International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Assessment of Land Use Changes Using Remote Sensing and Geographic Information System (GIS) in Kumbotso Local Government Area, Kano State

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A B S T R A C T

The rapid urbanization and agricultural expansion in Kumbotso Local Government Area, Kano State, Nigeria, have prompted significant land use and land cover (LULC) changes over recent decades. To understand the interactions of human activities within the physical environment, it is pertinent to study the land use and land cover of the area under investigation. This study employs Remote Sensing and Geographic Information System (GIS) techniques to assess these changes from 2000 to 2023. Satellite imagery from Landsat 8–9 OLI/TIRS C2 L2, coupled with supervised classification and change detection methods using ArcGIS 10.8 software, reveals substantial shifts in land use patterns. The results obtained show some changes in land use and land cover classes within the period (2003–2023); bare land experienced a rapid increase of 52.3 km2, the built-up area increased by 49.8 km2, and vegetation decreased by 99.5 km2. Decreases were also observed in water bodies, with a reduction of 5.6 km2. The study underscores significant urbanization impacts and the importance of sustainable land management practices to mitigate adverse environmental impacts. It is, therefore, recommended that implementing land use zoning, promoting green infrastructure, and fostering community engagement address evolving land use dynamics and enhance environmental resilience. The findings inform policy formulation and guide future research towards sustainable development in the study area.

Keywords: Environmental Management, GIS, Land Cover, Land Use, Remote Sensing, Satellite Imagery and Urban Planning

1. Introduction

The land is one of the most significant natural resources that is essential to life. It has been used for building and farming over the decades. Knowing how land has been used requires a good understanding of the old land use principles and their impacts on human activity. The size and nature of land have changed over time due to human activities. Population density, circulation, economic development, and technological advancements are among the factors contributing to changes in land (Lambin & Meyfroidt, 2018).

Physical and biological components usually interact with human activities on land, resulting in various changes. Conventional techniques have historically been used to assess land use changes. However, modern town planners and geographers now employ remote sensing and Geographic Information System (GIS) technology to monitor these changes. Since the study of land use change is closely related to the study of agriculture, remote sensing plays a crucial role in environmental management (Xiao et al., 2020).

Land use comprises of human activities on land and sea. Therefore, proper information is needed for updating land use changes. Assessing land use changes is important for the planning and management of land for economic growth. Operative observation requires regular updating and mapping (Huang et al., 2020). The management of land has changed due to advancements in remote sensing and GIS technologies. Changes in land use were detected using labour-intensive and time-consuming methods such as tracing paper and topographic sheets before the creation of these technologies. According to Zhang et al. (2019), remote sensing has made it possible to draw maps of land use and to regularly monitor changes in these areas. For hard-to-reach areas, remote sensing and GIS are among the tools used in gathering data. These technologies enable professionals to acquire timely data and observe periodic changes. Remote sensing offers a wide range of analyses on the needs of rural areas (Ding et al., 2020).

One of the factors in determining land use change due to urbanization is differentiating between rural and urban areas. Remote sensing and GIS tools can classify types of land use in large areas (Natural Resources Canada, 2023).

2. Statement of Research Problem

There have been several changes in land use and land cover (LULC) in Kumbotso Local Government Area (LGA) in Kano State, Nigeria, over the past few decades. The area has witnessed a lot of changes due to the rapid agricultural and urban development resulting in the change in landscape. There is a lack of available data on the temporal and spatial dynamics of land use changes in this area presently. According to Huang et al. (2020) and Xiao et al. (2020), lack of data is impeding the development of sustainable land management policies and practices.

Because the existing methods for monitoring land use changes are manual, it is difficult to map the changes happening in Kumbotso LGA. GIS and RS offer fast and efficient ways to monitor and evaluate changes in land use. The use of these tools made having spatial data easier for understanding the dynamics of changing land use patterns (Liu et al., 2021). The major aim of the study is to solve the problem of poor knowledge and documentation of LULC changes in Kumbotso LGA through the use of GIS and RS.

Research using RS and GIS is required to evaluate these shifts and provide recommendations for sustainable land use planning. These kinds of studies are limited, which limits the ability of stakeholders to make informed decisions on environmental management, urban growth, and land use (Lambin & Meyfroidt, 2018; Zhang et al., 2019). Thus, the goal of this study is to close this gap by assessing changes in LULC in Kumbotso LGA during a 20-year span, from 2003 to 2023. The study will identify the trends, patterns, and factors influencing land use changes.

3. Literature Review

Land use and cover changes (LULC) are good research areas as they have a great influence on environmental management and urban development. Tracking and analyzing these changes requires the use of Geographic Information System (GIS) and Remote Sensing (RS) technology. They offer quick and reliable data that give us clearer insights about land use changes. Satellite imagery is used in remote sensing to collect data about the Earth's surface. GIS is also an important tool for spatial data analysis; when combined with other tools, researchers can detect changes in land use and land cover in large areas over long periods of time (Chen et al., 2021). The ability of RS and GIS to assess and evaluate changes has become valuable for urban planning and environmental management (Liu et al., 2021).

Several studies have confirmed the usefulness of RS and GIS in discovering LULC changes. Ding et al. (2020) discovered major impacts on the natural environment, while Xiao et al. (2020) confirmed how urban growth affects the environment. These technologies have been fundamental to urban growth and agricultural development. For example, Huang et al. (2020) evaluated landscape fragmentation and highlighted the importance of human activities in changing land cover forms. These studies show how RS and GIS are used in determining land use changes. Some of the challenges in using RS and GIS include data availability, resolution, and processing capabilities (Chen et al., 2021). However, higher-resolution satellite imagery and improved data processing systems have solved so many of the issues by making land use change more accurate and dependable (Liu et al., 2021).

Urban growth and agricultural development have led to major LULC changes in Nigeria, demanding research to suggest viable proposals. The use of RS and GIS in Nigeria has shown how land use changes affect local environments and communities. Ding et al., 2020, noted how urban sprawl in major cities like Lagos and Abuja impacts natural surroundings and aquatic resources. Land Use and Land Cover Change Detection and Analysis in Minna, Niger State, Nigeria; A Study by Musa et al (2018) concluded that deforestation, overgrazing, and clearing of sites for construction have serious impacts on vegetation and climate change. This is due to urbanization and the need for settlement areas occasioned by rapid population growth leading to major conversions in land use/land cover such as from empty land, plants or water bodies to built-up area. These activities also lead to problems like increased environmental temperatures as well as flooding. So that; the increase in rural-urban migration leads into an increment of settlement areas brought about by increasing urbanization.

Limited studies have been conducted in LGA's like Kumbotso in Kano State, despite the recent advances in technology. Concern about land use changes in this area calls for local studies that can highlight the challenges and make recommendations. Environmental managers and urban planners now use RS and GIS technologies in LULC studies. They help in better understanding of land use dynamics and guide decision-makers by giving first-hand information. This research aims to fill the gap in Kumbotso LGA to support Nigeria’s sustainable land management goals.

4. Research Methodology

Kumbotso Local Government Area lies between latitudes 11° 50′ S to 12° N and longitudes 8° 24′ W to 8° 40′ E at a Kano settlement zone surrounded by Madobi on the south and south–west, Rimingado on the north–west, Gwale on the north and Tarauni on the east. It covers 158 km², and in 2016 had a population of around 409500. The area code of the place is 700.

The study was conducted using a quantitative research design, employing remote sensing data analysis and GIS techniques to identify land use and land cover change in Kumbotso LGA. This analysis includes data acquisition, data pre-processing, classification, a change detection system, and data interpretation. The research design allowed the study to be conducted in a systematic and structured manner, which helped to meet the research objectives and gain an in-depth insight into the spatio-temporal dynamics of land use changes in the study area. The data collection techniques of the study are as follows: multi-spectral and multi-temporal LANDSAT satellite imagery for different time scales, such as 2003, 2013, and 2023 for Kumbotso, were obtained. With a 30×30-metre resolution, the satellite images provide sufficient detail for land use classification and change detection analysis. 2003 and 2023 pictures are from June, but 2013 is from April. The choice of these months was made to guarantee images without fog, conditions, rain, and so on. ArcGIS 10.8 was utilised to showcase images, combine them into mosaics, georeferenced the images, perform image classification through assessment, and establish the land cover and land use layout. The images of Landsat 8-9 OLI/TIRS C2 L2 for 2003, Landsat 8-9 OLI/TIRS C2 L2 for 2013, and Landsat 8-9 OLI/TIRS C2 L2 for 2023 were obtained through the USGS (United States Geological Survey).

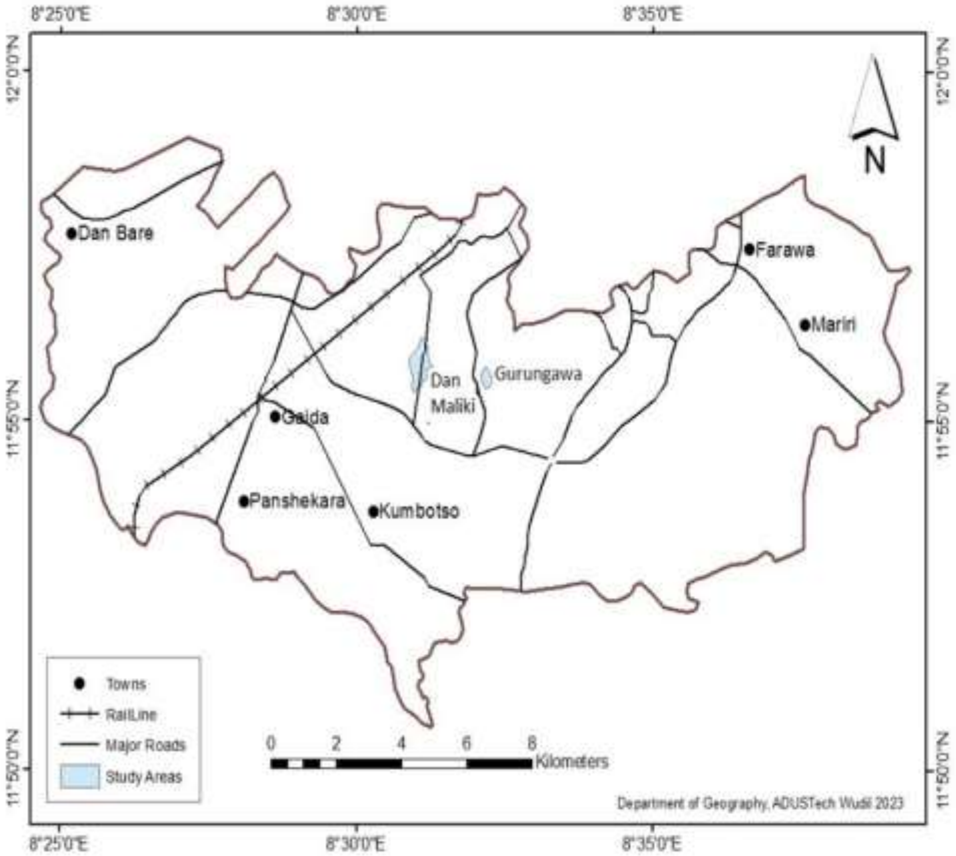

Figure 1: A Map of Kumbotso LGA Showing the Study Areas

Source: Cartography and GIS, Department of Geography ADUSTech Wudil

Table 1: Data source

S/NO	Data type	Date of production	Scale	Sources
1	Landsat image (8-9 OLI/TIRS C2 L2)	09-04-2003	30m	United states geological survey(USGS) www.usgs.gov
2	Landsat image (8-9 OLI/TIRS C2 L2)	20-06-2013	30m	United states geological survey(USGS) www.usgs.gov
3	Landsat image (8-9 OLI/TIRS C2 L2)	23-06-2023	30m	United states geological survey(USGS) www.usgs.gov

4.1 Development of a Classification Scheme:

The classification scheme, which gives a broad classification of the land use and land cover of the study area, is shown in Table 2 below:

Table 2: Classification scheme

S/NO.	CLASS
1	Bare land
2	Built up
3	Vegetation
4	Water body

4.2 Image Classification and Processing

The remote sensing data underwent several image processing and classification steps:

1. pre-processing: The satellite image data was processed to eliminate radiometric and atmospheric distortions. through geometric correction, atmospheric correction, radiometric correction, and normalisation.

2. Additional analysis: The satellite image quality was enhanced to increase visual contrast and interpretability by applying filters, histogram stretching, and contrast manipulation.

3. Image classification: Different land use and land cover classes were derived from the satellite imagery by applying either supervised or unsupervised classification techniques. Unsupervised classification was able to detect groupings, while supervised classification was not.

4.3 Change Detection Analysis

Change detection analysis facilitates the location and measurement of such changes in land use due to the passage of time. Change detection analysis was carried out by following these steps:

a) Post-Classification Comparison: This type of change detection analysis was used to detect changes and conversions between land use classes by comparing land use and land cover maps of three different time periods (2003, 2013, and 2023).

b) T-difference image analysis: The pixel-by-pixel subtraction of images using the Image differencing procedure available in ArcMap allowed detecting changes in use of the T-difference images. ArcMap tools were used in creating a threshold to give human-usable samples for picture classification.

4.4 Classification

Land use maps for the years 2003, 2013, and 2023 have been created using ArcGIS for land use analysis (shown in Figures 3, 4, and 5). The steps followed for analysis are:

(a) Digitization of different classes using the polygon tool.

(b) Displaying all the different classes in the same layer.

(c) Calculating the area of each class. These data for three years were analysed, and changes in land use patterns were detected by creating a land use table (Table 3), which featured the areas of different classes.

5. Results and Discussions

This chapter presents the results of the land cover and land use analysis of multi-temporal satellite images, as depicted in Table 3.

Table 3: Land Use/Land Cover Mapping

Land use/Land cover	2003		2013		2023	
	Square km	%	Square km	%	Square km	%
Bare land	34	21	67	41	86.3	53
Build up	10.1	6	39.6	24	59.9	37
Vegetation	111	69	44.5	27	11.5	7

Water body	6.9	4	11	7	4.4	3
Total	162		162		162	

Table 3 displays the area and percentage of each category of land use and/or land cover for the three distinct years. The largest area in 2003 was covered by vegetation (111 square kilometres), while the smallest area was made up of water bodies (6.9 square kilometres). There were some significant shifts in land use trends between 2003 and 2023:

- Vegetation: A notable decline in vegetation between 2003 and 2023 (from 111 square kilometres to 11.5 square kilometres) suggests extensive deforestation or land conversion.
- Build-up: The area that was covered by built-up areas increased dramatically from 10.1 square kilometres in 2003 to 59.9 square kilometres in 2023, indicating a rapid expansion of infrastructure and urbanization.
- Bare land: From 34 square kilometres in 2003 to 86.3 square kilometres in 2023, the amount of bare land increased significantly, indicating either land degradation or the conversion of vegetated areas.
- Water bodies: Concerns regarding water resource management and environmental conservation measures are raised by the drop in water body from 6.9 square kilometres in 2003 to 4.4 square kilometres in 2023.

These modifications emphasise how land use is dynamic and stress the significance of sustainable land management techniques in reducing negative environmental effects and maintaining ecological integrity over the long run. The land cover and land use maps for the years 1975, 1992, and 2005 are depicted in Figures 3, 4, and 5 respectively.

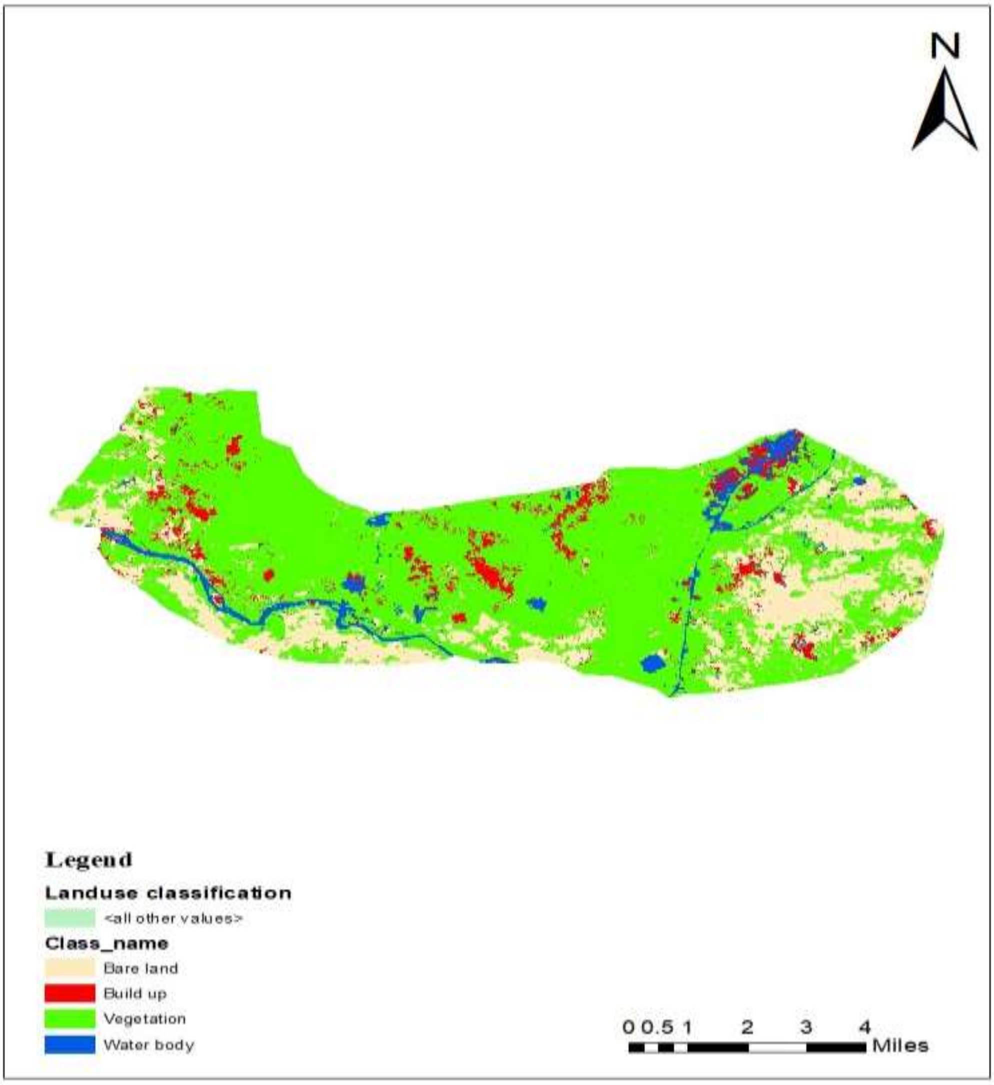

Figure 3: Land Use/Land Cover Map of Kumbotso in 2003

The 2003 map shows that the study area is mostly covered in dense vegetation. Only six percent of the entire area, or 10.1 square kilometres, were built-up areas. The study area was covered by vegetation in an area of 111 square kilometres, or 69%. Twenty-one square kilometres, or 21% of the entire study area, were made up of bare ground. Sixty-nine square kilometres, or 4% of the entire study area, were covered by water bodies. In 2003, the least amount of land was covered by water bodies, while the biggest amount was covered by vegetation. When comparing 2003 to 2013, there were notable changes in the patterns of land use and cover. Over 40% of the vegetative area has been significantly reduced.

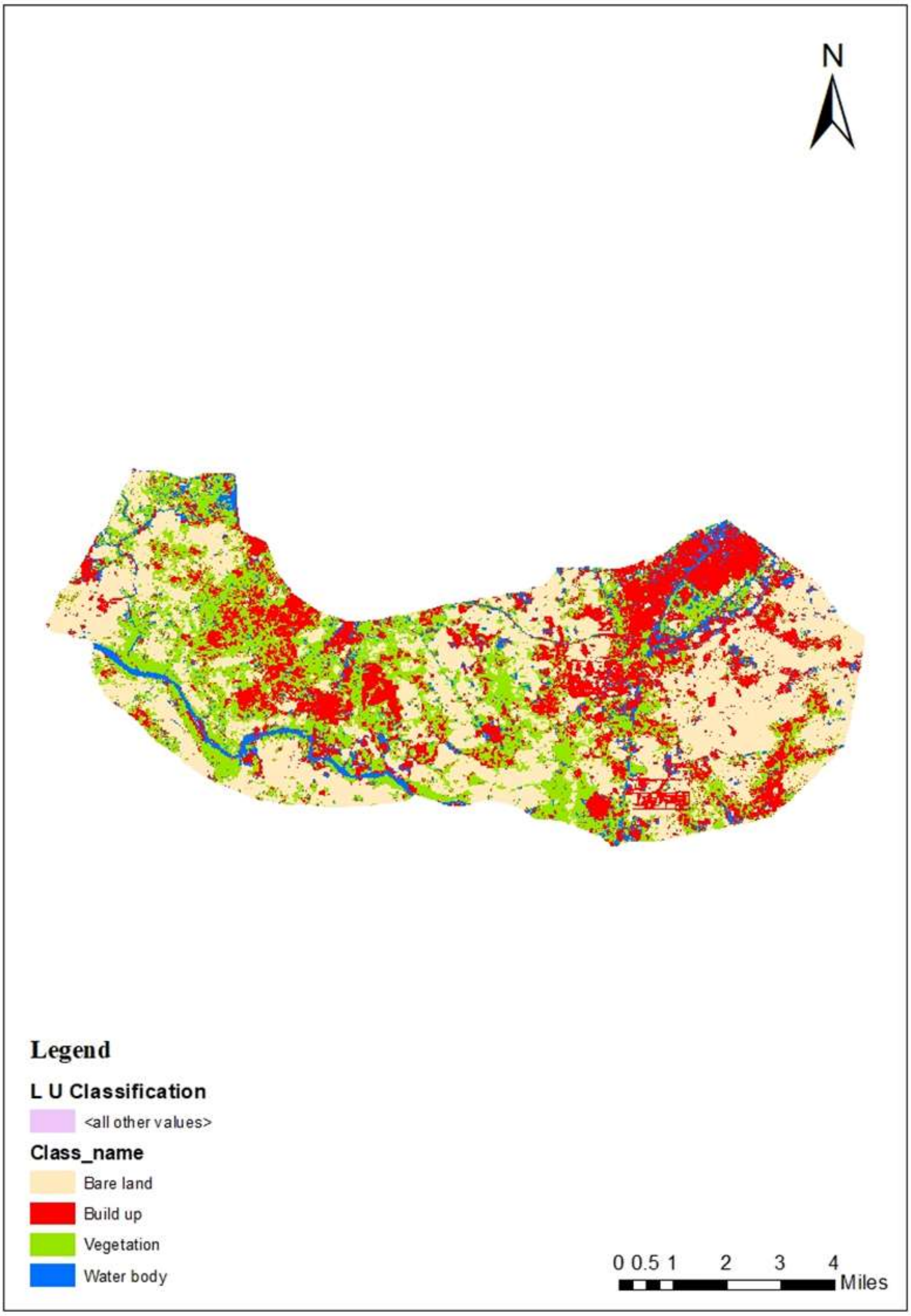

Figure 4: Land Use/Land Cover Map of Kumbotso in 2023

The area occupied by bare land increased from 34 square kilometres to 67 square kilometres, accompanied by a decrease in vegetation from 111 square kilometres to 44.5 square kilometers. Bare land became the dominant class, covering 41 percent of the total area in 2013. Water bodies occupied the smallest percentage of the total area in 2013. The decrease in vegetation area is attributed to deforestation for settlement and related activities due to rapid urbanisation, as well as human pressure on forests for fuelwood and cattle grazing. Additionally, the built-up area increased from 10.1 square kilometres in 2003 to 39.6 square kilometres in 2013.

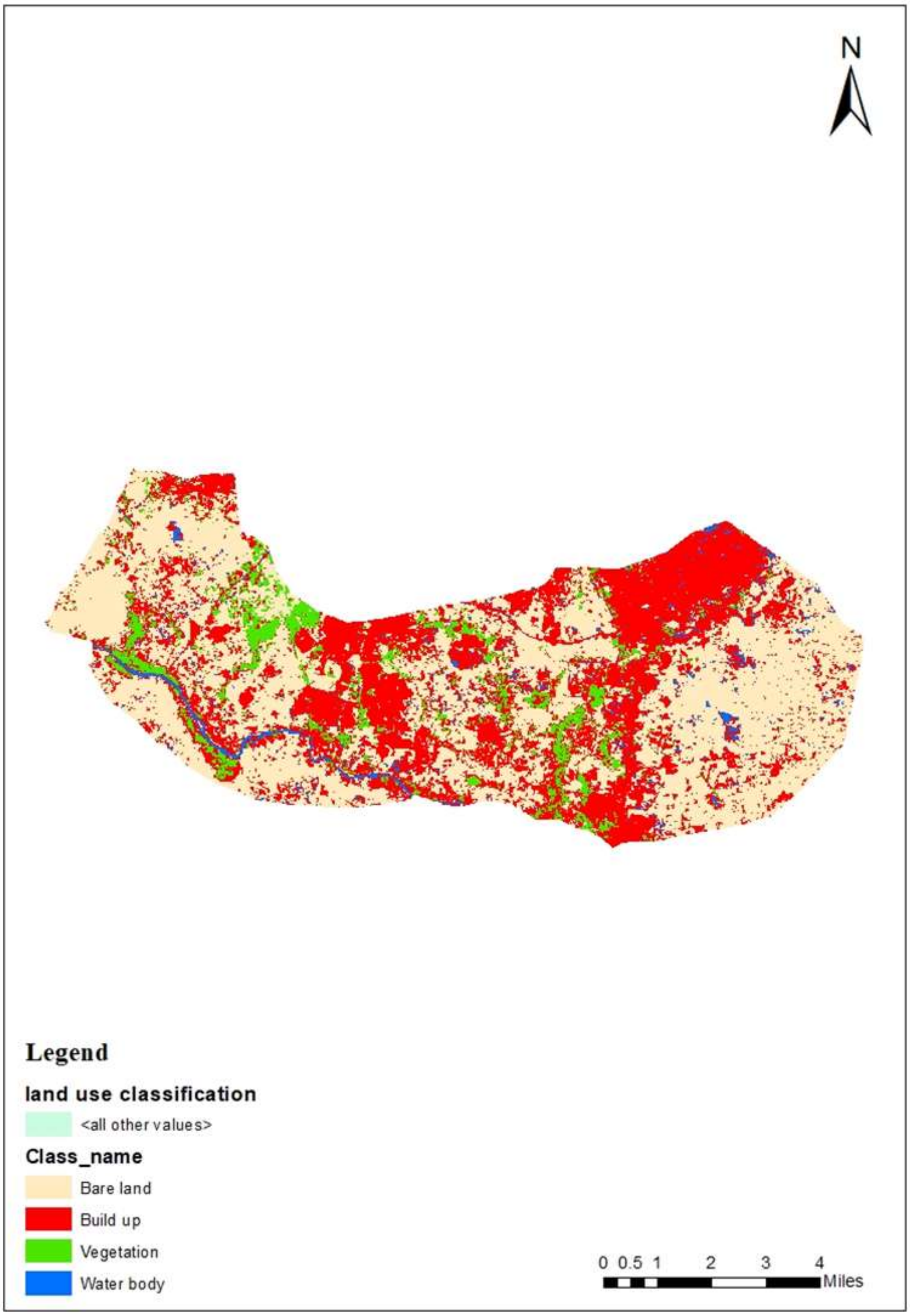

Figure 5: Land Use/Land Cover Map of Kumbotso in 2023

The land use and land cover patterns in 2003 remained the same as those in 2013. There was a huge decrease in vegetation from 2003 to 2023, amounting to 99.5 square kilometres, with a percentage decrease of 62 percent. The area occupied by water bodies decreased to 4.4 square kilometres from 11 square kilometres in 2013. Bare land increased from 67 square kilometres in 2013 to 86.3 square kilometres in 2023, representing a total increment of 52.3 square kilometres and a 32 percent increase in area and percentage, respectively. The built-up area witnessed an increase to 59.9 square kilometres in 2023, a 53.2 percent increase from 2003 to 2023, totalling an increase of 49.8 square kilometres and 31 percent in square kilometres and percentage, respectively. This increase is a result of population growth and urbanisation, leading to a higher demand for residential areas.

6. Conclusion and Recommendations

6.1 Conclusion

The study has highlighted the spatial changes occurring in Kumbotso LGA. The data demonstrate the degree of urbanisation, which includes a decline in vegetation between 2003 and 2023. The increase in built-up areas is indicative of the demand for infrastructure and additional residential areas, as well as the rapid growth of the study area. These changes affect the climate, fauna, and natural resources. In addition, the research revealed the degradation of water bodies and the conversion of natural habitats into buildings. In order to address the issues, the results emphasise the critical necessity for sustainable land management and efficient urban development. The government agencies tasked with developing and protecting the environment can benefit from the knowledge gained from this study. By combining geographic analysis and remote sensing techniques, future studies can focus on environmental conservation measures and urban planning interventions for sustainable land use management.

6.2 Recommendations

- Government should introduce land use zoning regulations taking into account the environment, infrastructure and community needs for proper development.
- Develop recreational facilities and green areas to fight climate change. This will help reverse the vegetation cover that was lost due to expansion in buildup areas.
- Encourage transit oriented development (TOD) to reduce dependence on private vehicles to curb congestion and urban sprawl.
- Implement sustainable water management strategies to address water scarcity and mitigate flood risks associated with land use changes.
- Preserve and protect natural habitats through conservation and maintaining the ecosystem.
- Encourage community participation in the land use planning process so that societal needs are considered.
- Support sustainable agriculture and land management to limit deforestation and land degradation.

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