LAND USE/LAND COVER CHANGE IN MAKURDI, BENUE STATE, NIGERIA USING REMOTE SENSING TECHNIQUES

by

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1. Introduction

Recently, Land use and land cover (LULC) changes have drawn increased attention due to the intensity and rate at which they occur, resulting in unprecedented consequences on the environment. LULC change is currently regarded as one of the world's major environmental challenges (Radwan et al., 2019). These consequences include water pollution, biodiversity loss, climate change, and others (Barakat et al., 2019; Obeidat, Awawdeh and Lababneh, 2019). The current rate of LULC changes driven by human activities, is primarily attributed to rapid urbanization (Hind et al., 2022). This phenomenon is more prevalent in developing countries than in developed countries, often associated with rapid population growth (Obeidat, Awawdeh and Lababneh, 2019). By 2030, it is predicted that 60% of the world's population will reside in urban areas, with developing countries accounting for the majority of this growth (Rahman et al., 2011). Urban expansion eventually results in sprawl when planning and infrastructure are lacking, resulting in the risk of valuable agricultural land ultimately being converted into urban areas (Coulter et al., 2016). As the world deals with the complexities of urban expansion, the need to comprehensively understand the patterns and implications of these changes becomes critical. Hence, the assessment of LULC change is crucial to address issues of rapid and uncontrolled urban expansion, loss of valuable agricultural areas, destruction of significant wetlands, and declining environmental quality (Dangana, Asiribo-Sallau and Halilu, 2016; Barakat et al., 2019). In assessing LULC changes, an effective method is through the use of remote sensing techniques (Dewan and Yamaguchi, 2009; Coulter et al., 2016). Therefore, this report aims to assess and analyze LULC changes, with a specific focus on urban expansion, in Makurdi Benue State, Nigeria from 2001 to 2020, using remote sensing data.

1.1 Remote Sensing of LULC

Remote sensing techniques have become an effective tool for assessing LULC changes using satellite imagery (Coulter et al., 2016; Radwan et al., 2019). Remote sensing data provide multi-temporal data useful for examining LULC changes (Dewan and Yamaguchi, 2009). The basis of LULC change analysis is historical LULC data, which tracks and evaluates past land changes (Radwan et al., 2019). Remotely sensed data are captured and stored, providing an opportunity to analyze historical data for assessing LULC changes over time. (Emad Hawash et al., 2021). Using satellite imagery, several researchers have assessed LULC changes in several parts of the world. Dewan and Yamaguchi (2009) evaluated land use/cover changes and urban expansion in Greater Dhaka, Bangladesh, from 1975 to 2003 using Landsat data (MSS, TM, and ETM+), Radwan et al. (2019) analyzed LULC changes and simulated LULC changes to 2030 in the Nile Delta, Egypt from 1992 to 2015 using twenty-four LULC maps, Ali et al. (2021) assessed the implication of land cover change on flood events in Benue state, Nigeria from 1990 to 2020 using Landsat (TM, ETM, and OLI), Coulter et al. (2016) utilized the dense stack approach to classify images with extremely cloudy, multi-temporal Landsat 7 ETM+ imagery to map and examine LCLU changes within southern Ghana, Emad Hawash et al. (2021) analyzed LULC, land water changes (LWC) and urban expansion of Port Sudan from 1999 to 2018 using Landsat (ETM and OLI), Barakat et al. (2019) evaluated the environmental degradation in Béni-Mellal District, Morocco based on the LULC changes from 2002 to 2016 using Sentinel-2A data, and Hussain et al. (2022) assessed the impact of changes in LULC on land surface temperature in Southern Punjab, Pakistan from 1987 to 2017 using Landsat (TM, ETM, and OLI). Despite the demonstrated effectiveness of applying remote sensing techniques using satellite data in assessing LULC changes, it offers a cost and time-effective alternative to ground-based survey methods which are more expensive and time-consuming, making satellite data particularly beneficial for developing countries (Dewan and Yamaguchi, 2009; Obeidat, Awawdeh and Lababneh, 2019).

1.2 Objectives

The specific objectives of this study include:

(1) To identify and define relevant class labels associated with LULC in the study area, particularly emphasizing transitions from non-urban to urban areas.
(2) To generate comprehensive LULC maps spanning a period of 20 years (2001 to 2020)
(3) To determine the LULC changes within the study area over the designated period.
(4) To evaluate the extent of urban expansion over the designated period in the study area.
(5) To conduct an accuracy assessment of the LULC product.

2. Materials and Methods

2.1 Study area

The study is focused on the urban area of Makurdi, the capital city of Benue State, Nigeria. It is located between Latitudes 7° 37″ and 7° 47″ N, and on longitudes 8° 28″ and 8° 40″ E. As shown in Figure 1, on the upper left the map of Nigeria shows Benue State, while on the lower left is Benue State showing the location of the study area and the study area on the right. The city is located in North Central Nigeria, approximately 300 kilometres south of Plateau State and 450 kilometres south of Enugu State. It is situated along the Benue River which flows through the town from the northeast to the northwest thereby dividing the town into two main areas, the northern and southern areas, which are together referred to as the North Bank and South Bank districts (Okonufua et al., 2022). Benue State is part of the Guinea Savanna Belt, Nigeria's largest vegetated area, which is distinguished by a variety of types of grasses and trees (Nyagba, 1995). As a result, Makurdi is surrounded by enormous, productive agricultural fields that serve as a primary region for high agricultural production. It is well known for its crucial role in Nigeria’s agricultural sector.

Based on the census data from 1991 and 2006, Makurdi had a population of 239, 889, and 297 398 respectively. With a projected growth rate of 0.03%, Makurdi LGA had a total population of 517,342 people in 2017 (Shabu, Fate and Ukula, 2021). However, among other things, this population growth results in a rise in the demand for productive agricultural land being converted to other land use types such as land for housing and industrial areas. The significance in the agricultural sector, coupled with observable Land Use/Land Cover (LULC) changes and the availability of comprehensive historical data, makes Makurdi an ideal focal point for this study. The research spans a substantial period of twenty years, from 2001 to 2020, offering a comprehensive timeframe to analyze LULC changes, with a particular emphasis on urban expansion within the study area.

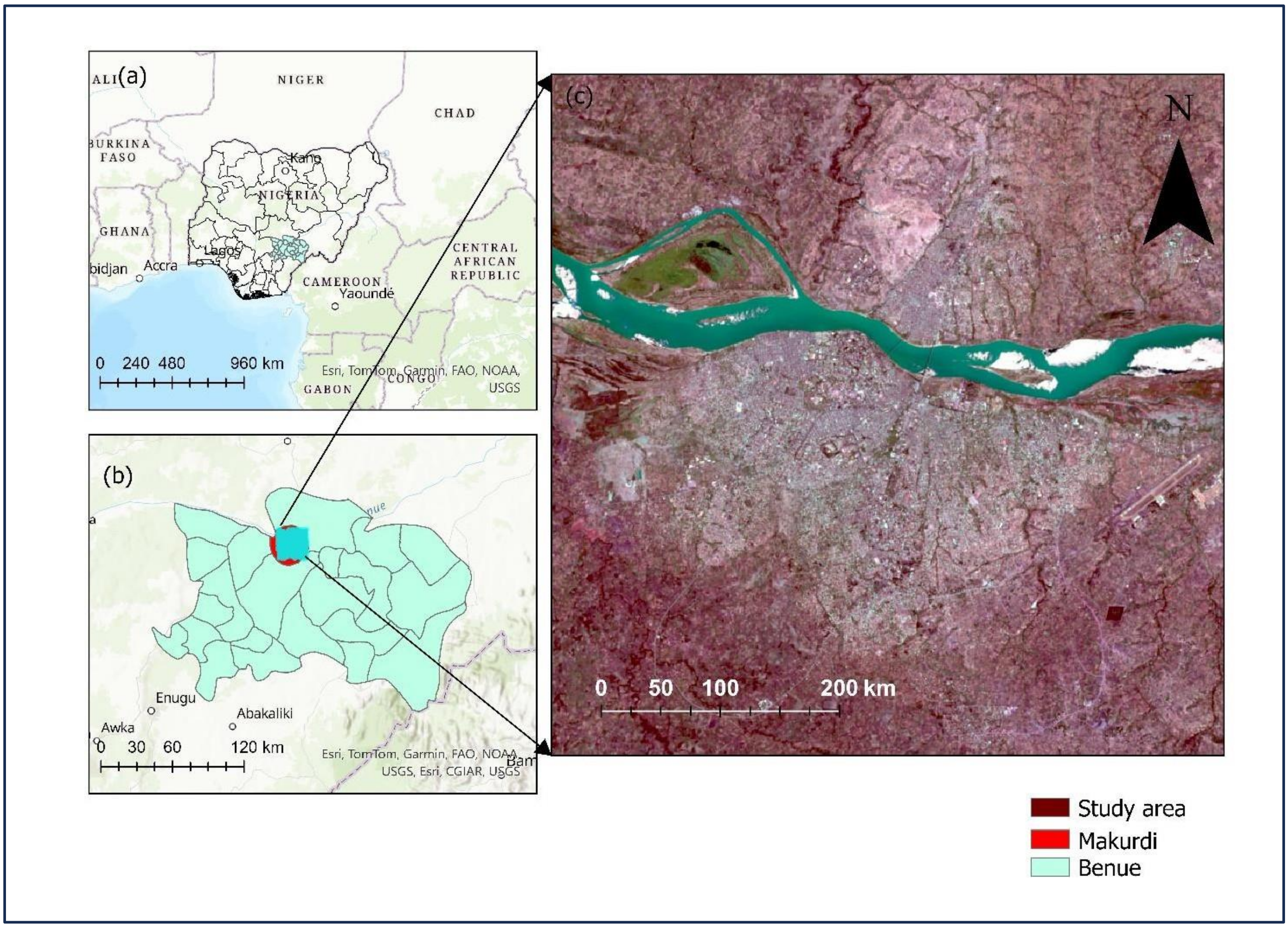

Figure 1. Study area (a) location of Benue State in Nigeria; (b) location of Makurdi in Benue State; (c) the study area (Makurdi city)

2.2 Datasets used

Landsat images with a spatial resolution of 30m x 30m which covers the city of Makurdi were acquired from the United States Geological Survey (USGS) website. The data includes Landsat 7 (ETM+), for the year 2001 and Landsat 8 Operational Land Imager (OLI) for the year 2020 acquired at 02-12-2001 and 30-11-2020 respectively (Table 1). The images were acquired in November. This decision was made to aid in reducing the effects of clouds that are frequent during the rainy season. An overview of the image properties for the dataset used is provided in Table 1. High-resolution Google Earth images were also utilized to help with the classification process and to check the overall accuracy of the classification results.

Table 1 Satellite images used

Landsat image	Sensor	Spatial resolution	No. of Bands	Acquisition date	Source
Landsat 7	ETM	30m	7	30/11/2020	USGS
Landsat 8	OLI	30m	7	02/11/2001	USGS

2.3 Satellite data analysis approach

2.3.1 Image pre-processing and classification

The satellite imagery used in this study was obtained at Level 2. The preliminary processing of the data, such as geometric and radiometric corrections has been performed from the data source. Preprocessing of the data was performed using ERDAS Imagine software for layer stacking and subsetting of the image based on the Area of Interest (AOI) and band combination (Hussain et al., 2022; Ali et al., 2021). A false color composite was generated to aid in identifying the different features in the imagery (Ali et al., 2021). Based on the band combination, high-resolution Google Earth images, and prior knowledge of the study area, the LULC classes were established. The LULC classes consist of water bodies, built-up areas, barren land, and vegetation areas (Table 2). Training samples were selected based on the reflectance properties of the various LULC classes, by drawing polygons around the various classes to produce spectral signatures of the satellite imagery. The maximum likelihood classification (MLC) algorithm was applied to each image. One of the supervised classification techniques that is often applied in remote sensing classification applications is the MLC approach (Dewan and Yamaguchi, 2009; Hind et al., 2022). The method determines which class a pixel is most likely to belong by calculating its likelihood and assigning each pixel to the class with the highest probability (Hind et al., 2022). However, in the supervised classification process, a few of the classes were misclassified; for example, several built-up areas were mistakenly classified as barren land due to the similarity in their spectral characteristics. Hence additional training samples were selected to achieve a satisfactory outcome. Four land cover classes were produced by the classification (water bodies, built-up area, barren land, and vegetation land) as shown in Table 2.

2.3.2 Accuracy assessment

Furthermore, the derived results were imported into ArcGIS Pro to assess the accuracy of the LULC classification. 90 stratified random pixels were generated for both sets of results. The accuracy assessment involved utilizing high-resolution images and Google Earth images, followed by executing a confusion matrix operation. The next chapter provides a summary of the accuracy and reliability assessment of the LULC classification results. The flow chart of methodology is shown in Figure 2

Table 2 Scheme and description of LULC classes

Land use land cover class	Description
Water bodies	Rivers, lakes, ponds, streams, canals, and reservoirs
Built-up	Residential, industrial, commercial, utilities and services, and roads
Barren	Exposed soils, landfill sites, and excavation sites
Vegetation	Cultivated lands, plantations, forests, and fallow land

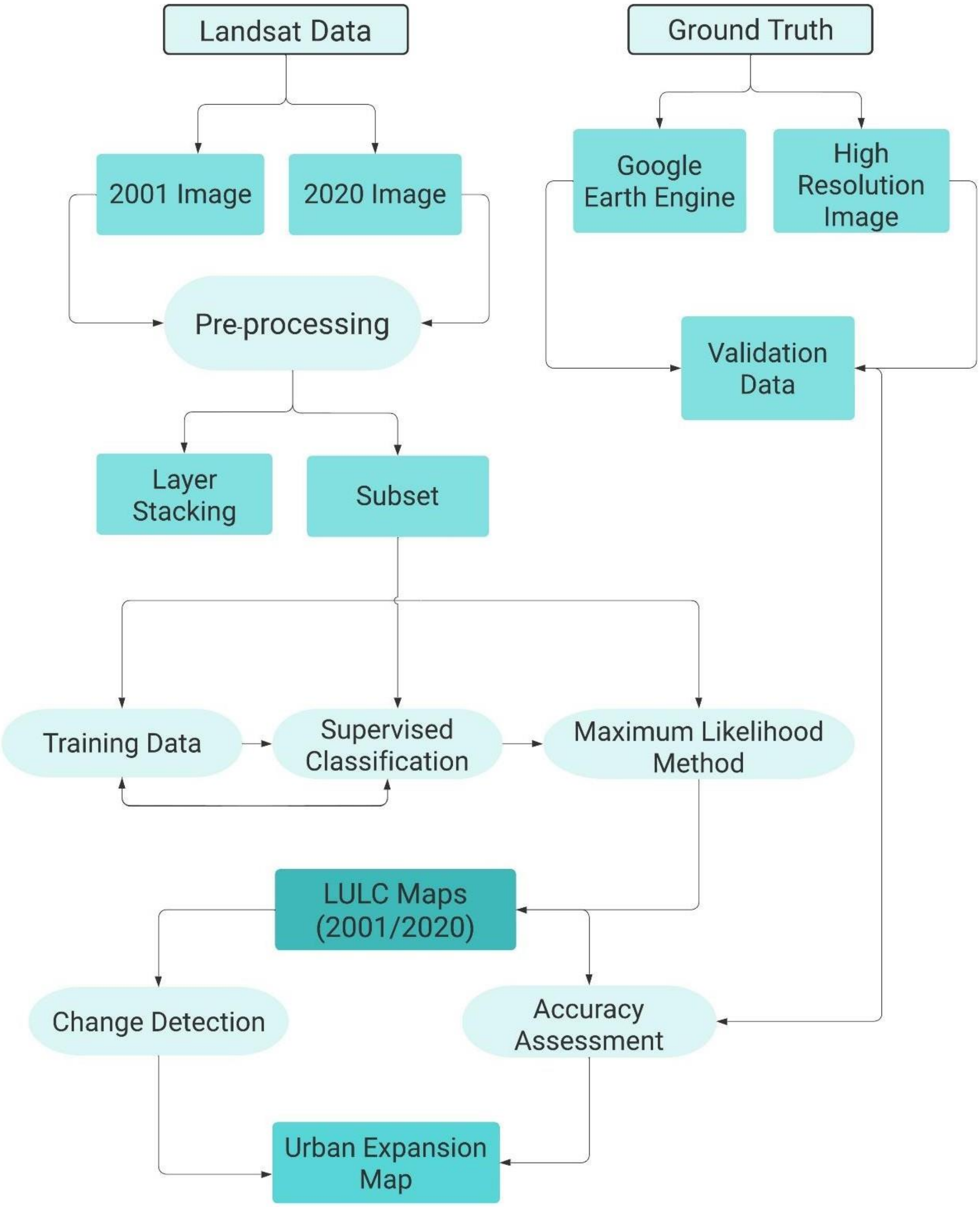

Figure 2. Flow chart illustrating the methodology used in this study.

3 Results and discussion

3.1 LULC of Makurdi from 2001 to 2020

The successful classification of the satellite images resulted in the LULC maps revealing the spatial distribution patterns of the LULC for 2001 and 2020 in the study area as shown in Figures 3 and 4 respectively. The LULC product showed a remarkable capacity to distinguish between the LULC types. Particularly, the water bodies were well discriminated clearly showing the boundaries of the river Benue, and the built-up areas were distinctly defined which is essential for comprehending the dynamics of urban expansion. However, one notable challenge observed in the LULC maps was the difficulty in effectively distinguishing between built-up areas and barren land. The classification process exhibited limitations in distinguishing areas characterized by little or no vegetation cover from built-up areas. This challenge can be attributed to similar spectral signatures of the two classes hence making it difficult for the classification algorithm to distinguish between the two classes. Also, the spatial resolution of the satellite image may have contributed to the problem as this often occurs when using medium spatial resolution images such as Landsat (Dewan and Yamaguchi, 2009). In future investigations, exploring the use of higher spatial resolution imagery will be considered.

Table 3 Distribution of LULC classes in Makurdi (2001 and 2020)

	2001		**2020**	
LULC class	**Area (Km^2)**	**%**	**Area (Km^2)**	**%**
Water body	931.68	4.53	599.01	2.91
Built-up	608.31	2.96	1854.51	9.01
Barren	4715.16	22.94	10169.43	49.43
Vegetation	14300.91	69.57	7951.59	38.65
Total	20556.06	100	20574.54	100

3.2 LULC changes and the dynamics of urban expansion

Analyzing the derived LULC product revealed some promising results, particularly in identifying the temporal trends of land cover changes within Makurdi. In 2001, about 69.57% (14300.91 km^2) of the study area was dominated by vegetation, 22.94% (4715.16km^2) by barren land, 4.53% (931.68km^2) by water bodies, and 2.96% (608.31 km^2) by built-up area. Whereas in 2020, about 49.43% (10169.43km^2) of the study area was dominated by barren land, 38.65% (7951.59km^2) by vegetation, 9.01% (9.01km^2) by built-up area and 2.91% (2.91km^2) by water bodies (Table 3). As seen in Table 4 clearly shows the changes in LULC in the study area from 2001 to 2020. The built-up area and barren land have increased significantly while the vegetation and barren land have decreased over time. In particular, there is a significant expansion of the built-up area from 608.31km^2 representing 2.96% of the entire land area in 2001 to 854.51km^2 representing 9.01% of the entire land area in 2020. Whereas, there is a decrease in other land uses and covers, particularly vegetation, which decreased from 14300.91km^2 in 2001 representing 69.57% of the entire land area to 7951.59km^2 representing 38.65% of the entire land area in 2020. The change in built-up area tripled in 2020 with a percentage increase of 6.05%, this growth in urbanization has been to the detriment of vegetation areas which decreased by 30.92%. The extent of urban expansion within the study area can be seen in Figure 5. Interestingly, the result shows that urban expansion in the study area has occurred around the city centre. Moreso, there is a notable replacement of vegetation and barren land by built-up areas.

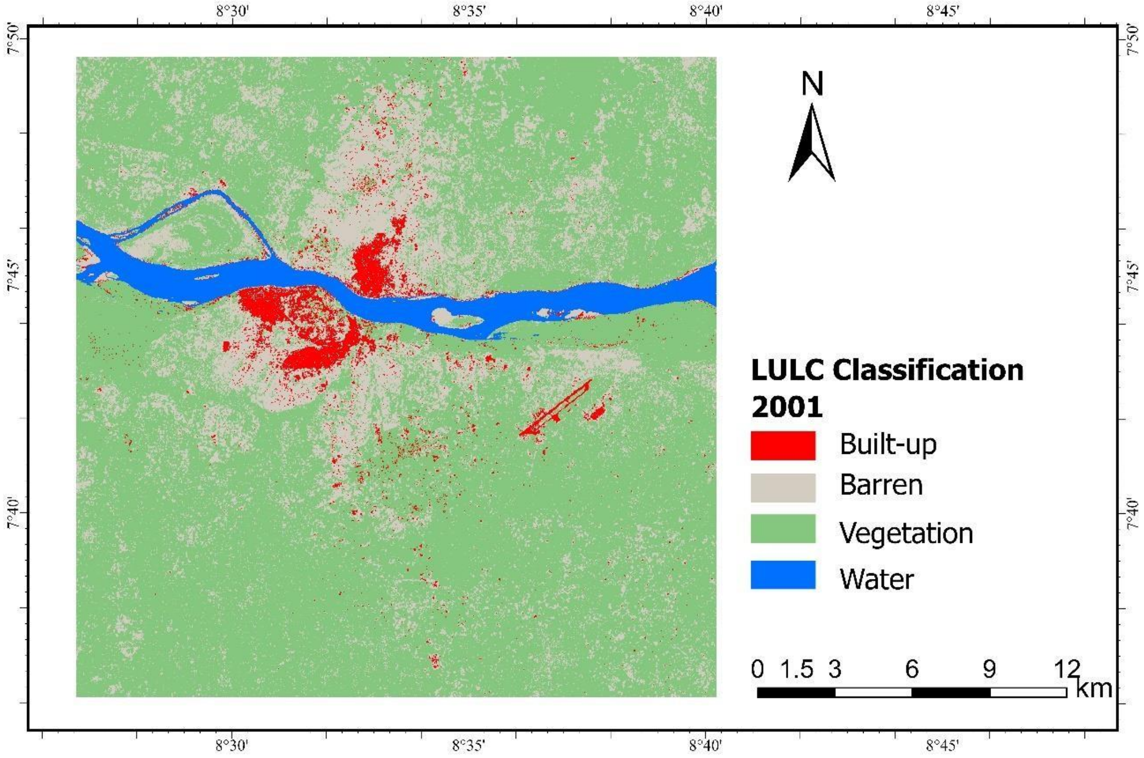

Figure 3. LULC of Makurdi in 2001

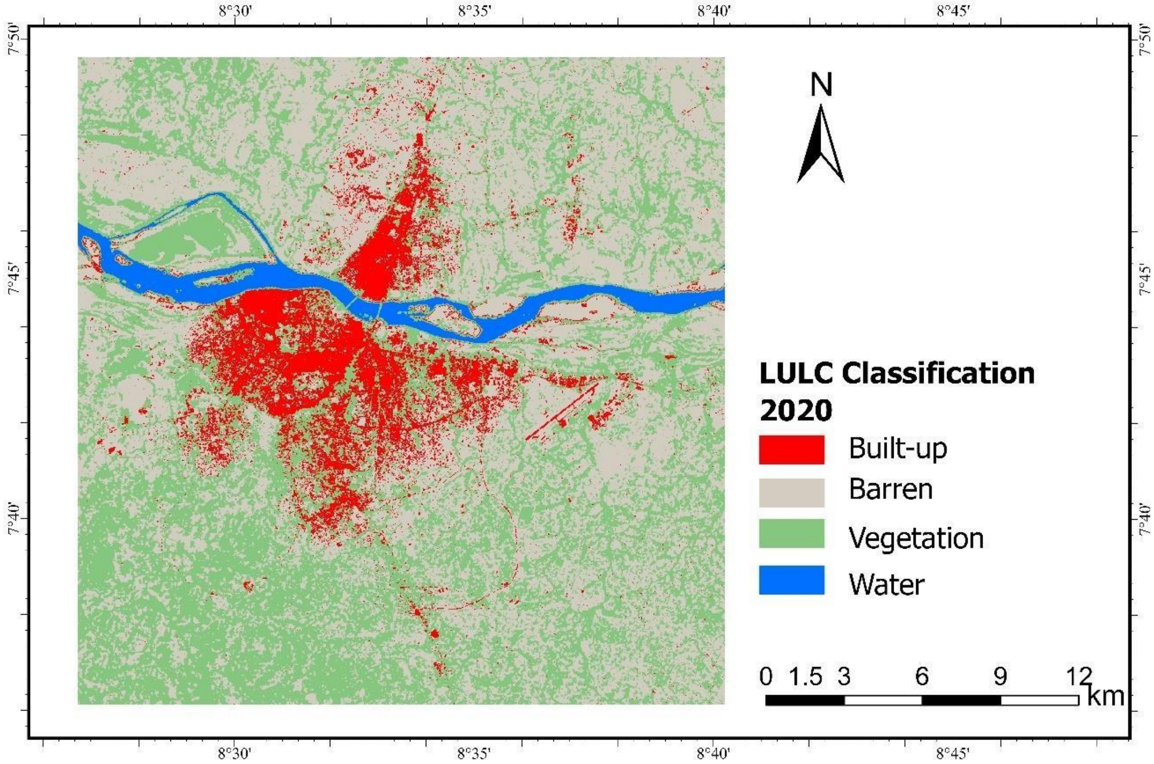

Figure 4. LULC of Makurdi in 2020

Table 4 LULC change in Makurdi from 2001 – 2020

LULC class	Area (Km^2) in 2001	Area (Km^2) in 2020	Change in Area (Km^2) 2001-2020	% Change
Water body	931.68	599.01	-332.67	-1.62
Built-up	608.31	1854.51	1246.2	6.05
Barren	4715.16	10169.43	5454.27	26.49
Vegetation	14300.91	7951.59	-6349.32	-30.92

3.3 Accuracy assessment

Tables 5 and 6 present the accuracy assessment results for the individual LULC maps from 2001 and 2020. The overall accuracy of the derived LULC map of 2001 was 91% and 81% for 2020. The validation against high-resolution imagery and Google Earth imagery showed consistently high accuracy scores for the LULC classes. However, the challenge in distinguishing some LULC classes is acknowledged. For further study, exploring higher-resolution imagery would be considered.

Table 5 Accuracy assessment results for the 2001 LULC product

2001 classified class	Water	Built-up	Barren	Vegetation	Total	User's Accuracy	
Water	0	0	0	10	10	100	
Built-up	10	0	0	0	10	100	
Barren	0	17	1	0	18	94	
Vegetation	1	3	52	0	56	93	
Total	11	20	53	10	94		
Producer's Accuracy	90%	85%	98%	100%			
						Overall accuracy	91%

Table 6 Accuracy assessment results for the 2020 LULC product

2020 classified class	Water	Built-up	Barren	Vegetation	Total	User's Accuracy	
Water	10	0	0	0	10	100%	
Built-up	0	7	3	0	10	70%	
Barren	1	0	35	4	40	88%	
Vegetation	0	1	2	28	31	90%	
Total	11	8	40	32	91		
Producer's Accuracy	91%	88%	88%	88%			
						Overall accuracy	81%

In conclusion, this study demonstrates the application of remote sensing techniques and satellite imagery in assessing LULC changes and the dynamics of urban expansion in Makurdi, Benue State, Nigeria between 2001 to 2020. The results presented show rapid changes in LULC in Makurdi, particularly in the built-up areas. The analysis showed that between 2001 and 2020, built-up areas expanded by 1246.2km resulting in a decrease in the vegetation and barren land. The construction of new infrastructure and the growth of residential areas could impact natural resources. The comprehensive analysis of LULC changes and urban expansion can provide insights to urban planners and policymakers in effectively planning urban growth without disturbing natural resources. The Integration of remote sensing techniques could thus be effectively used to assess and analyze the temporal and spatial dynamics of LULC changes.

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