



## The Application of Remote Sensing and GIS on Urban-Induced Land-Use Land-Cover Changes in Urban Zaria, Kaduna State, Nigeria

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### ABSTRACT

*The research analyzed urban-induced land-use land-cover changes in urban Zaria between 2018 and 2000. The study determined the magnitude of urban-induced land-use landcover and the rate of changes in the Zaria metropolis. The study used Landsat TM images from 2000, 2006, 2012, and 2018 obtained from the National Center for Remote Sensing, Jos. Google Maps were acquired from Google Earth Inc. The image analysis period from 2000, 2006, 2012, and 2018 was carried out using GIS software ArcGIS 10.2, while simple descriptive statistics (frequency table and percentage) were used to analyze the data generated. From the findings, the built-up area showed a consistent increase over time, and this is because of increased population and consequent conversion of other land uses into residential areas. The rate of urban-induced land-use land-cover changes portrayed an annual rate change of 21.7% overall for the study period. The research recommends an urban-induced land-use land-cover change information database that can be generated using remote sensing and GIS techniques for proper planning and monitoring in urban Zaria; the government should adopt stringent urban development control measures.*

### ARTICLE INFO

#### Article History

Received: May, 2024

Received in revised form: July, 2024

Accepted: September, 2024

Published online: December, 2024

### KEYWORDS

Remote Sensing, GIS, Urban, Land-use  
Land-cover, Zaria

### INTRODUCTION

Land-use land-cover changes are major environmental concerns. The rapid growth and expansion of urban centers, rapid population growth, scarcity of land, the need for more production, and changing technologies are among the many drivers of land use today (Baros, 2004). Land-use land-cover responds to socio-economic, political, cultural, demographic, and environmental conditions and forces largely characterized by a high human population. Land-use land cover has become one of the major concerns for researchers and decision-makers around the world today.

Many researchers have argued that land-use land-cover has emerged as a major aspect in the wider debate of global change originating from the human-induced effect on the environment and the implications of climate change. The indicators of these changes can be

seen in the current major global concerns, such as increasing concentration of carbon dioxide (CO<sub>2</sub>) in the atmosphere, loss of biological diversity, conversion and fragmentation of natural vegetation areas, and accelerated emission of greenhouse gases.

Urbanization is the increasing proportion of a population living in settlements defined as urban centers. This usually results from the net movement of people from rural to urban areas or natural increase; the excess of births over deaths (Isma'il, Salisu, Yusuf, and Muhammed, 2013). However, the definition of what qualifies as an urban center differs from one country to another, depending on the criteria used. Whatever criteria are used in defining urban centers, Satterthwaite (2005) noted that many aspects of urban change from 1950-2000 were unprecedented.

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According to the United Nations (2011), 3.6 billion of the world's population (52%) were urban dwellers. Universally, urbanization is expected to rise to 67% by 2050. In the less developed regions, the urban population is expected to grow from 47% in 2011 to 64% by 2050 (UN DESA, 2018). In Africa, the urban population is expected to triple from 414 million in 2011 to 1.2 billion in 2050 (UN-HABITAT, 2011). Africa holds a peculiar situation; despite its place as the least urbanized region in the world (39.1%), it has the highest urban growth in the world: 3.3% per year between 2000 and 2005 (UN-HABITAT, 2011). The built-up area of developing-country cities is expected to increase from 200,000 km<sup>2</sup> in 2000 to more than 600,000 km<sup>2</sup> by 2030 (Angel et al, 2005). This implies that the urban population in developing countries is growing with increasing ubiquitous city expansion encroaching into their hinterlands.

There has been a significant increase in Nigeria's urban population since its independence in 1960. Only 15% of the population lived in urban areas. The proportion, however, rose to 43.3% in the year 2000, and 54.3 % in 2023 (Knoema.com 2024). The total area taken up by urbanization in Nigeria during the same period increased by 131% (from 2,083 sq. km in 1976 to 5,444 sq. km in 2000) with an average rate of urbanization estimated at 3.7% per year. (National Population Commission, 2004). Urbanization in Nigeria is driven by a high population growth rate, the concentration of development activities in urban centers, the rapid growth of formal education, and rural-urban wage differentials (Halidu, 2009). Rapid urban population growth increases the demand for urban land, particularly for housing and other urban uses (Thujo, 2013).

Zaria has continually experienced an increase in population, due to many educational institutions and a historical and cultural center. This increase in population has consequently brought about human influence, leading to a high rate of land use change. The 1952 census recorded 56,000 for the population of Zaria, including Tudun-Wada and Sabon-Gari across the Kubani River to the north. By the 1963 Census, the population had risen to about 110,000, and the

built-up area covered some 33.67 square kilometers (Mortimore, 1970). However, during the 1991 national census, Zaria recorded a population of 489,858 with a 2.86 annual growth rate (NPC, 1991). By 2006, the region recorded a population of 695,109 with a 3.2 growth rate (Federal Republic of Nigeria, 2007). These figures show that the population of Zaria has rapidly grown, owing to the range of functional activities, such as agricultural, economic, educational, administrative, health, military, and industrial functions, which have spread and diversified over the area under study, with serious effects on the land use pattern of the environment. Ndabula (2013) analyzed the spatiotemporal dynamics of land use and land cover structures in the Kaduna inner core city region, Nigeria. They examined the extent, rate, and magnitude of change among various land use and land cover in the study area, provided a basis for comparison with other places, and explained the nature of spatiotemporal dynamics of land use and land cover as an index of land degradation.

Uhwache, Sawa, and Jaiyeoba (2015) did a study on Land-use dynamics in Zaria between 1973 and 2009. The findings indicated that Zaria is experiencing rapid expansion leading to a large chunk of the scrubland, farmlands, and even part of the flood plains giving way to residential buildings with built-up areas increasing from 44.27km<sup>2</sup> in 1973 to 130.25 km<sup>2</sup> in 2009, while 'fadama' lands decreased from 146.35km<sup>2</sup> in 1973 to 71.29 km<sup>2</sup> in 2009, plantation/forest decreased from 89.24 km<sup>2</sup> in 1973 to 63.36 km<sup>2</sup> in 2009, scrubland decreased from 1,765.72 km<sup>2</sup> in 1973 to 1,350.39km<sup>2</sup> in 2009 and water bodies from 38.16km<sup>2</sup> in 1973 to 4.20km<sup>2</sup> in 2009. The study covered from 2000 to 2018. To the best of the researcher's knowledge, none of the research attempted to study urban-induced land-use land-cover changes in Zaria with emphasis on the effect of urban growth on various aspects of the land-use and land-cover of the environment, such as water bodies, floodplain, and vegetation cover, using GIS and Remote Sensing techniques covering a temporal scope of 18 years.

### Aim of the Study

The study aims to analyze the urban-induced land use and land-cover changes in Zaria between 2000 and 2018.

### The Study Area

The study area is located between Latitudes 11°01'30"N and 11°12'00"N and Longitudes 7°36'00"E and 7°46'30"E. The total area covered is about 2638.20 km<sup>2</sup> with an altitude of about 762 meters above sea level (Ogunleye, 2006). Zaria lies in the Northern part of Kaduna state. It is a historical, ancient, and traditional center of the north with its

administrative capital situated at Birnin Zazzau (Zaria City). It remains a strategic political center of the north with authority vested solely in the hands of the Emir of Zazzau (Mortimore, 1970). Essentially, the study area is bounded to the south by Igabi LGA, north by Kudan LGA, to the east by Soba LGA, and to the west by Giwa LGA. Zaria is 156km south-west of Kano, and 84km north-east of Kaduna. Zaria is about 698km north of the Atlantic Ocean. Zaria is the second largest city in Kaduna, covering a total landmass of about 61km<sup>2</sup> making it a nodal point in terms of road and rail transport because of location factors (Jatau, 1999).

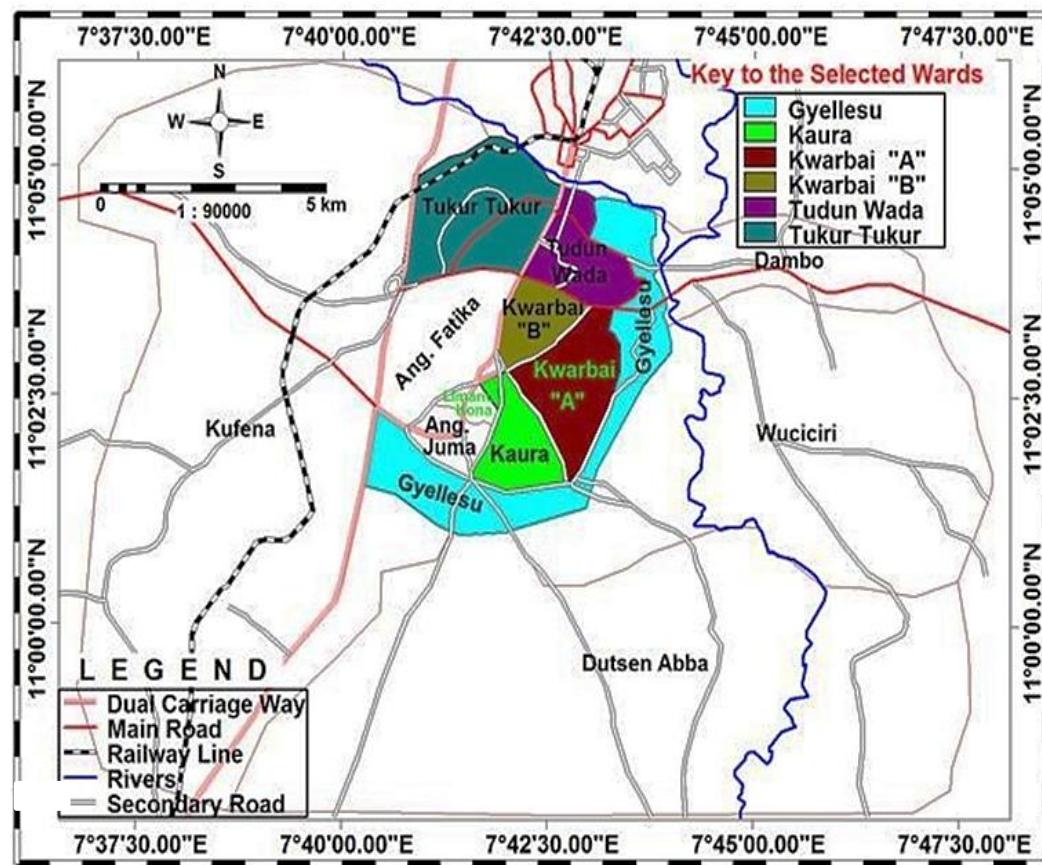


Fig.1 Map of the Study Area

### MATERIALS AND METHODS

This segment focuses on the reconnaissance survey, types and sources of the

data used, hardware and software used, sample size and design as well as the techniques of data analysis.

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### Reconnaissance Survey

A reconnaissance survey was done to acquaint the researcher with the study area and acquire relevant information. Also, relevant community leaders in the study area were consulted to inform them of the purpose of the study and to seek their consent and cooperation.

### Types and Sources of Data

Data for this study were obtained through primary and secondary sources.

#### Primary Data

- i. Landsat TM was acquired on 18<sup>th</sup> February 2000; Landsat TM was acquired on 7<sup>th</sup> December 2006; Landsat TM was acquired on 25<sup>th</sup> June 2012; Landsat TM was acquired on 3<sup>rd</sup> April 2018, and they were sourced from the National Centre for Remote Sensing, Jos. For satellite images to be useful in change detection studies, such images should be acquired about the same time, with 6-year interval between each. This was to monitor the trend of urban land-use land-cover changes and predict future changes.
- ii. Google Map sourced from Google Earth Inc.
- iii. Detailed field Observation/Survey.

#### Secondary Data

The secondary data was derived from the following sources.

- i. Review of related literature from journals, textbooks, internet materials,
- ii. conference papers, theses, and dissertations.
- iii. Administrative Maps of Kaduna State, Zaria Local Government, and the thirteen
- iv. Geopolitical wards were sourced from the Department of Geography, Federal College of Education, Zaria.
- v. Population census figure sourced from the National Population Commission

### Software and Hardware Used

The software used for the study includes the following.

- i. ArcGIS 10.2 for production, processing, and digitizing of base map

- ii. Google Map sourced from Google Earth Inc.
- iii. Microsoft Word for the presentation of the report
- iv. Computer and accessories like a mouse, printer, scanner, etc.

### Data Analysis

#### *To determine the urban-induced land-use/land-cover changes in Zaria metropolis.*

The researchers achieved this by importing the Landsat images of 2000, 2006, 2012, and 2018 into ArcGIS 10.2 software. ArcGIS 10.2 was used for the bulk of digital image processing, which includes image enhancement and classification. ArcGIS 10.2 was used mainly for georeferencing, the generation of land-use land-cover maps, GIS analysis, cartographic outputs, change detection, and prediction.

The satellite images were acquired in an ortho-rectified form and were georeferenced from the source, thereby reducing the time for image processing. Digital image processing was carried out to improve the pictorial quality of the image for easy interpretation. The following operations were performed on the acquired images: color composite, sub-map, image classification, and cellular automata modeler analysis. Supervised classification using a maximum likelihood algorithm was carried out for the classification. The land uses were classified into 4 classes: built-up area, agricultural land, vegetation land, and water body. Also, a confusion matrix was used to identify land use classes and determine the accuracy of the classification.

## RESULTS AND DISCUSSION

### Pattern of Urbanization in Urban Zaria

This section presents the analysis of the extent of urbanization. The extent of urbanization was obtained by selecting the built-up area layer from each classified image. Table 1 shows the quantitative limits of urban growth.



**Table 1:** The Pattern of Urbanization in Zaria

Period	Year	Growth rate/year			
		Base (Km <sup>2</sup> )	Magnitude (Km <sup>2</sup> )	%Km <sup>2</sup> /Year	Annual Rate (YR)
2000-2006 (6 years)	2000	32.12	13.20	41.10	6.85
	2006	45.32			
2006-2012 (6 years)	2006	45.32	18.10	39.94	6.67
	2012	63.42			
2012-2018 (6 years)	2012	63.42	31.14	49.10	8.18
	2018	94.56			
2000-2018 (18 years)	2000	32.12	52.44	129.30	21.7
	2018	84.56			

Table 1 shows a progressive increase in urban extent throughout the study period. Between 2000 and 2006 urban area grew by 41.10% while the period between 2006 and 2012 witnessed an urban growth of 39.94%. The period between 2012-2018 saw an urban expansion of 49.10%. The overall growth (2000-2018) witnessed an urban expansion of 129.30%. This finding agrees with Abbas et al., (2011) and Odeh (2013) who reported that Zaria is experiencing rapid expansion because of the increase in built-up areas. However, 2006-2012 witnessed the lowest urban increase (39.94). This could be attributed to the riot incident in Zaria within this period which might have necessitated the movement of people out of Zaria.

The direction of growth throughout 2000-2018 concerning the extent of urban area and land use of the study area, showed remarkable rises in the built-up. For instance, between 2000 and 2006 the urban growth was towards the north-east direction along the Gyallesu and Tudun Wada wards. This could be attributed to the feeling of the people being more

secure staying towards the Higher institutions (A.B.U Kongo Campus and F.C.E Zaria) in the area, given a security concern, especially among the non-indigenes. Between 2006 and 2012, the urban growth changed from North-East to South-East along Kwarbai A, Kwarbai B, and Kaura. However, between 2012 and 2018 the extent of urban growth in the area still shifted from the North-East direction to the North-West direction along Tukur-Tukur ward, although the physical development tends to be more concentrated in the area. Also, continuous growth in this direction is due to the increase in population and the presence of higher institutions of learning (Ameer Shehu Idris College of Advance Studies and Nuhu Bamalli Polytechnic Zaria).

#### Static Land-use Land-cover

Table 2: shows the status of land-use land-cover distribution for 2000, 2006, 2012, and 2018 obtained by classifying the image of each year into defined land-use land-cover.

**Table 2:** Land-use Land-cover Distribution of Zaria

	2000		2006		2012		2018	
	Km <sup>2</sup>	(%)	Km <sup>2</sup>	(%)	Km <sup>2</sup>	(%)	Km <sup>2</sup>	(%)
Built-up	32.12	11.95	45.32	17.50	63.42	25.45	94.56	37.13
Agricultural Land	176.50	65.69	167.98	64.84	149.02	59.79	134.56	52.84
Vegetation Land	57.98	21.58	43.76	16.89	34.98	14.03	24.07	9.45
Waterbody	2.12	0.78	2.01	0.77	1.82	0.73	1.47	0.58
Total	268.72	100	259.07	100	249.24	100	254.66	100

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Table 2 shows static land use and land-cover distribution over the study period. Built up had the highest proportion covering almost 37% of the area in 2018. In 2000 agricultural and vegetation lands had the highest proportion covering about 65.69% and 21.58% respectively and water bodies with about 0.78% in 2000. From the analyses in Table 2, land use and land cover have undergone considerable changes. While the built-up areas have expanded significantly during the eighteen years under study, the agricultural lands, vegetation, and water bodies declined.

Growths in population and physical developments have led to the sprawling of urban areas, for instance, the Nagoyi, Anguwan Kaya, Tukur-Tukur, and Amaru, forests were cleared to construct houses and roads.

#### The spatial extent of land-use land-cover changes of urban Zaria in 2000.

The spatial extent of land-use land-cover changes in urban Zaria in 2000 is presented in Table 2 and displayed in Figure 2.

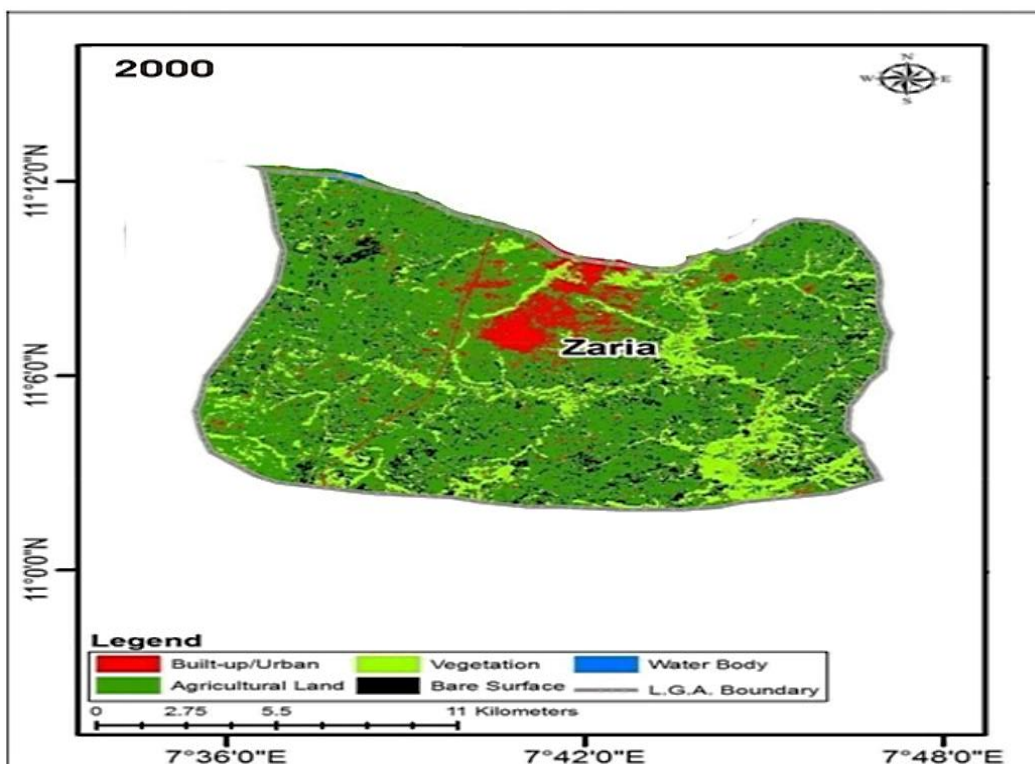


Fig.2 Spatial extent of land-use land-cover changes in urban Zaria LGA in 2000

The result of this analysis in Figure 2 shows that in the year 2000, the built-up area was 32.12km<sup>2</sup> (11.95%), agricultural land was 176.50km<sup>2</sup> (65.69%), vegetation stood at 57.98km<sup>2</sup> (21.58%) while water body was 2.12km<sup>2</sup> (0.78%), implying the dominance of agricultural and vegetal land cover in urban Zaria.

#### The spatial extent of land-use land-cover changes of urban Zaria L.G.A in 2006.

The analysis in Figure 2 indicates that the rate of built-up areas in Zaria as of 2006 increased to 45.2km<sup>2</sup> (17.50%), while the agricultural 167.98km<sup>2</sup> (64.84%), vegetation 43.76km<sup>2</sup> (16.89%) and water bodies 2.01km<sup>2</sup> (0.77%), in urban Zaria, experience a decline.

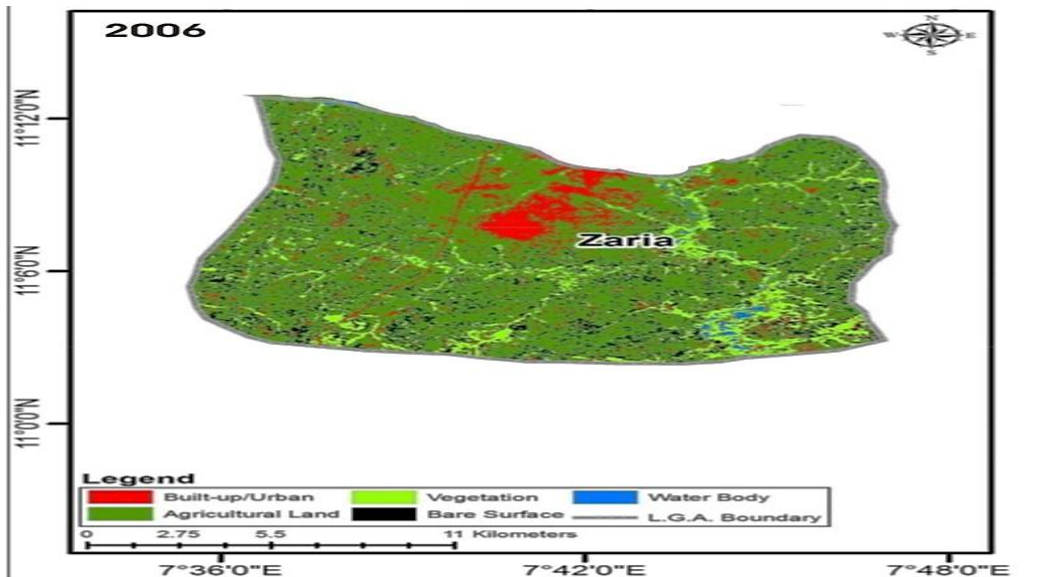


Figure 3 The spatial extent of land-use land-cover changes in urban Zaria in 2006

#### The spatial extent of land-use land-cover changes of urban Zaria in 2012.

This shows the rate of the built-up area in urban Zaria increasing by 63.42km<sup>2</sup> (25.45%), while agricultural land reduced to 149.02km<sup>2</sup>

(59.79%), vegetation 34.98km<sup>2</sup> (14.03%) and water body 1.82km<sup>2</sup> (0.73%). The encroachment of built-up areas on agricultural land can lead to food shortages.

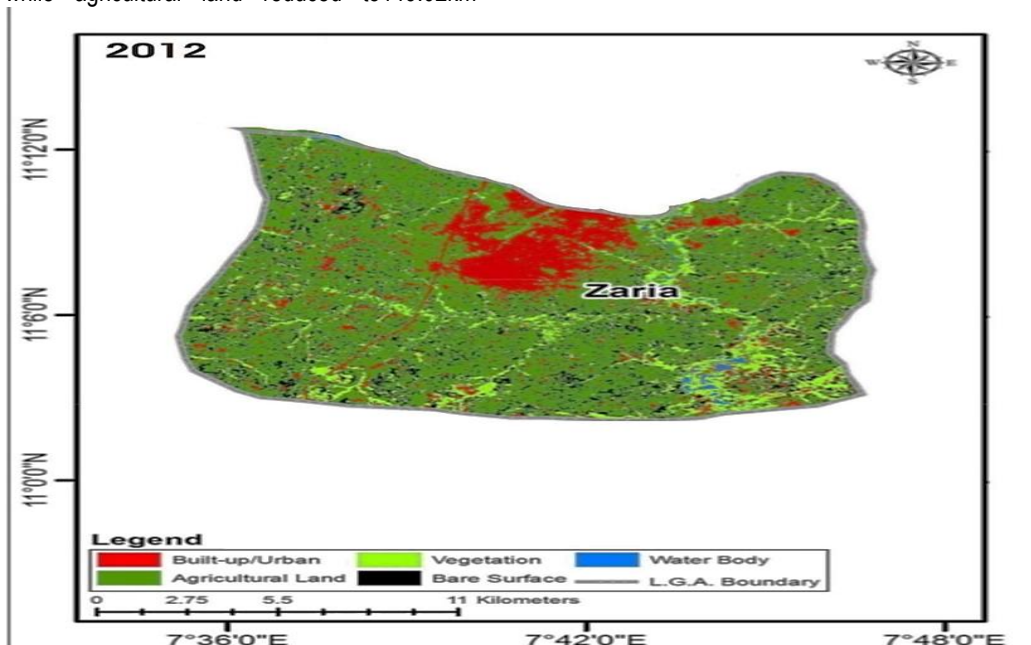


Fig. 4: Spatial extent of land-use land-cover changes in urban Zaria in 2012.

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**The spatial extent of land-use land-cover changes of urban Zaria in 2018.**

The spatial extent of land-use land-cover changes in urban Zaria in 2018 is displayed in Figure 5.

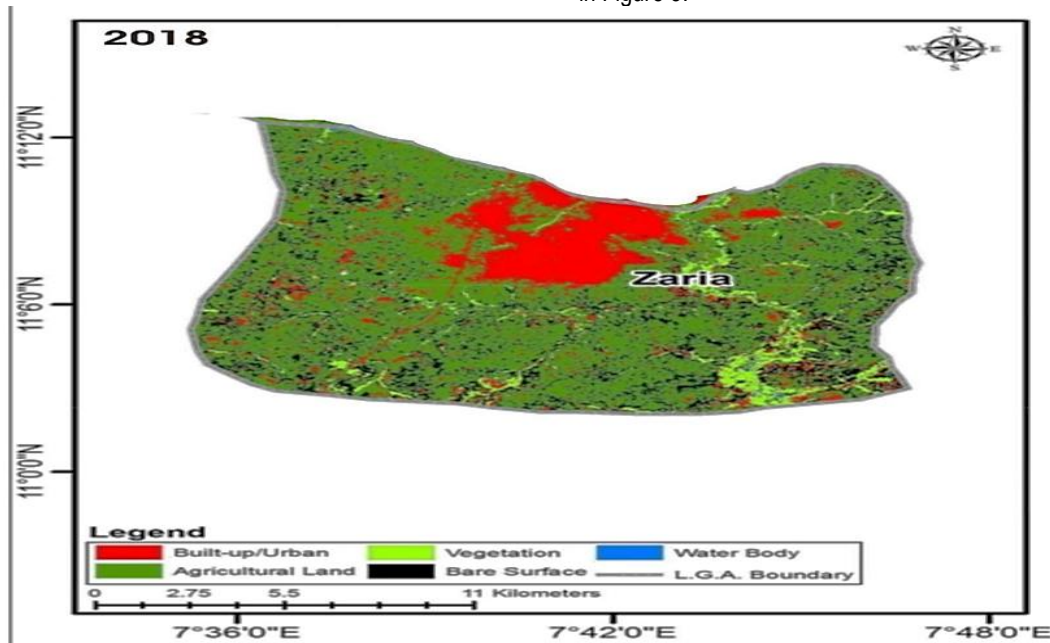


Fig 5 Spatial extent of land-use land-cover changes in urban Zaria LGA in 2018

This shows a further increase in built-up areas in urban Zaria at 94.56km<sup>2</sup> (37.13%), while agricultural land further depreciates to 134.45km<sup>2</sup> (52.84%), vegetation 24.07km<sup>2</sup> (9.45%) and water bodies 1.47km<sup>2</sup> (0.58%). The implications are increased poverty, food scarcity, unemployment, flooding, and disruption of biodiversity/ecosystem.

## CONCLUSION

Advancements in remote sensing and GIS technologies provide powerful tools for mapping and detecting changes in land use land cover. It helps in understanding the extent, rate, and magnitude of land use and land cover dynamics, digital image processing techniques (Remote sensing and GIS) have enabled speedy, accurate, and objective interpretation of the multispectral data received from satellites. This has helped in a major way to observe the land-use land-cover at local, regional, and global levels.

The study witnessed an increase in the extent of urban growth throughout the study

period. Also, the extent of land-use land-cover changes showed an increase in built-up areas and a significant decrease in natural vegetation and agricultural lands. Urban-induced land-use land-cover changes showed agro-lands and natural vegetation having the highest change to built-up areas for the study periods and signifies a progressive encroachment of built-up areas on other land uses. The rate of urban-induced land-use land-cover changes from the study showed an annual rate of change of (21.7%) for the study period. Due to the rapid population growth in Zaria, there is an increase in the diversity of functional activities and a growing demand for land for residential housing and other land-based activities.

## RECOMMENDATIONS

The study has indicated that urbanization and its functional activities are taking over the marginal lands. The findings of this research can assist in providing information for





planners and decision-makers and support sustainable urban development initiatives. However, based on the findings of this study, the following are recommended:

- i. Regular land-use change studies should be done more frequently to detect urban-induced land-use/land-cover changes for sustainable urban development.
- ii. The government should adopt stringent urban development control measures. This should take the form of decentralization or removal of certain establishments based in urban centers. Some new ones should also be prevented from establishing in these overcrowded urban centers.
- iii. Well-trained personnel should be employed to take charge of urban administration. These should include geographers, town and regional planners, architects, etc.
- iv. A strong urban administration should be established to coordinate both public and private urban functions. This should either take the form of a strong metropolitan government or a powerful planning agency, which should possess an internal revenue-generating capacity.
- v. The implementation of urban housing programs. In this direction, it is suggested that building societies within the urban centers should be given every encouragement by the government so that enough accommodation can be available.
- vi. There is a need to use an urban-induced land-use land-cover change information database that can be generated using remote sensing and GIS techniques.

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