Assessment of Land Use/Land Cover Change and Vegetation Dynamics in Mokwa Local Government Area, Niger State, Nigeria

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Abstract

Land use and land cover (LULC) changes have significant implications for environmental sustainability, biodiversity conservation, and natural resource management. This study assessed the spatial and temporal changes in land use/land cover in Mokwa Local Government, Niger State, Nigeria, between 2000 and 2020 using Landsat ETM (2000 and 2010) and Landsat OLI (2020) satellite imagery integrated with Geographic Information System (GIS) techniques. Ground truthing was conducted to validate the classified images, while supervised image classification, change detection analysis, overlay operations, cross-tabulation, and the Normalized Difference Vegetation Index (NDVI) were employed to quantify land cover transitions and vegetation dynamics. The result of this study revealed a progressive decline of vegetal cover of the study area from 228,691 hectares (53.3%) in the year 2000, to 171,170 hectares (39.8%) and 119,972 hectares (28.1%) in 2010 and 2020, respectively. On the contrary, built-up and bare surfaces increased from 23,351 hectares (5.4%) and 143,947.2 hectares (33.7%) in 2000 to 53,226 hectares (12.3%) and 181,305.1 hectares (42.3%) respectively in 2010 and a further increase in 2020. In addition, the result of the study revealed that the mean decadal trend of deforestation was 61%, which showed that the vegetation declined by about 61% from 2000 to 2020. The study demonstrates the effectiveness of integrating remote sensing and GIS for monitoring land use dynamics and provides valuable information to support sustainable land-use planning, environmental conservation, and policy formulation aimed at mitigating further land degradation.

Keywords: *Land use/land cover change (LULCC); Remote Sensing (RS); Geographic Information System (GIS); Normalized Difference Vegetation Index (NDVI).*

1. INTRODUCTION

Human activities have modified the Earth's surface since ancient times to support livelihoods and ensure the continuous existence of humankind. Human development and advancement have led to many infrastructural projects and economic activities within the ecosystem (Madaki *et al.,* 2019). These developments have altered the natural patterns of the Earth's surface, including reductions in forest resources and biodiversity. Forest resources are important for national development and generate revenue through international trade (Nyatuame & Agodzo, 2017). However, their economic value has encouraged continuous exploitation, and overuse has led to a steady decline in both their quality and extent.

The rapid increase in the human population has increased the demand for food. As a result, more land is being cleared and cultivated for farming.

Agriculture is a major economic activity in developing countries, especially in Africa (Amaechi *et al.,* 2021). Large areas of land are used to grow cash crops to support national economies. Fishing is also an important agricultural activity, but it can negatively affect water systems and aquatic life. In addition, livestock rearing through grazing and transhumance has further placed pressure on the ecosystem (Adetumberu, 2000).

In Nigeria, deforestation is a major environmental problem linked to various human activities. Farming and the indiscriminate cutting of trees for domestic and industrial purposes have greatly reduced forest quality and size (Madaki *et al.,* 2019). Other practices, such as shifting cultivation, clear-cutting, and slash-and-burn agriculture, also contribute significantly to forest degradation. In many instances, these activities exceed sustainable limits, leading to permanent alterations of forest ecosystems (Tariq *et al.,* 2015). The removal of vegetation exposes the soil surface to the direct impact of rainfall, resulting in accelerated soil erosion, nutrient depletion, and land degradation. Consequently, flooding and gully erosion become more severe, causing damage to farmlands, settlements, roads, dams, and bridges (Adetumberu, 2000). These environmental impacts ultimately reduce agricultural productivity and threaten food security. In Mokwa Local Government Area, deforestation has been intensified by the growing demand for agricultural land, urban expansion, commercial logging, and increasing dependence on fuelwood as a primary source of domestic energy (Oyewale, 2006).

Deforestation has significantly altered land use and land cover patterns across many regions. Land use and land cover changes are driven by the interaction of natural processes and human activities, and they influence biodiversity, local climate, ecosystem functioning, and socio-economic development (Bako *et al.,* 2015). Understanding the spatial and temporal dynamics of these changes is essential for evaluating the extent of environmental degradation and developing effective conservation and land management strategies. Consequently, land use and land cover mapping, together with change detection analysis, have become indispensable approaches for identifying patterns of landscape transformation and supporting evidence-based environmental planning (Ayele, 2018).

Advances in Remote Sensing and Geographic Information Systems (GIS) have greatly enhanced the ability to monitor and quantify environmental changes over large geographical areas with high accuracy and temporal consistency. Remote sensing provides multi-temporal satellite imagery that enables continuous observation of the Earth's surface, making it possible to detect changes in vegetation cover over time without extensive field surveys. GIS complements remote sensing by providing efficient tools for storing, processing, integrating, analysing, and visualizing spatial data, thereby facilitating accurate mapping and change detection (Nwobodo, 2018). This study assesses land use/land cover changes and the trend of deforestation in Mokwa Local Government Area between 2000 and 2020.

2. MATERIALS AND METHOD

Study Area

Mokwa Local Government Area is located in Niger State, Nigeria, between Longitude 4°45′00″E and 5°45′05″E and Latitude 8°45′00″N and 9°40′00″N. The Local Government Area covers approximately 4,338 km² and had a projected population of 404,448 in 2021 (Beranrd, 2019). It shares boundaries with Mashegu Local Government Area to the north, Lavun to the east, Edati to the southeast, and Borgu to the west. Mokwa Local Government Area experiences a tropical wet-and-dry (Sudan Savannah) climate, with annual rainfall ranging from 1,000 – 1,300 mm and temperatures between 25°C and 35°C. The area is characterized by fertile ferruginous tropical and alluvial soils that support extensive cultivation of crops such as rice, maize, millet, sorghum, yam, and cassava (Jeminiwa *et al.,* 2020). Its vegetation consists mainly of Southern Guinea Savannah grassland with scattered economic tree species, although agricultural expansion, logging, and fuelwood harvesting have significantly reduced the natural vegetation. Agriculture, livestock rearing, fishing, and trading constitute the major socio-economic activities, while its strategic location also makes Mokwa an important transportation and commercial hub (Jeminiwa *et al.,* 2020).

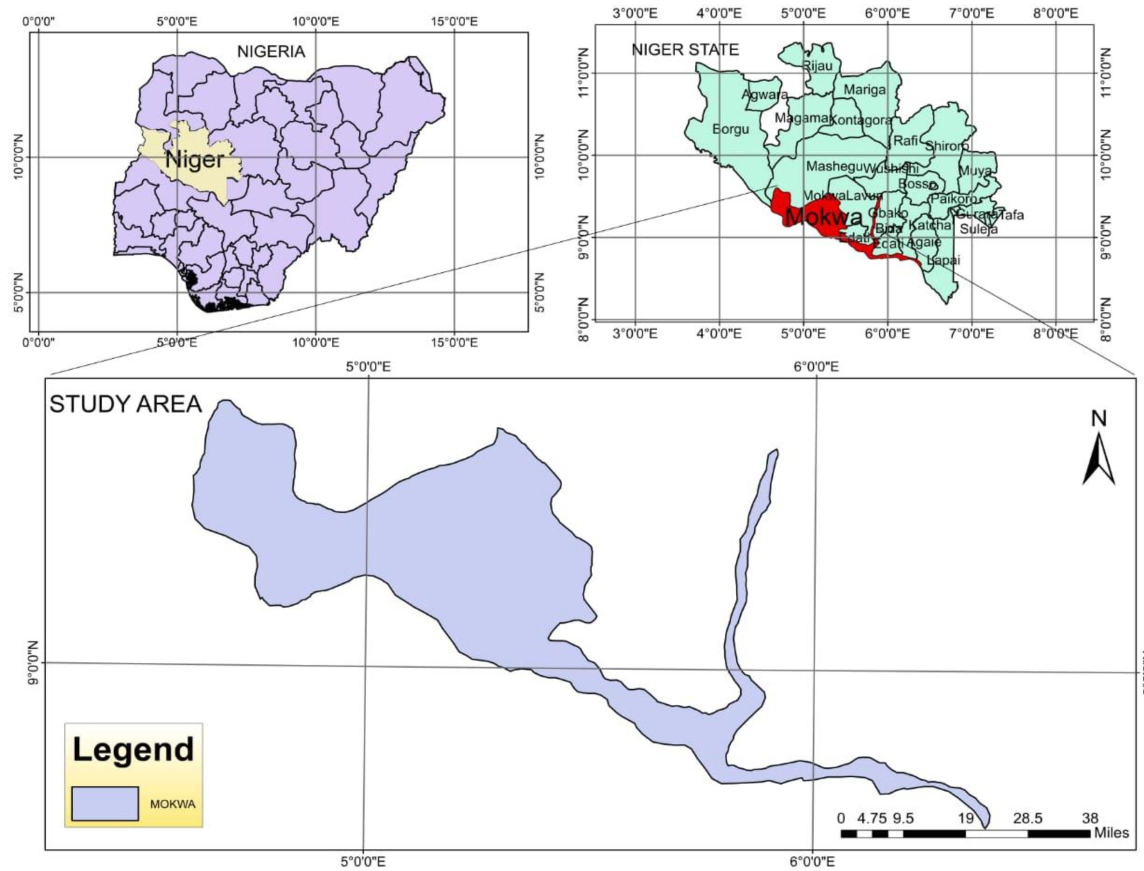

Figure 1: Mokwa Local Government Area, Niger State, Nigeria,

Methodology

The study utilized secondary data obtained from Landsat satellite images comprising Landsat ETM+ (2000), Landsat ETM+ (2010), and Landsat 8 OLI (2020). These multi-temporal satellite images were used to assess land use/land cover (LULC) changes and deforestation trends in Mokwa Local Government Area.

Table 1: Satellite imageries used

Year	Satellite	Sensor	Spatial Resolution	Source
2000	Landsat 7	ETM+	30m	USGS
2010	Landsat 7	ETM+	30m	USGS
2020	Landsat 8	OLI	30m	USGS

Ground Truthing

Ground truthing was conducted to validate the accuracy of the land use/land cover classification derived from the Landsat images. Representative locations for the major land use/land cover classes (built-up area, vegetation, water bodies, and bare land) were visited during fieldwork. Field observations, photographs, and visual identification of land cover features were compared with the classified satellite images to verify that each land cover class corresponded with the actual ground conditions. Where discrepancies were observed, the image classification was refined to improve its accuracy.

Land Use/Land Cover Change Analysis

The assessment of land use/land cover changes between 2000 and 2020 involved the following procedures:

i. Area Calculation

After image classification, the number of pixels belonging to each land use/land cover class was determined. Since Landsat imagery has a spatial resolution of 30 m × 30 m, each pixel represents an area of 900 m^2 (0.09 hectares). The area occupied by each land use class was therefore calculated using:

Area (ha) = Number of pixels × 0.09

The percentage area of each land use/land cover class was computed as:

Percentage Area = (Area of a LULC class / Total Area of the Study Area) × 100

The calculated areas for the years 2000, 2010, and 2020 were compared to determine the magnitude and direction of land use/land cover changes over the study period.

ii. Overlay Analysis

Overlay operations were performed by superimposing classified raster images from different years on a pixel-by-pixel basis. This technique made it possible to identify areas where land use/land cover classes had changed over time and quantify the extent of these changes.

iii. Cross-tabulation Analysis

Cross-tabulation was used to compare the classified images for the three study years and determine all possible transitions between land use/land cover classes. The analysis generated change matrices showing gains, losses, persistence, and conversions from one land cover category to another, thereby providing a comprehensive assessment of land cover dynamics.

iv. Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) was used to assess the condition and density of vegetation cover in the study area. NDVI was computed using the Near-Infrared (NIR) and Red bands of the Landsat imagery according to the equation:

NDVI = (NIR - RED) / (NIR + RED)

Where:
NIR = Near-Infrared band of the satellite image.
RED = Red band of the satellite image.

The resulting NDVI values range from -1 to +1, where values close to +1 indicate dense and healthy vegetation, values around 0 represent sparse vegetation or bare surfaces, and negative values correspond to water bodies or other non-vegetated surfaces. Comparison of NDVI maps for 2000, 2010, and 2020 was used to evaluate the trend and extent of deforestation in the study area.

Examination of the trend of deforestation in the study area from 2000-2020

The percentage change and NDVI were adopted. The percentage change is mathematically expressed as;

$$\text{(Trend) Percentage Change} = \frac{\text{observed change}}{\text{sum of change}} \text{ X } 100$$

3. RESULTS AND DISCUSSION

3.1 Land use/land cover changes in Mokwa LGA from 2000 to 2020

Table 1 presents the land use/land cover changes in Mokwa LGA from 2000 to 2020. The data are presented in percentages and hectares.

Table 2*: Land use and land cover changes in Mokwa LGA from 2000 to 2020*

		LULC2000	
Gridcode	**Class name**	**Area (Ha)**	**Percentage (%)**
1	Water	32701.9	7.6
2	Vegetation	228691.9	53.3
4	built up areas	23351.8	5.4
3	bare land	143947.2	33.7
		LULC2010	
Gridcode	**Class name**	**Area (Ha)**	**Percentage (%)**
1	Water	24307.7	5.6
2	Vegetation	171170.3	39.8
3	built up areas	53226.0	12.3
4	bare land	181305.1	42.3
		LULC2020	
Gridcode	**Class name**	**Area (Ha)**	**Percentage (%)**
1	Water	20534.6	4.8
2	Vegetation	119972.7	28.1
3	built up areas	79267.25	18.6
4	bare land	207463.9	48.5

Source: Author's Data Analysis

In the year 2000, built-up areas covered 23,351.8 hectares, constituting approximately 5.4% of the total land area. This relatively small proportion indicates that Mokwa LGA was still predominantly rural, with limited urban development and relatively low pressure on natural resources.

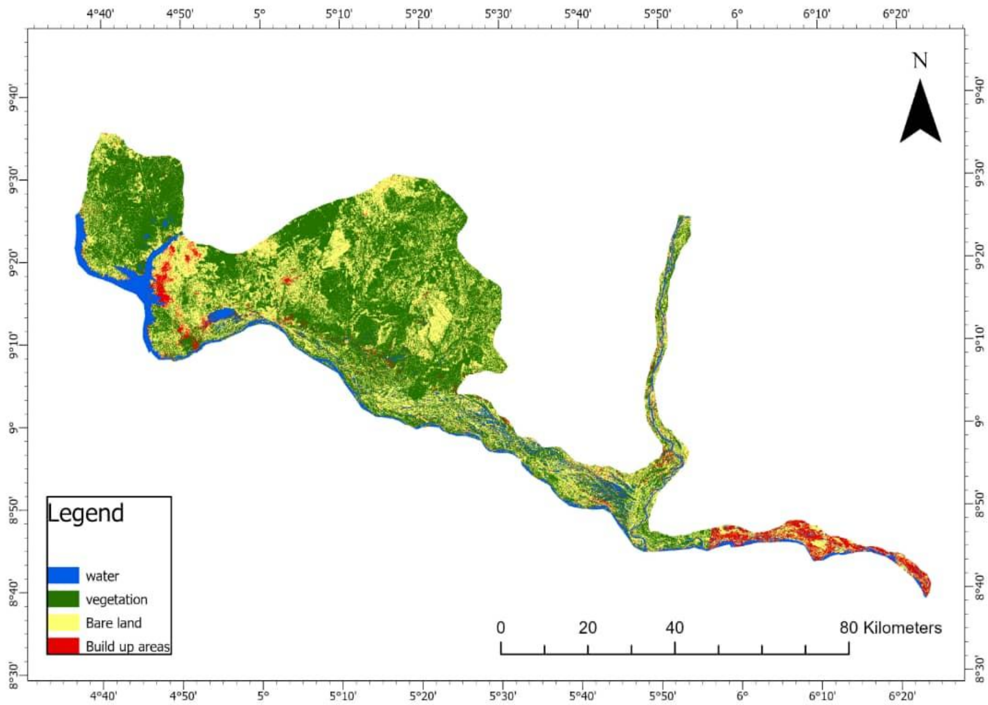

Figure 2: Land use/Land Cover Changes in 2000
Source: Author's Data Analysis

By 2010, built-up areas had expanded significantly to 53,226 hectares, representing about 12.3% of the total land area. The rapid increase suggests accelerated urban growth, increasing demand for housing, commercial activities, and infrastructure, which likely occurred at the expense of natural vegetation and agricultural land.

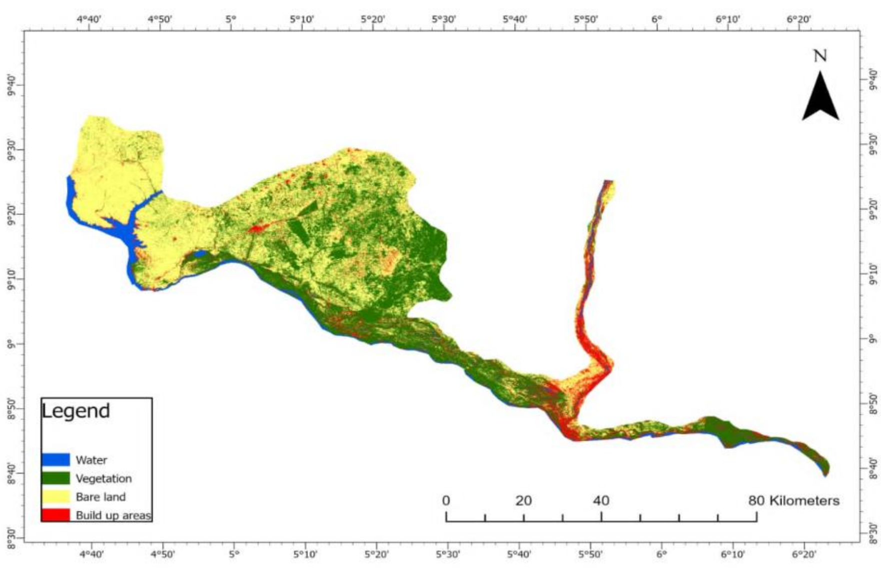

Figure 3: Land use/Land Cover changes in 2010
Source: Author's Data Analysis

In 2020, the trend continued, with built-up areas increasing to 79,267.25 hectares or 18.6% of the total land area. This expansion reflects sustained urbanization and population growth, indicating increasing pressure on land resources and the need for effective land use planning to ensure sustainable development.

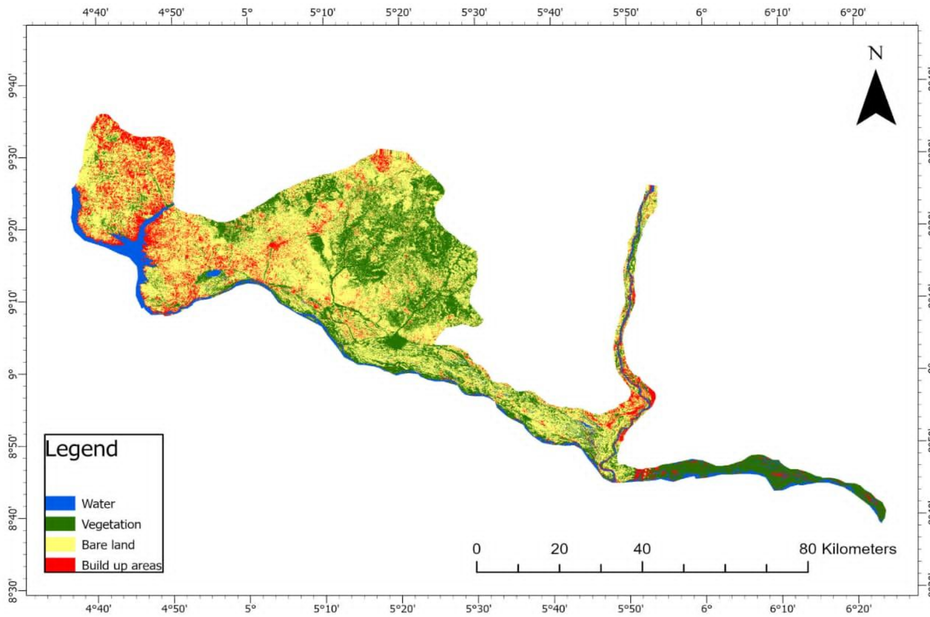

Figure 4: Land use/land cover changes in 2020
Source: Author's Data Analysis

This finding is consistent with that of Fatusin *et al.,* (2019), where built-up area increased from 1,044.71 hectares (7.06%) in 1986 to 2,033.061 hectares (13.78%) in 2002 and further to 7,934.06 hectares (53.61%) in 2018. This increase is likely due to population growth and urbanization, which drive the conversion of land to residential, commercial, and other urban uses.

In 2000, vegetation was the most dominant land cover, occupying about 228,691.9 hectares, representing 53.3% of the total land area. This indicates that the study area still possessed substantial vegetation cover capable of supporting biodiversity, maintaining ecological balance, and providing ecosystem services. By 2010, vegetation had declined to 171,170.3 hectares (39.8%), suggesting increasing human interference through agricultural expansion, logging, and settlement development. By 2020, vegetation had further reduced to 119,972 hectares (28.1%), indicating a significant loss of forest resources and natural habitats. The continuous decline implies increasing environmental degradation, loss of biodiversity, reduced carbon sequestration, and greater vulnerability to climate change. This finding agrees with Yakubu *et al.,* (2020), who reported a steady decline in vegetation cover from 823.86 km² (81.08%) in 1985 to 717.32 km² (70.60%) in 2000 and 576.29 km² (56.72%) in 2018. The reduction may be attributed to deforestation for agricultural expansion, urban development, infrastructure projects, overexploitation of forest resources, and unsustainable land management practices.

Water bodies also showed a continuous decline throughout the study period. In 2000, water bodies occupied about 32,701.9 hectares (7.6%), indicating relatively stable surface water resources capable of supporting domestic use, irrigation, fishing, and ecological functions. By 2010, the area decreased to 24,307.7 hectares (5.6%), suggesting increasing pressure on available water resources due to climatic variability and growing human activities. In 2020, water bodies further declined to 20,534.6 hectares (4.8%), implying a reduction in water availability that could negatively affect agriculture, aquatic ecosystems, and local livelihoods. This finding is consistent with Koko *et al.,* (2021), who reported a decline in water bodies from 216.08 km² (12.54%) in 1990 to 53.86 km² (3.13%) in 2019. The observed reduction may be associated with increased water abstraction for agriculture and domestic purposes, sedimentation, and the conversion of wetlands and water bodies into other land uses.

Bare surfaces increased consistently over the study period. In 2000, bare surfaces covered 143,947.2 hectares, accounting for 33.7% of the study area, indicating that a considerable proportion of the land had already been exposed or degraded. By 2010, bare surfaces expanded to 181,305.1 hectares (42.3%), suggesting intensified vegetation removal and increasing land degradation. In 2020, bare surfaces became the dominant land cover, occupying 207,463.9 hectares (48.5%) of the total land area. This indicates severe environmental degradation, reduced vegetation productivity, increased susceptibility to erosion, and declining land quality. The finding agrees with Koko *et al.,* (2021), who reported an increase in bare surfaces from 981.71 km² (56.98%) in 1990 to 1,210.75 km² (70.28%) in 2009. The observed increase may be attributed to deforestation, overgrazing, unsustainable agricultural practices, soil degradation, and the expansion of settlements and infrastructure, all of which expose the land surface and reduce vegetation cover.

3.2 Trend of Deforestation in Mokwa LGA from 2000-2020

Table 2 Presents the trend in deforestation in Mokwa LGA from 2000-2020. The decadal trend was given in percentages and hectares.

Table 3: Decadal Trend of Deforestation

S/NO	Year	Decadal Trend (Hectares)	Trend (Percentage)
1.	2000	-	-
2.	2010	-277	-49%
3.	2020	-415	-73%

Source: Author's Analysis

Table 3 presents the decadal trends in vegetal cover. During the first decade (2000 - 2010), there was a loss of 277 hectares of vegetal land, representing a 49% decline in vegetation cover. This substantial reduction indicates an extensive conversion of natural vegetation to other land-use types within a relatively short period. The observed decline suggests that agricultural expansion, fuelwood extraction, logging, and infrastructure development intensified during this period, resulting in the conversion of forested land into other land use categories. Ecologically, the reduction in vegetation cover implies a decline in biodiversity, fragmentation of wildlife habitats, increased soil exposure to erosion, reduced carbon sequestration capacity, and disruption of local hydrological processes. These findings are consistent with Yakubu *et al.,* (2020), who reported a continuous decline in vegetation cover attributed to agricultural encroachment and settlement expansion, and with Fatusin *et al.,* (2019), who observed that increasing urbanization was accompanied by substantial vegetation loss in southwestern Nigeria.

During the second decade (2010 - 2020), deforestation intensified considerably, with an additional loss of 415 hectares of vegetal land, corresponding to a 73% decline in vegetation cover. The accelerated decline indicates that anthropogenic pressures on forest resources became more severe, probably due to increasing population growth, urban expansion, commercial agriculture, fuelwood harvesting, and road development. The ecological implications are profound, as continued vegetation depletion reduces ecosystem resilience, accelerates land degradation, alters local microclimatic conditions, increases surface runoff and flooding risk, and further threatens wildlife populations through habitat destruction. The persistent reduction in vegetation also limits the landscape's capacity to regulate atmospheric carbon dioxide, thereby contributing to climate change. Similar trends have been reported by Koko *et al.,* (2021), who documented continuous forest degradation and expansion of bare surfaces in response to unsustainable land use practices, and by Bako *et al.,* (2015), who associated vegetation decline with rapid land use conversion and increasing human activities.

Overall, the decadal trend reveals a sustained decline in vegetation cover throughout the 2000 - 2020 study period, indicating that deforestation has become an increasingly significant environmental challenge in Mokwa Local Government Area. The continuous reduction in vegetation demonstrates that existing land use practices are ecologically unsustainable and have contributed to biodiversity loss, declining ecosystem services, deterioration of soil quality, and increased environmental vulnerability Arekhi *et al.,* (2019). The findings therefore underscore the urgent need for sustainable forest management, afforestation and reforestation programmes, stricter regulation of logging and fuelwood exploitation, and improved land use planning to reduce further degradation. This overall trend agrees with previous studies conducted across Nigeria, which consistently report that agricultural expansion, urbanization, and unsustainable exploitation of forest resources remain the principal drivers of long-term vegetation decline FAO (2020).

4. CONCLUSION

This study assessed the spatial and temporal dynamics of land use/land cover in the study area over a 20-year period (2000 – 2020) using Landsat satellite imagery, GIS techniques, and NDVI analysis. The results demonstrated significant changes in land use patterns, with notable increases in anthropogenic land uses, particularly agricultural and built-up areas, accompanied by corresponding declines in natural vegetation and other ecological land cover types. The observed changes indicate increasing pressure on land resources resulting from population growth, urban expansion, and agricultural activities. The integration of remote sensing, GIS, and field-based ground truthing proved to be an effective and reliable approach for detecting, quantifying, and analyzing land use/land cover changes over time. Furthermore, NDVI analysis confirmed changes in vegetation health and distribution, highlighting the impacts of continued land conversion on ecosystem integrity.

The findings provide important baseline information for environmental monitoring and sustainable land management. They also underscore the need for effective land-use planning and conservation strategies to minimize further degradation of natural resources while promoting sustainable socio-economic development.

5. RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed:

1. Relevant government agencies should strengthen land use planning and enforce existing land use regulations to minimize uncontrolled expansion of settlements and agricultural activities into environmentally sensitive areas.
2. Afforestation and ecosystem restoration programmes should be intensified to restore degraded vegetation and improve ecosystem services within the study area.

3. Continuous monitoring of land use/land cover changes should be undertaken using high-resolution satellite imagery, GIS, and field verification to provide up-to-date information for environmental management and policy decisions.

4. Community awareness programmes should be implemented to educate local residents on sustainable land management practices and the environmental consequences of indiscriminate land conversion.

5. Future studies should incorporate higher spatial resolution satellite data and advanced classification techniques, including machine learning algorithms, to improve classification accuracy and provide more detailed assessments of land use dynamics.

6. Policymakers should integrate the findings of this study into regional development plans to balance economic growth with environmental conservation and sustainable natural resource management.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this manuscript, the authors utilized ChatGPT to improve grammar and phrasing. Following the use of this service, the content was thoroughly reviewed and edited by the authors, who accept full responsibility for the final publication.

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