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Land Use/ Land Cover Dynamics and the Decline of Grazing Resources in Dauchi Grazing Reserve, Adamawa State, Nigeria

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ABSTRACT

Land use and land cover (LULC) change is a major driver of rangeland degradation, threatening grazing resources and pastoral livelihoods in the Guinea and Sudan savanna ecosystems of northeastern Nigeria. This study evaluates the impact of LULC change on grazing resources in Dauchi Grazing Reserve, Song LGA, Adamawa State, Nigeria, using multi-temporal satellite imagery covering forty years. Satellite data were processed and classified using supervised classification techniques within a Geographic Information System (GIS) and remote sensing framework. Six LULC classes—grassland, shrubland, cropland, bare surface, built-up areas, and water body—were mapped and analysed to assess spatial and temporal transformations. Change detection analysis was employed to quantify transitions among land cover classes and assess implications for pasture availability. Results revealed a substantial decline in natural grazing resources, particularly grassland, which decreased from 32.77 km² (54.05%) in 1984 to 5.36 km² (8.84%) in 2024, representing a loss of 27.41 km². Conversely, cultivated land expanded considerably, increasing from 21.47 km² in 1984 to 46.35 km² in 2024. These changes reduced the availability and spatial continuity of natural grazing areas, potentially constraining forage availability and grazing capacity. The findings demonstrate that sustained LULC transformation has significantly altered the spatial distribution of grazing resources in Dauchi Grazing Reserve, creating challenges for sustainable livestock production and ecosystem resilience. The study recommends rangeland restoration, controlled grazing, integrated land-use planning, and protection of remaining natural vegetation to conserve grazing resources and support pastoral livelihoods.

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INTRODUCTION

Background of the Study

Land use and land cover (LULC) change is among the most significant environmental issues affecting ecosystem structure, biodiversity, and the sustainable management of natural resources globally (Shah, Abbas, Olohunlana, & Sinha, 2023). Driven by population growth, agricultural expansion, urbanisation, climate variability, and evolving socio-economic conditions, LULC changes alter landscape composition and function, frequently resulting in habitat degradation, vegetation loss, soil erosion, and reduced ecosystem services (Zhi et al., 2025; Shah et al., 2023; Obiahu & Elias, 2020). Advances in remote sensing and Geographic Information Systems (GIS) have substantially improved the capacity to monitor these changes over time, providing reliable spatial data for environmental assessment, land management, and policy formulation (Gajardo et al., 2023; Turner et al., 2007).

Rangelands represent some of the largest terrestrial ecosystems globally and provide essential ecosystem services, including forage production, biodiversity conservation, carbon sequestration, and livelihood support for millions of pastoral households (Zhao et al., 2020; Briske et al., 2023; Muhammad et al., 2024). However, these ecosystems face increasing threats from land conversion, overgrazing, deforestation, invasive species, and climate change. The transformation of natural grasslands into cropland, settlements, and other land uses has significantly reduced forage availability, disrupted livestock mobility, and weakened the ecological resilience of grazing systems, particularly in semi-arid regions of Sub-Saharan Africa. These changes have intensified competition for natural resources and contributed to conflicts between pastoralists and crop farmers. Over the past four decades, Nigeria has experienced rapid land-use transformation driven by agricultural expansion, urbanisation, infrastructure development, and population growth. This transformation has converted forests, shrublands, wetlands, and rangelands into cultivated land and built-up areas, increasing pressure on the country's natural ecosystems (Asadu et al., 2004; Arowolo & Deng, 2018; Olayungbo, 2021). In northern Nigeria, where livestock production is a major component of rural livelihoods, grazing lands have degraded substantially due to population growth, unsustainable land management, overgrazing, and climate-induced environmental changes. These factors have reduced land productivity and increased pressure on pastoral resources (Macaulay, 2014; Yabo et al., 2025). As a result, grazing reserve productivity has declined, threatening livestock production, food security, and pastoral livelihoods. Adamawa state occupies a strategic position within Nigeria's livestock production system because it contains one of the country's largest concentrations of designated grazing reserves and supports extensive pastoral activities (Okoli and Onoga, 2022). The state lies within the Guinea and Sudan savanna ecological zones, providing favourable conditions for cattle production. Nevertheless, increasing agricultural encroachment, settlement expansion, bush burning, fuelwood harvesting, and other anthropogenic activities have accelerated land-use changes in many grazing landscapes (Rahimi et al., 2021). Recent studies in Adamawa State have reported substantial reductions in vegetation cover and corresponding increases in bare surfaces and cultivated land, indicating significant pressure on natural ecosystems and highlighting the need for sustainable land management interventions (Dishan, Yekini, & Isa, 2022; Alhamdu, Japheth, & Faive, 2020).

The consequences of these land transformations extend beyond changes in land cover patterns. Declining pasture quality and quantity reduce livestock carrying capacity, increase seasonal feed shortages, lengthen livestock migration routes, and intensify competition over limited grazing resources (Rahimi et al., 2021). Additionally, deteriorating grazing reserves have led to reduced patronage by pastoralists due to inadequate pasture, water scarcity, and declining infrastructure (Gailyson, Ray, & Ati 2023). These challenges undermine the original objectives of grazing reserves, which were intended to provide secure grazing land, permanent water supplies, and sustainable livestock production systems. While studies have investigated land use and land cover dynamics in different parts of Adamawa State, including forest reserves and urban landscapes, relatively few have explicitly examined how these changes influence grazing resources over long time periods. Existing studies have largely focused on mapping land cover transitions without adequately linking observed landscape changes to the availability and sustainability of pasture resources essential for pastoral production. This knowledge gap limits policymakers' and land managers' capacity to design evidence-based strategies to improve grazing reserve management and sustain livestock production. Against this background, this study assesses the impact of land-use and land-cover change on grazing resources in Adamawa State, Nigeria, using multi-temporal satellite imagery integrated with GIS techniques. Specifically, the study quantifies spatiotemporal changes in major land cover classes, evaluates their implications for grazing resources, and provides spatial evidence to support sustainable rangeland management and policy decisions. The findings are expected to contribute to the growing body of knowledge on land-use dynamics and provide practical information to enhance the conservation and management of grazing reserves in Nigeria, strengthening the link between observed change and management response.

MATERIALS AND METHODS

Description of the Study Area

The study area, Dauchi Grazing Reserve in Adamawa State, northeastern Nigeria, is situated between latitudes 9°41′24″N and 9°46′39″N and longitudes 12°26′23″E and 12°34′44″E. The reserve is located approximately 15 kilometers from Song town and is bounded by major road networks: the Dumne-Loko road to the northwest leading to Hombo junction, the Mararaba Dumne–Hombo junction route to the south, and the Yola–Song main road to the east. The reserve falls within the Sudan and Northern Guinea Savanna ecological zones, which are characterised by extensive grasslands, shrublands, and agricultural landscapes that support both crop farming and livestock production. The climate is tropical, with a distinct wet season from April to October and a dry season from November to March. Annual rainfall ranges from approximately 700 to 1,600 mm. Livestock production, particularly cattle rearing under pastoral and agro-pastoral systems, constitutes a major economic activity, making the reserve a pertinent setting for examining grazing resources.

Data Collection

A geospatial change-detection research design was adopted using multi-temporal satellite imagery, Geographic Information Systems (GIS), and remote sensing techniques. This approach integrated image classification, change detection, and spatial analysis to quantify land use/land cover (LULC) changes and assess their impacts on grazing resources over time. Classification was performed for five decadal epochs (1984, 1994, 2004, 2014, and 2024) using Landsat satellite imagery from WRS-2 Path 186, Row 054. Six land use and land cover (LULC) classes were mapped: Bare surface, Built-up Area, Cropland, Grassland, Shrubland, and Waterbody. For each classification epoch, a target of N = 237 to 269 stratified random reference points was allocated within the reserve, following the recommendations of Stehman and Foody (2019) for studies involving more than four LULC classes.

Primary data included Ground Control Points (GCPs) collected with a portable Global Positioning System (GPS) receiver, field observations to validate land-cover classes, and photographs documenting vegetation and grazing conditions. Secondary data consisted of Landsat 5 TM (1984 and 1994), Landsat 7 ETM+ (2004), Landsat 8 OLI/TIRS (2014), Landsat 8/9 OLI-2 (2024), and administrative boundary shapefiles for Adamawa State and grazing reserve boundaries. All satellite imagery was obtained as Landsat Collection 2 Level-1 Terrain Precision (L1TP) products from the USGS Earth Resources Observation and Science (EROS) Center via EarthExplorer. This product level was selected because it provides radiometrically calibrated and geometrically corrected data suitable for multi-temporal analysis. Image pre-processing was conducted in ERDAS Imagine and ArcGIS 10.8 to enhance image quality and ensure consistency across datasets from different Landsat sensors. Landsat Collection 2 Level-2 products were used for all five epochs. All images were acquired during the dry season (November–March) to minimise phenological variability and cloud contamination, and to maximise spectral contrast between cropland harvest residue, bare soil, and woody vegetation. Classified rasters were exported to ArcGIS 10.8 for accuracy assessment and change detection. A confusion matrix was generated in ArcGIS 10.8 to calculate Overall Accuracy (OA), Producer's Accuracy (PA), User's Accuracy (UA), and the Kappa Coefficient. An overall classification accuracy of at least 80% and a Kappa coefficient above 0.80 were considered acceptable for reliable LULC analysis.

RESULTS AND DISCUSSION

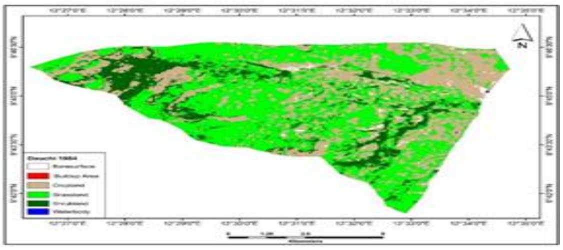

Figure 1: LULC Classes of DGR in 1984

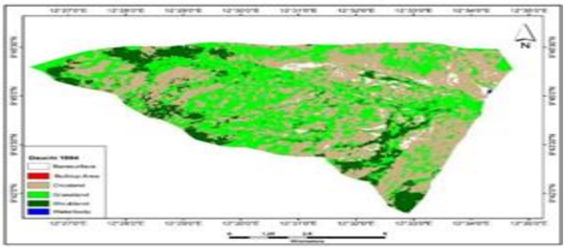

Figure 2: LULC Classes of DGR in 1994

Figure 3: LULC Classes of DGR in 2004

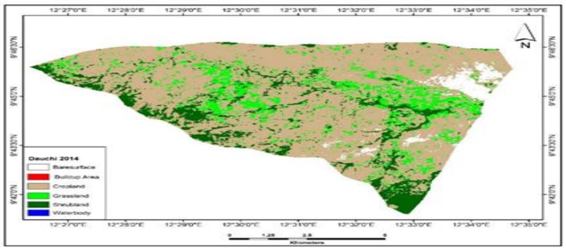

Figure 4: LULC Classes of DGR in 2014

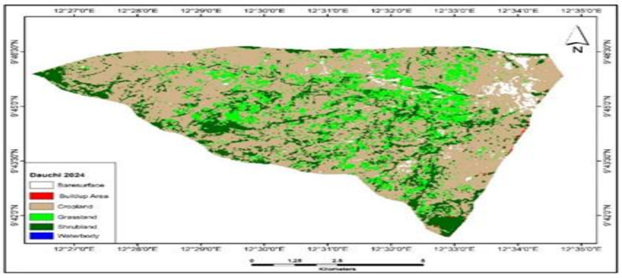

Figure 5: LULC Classes of DGR in 2024

Source: United States Geological Survey Archive 2024

Table 1: LULC Classification and Change Detection Analysis of Dauchi Grazing Reserve

Classes	1984		1994		2004		2014		2024	
	Area (km^2)	Percentage	Area (km^2)	Percentage	Area (km^2)	Percentage	Area (km^2)	Percentage	Area (km^2)	Percentage
Bare surface	0.74	1.22	1.71	2.81	2.78	4.58	2.70	4.45	2.01	3.32
Built-up	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.09	0.15
Cropland	21.47	35.42	32.61	53.80	44.38	73.21	50.29	82.97	46.35	76.47
Grassland	32.77	54.05	22.86	37.70	6.18	10.20	3.51	5.79	5.36	8.84
Shrubland	5.62	9.28	3.39	5.60	7.26	11.98	4.10	6.77	6.79	11.20
Waterbody	0.02	0.03	0.03	0.06	0.00	0.00	0.00	0.00	0.00	0.00
Total	60.60	100.00	60.60	100.00	60.60	100.00	60.60	100.00	60.60	100

Source: Satellite Image Analysis (2025)

Table 2: Changes Trend and Annual Rate of Change in Dauchi Grazing Reserve

	Changes					Annual rate of change			
	1984-1994	1994-2004	2004-2014	2014-2024	1984-2024	1984-1994	1994-2004	2004-2014	2014-2024
Bare surface	0.97	1.60	-0.08	-0.69	+1.8	0.10	0.16	-0.01	-0.07
Built-up	0.00	0.00	0.00	0.09	+0.09	0.00	0.00	0.00	0.01
Cropland	11.14	11.77	5.91	-3.94	+24.88	1.11	1.18	0.59	-0.39
Grassland	-9.91	-16.68	-2.67	1.85	-27.42	-0.99	-1.68	-1.67	-2.75
Shrubland	-2.23	3.87	-3.16	2.69	+1.17	-0.22	0.39	-0.27	0.27
Waterbody	0.01	-0.03	0.00	0.00	-0.02	0.00	0.00	0.00	0.00

Source: Satellite Image Analysis 2025

Table 3: Epoch-wise Accuracy Summary for Dauchi Grazing Reserve

Reference \ Classified	1984		1994		2004		2014		2024	
	PA%	**UA%**	**PA%**	**UA%**	**PA%**	**UA%**	**PA%**	**UA%**	**PA%**	**UA%**
Bare surface	85.7%	90.9%	88.6%	91.2%	85.7%	90.9%	91.4%	97.0%	94.3%	97.1%
Built-up	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	96.9%	100.0%
Cropland	88.7%	83.9%	89.8%	88.3%	92.1%	89.2%	94.1%	91.4%	94.4%	93.2%
Grassland	86.7%	86.7%	88.7%	88.7%	89.2%	84.6%	88.6%	86.1%	88.9%	86.5%
Shrubland	85.5%	87.0%	85.7%	85.7%	85.7%	92.3%	87.2%	91.9%	90.0%	92.3%
Waterbody	93.8%	93.8%	93.8%	93.8%	96.8%	93.8%	100.0%	96.8%	100.0%	96.8%
OA	90.0%		90.5%		91.2%		93.2%		93.9%	
Kappa	0.8762 ±0.0443		0.8839 ±0.0442		0.8923 ±0.0440		0.9171 ±0.0392		0.9246 ±0.0370	

Source: Satellite Image Analysis (2025)

In 1984, the study area was dominated by natural vegetation and agricultural land, with minimal urban development. The main land covers were grassland (32.77 km², 54.05%) and cropland (21.47 km², 35.42%), followed by shrubland (5.62 km², 9.28%), bare surface (0.74 km², 1.22%), and water body (0.02 km², 0.03%). The accuracy assessment showed high reliability, with all classes achieving Producer's and User's Accuracy values above 85%, an Overall Accuracy of 90.0%, and a Kappa coefficient of 0.8762 ± 0.0443.

The 1994 land use/land cover data for Dauchi Grazing Reserve indicate a significant structural transformation compared to 1984. The landscape shifted from predominantly natural grassland to an agriculture-dominated system. Cropland became the dominant land use class, increasing from 35.42% in 1984 to 53.80% in 1994, while grassland decreased from 54.05% to 37.70%. This shift suggests conversion of grazing land to cropland, reduced pasture availability, and an ecological transition from natural vegetation to managed agricultural land. Shrubland declined from 9.28% to 5.60%, likely due to clearance for cultivation, fuelwood extraction, and farming expansion, indicating biodiversity loss and diminished ecological buffers. Bare surface increased from 1.22% to 2.81%, reflecting land degradation from over-cultivation, soil exposure, early signs of erosion, and possible fallow or abandoned farmland. This trend signals emerging environmental stress. The accuracy assessment for the 1994 classification, as shown in Table 3, reports an Overall Accuracy of approximately 90.5% and a kappa coefficient of 0.8839 ± 0.0442, confirming high classification reliability. Producer's Accuracy was 88.6%, and User's Accuracy was 91.2%. These values exceed the 80% threshold, supporting the data's suitability for land use/land cover change analysis and sustainable land management planning.

Figures 3 and Table 1 show the 2004 LULC, revealing a major ecological shift toward agricultural dominance and a substantial reduction in natural vegetation compared with previous years. Cropland increased sharply from 53.80% in 1994 to 73.21% in 2004, with nearly three-quarters of the land under cultivation, marking a shift to a highly agriculture-driven environment. Grassland decreased from 37.70% in 1994 to 10.20% in 2004, indicating intense cultivation pressure. In contrast, shrubland increased from 5.60% to 11.98%. Bare surface continued to rise, reaching 4.58% in 2004. The 2004 classification achieved an Overall Accuracy of approximately 91.2% and a kappa coefficient of 0.8923 ± 0.0440, as shown in Table 3.

The 2014 land use/land cover data reflect the peak of agricultural dominance over the 30 years (1984–2014). Cropland expanded to 82.97%, representing more than four-fifths of the total land area, while grassland declined to 5.79%. The near disappearance of grassland indicates significant landscape alteration. Shrubland decreased from 11.98% in 2004 to 6.77% in 2014, and together, shrubland and grassland accounted for less than 13% of the total area, indicating a major ecological imbalance. Bare surface slightly decreased to 4.45% but remained higher than in earlier decades, continuing to signal environmental stress. The persistent absence of surface water suggests ongoing hydrological stress, drying of seasonal streams, and increased reliance on groundwater. Built-up area remained negligible or below detection thresholds. The 2014 LULC data demonstrate that DGR reached maximum agricultural expansion, with natural vegetation nearly eliminated. While this reflects agricultural intensification and dependence on rural livelihoods, it raises concerns about long-term environmental sustainability and ecosystem resilience. The accuracy assessment for this classification, presented in Table 3, revealed an Overall Accuracy of 93.2% and a kappa coefficient of 0.9171 ± 0.0392.

The 2024 land use/land cover data indicate a slight structural adjustment in the Dauchi landscape compared to 2014. While agriculture remains the dominant land use, the data indicate minor vegetation recovery and the emergence of built-up development. Cropland, though still the largest land use class, declined from 82.97% in 2014 to 76.47% in 2024. Despite this reduction, the landscape remains highly cultivated relative to earlier decades. Grassland increased from 5.79% to 8.84%, suggesting partial regeneration of natural vegetation, abandonment of less productive farms, or reduced cultivation intensity in certain areas. However, grassland coverage remains substantially lower than the 1984 level of 54.05%. Shrubland increased from 6.77% to 11.20%, which may reflect secondary vegetation succession, regrowth on fallow land, or reduced pressure on marginal lands. Bare surface decreased from 4.45% to 3.32%. Notably, built-up area appears for the first time in the four-decade analysis, covering 0.09 km² (0.15%), indicating emerging settlement or infrastructural expansion and gradual population growth. Although the proportion is small, it marks the onset of structural transformation beyond agriculture. Table 3 reports an Overall Accuracy of 93.9% and a kappa coefficient of 0.9246 ± 0.0370 for this classification.

The results demonstrate Land Use/Land Cover (LULC) changes in Dauchi Grazing Reserve from 1984 to 2024, with percentage increases and decreases observed across six classes. The trends indicate progressive environmental transformation, primarily characterised by agricultural expansion and vegetation decline of varying intensity. Bare surface initially increased for two decades and then declined for the last two decades (+0.97, +1.07, -0.08, -0.69), suggesting gradual land degradation from vegetation clearing, overgrazing, and soil exposure due to continuous cultivation. Empirical studies in dryland and semi-arid environments show that increased grazing pressure reduces vegetation cover and soil organic carbon, while vegetation loss and continuous grazing increase soil exposure, erosion, and degradation (Gebremedhn, 2025; Macheroum et al., 2025).

Table 2 indicates no observable change in built-up area over three decades, with built-up area emerging only in the last decade. This suggests limited infrastructural expansion within the study area. Cropland expanded substantially (+11.14, +11.77, +5.91, -3.94) over three decades and then declined in the last decade, with the highest increase occurring during 1994–2004 (+11.77), indicating intensified cultivation. The widespread increase in cropland aligns with global and regional findings that identify agriculture as the primary driver of land-use change (Tamiru 2025). Sub-Saharan Africa has experienced significant cropland expansion at the expense of natural vegetation, particularly shrubland and grassland, in recent decades. A comprehensive regional assessment found that cropland increased by approximately 20 million hectares between 1992 and 2015, largely at the expense of forests and shrubland, highlighting agriculture as a dominant driver of land transformation in the region (He, Chen, Wang, & Li, 2024). This pattern is consistent with broader trends across Sub-Saharan Africa, where agricultural expansion frequently replaces natural ecosystems (He *et al*., 2024).

CONCLUSION

The data show a continuous, accelerating decline in grassland over the first three decades (–9.91, –16.35, –2.67, +1.85), followed by a slight increase between 2014 and 2024. Omwoyo, Onwonga, Wasonga, and Kinyanjui (2024) reported similar declines in grassland and shrubland in Kibwezi West, Kenya, where these land-cover classes are among the most vulnerable and are often converted to cropland or other uses over time. Such changes reduce vegetation cover and contribute to declining ecosystem integrity. Research in Southeast Asia demonstrates that cropland expansion can offset the greening effects of environmental factors, such as CO_2 fertilisation, by reducing vegetation greenness indices like Leaf Area Index (LAI). This parallels the ongoing vegetation depletion observed in the study area, indicating that although some vegetation remains, its intensity and quality are declining where agricultural expansion is most pronounced (Pfeiffer, Hoffmann, Scheiter, Nelson, Isselstein, Ayisi, & Rötter, 2022)

Shrubland exhibited considerable temporal fluctuations throughout the study period (-2.23, +3.87, -3.16, +2.69). The initial decline and subsequent fluctuations in shrubland likely reflect changes in agricultural intensity, grazing pressure, and vegetation disturbance. The reduction between 1984 and 1994 occurred alongside a substantial increase in cropland from 35.42% to 53.80%, suggesting that some shrubland may have been cleared for cultivation. This interpretation is consistent with empirical evidence from Nigeria showing that agricultural expansion commonly occurs at the expense of shrubland, grassland, and forest vegetation (Eze et al. 2023. Water body showed minimal fluctuation (+0.01, -0.03), suggesting insignificant change that may reflect seasonal or climatic variability rather than long-term transformation. Multiple studies and community-based research projects have documented reduced water availability in pastoral grazing zones. Gebreyesus, Eyerusalem, and Zeleke (2024) reported reductions in grazing land and water resources in Bale Zone, Ethiopia, while a regional study in the Horn of Africa found that, due to overuse and insufficient rainfall, water catchments of essential grazing sites were largely dry, increasing pasture degradation and livestock mortality (African Development Bank, 2010). In Mongolia, large-scale eco-hydrological modelling has also linked declining groundwater levels to high livestock water demand, indicating that pastoral areas face significant water stress (Nakayama, 2025).

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