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RESEARCH ARTICLE

Spatiotemporal Analysis of Land Use and Land Cover Change in Gombe Local Government Area, Gombe State, Nigeria Using Remote Sensing Data

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Abstract
There has been a growing pressure on land resources and how natural areas are being transformed for human use in Nigeria, especially in Gombe State, which is located in the North-Eastern part of the country. Land cover and land use form a complex relationship in Gombe, particularly between vegetation and built-up areas. The conversion of usable vegetation to other land uses is occurring at an alarming rate. To track these changes, remote sensing and GIS offer a unique approach. This study investigates the dynamics of land use and land cover (LULC) change in Gombe Local Government Area, Nigeria, over a 30-year period (1991–2021) using Landsat imagery. By employing both supervised and unsupervised classification methods, five land cover classes—Bare Soil, Built-up Area, Dense Vegetation, Farmland, and Vegetation—were identified and analyzed. The results reveal a significant expansion of urban areas, with Built-up Area increasing from 10% in 1991 to over 61% in 2021, while Farmland and Vegetation showed considerable declines. The classification process achieved an overall accuracy of 84% and a Kappa coefficient of 78.84% for 2021, supporting the reliability of the analysis. These findings have important environmental and policy relevance, providing evidence to guide sustainable land management, climate adaptation measures, and regional urban planning initiatives.

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1.0 INTRODUCTION

1.1 Background to the Study

Land Use and Land Cover (LULC) changes are critical indicators of both natural and anthropogenic transformations affecting the Earth's surface (Junye *et al.,* 2022; Arowolo *et al.,* 2018). These changes, often driven by urbanization, deforestation, agricultural expansion, and climate variability, have significant ecological and socio-economic consequences (Lu *et al.,* 2004; Rawat and Kumar, 2015). Understanding the spatial and temporal dynamics of LULC is essential for informed policy-making and sustainable resource management (Yanjiao *et al.,* 2019; Albert *et al.,* 2024).

For clarity, several specialized terms related to remote sensing and GIS are used in this study. Supervised classification refers to a method where the analyst defines known land cover types using training samples, and the algorithm classifies the remaining pixels accordingly, while unsupervised classification automatically groups pixels into clusters based on spectral similarities without prior knowledge of classes

(Lillesand et al., 2015; Karthik & Shivakumar, 2021). Land Use and Land Cover (LULC) change denotes the transformation of natural or human-modified landscapes over time, often monitored using multi-temporal satellite imagery (Lu et al., 2004; Rawat & Kumar, 2015). Techniques such as post-classification comparison allow quantification of changes between classified images from different periods (Peiman, 2011). Additionally, remote sensing involves the acquisition of information about the Earth's surface from satellite or airborne sensors, and Geographic Information Systems (GIS) provide tools for storing, analyzing, and visualizing spatial data (Ahmad & Yahaya, 2017; Lim et al., 2024). These definitions provide context for understanding how LULC dynamics in Gombe LGA were mapped and analyzed.

Remote Sensing (RS) and Geographic Information Systems (GIS) have proven to be effective tools for detecting and analyzing LULC changes over time (Olorunfemi *et al.,* 2020). Satellite imagery provides cost-effective, repetitive, and synoptic observations that enable researchers to monitor land surface changes at various spatial and temporal scales (Lillesand *et al.,* 2015).

In Nigeria, rapid population growth and urban expansion have exacerbated land use changes, especially in urban centers like Gombe (Bulus and Mala, 2017). The city is experiencing increased pressure on land resources due to agricultural encroachment, construction, and environmental degradation (Hashidu *et al.,* 2019).

Despite the growing relevance of RS and GIS for LULC studies in Nigeria, there remains limited localized research focusing on secondary cities such as Gombe. This study, therefore, aims to fill this gap by analyzing LULC changes in Gombe Local Government Area (LGA) from 1991 to 2021 using Landsat satellite imagery. The findings will support local planning authorities in sustainable land and environmental management.

The objective of this research is to assess the LULC changes in the study area in the period of 1991 – 2021 and identify the difference between natural and artificial. The land cover features for the study area have been divided into four types as follows: Dense Vegetation, Farmland, Vegetation, Bare Surface, and Built-Up Area. The scope of this research is to analyze the land use/land cover of the study area using two classification methods: Interactive Supervised Classification and ISO Cluster Unsupervised.

2.0 METHODOLOGY

2.1 Study Area

Gombe Local Government Area (LGA) is located in the north-eastern part of Nigeria and serves as the administrative headquarters of Gombe State. It lies approximately between latitudes 10°15′N and 10°20′N and longitudes 11°00′E and 11°10′E, covering an area of about 52 km². According to the National Population Commission (NPC, 2006), Gombe LGA had an estimated population of 266,844.

The topography of the area is generally undulating, with isolated hills and ridges. The region is drained by several rivers, including the River Gongola and its tributaries (Udo, 2023). The vegetation consists primarily of Sudan savannah, characterized by grasses and scattered shrubs.Gombe experiences a tropical climate with two distinct seasons: a rainy season (May to October) and a dry season (November to April). The annual rainfall ranges from 850 mm to 1,200 mm, while the average temperature is around 30°C (Ahmad and Yahaya, 2017).

The area is predominantly agrarian, with farming and trading serving as major economic activities (Malchau, 2002). However, urbanization and infrastructural development have been increasing, leading to pressure on land resources and significant land cover transformations.

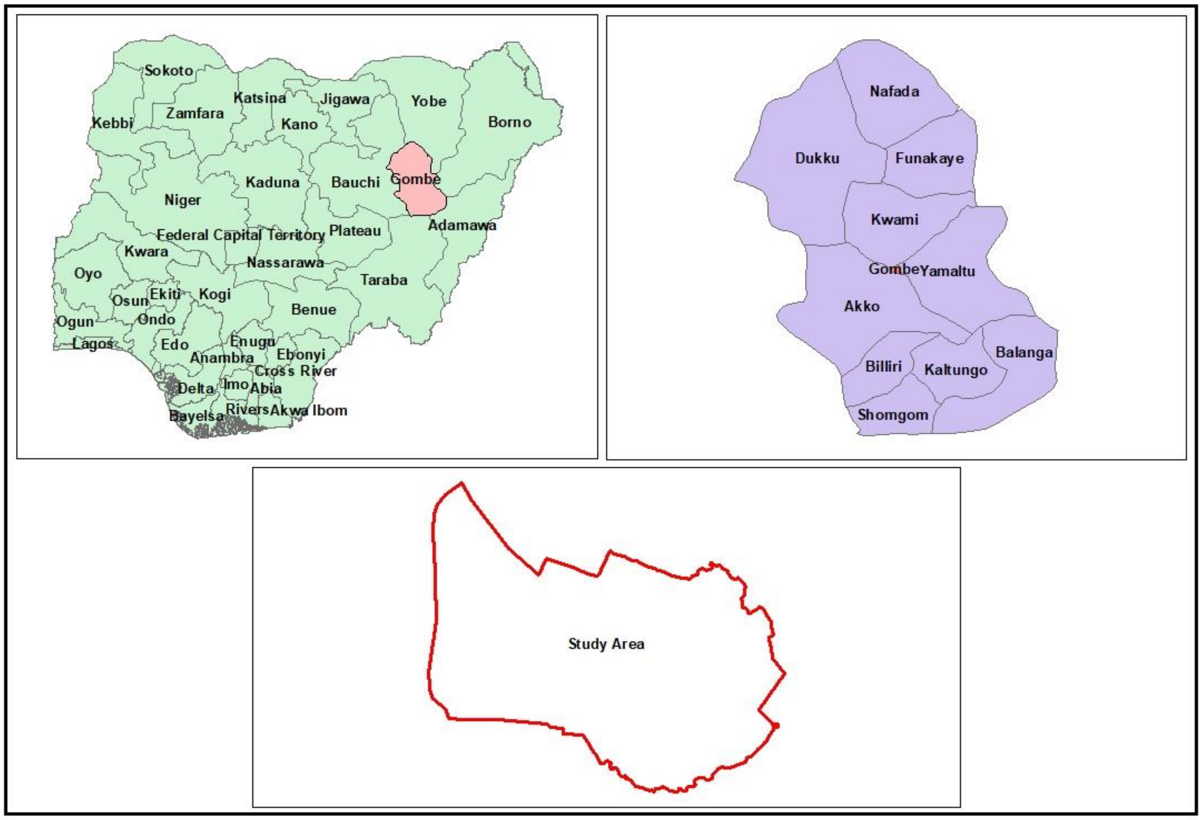

Figure 1: Map of Study Area

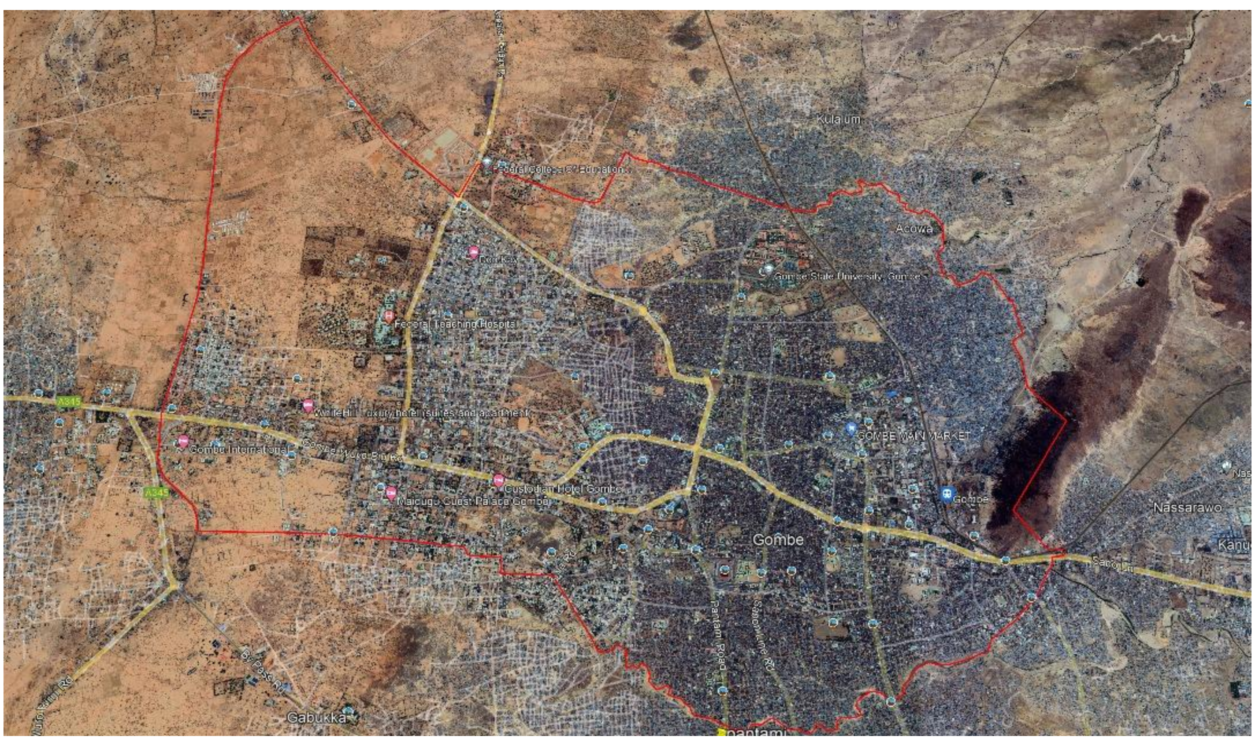

Figure 2: Satellite view of the Study Area

2.2 Dataset
In this research, four (4) Landsat imageries were used. Images of the study area were downloaded from the USGS Earth Explorer; the details of the images are shown in Table 1. The selection of the dates of the datasets is based on the objectives of the research, which is to monitor the changes in the land cover during the period. A solid correlation of LULC is needed to obtain these changes.
Landsat imagery is selected due to high-quality images and multispectral bands that allow the extraction of valuable information (Lim *et al.,* 2024). With the moderate spatial resolution (30m), it has provided many layers of data across the visible and invisible light spectrum. These data can be manipulated to reveal what the Earth's surface looks like, including what types of vegetation are present or how a natural disaster has impacted an area (Miller *et al.,* 2011). The band adopted in this study for the LULC include Natural colour composite (4 Red, 3 Green, 2 Blue).

Table 1: Properties of Landsat data

Details/Data	Landsat 5	Landsat 7	Landsat 8	Landsat 8
Acquisition date	16 October 1991	29 December 2001	13 November 2013	02 October 2021
Source	USGS	USGS	USGS	USGS
Spatial Resolution	30m	30m	30m	30m

2.3 Data collection
This study utilized multi-temporal satellite imagery from the Landsat series, covering the years 1991, 2001, 2013, and 2021. Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI) data were obtained from the United States Geological Survey (USGS) Earth Explorer platform. These images were selected based on minimal cloud cover and temporal consistency to ensure accurate land cover comparison.

2.4 Image preprocessing
Preprocessing tasks were conducted using ENVI 5.3 and ArcGIS 10.7. The steps included radiometric correction, geometric correction, and sub-setting of images to the study area. False-color composites were generated to aid visual interpretation and classification (Bajwa *et al.,* 2020).

2.5 Classification method
A hybrid classification technique combining unsupervised and supervised classification was employed. Initially, the unsupervised ISODATA algorithm was used to generate spectral clusters (Karthik, 2021). Training samples were then collected from known land cover types to guide the supervised Maximum Likelihood Classification (MLC). Five land cover classes were identified: Bare Soil, Built-up Area, Dense Vegetation, Farmland, and Sparse Vegetation.

2.6 Accuracy assessment
Classification accuracy was assessed using confusion matrices derived from ground truth data and high-resolution Google Earth imagery (Weijia *et al.,* 2020). Metrics such as Overall Accuracy and Kappa Coefficient were computed to evaluate classification reliability. The accuracy assessment sample size for the work is 100.

2.7 Change detection analysis
Post-classification comparison was used to detect land cover transitions over the selected years (Peiman, 2011). Area statistics were generated for each class, and change trends were analyzed using tabular and graphical representations. Figure 1 describes the methodology work frame from the reconnaissance to data presentation.

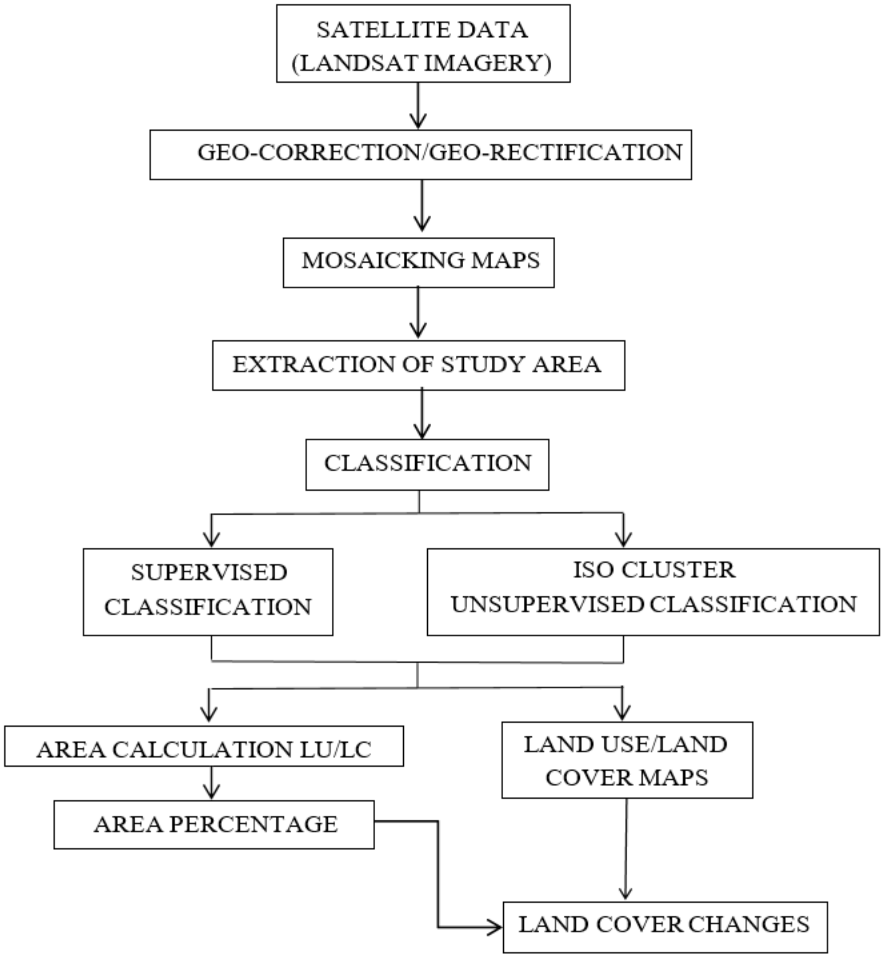

Figure 3: Methodology flow diagram

3.0: RESULTS AND DISCUSSION

3.1 Presentation of results

The processing and analysis of the data acquired were done using ArcMap 10.7 and Microsoft Excel (version 2020), as discussed in the previous session. The results of the research include Land Use/Land Cover of Gombe Local Government area, Gombe State (1991, 2001, 2013 and 2021).

- **Land Use/Land Cover of Gombe Local Government area, Gombe State (1991 Imagery):**

The LU/LC of the study area, as of 1991, was classified into five categories as described in the previous section: Bare soil, Built-up Area, Dense Vegetation, Farmland, and Vegetation. The analysis shows that 31% of the study area, approximately 12.08 Km^2 for Bare Soil, followed by 10% of the study area, which is approximately 3.89 Km^2 are covered with a Built-up Area, followed by 3% of the study area, which is approximately 1.28 covered with Dense Vegetation, 42% of the study area, approximately 16.04 Km^2 covered with Farmland, and 14% of it is covered with approximately 5.34 Km^2 covered with Vegetation. Farmland highly dominated the local government as at 1991.

Table 2: Analysis of the classification carry out on Gombe Local Government Area, Gombe State (1991 Imagery)

Class	Area (Km^2)	Percentage (%)
Bare Soil	12.08	31.28
Built-Up Area	3.89	10.06
Dense Vegetation	1.28	3.32

Class	Area (Km^2)	Percentage (%)
Farmland	16.04	41.51
Vegetation	5.34	13.83
Grand Total	38.63	100

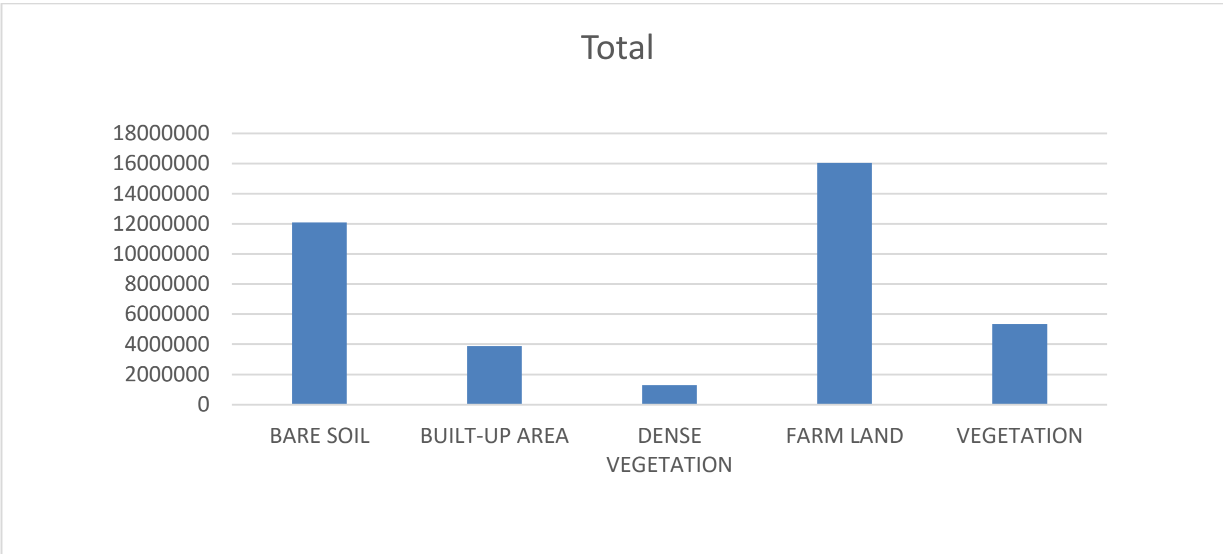

Figure 4: Graphical Representation of 1991 Imagery Classification

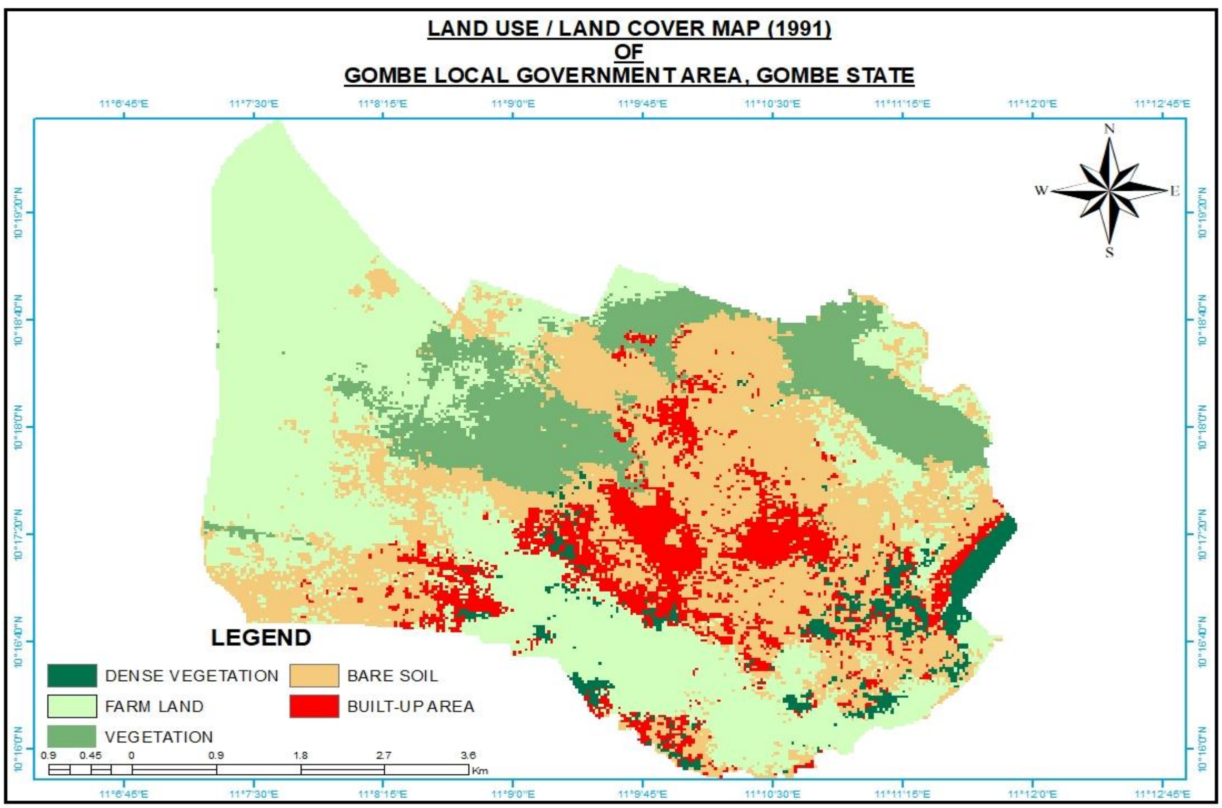

Figure 5: Supervised Classification (1991)

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- **Land Use/Land Cover of Gombe Local Government area, Gombe State (2001 Imagery):**

The LU/LC of the study area as of 2001 was classified into five categories as described in the previous section: Bare soil, Built-up Area, Dense Vegetation, Farmland, and Vegetation. The analysis shows that 29% of the study area, approximately 11.15 Km^2 for Bare soil, followed by 17% of the study area, which is approximately 6.66 Km^2 covered with Built-up Area, followed by 1% of the study area, which is approximately 0.25 Km^2 covered with Dense Vegetation, 38% of the study area, approximately 14.58 Km^2 covered with Farmland and 15% of approximately 6.00 Km^2 covered with Vegetation.

Table 3: Analysis of the classification carry out on Gombe Local Government area, Gombe State (2001 Imagery)

Class	Area (Km^2)	Percentage (%)
Bare Soil	11.15	28.85
Built-Up Area	6.66	17.24
Dense Vegetation	0.25	0.65
Farmland	14.58	37.72
Vegetation	6.00	15.54
Grand Total	38.64	100

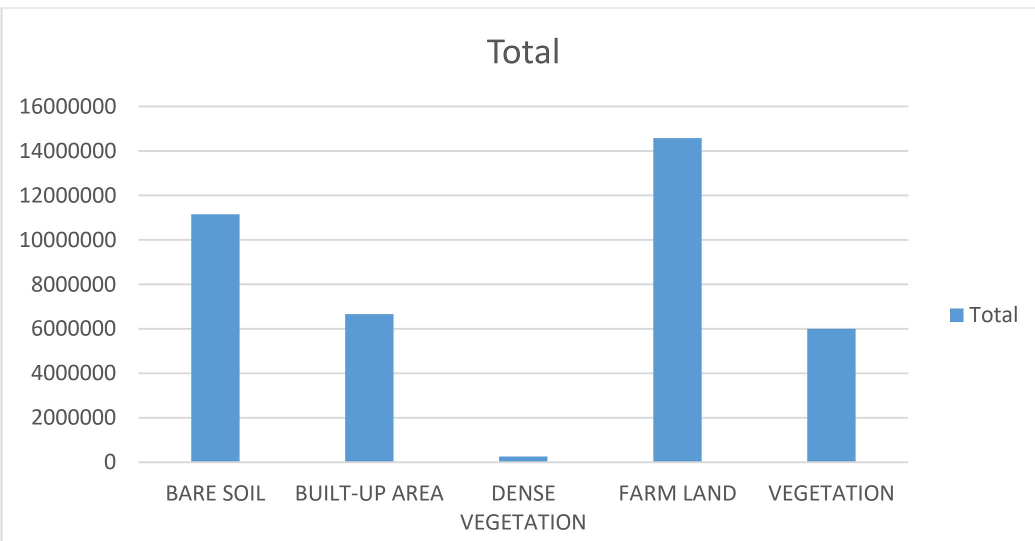

Figure 6: Graphical Representation of 2001 Imagery Classification

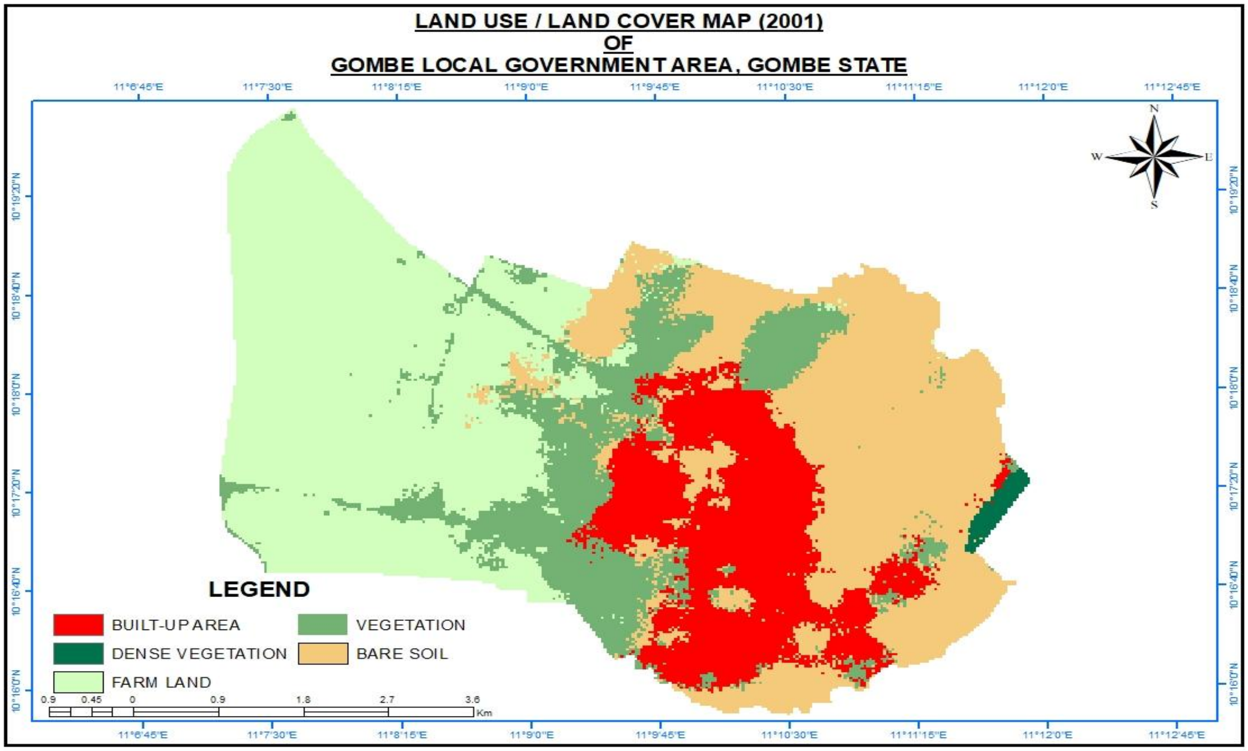

Figure 7: Supervised Classification (2001)

- **Land Use/Land Cover of Gombe Local Government Area, Gombe State (2013 Imagery):**

The LU/LC of the study area as of 2013 was classified into five categories as described in the previous section: Bare soil, Built-up Area, Dense Vegetation, Farmland, and Vegetation. The analysis shows that 5% of the study area, approximately 1.90 Km^2 for Bare Soil, followed by 39% of the study area, which is approximately 15.12 Km^2 covered with Built-up Area, followed by 1% of the study area, which is approximately 0.24 Km^2 covered with Dense Vegetation, 24% of the study area, approximately 9.26 Km^2 covered with Farmland and 31% of approximately 12.11 Km^2 covered with Vegetation.

Table 4: Analysis of the classification carried out on Gombe Local Government area, Gombe State (2013 Imagery)

Class	AREA (Km^2)	Percentage (%)
Bare Soil	1.90	4.92
Built-Up Area	15.12	39.14
Dense Vegetation	0.24	0.63
Farmland	9.26	23.96
Vegetation	12.11	31.36
Grand Total	**38.63**	**100**

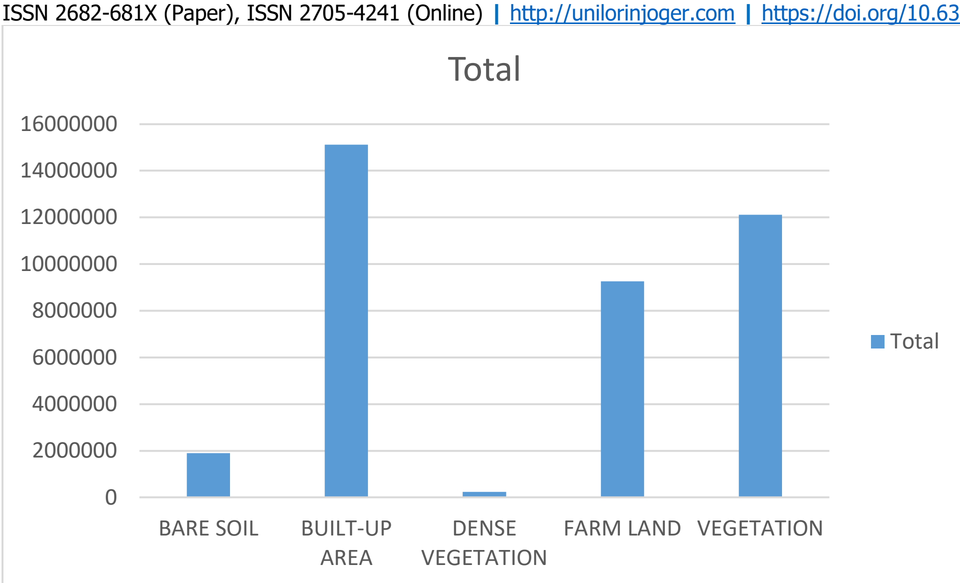

Figure 8: Graphical Representation of 2013 Imagery Classification

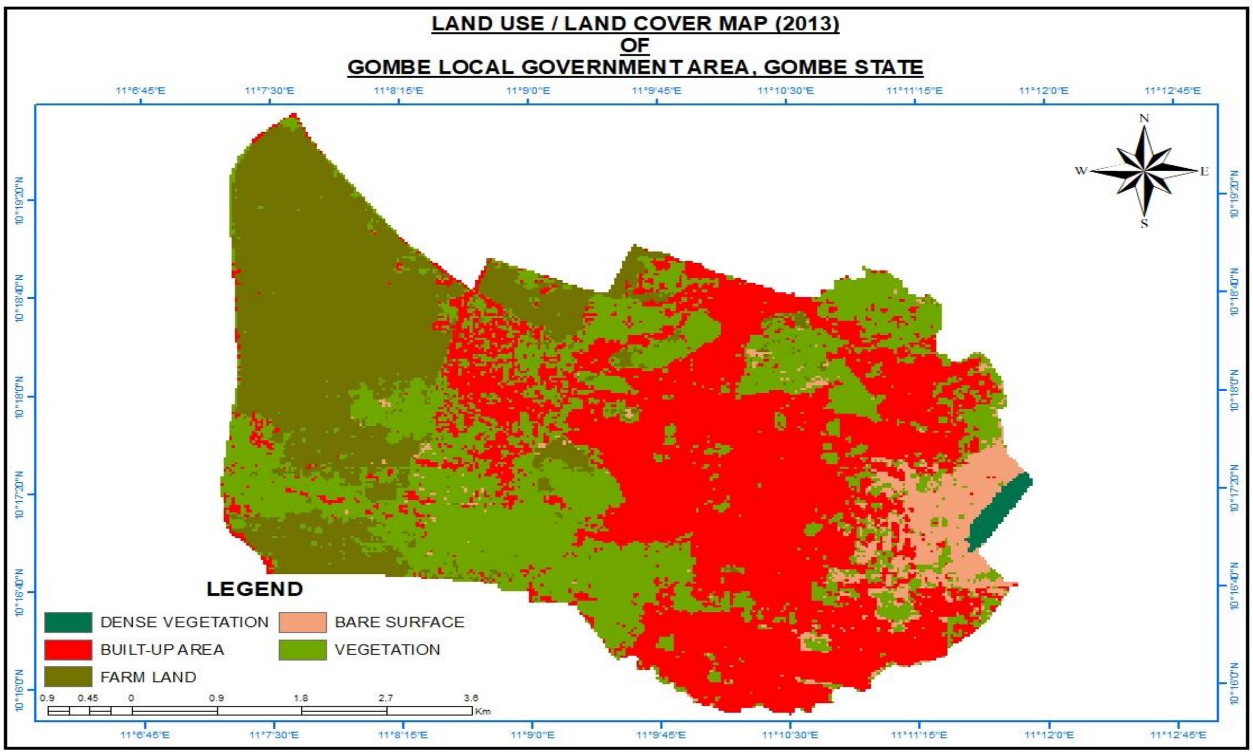

Figure 9: Supervised Classification (2013)

- **Land Use/Land Cover of Gombe Local Government area, Gombe State (2021 Imagery):**

The LU/LC of the study area as of 2021 was classified into five categories as described in the previous section: Bare soil, Built-up Area, Dense Vegetation, Farmland, and Vegetation. The analysis shows that 11% of the study area, approximately 4.16 Km^2 for Bare Soil, followed by 61% of the study area, which is approximately 23.53 Km^2 covered with Built-up Area, followed by 2% of the study area, which is

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approximately 0.76 Km^2 covered with Dense Vegetation, 24% of the study area, approximately 9.22 Km^2 covered with farmland, and 2% of the area, approximately 0.96 Km^2, was covered with urban areas.

Table 5: Analysis of the classification carry out on Gombe Local Government area, Gombe State (2021 Imagery)

Class	Area (Km^2)	Percentage (%)
Bare Soil	4.16	10.76
Built-Up Area	23.53	60.91
Dense Vegetation	0.76	1.97
Farmland	9.22	23.88
Vegetation	0.96	2.49
Grand Total	38.63	100

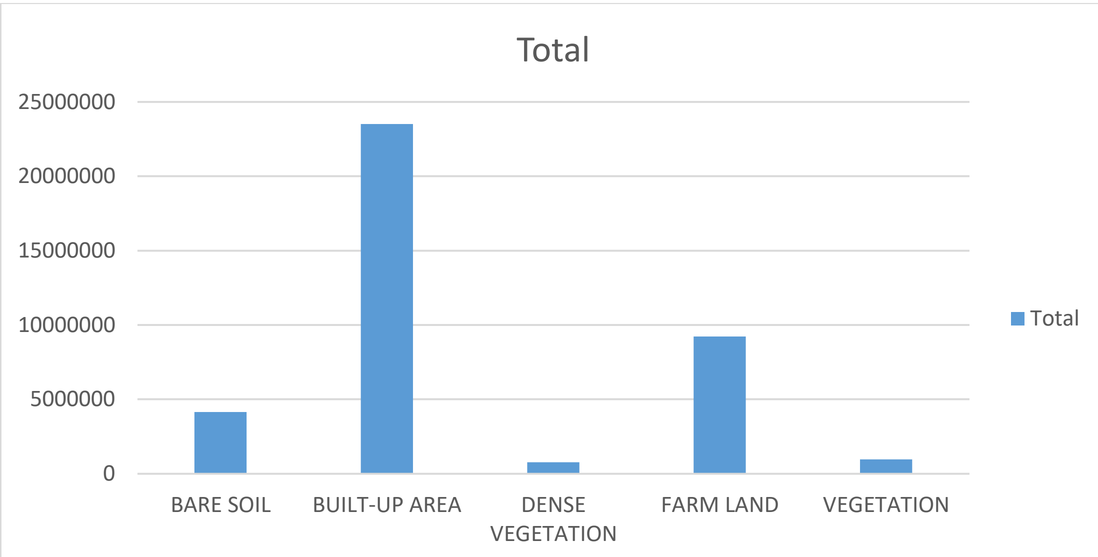

Figure 10: Graphical Representation of 2021 Imagery Classification

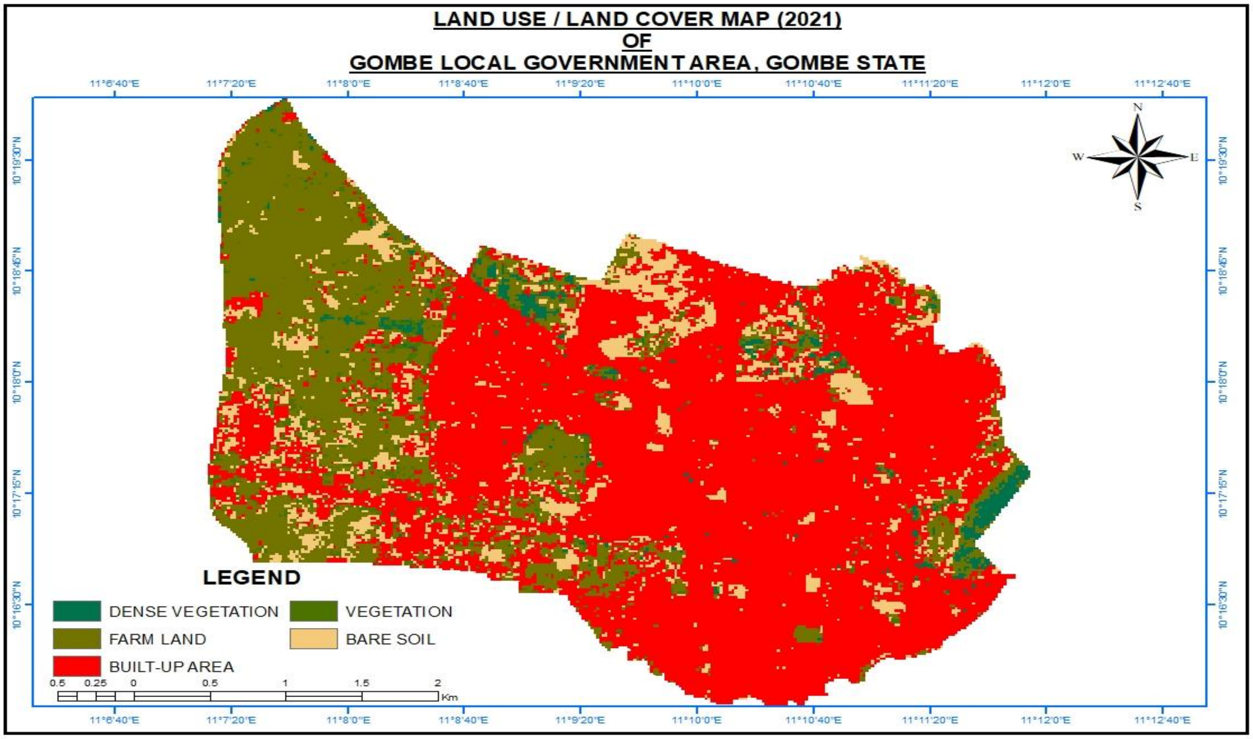

Figure 11: Supervised Classification (2021)

3.2 Change Detection

The change detection analysis indicates that Gombe LGA has undergone substantial transformation, with the most prominent being the growth in built-up areas from 10% in 1991 to over 61% in 2021. This 51% increase suggests intense urban encroachment driven by population growth and administrative significance. Concurrently, farmland experienced a steady decline, dropping from 42% to 24%, while total vegetative cover (including both sparse and dense vegetation) fell from 17% to just 4%. These shifts suggest unsustainable land conversion practices, which, if unregulated, could undermine environmental integrity and resource availability in the region. The result of this changes are shown in Table 6 and Figure 2.

The table below presents the rate of change detection for the comparison result and the overall changes between the years 1991 and 2021.

Table 6: Changes rate based on comparison result

Class/Year	1991	2001	2013	2021	Rate of Change (1991-2001)	Rate of Change (2001-2013)	Rate of Change (2013-2021)
Bare Soil	31%	29%	5%	11%	-2%	-24%	6%
Built-Up Area	10%	17%	39%	61%	7%	22	22%
Dense Vegetation	3%	1%	1%	2%	-2%	0%	1%
Farmland	42%	38%	24%	24%	-4%	-14%	0%
Vegetation	14%	15%	31%	2%	1%	-16%	-30%

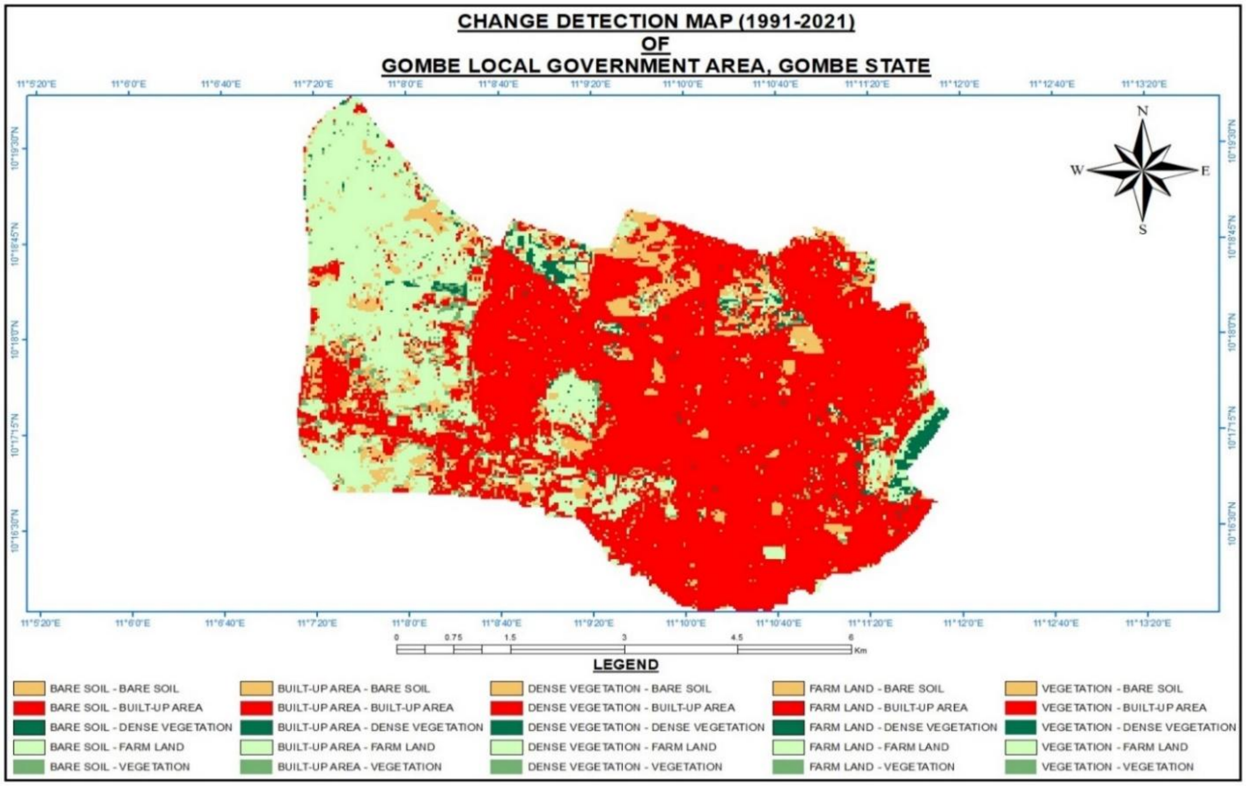

Figure 12: Change Detection Map

3.3 Accuracy Assessment

This section shows the level of accuracy of the analysis following the procedure stated below:

The classification accuracy analysis validates the robustness of the adopted classification method. The overall accuracy for 2021 reached 84%, supported by a Kappa coefficient of 78.84%, indicating strong agreement between classified results and reference data. Similar accuracy levels were achieved in previous years (82–88%), underscoring the reliability of the image processing workflow. The inclusion of high-resolution Google Earth imagery and field-truthing enhanced confidence in class assignments, particularly in differentiating subtle land cover types such as sparse vegetation and bare soil (Lu *et al.,* 2004; Weijia *et al.,* 2020).

Table 7: Accuracy and Kappa Co-efficient Table

Year	Accuracy (%)	Kappa Co-efficient (%)
2021	84	78.84
2013	88	82.92
2001	84	76.92
1991	82	77.47

3.4 DISCUSSION

The spatiotemporal analysis of land use and land cover (LULC) in Gombe Local Government Area (LGA) reveals a significant shift from natural to built environments over the 30-year period under study. The drastic expansion of built-up areas from 10% in 1991 to over 61% in 2021 mirrors broader urbanization trends observed across sub-Saharan Africa, where rapid demographic growth and administrative upgrading of towns to state capitals drive increased infrastructure development and land demand (Arowolo and Deng, 2018). These findings confirm that population growth and economic pressures have a strong spatial footprint that transforms previously agricultural and vegetated landscapes into impervious surfaces.

Additionally, the study revealed a marked decline in agricultural and vegetated land uses, which raises significant environmental concerns. Farmland coverage dropped by almost 18%, while vegetation decreased by over 11% between 1991 and 2021. This loss of green cover may result in reduced biodiversity, increased surface runoff, and the exacerbation of microclimatic anomalies such as the urban heat island effect (Rawat and Kumar, 2015).The implications extend beyond ecology into food security and livelihoods, especially in regions like Gombe where farming remains a key economic activity (Malchau, 2002).

The dual use of supervised and unsupervised classification techniques, combined with multi-temporal Landsat data, enhanced the detection of these changes. The 2021 dataset yielded an overall accuracy of 84% and a Kappa coefficient of 78.84%, indicating high reliability in classification performance. This aligns with the assertions of Lim *et al.,* 2024, who emphasized the importance of combining multiple classification methods and ancillary high-resolution data to improve mapping precision in heterogeneous landscapes.

The observed LULC changes have notable socio-economic implications. The reduction in agricultural lands, which fell by almost 18% between 1991 and 2021, may threaten local food security and reduce income opportunities for farmers, potentially increasing rural-to-urban migration and placing pressure on urban social services. Expansion of built-up areas can also stimulate economic activities such as trade, construction, and service provision, highlighting a complex balance between development and livelihood sustainability. These dynamics are particularly relevant given Nigeria's National Urban Development Policy (2012) and the Gombe State Economic Empowerment initiatives, which encourage urban growth and infrastructure expansion but also emphasize sustainable land management and agricultural productivity.

Environmental implications are equally significant. The decline in vegetation cover by over 11% may reduce biodiversity, degrade soil quality, and exacerbate microclimatic issues such as the urban heat island effect, while increasing surface runoff and flood risk (Rawat and Kumar, 2015). These impacts reinforce the need for environmental planning and the implementation of policies like the Nigerian National Environmental Standards and Regulations Enforcement Agency (NESREA) guidelines on sustainable land use, which aim to integrate ecological considerations into urban and regional development.

Methodologically, the dual use of supervised and unsupervised classification techniques, combined with multi-temporal Landsat data, enhanced the detection of these changes. The 2021 dataset yielded an overall accuracy of 84% and a Kappa coefficient of 78.84%, indicating high reliability in classification performance. This aligns with Lim et al. (2024), who emphasized the importance of combining multiple classification methods and ancillary high-resolution data to improve mapping precision in heterogeneous landscapes.

4.0 CONCLUSION AND RECOMMENDATION

This study examined the land use and land cover (LULC) changes within Gombe Local Government Area between 1991 and 2021 using satellite imagery and remote sensing techniques. The findings revealed a remarkable transformation of the area over the thirty-year period, characterized by a substantial increase in built-up areas from 10.1% in 1991 to 61.2% in 2021. This rapid urban expansion occurred alongside a notable decline in agricultural land, sparse vegetation, and dense vegetation. These changes are largely attributed to the combined effects of population growth, urbanization, and infrastructural development, which have led to the widespread conversion of farmlands and natural vegetation into built-up spaces. The resulting implications include environmental degradation, reduced agricultural productivity, and loss of biodiversity, all of which pose significant challenges to sustainable development in the area.

To mitigate these adverse impacts and ensure a more sustainable balance between development and environmental conservation, it is recommended that urban growth be guided by comprehensive and sustainable planning frameworks that incorporate green infrastructure and preserve ecological zones. Authorities should also strengthen land use regulations and enforce zoning laws to curb the indiscriminate conversion of agricultural and vegetated lands into urban structures. Furthermore, afforestation and reforestation programmes should be implemented to restore lost vegetation cover, improve ecological stability, and reduce climate-related risks. Promoting public awareness and community engagement is equally essential, as it encourages the adoption of sustainable land management practices among local populations. Finally, future research should focus on employing higher-resolution satellite imagery and field validation techniques to provide more detailed and accurate insights that can inform effective land use monitoring and environmental management strategies in the region.

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