

ASSESSMENT OF URBAN LAND USE ENCROACHMENT ON AGRICULTURAL LAND IN CHIKUN LOCAL GOVERNMENT AREA, KADUNA STATE, NIGERIA USING GIS AND REMOTE SENSING

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ABSTRACT

Land use and land cover (LULC) dynamics have become one of the most significant indicators of environmental transformation globally, particularly in rapidly urbanizing regions of developing countries. Anthropogenic activities largely drive these changes and have profound implications for ecological sustainability, agricultural productivity, and socio-economic development. The study aimed at assessing the encroachment of urban land uses on agricultural land which leads to disappearance of fertile land uses for agriculture in Chikun local government area for a period of 2011 and 2023 and the aim was achieved through the following objectives: identify the different urban land uses in the study area; examine the extent of encroachment of urban land uses on agricultural land in the study area; identify the negative effect of covering agricultural land use and vegetation into urban land uses. The data used for the study were Landsat 7 Enhanced Thematic Mapper Plus (ETM+) data from 2011, Landsat 7 (ETM+) of 2020, Landsat 8 Enhanced Thematic Mapper Plus (ETM+) of 2017 (ETM+ of 2023); all were sourced from the National Center for Remote Sensing (NCRS), Jos. Supervised image classification using a maximum-likelihood algorithm was applied to the three images. Five land-use classes were identified: built-up area, vegetation, bare surface, rock outcrop, and water body. Accuracy assessment was performed on the output images from 2011, 2017, and 2023, using error matrices to assess the accuracy of each image. The findings revealed a significant increase in built-up area from 464.5 km² to 1207.7 km² and 1207.7 to 1718.65 km² in 2011, 2017 and 2023 respectively. The most direct economic consequence of decreasing agricultural land is the farmer's loss of profits from agricultural production; decreasing agricultural land also results in food insecurity.

Keywords: Urban expansion, Agricultural land loss, Urban growth, Peri-urban

INTRODUCTION

Land use and land cover (LULC) dynamics have become one of the most significant indicators of environmental transformation globally, particularly in rapidly urbanizing regions of developing countries. These changes are largely driven by anthropogenic activities and have profound implications for ecological sustainability, agricultural productivity, and socio-economic development (Lambin et al., 2014; Foley et al., 2011). LULC changes directly influence the availability of critical biophysical resources such as soil, vegetation, water, and biodiversity, thereby affecting food production systems, environmental quality, and rural

livelihoods (Ellis, 2021). In contemporary times, the rate, magnitude, and intensity of land transformation have increased tremendously due to accelerated urbanization, industrial expansion, population growth, and infrastructural development across many developing nations, including Nigeria (Seto et al., 2012).

Land constitutes a fundamental natural resource that supports human existence and provides the spatial basis for socio-economic activities. It plays a crucial role in agricultural production, settlement development, transportation, and industrial activities. However, increasing pressure on land resources resulting from rapid population growth and urban expansion has led to intense competition between urban land uses and agricultural land (FAO, 2022). Consequently, fertile agricultural lands in peri-urban and fringe areas are increasingly being converted to residential, commercial, and industrial uses to accommodate expanding urban populations (UN-Habitat, 2020).

Globally, urban land expansion is occurring at an unprecedented rate. Recent projections by the United Nations indicate that about 68% of the world's population will reside in urban areas, up from 56% in 2020 (United Nations, 2022). Most of this urban growth is expected to occur in developing countries, in Africa and Asia, where weak land-use planning systems and rapid demographic changes contribute significantly to uncontrolled spatial expansion into agricultural lands (Angel et al., 2018). In Sub-Saharan Africa, urban land expansion has been identified as a major driver of agricultural land fragmentation, reduced food security, and environmental degradation (OECD, 2021).

Nigeria, being one of the fastest-growing urban populations in the world, is currently experiencing rapid urban expansion across major cities and their surrounding rural environments. With an estimated population exceeding 220 million as of 2023 and an annual growth rate of about 2.6%, urban centres in Nigeria, such as Kaduna, are expanding spatially beyond their planned limits (World Bank, 2023). This expansion has resulted in the encroachment of built-up areas into adjoining agricultural lands, particularly within peri-urban local government areas such as Chikun. The proximity of Chikun Local Government Area to Kaduna metropolis and its strategic location along the Kaduna–Abuja growth corridor have made it highly susceptible to urban land-use conversion and uncontrolled development pressures (Kaduna State Urban Planning Authority, KSUPA, 2021).

Agricultural lands within Chikun LGA have historically supported subsistence and commercial farming, thereby contributing significantly to food supply and rural livelihoods in Kaduna State. However, recent trends indicate increasing transformation of

farmland into residential estates, road infrastructure, institutional land uses, and commercial developments. This process of urban encroachment not only reduces the availability of arable land but also threatens local food security, increases land degradation, and disrupts traditional farming systems (Adelakun et al., 2020). Furthermore, inadequate land-use planning and weak monitoring mechanisms accelerate the conversion of agricultural lands to non-agricultural uses.

Advancements in geospatial technologies, such as Remote Sensing and Geographic Information Systems (GIS), have enhanced the capacity to monitor, analyze, and quantify LULC changes over time. These technologies provide reliable spatial and temporal data to assess urban growth patterns and evaluate their effects on agricultural land resources (Weng, 2014). The integration of satellite imagery with GIS-based analytical techniques enables the detection of urban encroachment patterns and supports evidence-based land use planning and sustainable development strategies.

Considering the rapid pace of urban expansion and its impacts on agricultural land resources in peri-urban environments, there is a critical need to assess the extent and pattern of urban land-use encroachment in the Chikun Local Government Area. Such an assessment will provide valuable insights into the spatial dynamics of land-use change and inform policy decisions to achieve sustainable urban development while preserving agricultural land for food production and environmental sustainability.

Despite growing concerns about urban expansion in peri-urban environments, there is limited empirical, spatially explicit information on the magnitude, patterns, and rates of urban land-use encroachment on agricultural land within the Chikun Local Government Area. Without adequate assessment and geospatial analysis of this transformation, planning authorities and policymakers may lack the necessary evidence required to formulate sustainable land management strategies (Weng, 2014). Therefore, there is a pressing need to assess the extent and spatial dynamics of urban land-use encroachment on agricultural land in Chikun Local Government Area with a view to promoting sustainable urban development while safeguarding agricultural land resources for present and future food security.

MATERIAL AND METHODS

Study Area

Chikun Local Government Area is located between latitudes 10°05'00 "North and 10°50'00" North of the Equator and between longitudes 6°45'00 "East and 7°50'05" East of the Greenwich Meridian. The study area covers approximately 4645 km² (Figure 1). Chikun Local Government Area is underlain by granite rock of the basement complex (Russ, 1977). The study area is underlain by undifferentiated older alluvium, and younger lithic deposits are products of various materials, including crystalline igneous rocks and sediments. These superficial deposits are characterized by. Without adequate assessment and geospatial analysis of this transformation, planning authorities and policymakers may lack the necessary evidence required to formulate sustainable land management strategies (Weng, 2014). Without adequate assessment and geospatial analysis of this transformation, planning authorities and policymakers may lack the necessary evidence required to formulate sustainable land management strategies (Weng, 2014).

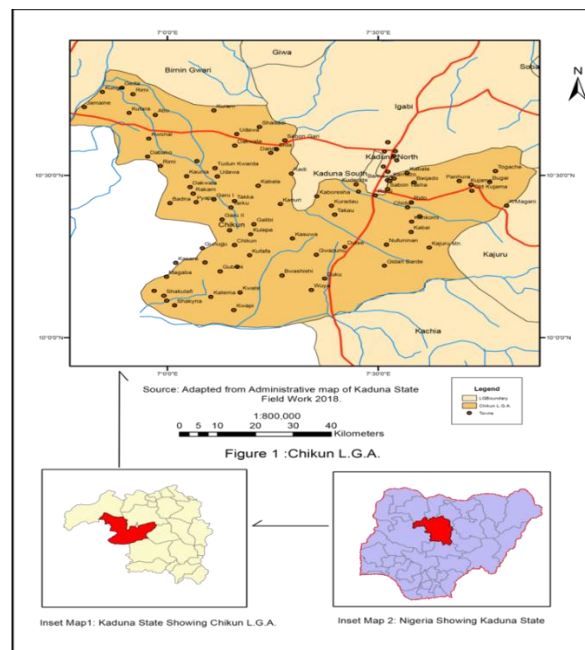


Figure 1: Location of Chikun Local Government Area in the inset Map of Kaduna State, and Nigeria

Source: Adopted and Modified Administrative map of Nigeria, 2023

Materials

Satellite imagery: The satellite imagery was acquired to generate land use and land cover (LULC) maps of the study area for the period 2011 to 2023. These images facilitated the visualization, identification, and extraction of information necessary for analyzing changes in land use and land cover. They include the following;

- i. Landsat 7 Enhanced Thematic Mapper (ETM +) with 30m spatial resolution of 2011, which was sourced from the National Centre for Remote Sensing (NCRS), Jos.
- ii. Landsat 7 Enhanced Thematic Mapper Plus (ETM +) at 30m spatial resolution of 2017, which was sourced from the National Centre for Remote Sensing (NCRS), Jos.
- iii. Landsat 8 Enhanced Thematic Mapper Plus (ETM +) at 30m spatial resolution of 2023, which was sourced from the National Centre for Remote Sensing (NCRS), Jos.

Topographical map: A topographic map at a scale of 1:250,000 was used to delineate the study area and extract settlement information. It was sourced from the Kaduna State Ministry of Lands and Surveys.

Radiometric and geometric corrections were applied to the images to improve their quality. since it is expected to have systematic errors, such as sensor spectral properties and atmospheric scattering, that creep into the data acquisition process and can degrade the remote sensor data quality.

Method of Data Analysis

Image classification

This was achieved using supervised classification. Image classification was performed, and real-world thematic classes were identified and assigned to the image pixels. Unsupervised classification was performed to estimate the number of training sites used in the supervised classification. The ISODATA clustering

algorithm, implemented in ERDAS 9.2 was used to classify the satellite images using an unsupervised classification approach, which groups pixels into clusters based on their spectral similarity. To perform supervised classification, "training sites or signatures" of the various land features were created. Using the Area of interest tool under the Basic Toolbar of ERDAS 9.2, the signature of the various land cover types was digitized. This was achieved using prior knowledge of the study area and by referencing high-resolution satellite images from Google Earth. The images were then classified using the maximum likelihood classification algorithm. This algorithm was used because it incorporates statistical analysis of the training samples before assigning the appropriate land cover class to each pixel. The individual images were classified into five distinct land-cover classes. The five different classes were differentiated based on their spectral analysis. The resultant maps were exported to ERDAS for classification and mapping. These features are presented in Table 1.

Table 1: Descriptions of the Land Use/Land Cover Classification System Used in the Study

S/No	Land Use Types	Definitions
1	Built-up area	Commercial, residential, industrial, government facilities, and settlement
2	Agricultural land	Farm land
3	Water Body	Rivers, Waterlogged areas
4	Bare land	Cleared land, Open field/space
5	Rock outcrop	Mountains, Hills

Source: Adopted and modified from FAO (2020).

Change Detection

For the classification-based approach, supervised classification was performed on the 2011 and 2017 satellite images for both test sites to identify and map land-use and land-cover classes. The main advantage of using supervised classification is that it enables the production of a consistent number of land use and land cover classes across all image datasets, ensuring comparability between the classified images. The classifications were then combined to produce a map of all class transitions (Erdas Imagine 9.4 Tour Guides 1999). The transitions were then assigned colors based on the type of change occurring, producing the final output image. The maps clearly express the spatial coverage of settlements in 2011 and 2023.

Growth rate

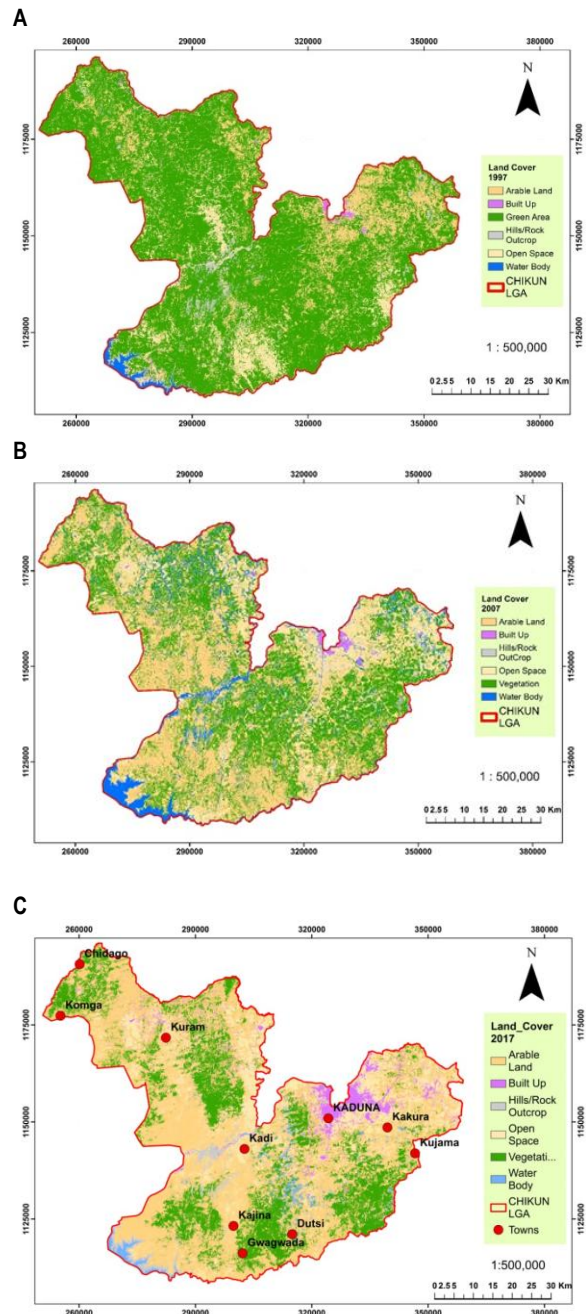
All classified land cover types for each period were added together to serve as a basis for calculating, most especially growth rate, using the formula below, adopted from (Zubair, 2002):

$$\text{Growth Rate} = \left(\frac{\text{Current Year} - \text{Previous Year}}{\text{Previous Year}} \right) = 100\%$$

RESULTS AND DISCUSSION

The different urban land uses and land cover types in Chikun Local Government Area. The land use/land cover maps for the years

2011, 2017, and 2023 are presented in Figures 2, 3, and 4, respectively, showing the spatial distribution of the various land use and land cover classes within the study area.



Source: Authors Analysis, 2024

Figure 2: Land use/landcover map of Chikun Local Government Area, (a)2011, (b) 2017, (c) 2023

Table 2: Area Extents of Landuse/Landcover in Chkun Local Government Area (2011 –2023)

Year	2011	Percentage	2017	Percentage	2023	Percentage
Land use	km ²	(%)	km ²	(%)	km ²	(%)
Arable land	743.2	16	510.95	11	418.05	9
Build-up area	464.5	10	1207.7	26	1718.65	37
Hill/Rock out crop	46.45	1	46.45	1	46.45	1
Open space	836.1	18	603.85	13	418.05	9
Vegetation	2368.95	51	2090.25	45	1858	40
Water body	185.8	4	185.8	4	185.8	4
Total	4645	100.0	4645	100.0	4645	100.0

Source: Author's Analysis, 2024

Figures 2, 3, and 4 show the map of the Chikun Local Government Area, with different colors assigned to each land-use and land-cover class, and Table 2 shows that Chikun LGA has a total land area of 4645 km². In 2011, vegetation covered the largest area in Chikun LGA, at 2368.95 km². Arable land ranked third in size after vegetation and open space, covering 743.2km², while hill/rock outcrops represented one of the smallest land cover classes, with an area of 46.45km². In 2017, the built-up area increased from 464.5 km² in 2011 to 1207.7 km² in 2017, while vegetation, open space, and arable land uses decreased by 2090.25 km², 603.85 km², and 510.95 km², respectively. This means that arable land, open space, and vegetation are converted to built-up area because of population growth, both from natural increase and from immigration. But the hill/rock outcrop and the water body remain the same size in both 2011 and 2023.

In 2017, vegetation remained the dominant land cover, constituting 45% of the total land area, equivalent to 2090.25km². The built-up area occupied 1207.7 km², representing 26% of the land cover in Chikun LGA. In the case of arable land, it reduces to 510.95km² in 2017 of about 11% of the total area from the previous one of 743.2km² in 2011. The 2023 map of Chikun LGA of land use/land cover classification shows the differences of only 3% between the vegetation cover and the built-up area, with 40% of vegetation and the total 1858km² while that of built-up area is 1718.65km² and the percentage is 37% which is the second in terms of total land area cover. Arable land is also reduced as is open space, which both have the same total land area of 418.05km² each and a percentage of nine (9%), while water bodies and hill/rock outcrop remain the same as 185.8km² and 46.45km² respectively.

Extent of encroachment of urban land uses on agricultural land in the study area

Table 3 shows the extent to which urban land uses have encroached upon agricultural land in the Chikun Local Government Area.

Table 3: Differences in Arable Land Area between 2011 and 2023

Year	2011	2017	Differences between 2017-2011(km ²)	2023	Differences between 2023-2017(km ²)
Arable land	743.2	510.95	-232.25	418.05	-92.9

Source: Author's Analysis, 2024

Table 3 shows the differences in arable land use between 2011 to 2017 which constitutes 232.25km² (decrease), this means from 2011 to 2017 there is reduction of 232.25km² which is almost one third of the total land area of arable land; while the differences between 2017 to 2023 is 92.9km² (decrease) which means from 2017 to 2023 there is reduction of 92.9km² which is one sixth of the total land area of 2017.

It has already been mentioned that during 2011-2017, agricultural land was rapidly converted to nonagricultural uses, but between 2017 and 2023, conversion was slower, with areas converted to settlement and other purposes in the study area; this conversion process is continuing. Build-up area, which is a settlement, is the most common and prominent land use. Settlements in the fringe area change as urban growth occurs, and over time, they are incorporated into the ever-growing urban center. The study reveals that agricultural land has been converted more for settlement purposes.

Identify the effects of urban land uses on agricultural land in the study area

The negative effects of converting agricultural land to urban land uses, and the loss of vegetation cover, depend on the nature of the initial and final land uses (Litman, 2010b). Although large-scale agricultural land use typically has both positive and negative consequences, this study focuses on the negative effects in line with stated objectives.

A decrease in agricultural land

The most direct economic consequence of decreasing agricultural land is the farmer's loss of profits from agricultural production. Decreasing agricultural land also reduces support for agriculture-based businesses. These businesses are associated with various

processing plants that incur direct losses when agricultural land declines.

- i. Loss of vegetation: Urban encroachment has led to the clearance of the vegetation cover for other purposes, most especially building. As observed from satellite imagery, forests are being cleared to make way for expansion and settlements in the Chikun Local Government Area. As rightly observed, some manifestations of these changes are evident in the rapid disappearance of vegetation cover, leading to a significant decline in forestland. Other consequences include increased soil erosion and degradation, greater biodiversity loss, changes in microclimatic conditions, and unfavorable hydrological changes.
- ii. Biodiversity losses: The conversion of agricultural land has encouraged farmers to cultivate high-yielding varieties (HYV) to increase production, which often reduces biodiversity. As a result, many traditional crops are almost extinct. Moreover, chemical fertilizers, pesticides, and insecticides are used in cultivation, which contributes to the extinction of some environmentally friendly faunal species.
- iii. Environmental degradation: The loss of vegetation and conversion of agricultural land use into urban land uses is responsible for environmental degradation and accelerating soil erosion.

Conclusion

The study demonstrated the effectiveness of Geographical Information Systems (GIS) and Remote Sensing (RS) techniques in capturing spatial-temporal data for monitoring of land use and land cover changes.

The analysis of encroachment of urban land uses on agricultural land in the Chikun Local Government Area, Kaduna State, Nigeria, between 2011 and 2017, and between 2017 and 2023. The decrease in agricultural land use in the Chikun Local Government Area between 2011 and 2023 can be attributed to population growth and migration from the Kaduna metropolis to parts of the area. The level of change in arable land shows the difference in arable land use between 2011 to 2017 which constitute 232.25km² (decrease), this means from 2011 to 2017 there is reduction of 232.25km² which is almost one third of the total land area of arable land; while the differences between 2017 to 2023 is 92.9km² (decrease) which means from 2017 to 2023 there is reduction of 92.9km² which is one sixth of the total land area of 2017.

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