

Mapping Agricultural Markets, Land Use, and Accessibility in Borno State, Nigeria

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ABSTRACT:

This study addresses the critical gap in integrated spatial data for Borno State, Nigeria, by analyzing land use and land cover (LULC) change, agricultural markets, and road network connectivity. Using geospatial techniques, we integrated 20 years (2002–2022) of European Space Agency CCI land cover data with a classified road network from DIVA-GIS and on-site surveys at seven agricultural markets to document their spatial distribution and associated produce. Agriculture was the dominant and expanding land cover, increasing from 84.47% to 86.23% of the total area (a net gain of 1,167.67 km²). Urban and forest areas also increased significantly by 110.05% and 156.82%, respectively, while grassland declined by 20%, largely converted to agricultural use. The surveyed markets form a strategically dispersed nodal network along primary roads, with clear produce specialization: northern Sahelian markets primarily supply grains and livestock, while southern markets focus on roots and tree crops. Lake Chad fringe markets like Monguno specialize in wetland produce and fish. The synthesis of these datasets reveals that Borno's primary agricultural constraint is not a lack of markets, but an inefficient spatial linkage between production zones and market nodes. Many markets, particularly those serving specialized catchments, lack direct connection to primary roads, implying higher travel times and weaker connectivity that suppresses regional trade potential. Therefore, this integrated analysis provides a foundational geospatial dataset for resilience-building in a conflict-affected region and directly supports the policy recommendation for selective feeder road improvements to enhance micro-connectivity and unlock inter-zonal trade. Future research should expand the market inventory and employ advanced metrics like travel-time and entropy analyses to further investigate barriers to market access.

1. INTRODUCTION

1.1 Background to the Study

Attaining sustainable agriculture and food security is essential for achieving Sustainable Development Goals 1 (No Poverty) and 2 (Zero Hunger). One critical pathway is providing access to crucial information, such as agricultural market data, time-series land use and land cover (LULC) change analysis, and infrastructure maps linking farmlands to markets (Adebayo *et al.*, 2023). This data serves as a valuable resource for farmers, businesspeople, investors, and policymakers.

In Nigeria and other parts of Africa, agricultural markets where farm produce are transacted are primarily located in rural and peri-urban areas and accessed by road. However, the World Bank (2024) reports that many rural road networks in those areas are dilapidated and require rehabilitation. Good roads and interconnectivity lower travel costs and time, enhancing the movement of goods and potentially increasing agricultural production and income (Aboyeji & Aguda, 2024). Conversely, a study in South-Eastern Nigeria found that improved road access did not have a statistically significant effect on smallholders' crop output or income (Udeuhele & Eze, 2022), indicating complex outcomes.

Remote sensing and GIS techniques are vital for LULC mapping and applications in agricultural planning and assessment. In northern Nigeria, high-resolution studies reveal that agriculture dominates the landscape. For Borno State, agriculture is the

predominant livelihood for over 80% of the population, yet the sector faces significant challenges (BOSIPA, n.d.; Ibrahim, 2023). Studies in the region's Sudan-Sahel agro-ecozone found arable land averaging 52.5% (Sedano *et al.*, 2020), and others have employed advanced methods like Google Earth Engine with machine learning to map cropland (Abubakar *et al.*, 2023). Further research has assessed built-up area dynamics affected by conflict in specific Borno Local Government Areas (Bala *et al.*, 2022; Bala *et al.*, 2023), alongside cultivation and suitability analyses elsewhere (Tukur *et al.*, 2024; Badamasi *et al.*, 2022). These studies highlight dynamic land use shifts but seldom link them directly to market systems.

Other research has examined market accessibility and connectivity. Studies cover food market accessibility (Benassai-Dalmu *et al.*, 2025), market-road network connectivity (Nchouji, 2008), the impact of transportation on agricultural marketing (Alarima *et al.*, 2020), and the influence of road conditions on produce accessibility (Fato *et al.*, 2023). Research also shows that many Nigerian grain markets are poorly integrated, with insecurity in the north severely disrupting rural livelihoods and market chains (Kassouri & Fofana, 2025; World Food Programme, 2025).

Collectively, the literature establishes broad links between roads, land use, and markets. While improved transport generally supports market participation and higher output (Aboyeji & Aguda, 2024), and remote sensing can quantify land use in conflict zones (Sedano *et al.*, 2020), the context of insurgency in northern Nigeria complicates this relationship. Insecurity can

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drastically reduce crop outputs and labor without necessarily shrinking the area farmed, as farmers may plant with lower inputs or miss harvests (Adelaja & George, 2019). Thus, in Nigeria’s conflict-affected north, the potential market gains from infrastructure are often muted, with remote markets remaining poorly linked.

Despite these insights, critical gaps persist for conflict-affected areas like Borno State. Firstly, there is a lack of sufficient studies that integrate fine-scale spatial data on markets, roads, and contemporary land use. Secondly, the connectivity of roads to agricultural markets is poorly documented, which critically affects farmers’ travel times. Finally, existing LULC maps for the area have not been linked to crop choices or market locations.

Therefore, this study utilizes remote sensing, field data, and geospatial techniques to: (1) map the changes and transitions in agricultural and other LULC classes over 20 years; (2) analyze agricultural markets and the produce types associated with each; and (3) assess market accessibility and the connectivity of the road network to existing markets.

1.2 Study Area

The Borno State (in Figure 1b) is a strategic and potential economic zone, boasting an international border with three countries (Niger, Chad, and Cameroon) and Lake Chad. It is located in the North-Eastern part of Nigeria. It is the second largest state in Nigeria with a total land area of slightly more than 70,000 km², and with Maiduguri as the State capital. The state is a predominantly agricultural area with the cultivation of different crops such as groundnuts, millet, sorghum, etc. It suffered from Boko Haram conflicts for about two decades, which significantly affected farming and other economic and social activities.

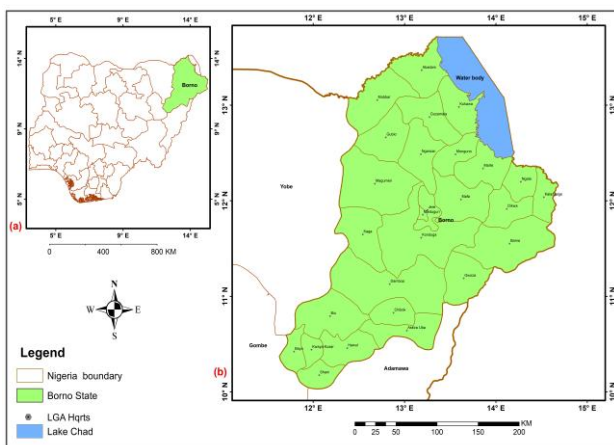


Figure 1. Locational maps: (a) Nigeria showing Borno State. (b) Borno State (Study area)

2. MATERIALS AND METHODS

2.1 Materials

Table 1 shows an overview of materials utilised in this study.

Type	Description / Specification	Source
Land Use / Land Cover (LULC) Data	ESA CCI Land Cover maps for 2002, 2012, and 2022 at 300m spatial resolution.	European Space Agency (ESA) Climate Change Initiative (CCI)

Type	Description / Specification	Source
Agricultural Markets Data	Spatial locations (points) and key attributes (e.g., name, produce type) of seven agricultural markets	Primary Field Survey & Questionnaire
Transport Infrastructure Data	Digital vector data of existing roads, classified by type	OpenStreetMap (OSM)
Administrative Boundary	Polygon layer defining the study area extent	GIS DIVA
R Programming	For converting netCDF to TIFF files, calculating transition matrices, generating charts, and other statistics.	R Foundation (Open Source)
ArcGIS	For geospatial analysis, map creation, reclassification, and generating composite maps	Esri

Table 1. Data Types and Sources

2.2 Methods

The methodology for this study followed the systematic workflow presented in Figure 2. First, the necessary data were gathered from multiple sources. The global Land Cover (LC) data for three epochs (2002, 2012, and 2022) listed in Table 1 were downloaded from the ESA CCI LC website. These datasets came with more than twenty classes, which were reclassified into six LULC classes: Urban, Agriculture, Forest, Grassland, Water, and Sparse Vegetation, to display the proportion of classes, especially the agricultural class, and their relationship to market produce. We also downloaded ancillary data, such as administrative boundaries and the existing road networks of the study area, from relevant sources. The existing road network layer was classified into Primary, Secondary, and Tertiary Roads, etc., and overlaid on the maps. We then visited the study area onsite and collected the locations and attributes of seven popular agricultural produce markets and their thirty-two commodities.

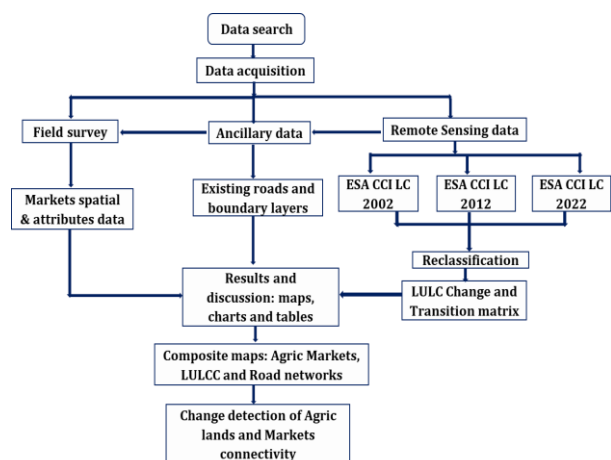


Figure 2. Methodology workflow diagram

Next, these datasets were integrated and processed. The land cover maps were reclassified to focus on relevant categories. A change detection analysis was then performed to identify area (1), and changes in agricultural lands over the 20 years, and to generate Land Use and Land Cover (LULC) change statistics and a transition matrix. The land use transition was computed in RStudio.

$$A_i = n \times R \quad (1)$$

Where A_i = Land use area (km²) of class i ; n = Class i Pixels Number; and R = Pixel Area in km²

The market maps were categorized based on the produce they supply, which were subsequently integrated with the LULC maps and the road networks. Finally, the results were synthesized and visualized. Composite maps were created to display the relationships between agricultural markets, LULC changes, and the road network. This allowed for an analysis of changes in agricultural lands and an assessment of market connectivity. The findings are presented using maps, charts, and tables.

3. RESULTS AND DISCUSSION

3.1 Change Detection and Land Use Transition

Tables 2 & 3, and Figures 3, 4, 5 & 6 show the LULC classification, and transition matrix with six major categories: Urban, Agriculture, Forest, Grassland, Water, Sparse Vegetation, and Lake Chad (standalone cover). There are significant transitions over the 20 years, with a dominant agricultural landscape having significant internal shifts. Agricultural land remained the predominant class (consistently >84% of the total area), increasing from 2002 to 2012 before a slight decline by 2022 (Figure 3), with a net gain of 1,167.67 km². The most notable changes occurred in other classes: Urban area more than doubled, with a 72% increase from 2012-2022, indicating rapid urbanization, while Forest cover increased by 156.82%, suggesting possible recovery or afforestation efforts. Conversely, Grassland and Sparse Vegetation both declined substantially, losing approximately 2,352 km² and 105 km² of the area, respectively, over the 20 years. These transitions point to an intensifying human footprint, with urbanization and agricultural expansion likely driving the conversion of natural grasslands and sparse vegetation.

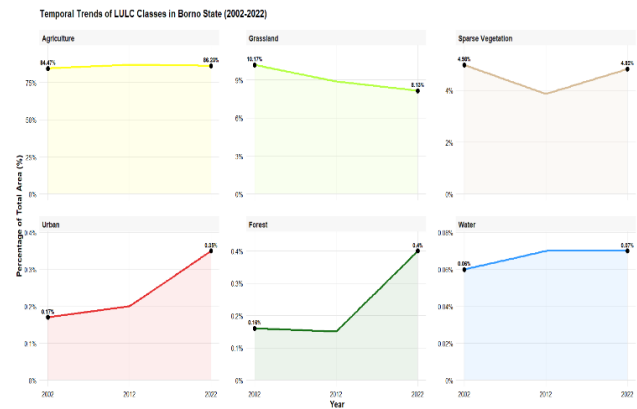


Figure 3: Temporal Trends of LULC Classes (2002-2022)

2002 → 2022 Class	Urban	Agri culture	Forest	Grass land	Water	Sparse Vege tation	Total
Urban	110.10	0.00	0.00	0.00	0.00	0.00	110.10
Agri- culture	100.76	55044.89	129.25	72.08	4.43	735.17	56086.58
Forest	0.00	0.00	102.01	0.00	1.44	0.00	103.45
Grass- land	16.84	1395.57	9.62	5327.32	0.00	2.50	6,751.85
Water	0.00	0.00	0.00	0.00	40.71	0.00	40.71
Sparse Vege- tation	3.56	813.80	24.83	0.19	0.10	2463.63	3306.11
Total 2022	231.26	57254.26	265.71	5399.59	46.68	3201.30	66398.80

Table 3: LULCC Transition Matrix 2002-2022

LULC Class Name	2002 Area (km ²)	2002 (%)	2012 Area (km ²)	2012 (%)	2022 Area (km ²)	2022 (%)
Urban	110.10	0.17	134.54	0.20	231.26	0.35
Agriculture	56086.59	84.47	57674.82	86.86	57254.25	86.23
Forest	103.46	0.16	102.11	0.15	265.72	0.40
Grassland	6751.86	10.17	5883.20	8.86	5399.60	8.13
Water	40.71	0.06	43.40	0.07	46.68	0.07
Sparse Vegetation	3306.11	4.98	2,561.73	3.86	3,201.30	4.82
Total	66309.80	100.00	66309.80	100.00	66398.81	100.00

Table 2. LULC area distribution (2002-2022)

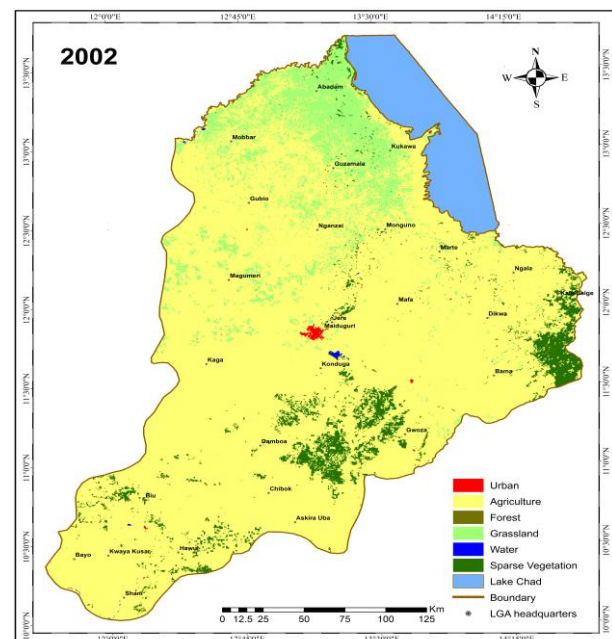


Figure 4. Borno LULC change map for 2002

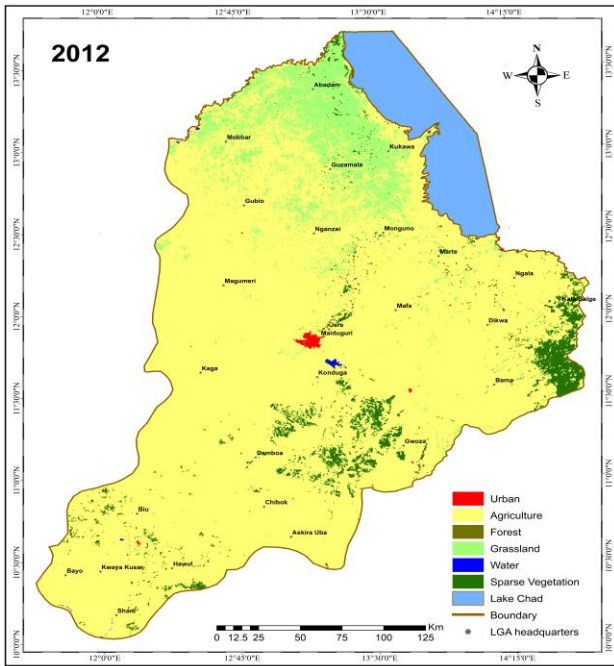


Figure 5. Borno LULC change map for 2012

Period	Transition	Area (km ²)
2002-2012	Grassland → Agriculture	910.23
2002-2012	Sparse Vegetation → Agriculture	780.60
2002-2022	Grassland → Agriculture	1,395.57
2002-2022	Sparse Vegetation → Agriculture	813.80

Table 4: Major LULC Transition 2002-2022

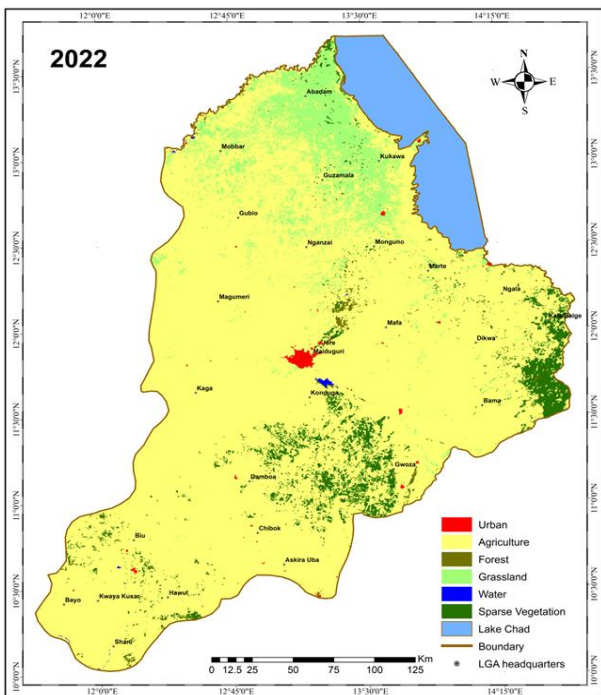


Figure 6. Borno LULC change map for 2022

Results in Table 4 also show that approximately 2,200 km² of natural land cover (specifically, Grassland and Sparse Vegetation) was converted to Agriculture during a 20-year period. While this expansion was most rapid from 2002 to 2012,

it continued at a significant pace over the full two decades, indicating sustained pressure to bring more land into cultivation. Over the 20-year period, the Borno State landscape was remarkably stable, with over 97% of the total area remaining unchanged in its land cover class. However, the rate of change increased, rising from 1.31% in the first decade (2002-2012) to 1.58% in the second (2012-2022) (Table 5). This indicates that while the overall landscape structure is persistent, land conversion processes have been intensifying, particularly in the most recent decade. Figure 7 shows net LULC changes in Borno State (2002-2022). Positive values indicate gain in area; negative values indicate loss.

Metric	2002-2012	2012-2022	2002-2022
Total study area (km ²)	66,309.80	66,398.81	66,398.80
Stable area (km ²)	65,438.36	65,347.81	64,488.66
Stability rate (%)	98.69%	98.42%	97.12%
Changed area (km ²)	871.44	1,051.00	1,910.14
Change rate (%)	1.31%	1.58%	2.88%

Table 5. LULCC Metrics 2002-2022

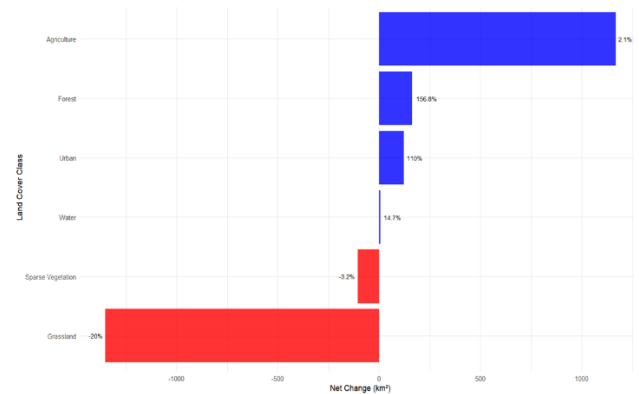


Figure 7. Net LULC changes (2002-2022) (gain in blue, loss in red)

3.2 Agricultural Markets

Figure 8 shows a total of seven markets (A–G: Benisheik, Dikwa, Gubio, Konduga, Kwaya-Kusar, Monguno, and Uba) and thirty-two produce and staple produce are available and widespread in the majority of the markets, and a market-produce legend associating each market with the commodities traded. All major markets handle staple cereals and oilseeds (sorghum, millet, maize, groundnut); that is, staples are available across the network. The markets situated on primary/secondary corridors show the largest set of traded commodities, including perishables and higher-value items, whereas peripheral markets trade a narrower set.

The map also classifies roads into primary, secondary, tertiary, and feeder roads. Some produce markets are not adjacent to primary roads, implying longer, lower-quality connectivity, and farmers may need to travel longer distances over tertiary roads to reach the nearest market. A small number of markets act as aggregation nodes for multiple LGAs (central hub function); upgrading links to those nodes would reduce cumulative travel for many producers.

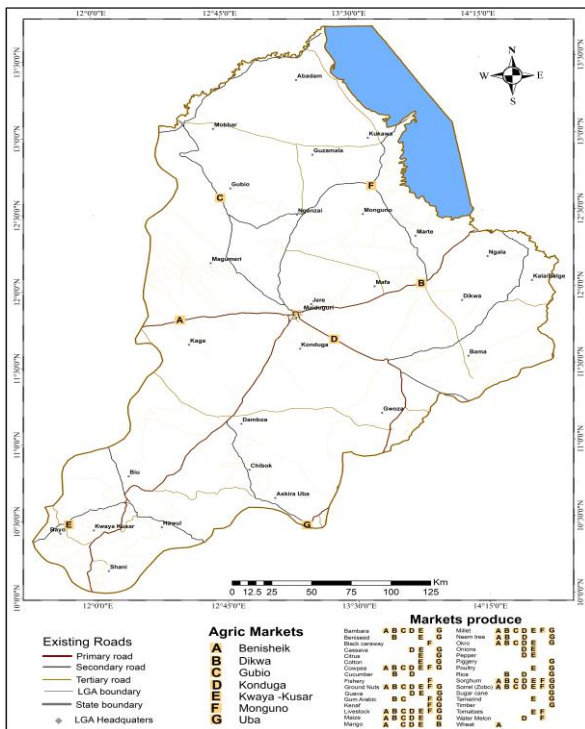


Figure 8. Spatial distribution of Agricultural markets

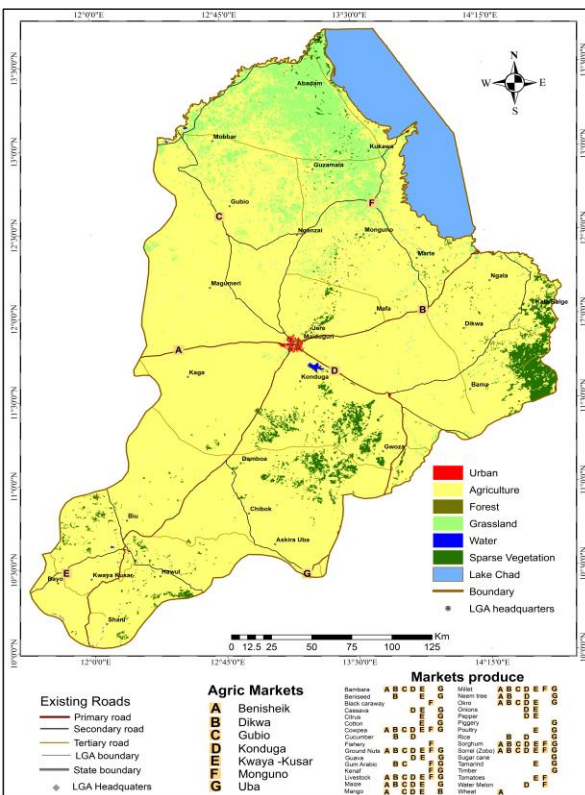


Figure 9. Composite map of LULCC and Agric produce markets

The composite land use/land cover (LULC) map in Figure 9 reveals that agricultural land dominates Borno State. Maiduguri acts as the primary consumption and aggregation hub, with road networks to other urban areas. The markets are spatially distributed, not clustered; however, inefficient spatial linkage between farmlands and the markets is more pronounced.

3.3 Discussion and comparison with previous studies

The composite land use and land cover (LULC) map reveals that agricultural land is the dominant feature of Borno State, constituting the vast majority of the territory outside the Lake Chad and sparse urban clusters. The landscape shows distinct patterns: the southern and southeastern parts display dense agricultural-green mosaics, while the northern Sahelian zone retains larger tracts of grassland. The urban core of Maiduguri acts as the primary regional hub for consumption and aggregation.

The seven identified agricultural markets: Benisheik, Dikwa, Gubio, Konduga, Kwaya-Kusar, Monguno, and Uba exhibit a strategic spatial dispersion along primary transport axes, forming a nodal network. This structure operates under the additional pressures of security incidents and seasonal accessibility challenges. These markets show clear functional specialization linked to their ecological zones. Markets such as Dikwa (B) and Monguno (F) serve wetland-dependent fishing and irrigated produce systems along the Lake Chad fringe, while Kwaya-Kusar (E) and Uba (G) represent highland agricultural catchments. Commodity listings indicate further specialization: northern Sahelian markets primarily supply grains, livestock, and staple food crops, whereas southern markets dominate in roots, vegetables, and tree crops.

Analysis of the road network reveals strong north-south primary trunk roads connecting Maiduguri to key towns like Gwoza and Biu. However, the tertiary links connecting these corridors to dispersed producers and local markets remain sparse and fragmented. The synthesis of LULC data, market locations, and road networks indicates that Borno's primary challenge is not a lack of markets but rather an inefficient spatial linkage between production zones and market nodes. In essence, while macro-level transport corridors are in place, micro-level connectivity is weak.

This finding of inefficient spatial linkage aligns with and contextualizes several studies in the literature. The expansion of urban areas noted in our LULC results aligns with findings by Bala *et al.* (2023), who documented an increase in built-up areas in parts of the state despite the ongoing conflict. The patterns of agricultural production reflected in our market produce maps correlate with suitability analyses, such as the work by Tukur *et al.* (2024), which identified areas around Askira/Uba, Chibok, and Damboa as highly suitable for groundnut cultivation.

The connectivity challenges posed by the road network are a critical factor. Our observation of pronounced disparities in rural travel times and limited market reach is closely related to the issues of food market accessibility examined by Benassai-Dalmou *et al.* (2025). The poor condition of many feeder roads, which forces farmers to use motorcycles, donkeys, or wheelbarrows for transport, directly supports the findings of Fato *et al.* (2023), who reported that 73.1% of respondents cited very bad road conditions as a major barrier. Furthermore, the location of most markets near existing roads supports Nchouji's (2008) observation that periodic markets are typically situated along roadsides or in nucleated settlements with road links, facilitating the rotation of merchants between market days. This practice is confirmed by local evidence that most markets in the study area are periodic, with farmers often relying on motorcycles to traverse poor-condition feeder roads to reach them, a finding consistent with Alarima *et al.* (2020).

4. CONCLUSION

This study reveals a continuous expansion of agricultural land in Borno State, signifying ongoing agricultural intensification. Mapping of existing markets further shows their spatial distribution and connectivity, along with the variety of produce available; these market locations are strongly influenced by and sited near roads to ensure better access.

The integrated spatial analysis of these elements demonstrates that Borno State possesses a structurally favorable land use and market geography. However, its full agricultural potential is suppressed by suboptimal accessibility. To unlock this potential and enhance inter-zonal trade complementarities between grain, livestock, vegetable, and fish-producing systems, policymakers should target selective improvements to feeder roads. This strategic intervention aligns with the resilience-building strategies advocated for conflict-affected agrarian economies.

4.1 Recommendations

Building on this analysis, we identify clear pathways for methodological advancement and deeper investigation. Future research should prioritize the application of machine learning and advanced geospatial techniques to derive more nuanced insights from spatial data. A primary limitation of this study is its sample of seven markets, constrained by security and logistical factors within the region. Consequently, expanding the survey to include a more comprehensive inventory of markets is essential to fully characterize the state's agricultural market network and its connectivity. To quantitatively address the identified problems of high travel times and limited market reach, future work should incorporate specific accessibility metrics. These include calculating travel time to the nearest market, measuring market availability within specified travel thresholds, and applying entropy-based measures to analyze the spatial distribution and efficiency of the market network.

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