map for the Ground Truthing. Having provided satisfactory measure of accuracy, the classified images were utilized to analyze land use/cover change and how much change has occurred and the trend of change.

Table 2: Land use and land cover classification scheme

Code	LULC Category	Description
1.	Built-up lands	All residential, commercial, and industrial areas, village settlements, and transportation infrastructure
2	Vegetation covers	Trees, shrubland and semi nature vegetation, deciduous, coniferous, and mixed forests, palms, orchids, herbs, gardens, and grasslands
3	Open lands	Fallow land, earth and sand land infillings, construction sites, excavation site, solid waste landfills, open space and exposed soil, rocky areas, dry grasses, etc.
4	Water bodies	River, permanent open water, lakes, ponds, canals, and reservoirs

Data Analysis

The data analysis includes percentage change, land consumption rate (LCR), and land absorption coefficient (LAC) (Sharma et al., 2012). The comparison of the land use/cover class statistics aided in identifying the percentage change, trend, and rate of change between 1991 and 2021 (Tables 3, 4 and 5). From the percentage change, the trend of change was calculated by dividing the observed change by the total sum of changes multiplied by 100, expressed in Equation 1 (Sharma *et al*., 2012).

$$PCT = \left(\frac{OC}{SC}\right) * 100 \qquad (1)$$

where PCT is the percentage change (trend), OC is the observed change, and SC is the sum of change.

The LCR and LAC were computed using Equations (2) and (3) (Sharma et al., 2012). LCR describes the measure of progressive spatial urbanization of a study area whereas LAC provides a measure of change of urban land by each unit increase in urban population (Olaleye et al., 2012; (Sharma et al., 2012)). The Land consumption rate and absorption coefficient formula are provided in Equations (2) and (3).

$$LCR = \frac{A}{P} \qquad (2)$$

where LCR is l$and\ consumption\ rate$, A is the aerial extent of the city (in hectares), and P is the population.

Also, the absorption coefficient is obtained as:

$$LAC = \frac{\mathrm{A2} - \mathrm{A1}}{P1 - P2} \qquad (3)$$

where LAC is the land absorption coefficient, A1 and A2 are the aerial extents (in hectares) for the early and later years, and P1 and P2 are population figures for the early and later years, respectively (Sharma et al., 2012).

The 1991 and 2002 population figures of the city (Table 3) were estimated using the recommended National Population Commission (NPC) 2.6% growth rate the population census figure of 1991 and the projected population for 2002 based on the 1991 figure (Equations (4) and (5)) (Olaleye *et al*., 2012). The 2021 population figure was estimated using the United Nations population estimates at a growth rate of 2.53% pa

Table 3: Projected population **for** Ilorin

S/No	Year	Population	Growth Rate
1	1991	479,000	2.35%
2	2002	659,000	2.01%
3	2021	974,000	2.53%

$$n = \frac{r}{100} \times Po \qquad (4)$$

where n is annual population growth, r is the growth rate (2.6%) and P_o is base year population (2006 population figure). Similarly,

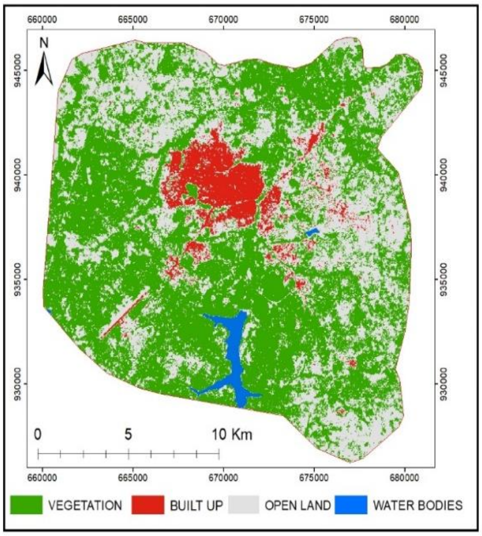
$$Pn = Po + (n \times t) \qquad (5)$$

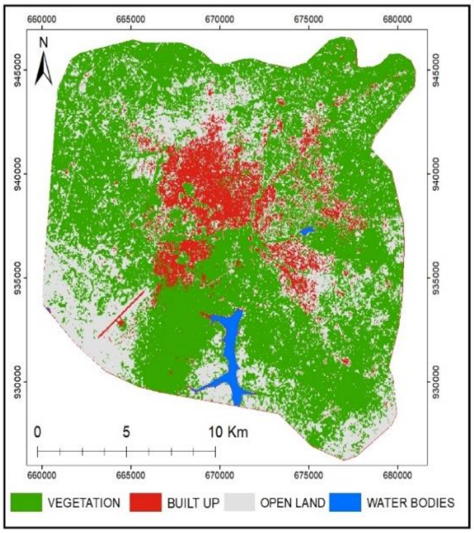
where Pn is estimated population (1991, 2021), n is annual population growth, and t is the number of years projecting for.

RESULTS AND DISCUSSION

Classification Results

Applying the MLC method, the land use/cover maps of 1991, 2002, and 2021 (Figure 2) were produced. For each of the maps, four distinct land use/cover classes are identified, these are vegetation, built-up area, open land, and water bodies. The class statistics for each year are presented in Table 4. Computation of the area each class occupies in the respective year allowed for detecting an increase and or reduction in land use/cover. From the quantitative analysis, a drastic reduction in vegetation land cover is detected between 1991 and 2021, compared to the built-up area and the open land that has shown extensive growth.





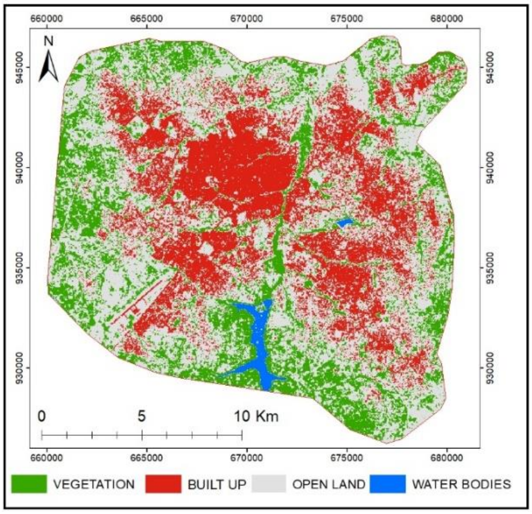


Figure 2: classified maps of (a) 1991, (b) 2002, and (c) 2021

Table 4: Land use/cover class statistics with their respective year

Land use/cover	1991	2002	2021
Vegetation	18489.92	20305.60	6774.94
Built-up	1916.77	3284.82	8770.79
Open land	11964.78	8863.96	16910.79
Water body	455.12	379.70	369.330

Change Analysis and Urban Sprawl

Comparison of the land use/cover maps and their statistics assisted in identifying changes, determining the trend, rate, and magnitude of change between 1991, 2002, and 2021 (Figure 3 and Table 5). In Figure 3, the rate of change in the respective land use/cover type across the years observed is shown. Between 1991 and 2021, the vegetation land cover has reduced from 56.33 % to 20.64% translating to a loss of 11714.98 hectares of land. Whereas, the open land and built-up area increased from 36.45% to 51.52% (4946.01 ha) and 5.84% to 26.72% (6854.02 ha), respectively. Unlike the other land cover categories, the water body remains relatively invariable (1.39% to 1.13%).

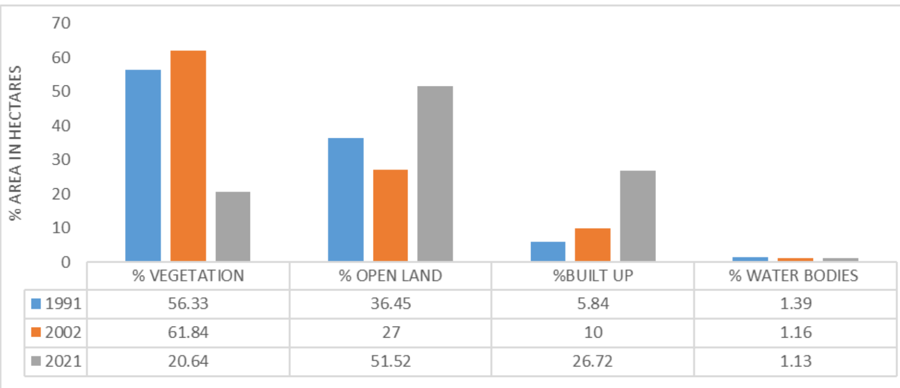


Figure 3: Land use/cover change pattern and percentage change

Table 5: Class area change and change trend

Year	Change between 1991 - 2002	2002 - 2021	1991 - 2021
Vegetation	1815.671	-13530.649	-11714.978
Built-up	1368.051	5485.966	6854.017
Open land	-3100.816	8046.828	4946.013
Water bodies	-75.427	-10.364	-85.791
% Change (Built-up)	9.98	40.02	50

The built-up class represents an urbanized area that provided an indicator of urban sprawl. From the analysis of the classified maps, it is evident that the city has expanded tremendously from 1916.77 ha in 1991 to 3284.82 ha in 2002, and 8770.79 ha in 2021 at a rate of 9.98%, 40.02%, and 50%, respectively (Tables 4 and 5). The city which appeared at the centre of the study area in 1991 has spread radially by approximately 12 km in 2021 (Fig. 4). Over 34 years, Ilorin has transformed into a metropolitan area of contemporary characteristics. The last two decades had witnessed a significantly rapid expansion in all directions. This may be attributable to the massive growth in industrialization, influx of higher institutions of learning, and consequently booming economic activities (Babatunde & Mayowa, 2014; El Garouani *et al.*, 2017; Oladehinde *et al.*, 2019) all of which are population pull factors. An increase in population brings about an increase in the demand for goods and services. This in turn puts pressure on environmental resources and invariably threaten the urban sustainability.

Another factor that influences widespread development is the topography. Ilorin has a relatively low relief landscape and flat to a low surface slope that minimizes the cost of construction and provides ease of transportation (Ajadi *et al*., 2011). Nevertheless, the growth recorded has resulted in a significant loss in vegetation and an increase in urban-related hazards. The rate of deforestation poses a major threat to biodiversity. For example, many plant and animal species are now extinction due to the loss of their habitat. In recent history also, the city has experienced sustained flooding events with great impacts on the socio-economic lives of the inhabitants (Babatunde & Mayowa, 2014).

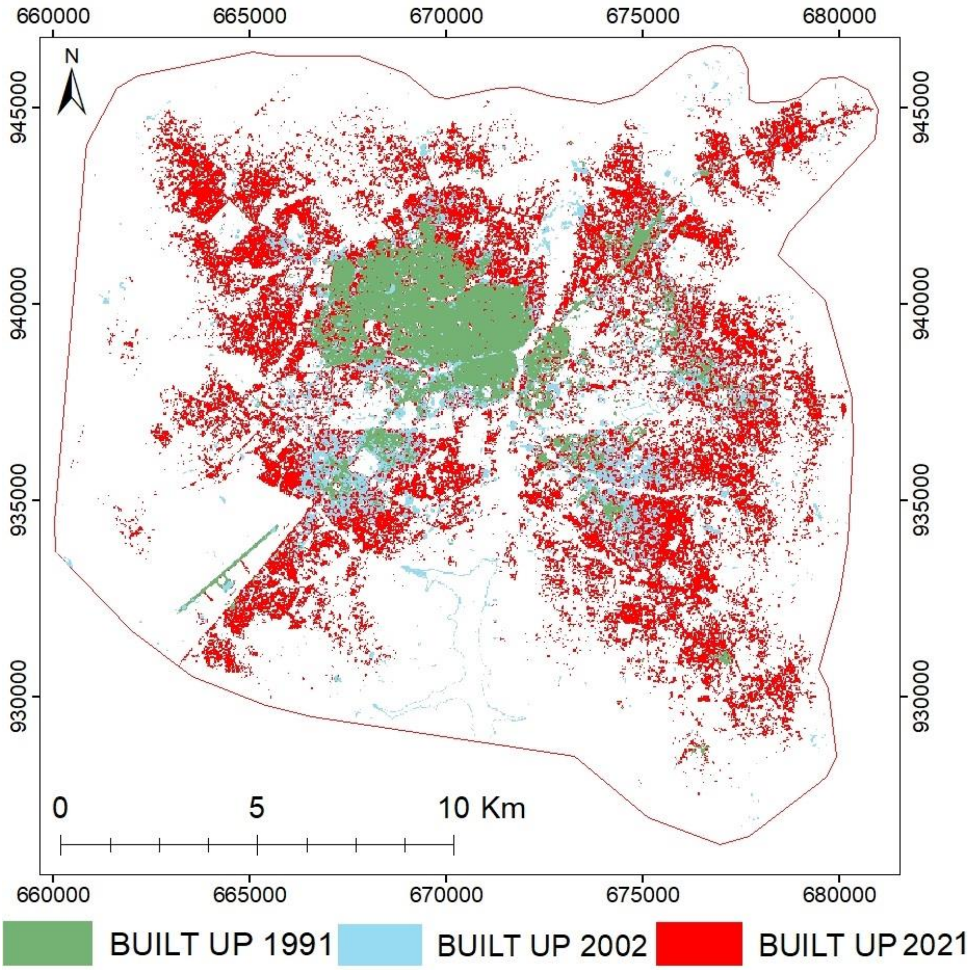


Figure 4: Urban sprawl pattern

The study reveals that the LCR for the years 1991, 2002, and 2021 is 0.004, 0.005, and 0.009, respectively. It was high till 2002 but slightly increased during 2002–2021 (see Table 6). The study shows the trend of increasing LCR is probable in near future. Furthermore, it indicates that the maximum urban area in the study area was used during 2021 since the LCR is relatively higher compared with the period 1991–2002. The study has shown that population growth and accelerated physical development are the main factors driving land use and expansion of built-up land in the suburb.

The findings of this study also indicate that the LAC for the periods 1991–2002 and 2002–2021 is 0.008 and 0.017, respectively (Table 6). The LAC reduced during the period 1991–2002 and increased during 2002–2021, indicating that during the former period (1991–2002) the population was mostly concentrated within the city, but thereafter spreads outward to provide an open space settlement as opposed to the densely populated neighbourhood. It equally suggests that the rate at which landed properties were acquired for developmental purposes is quite high for Ilorin city.

Table 6: LCR for the study period and LAC with time interval

LCR		LAC	
1991	0.004	1991/2002	0.008
2002	0.005	2002/2021	0.017
2021	0.009		

CONCLUSION

The objective of this study is to determine urban sprawl, trend, and the LCR and LAC using multitemporal Landsat datasets. The geospatial techniques provide accurate, cost-effective, and spatial dynamics of the land cover from 1991 to 2021. The methodology employed in this study, along with ground-truthing and field inventory will be useful in understanding the land use development, future planning, and proper management. The study indicates that changes have been taking place in the study area in the form of urban sprawl on the outskirts of the city particularly during the recent two decades. It is revealed that the changes and expansion observed occurred radially in all directions in a pattern indicative of development that trails linearly along entry routes to the city. The study further revealed that much of the agricultural and forest lands have been lost to urban expansion during the period under investigation. Thus, this study advocates the integration of urban renewal into the current strive to evolve a GIS-based digital master plan for the Ilorin metropolis to enhance the process of land development evaluation, monitoring, and management, especially in the suburbs. For effectiveness, this strategy should be complemented with planning compliance field officers for a routine on-site assessment. This will help in protecting agricultural lands to support crop production, sustain food supply for the urban inhabitants and as well mitigating environmental hazards. Further studies will attempt to predict future land use patterns using land use/cover changes information and other environmental and social-economic data as predictors.

REFERENCES

Aguda, A. S. & Adegboyega, S. A. (2013). Evaluation of Spatio-Temporal Dynamics of Urban Sprawl in Osogbo, Nigeria using Satellite Imagery & GIS Techniques. *International Journal of Multidisciplinary and Current Research*, *1*(2013), 60–73.

Ajadi, B., Adedapo, A. & Tunde, A. M. (2011). Impact of Climate on Urban Agriculture: Case Study of Ilorin City, Nigeria. *Global Journal of Human Social Science*, *11*(1), 25–30.

Allen, J. & Lu, K. (2003). Modeling and prediction of future urban growth in the Charleston region of South Carolina: A GIS-based integrated approach. *Ecology and Society*, *8*(2). https://doi.org/10.5751/es-00595-080202

Babatunde, I. R., Iyanda, B. A., Mayowa, R. W. & Ola, A. A. (2014). Appraisal of urbanization trends in Ilorin, Nigeria. *Journal of Sustainable Development in Africa*, *16*(January), 1–14.

Barnes, K., Morgan, J., Roberge, M. & Lowe, S. (2001). Sprawl Development: Its Patterns, Consequences, and Measurement. *Annals of Physics*, *54*, 24.

Chunwate, B. T., Yahaya, S., Amankwe, C. O., Samuel, A. & Madaki, B. R. (2019). Assessment of Urban Sprawl Using Geospatial Techniques in Awka Town, Anambra State, Nigeria. *Journal of Geographic Information System*, *11*(03), 359–370. https://doi.org/10.4236/jgis.2019.113022

El Garouani, A., Mulla, D. J., El Garouani, S. & Knight, J. (2017). Analysis of urban growth and sprawl from remote sensing data: Case of Fez, Morocco. *International Journal of Sustainable Built Environment*, *6*(1), 160–169. https://doi.org/10.1016/j.ijsbe.2017.02.003

Foody, G. M. (2002). Status of land cover classification accuracy assessment. *Remote Sensing of Environment*, *80*(1), 185–201. https://doi.org/10.1016/S0034-4257(01)00295-4

Ghosh, S., Singh, P. & Kumari, M. (2017). Assessment of urban sprawl and land use change dynamics, using remote sensing technique. A study of Kolkata and surrounding periphery, WB, India. *38th Asian Conference on Remote Sensing - Space Applications: Touching Human Lives, ACRS 2017*, *2017-October*.

Idrees, M. O., Omar, D. M., Babalola, A., Ahmadu, H. A., Yusuf, A. & Lawal, F. O. (2022). Urban land use land cover mapping in tropical savannah using Landsat-8 derived normalized difference vegetation index (NDVI) threshold. *South African Journal of Geomatics*, 11(1). http://dx.doi.org/10.4314/sajg.v11i1.9

Jibril, M. S. & Liman, P. D. H. M. (2014). Land Use and Land Cover Change Detection In Ilorin, Nigeria, Using Satellite Remote Sensing. *Journal of Natural Sciences Research*, *4*(8), 123–130.

Olanrewaju, R. M. (2009). The Climate Effect of Urbanization in A City of Developing Country: The Case Study Of Ilorin, Kwara State, Nigeria *Olanrewaju R.M. (Mrs). *Ethiopian Journal of Environmental Studies and Management*, *2*(2), 67–72

Olofsson, P., Foody, G. M., Herold, M., Stehman, S. V., Woodcock, C. E. & Wulder, M. A. (2014). Good practices for estimating area and assessing accuracy of land change. *Remote Sensing of Environment*, 148, 42–57. https://doi.org/10.1016/j.rse.2014.02.015

Owoeye, J. O. & Akinluyi F. O. (2018). Geospatial Analysis of Land Cover Change and Urban Sprawl Trend in Akure Region, Nigeria. *Arts & Humanities Open Access Journal*, *2*(1). https://doi.org/10.15406/ahoaj.2018.02.00028

Oladehinde, G., Fatusin, A. F. & Ojo, V. (2019). Urban Expansion and Loss of Agricultural Land in Osogbo, Osun State Nigeria, using Multi-Temporal Imageries. *Journal of African Real Estate Research*, *4*(1), 139–156. https://doi.org/10.15641/jarer.v4i1.735

Olaleye, J. B., Abiodun, O. E. & Asonibare, R. O. (2012). *Land-use and land-cover analysis of Ilorin Emirate between 1986 and 2006 using Landsat imageries*. *6*(April), 189–198. https://doi.org/10.5897/AJEST11.145

Oloukoi, J., Oyinloye, R. O. & Yadjemi, H. (2014). Geospatial analysis of urban sprawl in Ile-Ife city, Nigeria. *South African Journal of Geomatics*, *3*(2), 128. https://doi.org/10.4314/sajg.v3i2.2

Safder, Q. (2019). Assessment of Urbanization and Urban Sprawl Analysis through Remote Sensing and GIS: A Case Study of Faisalabad, Punjab, Pakistan. *International Journal of Academic Research in Business and Social Sciences*, *9*(4). https://doi.org/10.6007/ijarbss/v9-i4/5811

Sharma, L., Pandey, P. C. & Nathawat, M. S. (2012). Assessment of land consumption rate with urban dynamics changes using geospatial techniques. *Journal of Land Use Science*, *7*(2), 135–148. https://doi.org/10.1080/1747423X.2010.537790

Purwani & Arvianti (2020). An analysis of urban sprawl trend using remote sensing data and GIS techniques in Damaturu town, Nigeria. *Social Science Learning Education Journal*, *5*(6), 194–206. https://doi.org/10.15520/sslej.v5i06.2683

Ujoh, F., Kwabe, I., Ifatimehin, O. O. & D, I. (2010). Understanding urban sprawl in the Federal Capital City, Abuja: Towards sustainable urbanization in Nigeria. *Journal of Geography and Regional Planning*, *3*(5), 106–113.